Intra-regional wealth-deforestation relationships in the Brazilian Pantanal:

An examination of the Environmental Kuznets Curve Hypothesis

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Introduction, hypotheses and objectives

The Environmental Kuznets Curve (EKC) describes a hypothesized “inverted U” relationship between an environmental pollutant and per capita income (Seldon and Song 1994). An EKC for some measure of environmental degradation or pollution will initially show a positive relationship with per capita income, but past some turning point increases in per capita income are associated with decreasing environmental degradation or pollution. Issues surrounding the EKC include the potential path dependence of economic development, the absolute level versus the distribution of economic welfare, the distribution of claims to the natural resource base of a nation or region, and the distribution of the benefits gained from the use of those resources.

This paper provides an examination of the EKC Hypothesis applied to deforestation in the Brazilian Pantanal wetland. It is hypothesized that the unsustainable subdivision of many of the larger ranches due to inheritance may result in greater deforestation pressure than a less equal distribution of land and animal resources. The analysis advances understanding in this area on several dimensions: an intra-regional rather than international approach is examined, decreasing the consumptive, trade related, and ecological footprint concerns; deforestation, rather than the more typical industrial pollutants is addressed; land and cattle wealth serve as proxies for income and wealth among agriculturists, where income measures are notoriously poor indicators of welfare;

and both per capita and total deforestation (pollution) are modeled, unlike the majority of published accounts.

The Environmental Kuznets Curve Hypothesis

Proponents of the EKC argue that at very low levels of economic activity environmental impacts are generally low but, as development proceeds, the rates of land clearance, resource use, and waste generation per capita increase rapidly. However, at higher levels of development structural change towards information-intensive industries and services, coupled with increased environmental awareness, enforcement of environmental regulations, better technology, and higher environmental expenditures, result in leveling off and gradual decline of environmental degradation (Panayotou, 1995, 1997). The view that greater economic activity inevitably hurts the environment depends on static assumptions about technology tastes and environmental investments. As incomes rise, the demand for improvements in environmental quality will increase, as will the resources available for investment.

Evidence of an EKC has suggested that economic growth can be compatible with environmental improvement, if appropriate policy responses are taken. It does not suggest that only when income grows can effective environmental policies be implemented; "The strong correlation between incomes and the extent to which environmental protection are adopted demonstrates that, in the longer run, the surest way to improve your environment is to become rich" (Beckerman,1992)

To summarize the EKC literature, some environmental indicators (e.g. access to clean water, urban sanitation and urban air quality) show improvement with increased income, with or without an initial period of deterioration. Other indicators, however, show continued worsening as incomes rise (e.g, carbon monoxide emissions and municipal waste per capita). The turning point at which environmental improvement begins varies from study to study, but most often falls in the income range of middle-income countries.

Most environmental conditions that do improve with economic growth are those that have local impacts and abatement costs that are relatively inexpensive in terms of money and changes in lifestyle (Arrow *et al.*1995). Environmental problems that improve only at higher income levels or that continue to worsen as incomes rise generally create impacts that affect only a few people (e.g., solid waste) or that are separated by either space and/or time from those creating the pressures on the environment (e.g., carbon dioxide emissions). A number of the results also indicate a possible N shaped relationship, whereby the indicator of resource use or environmental stress begins to worsen again at higher incomes (Grossman and Krueger, 1995, 1996; Shafik and Bandyopadhyay, 1992; Grossman, 1995; de Bruyn *et al.*, 1997)

Background: Deforestation in the Brazilian Pantanal

At approximately 200,000 km^2, the Pantanal is considered the largest freshwater wetland in the world. The Pantanal lies at within the Upper Paraguay River Basin at the headwaters of the Paraguay River in the center of South America. Most (138,000 km^2) of the Pantanal lies within Brazil. The region is a cradle of biological diversity including more than 200 species of fish, 80 species of mammals and 2000 plant species. Mining, cattle ranching and fishing are the principal economic activities in the region. About 4 thousand cattle ranchers own approximately 95% of the seasonal wetland, where about 25 to 30 thousand people and 3 million cattle live (Silva *et al.* 2000); Guidance in the management of the Pantanal's natural resources cannot be successful without the complicity of cattle ranchers.

Pantanal forests are being converted to plant pastures in order to increase the carrying capacity of the land for cattle. Ranchers are managing only for the productive benefits the land for beef cattle rather than for the full array of potential benefits from Pantanal lands including: erosion control, water quality maintenance, wildlife habitat provision, fisheries habitat provision and maintenance. Management for beef cattle production alone imposes negative productive and consumptive externalities on the rest of the Pantanal's ecological economic system. Via tourism ranchers could capture some of these benefits, but non-rancher Pantanal residents capture other benefits (fish protein, fish tourism, health benefits, lower water treatment costs, lifestyle issues, etc); several of the goods and services affected by rancher behavior demonstrate features of regional common pool resources. These common pool resources are often managed as open access resources, but efforts continue to manage them as common property or to create a system of privatization for others.

Since deforestation on private ranch lands is the principal vehicle by which Pantanal ranchers impose externalities on the rest of the region, it is informative from a regional policy perspective to better understand the relationship between deforestation activity and cattle ranching (Seidl *et al.*, 2001; Seidl, 2001).

Data and Methods

Parcel level data from three census periods (1975, 1980, 1985) adjusted to reflect location in the Pantanal region are used. The data parcel information cannot be tracked from period to period; our data are, therefore, a time series of independent cross sections.

Data were organized into 11 subregions and 16 municipalities (Silva *et al.* 2000). The subregions may indicate the influence of physical features of the land on pollution pressure. The municipalities may indicate the influence of local policies, access to markets, population and infrastructure provision on pollution pressure. Gini ratios are calculated for each subregion and municipality for each census period based upon the land and cattle wealth associated with each parcel (Silva *et al.* 2000).

With regard to deforestation, the total stocks of forested land or total land are the stock variables and trees, stocking rates, or cattle marketed are the flow variables. The decrease in forested area and parallel increase in planted pastureland reflect changes in the amount of stock. Increases in the number of cattle marketed or in stocking rates reflect changes in the flow variables due to changes in the stock variables.

Generally, following the literature, the basic model is:

Eq 1: $E_{i,t} = ?_{0\ i,t} + ?_{1} Y_{i,t} + ?_{2} Y^{2}_{i,t} + ?_{3} Y^{3}_{i,t} + ?_{4} t + ?_{5} V_{i,t} + e_{i,t}$

Where,

Y is income or wealth;

E is total pollution or pollution per capita;

i is the country index;

t is a time index;

V_t reflects other variables (e.g., ppn density) that influence the relationship between E and Y;

e is the normally distributed error term; and

$?_4$ is used to detrend the series.

The hypothesis test typically explored is surrounds the direction and significance of the income and wealth coefficients in predicting the amount or flow of pollution. That is, Ho: $?_1$, $?_2$, $?_3 = 0$; Ha: $?_1$, $?_2$, $?_3 < 0$; $?_1$, $?_2$, $?_3 > 0$.

Where,

1) $?_1 > 0$ and $?_2 = ?_3 = 0$ reveals a monotonically increasing relationship, indicating that rising incomes are associated with rising levels of emissions;
2) $?_1 < 0$ and $?_2 = ?_3 = 0$ reveals a monotonically decreasing relationship;
3) $?_1 > 0$, $?_2 < 0$ and $?_3 = 0$ reveals a quadratic relationship, representing the EKC. The turning point of this representation of the inverted U curve is obtained by setting the derivative of equation 1 equal to 0, which yields $Y = - ?_1/2 ?_2$;
4) $?_1 > 0$, $?_2 < 0$ and $?_3 > 0$ reveals a cubic polynomial, representing an N shaped relationship, which yields two turning points by solving the quadratic equation $Y_{1,2} = 3 B_3 Y^2 + 2 B_2 Y + B_1$.

Following this template, amount of deforested land (cultivated pasture) provides the left hand side variable in the estimated relationship. Number of cattle, amount of land, number of cattle squared, amount of land squared, cattle cubed, land cubed, land in native pasture (substitute land), number of tractors (indicator of capital intensity), subregion and municipality, land and cattle Gini ratios, and time trend/census period dummies make up the unrestricted version of the right hand side of the estimated relationships.

Observations were truncated to exclude all parcels of less than 36 hectares, the absolute regional minimum size thought to exist as a beef cattle operation, and 1/100 of the regional land measurement standard; “legua” (Table 1). Table 1 provides descriptive statistics for 6563 parcel level records used in this analysis. By truncating the dataset at 36 hectares or greater, approximately 99.5 percent of Pantanal agricultural lands, cattle and tractors are still represented in this analysis. Subregional Gini coefficients were calculated using the entire dataset rather than the truncated version.

Table 1: Pantanal Deforestation, descriptive statistics.

	Cultivated Pasture (ha)	Area (ha)	Cattle (#)	Tractors (#)	Cattle Gini	Land Gini	Native Pasture (%)	People (#)
Median	6	1,321	285	0	0.929	0.920	57.92	6
Mean	340.43	5305.36	1440.32	0.48	0.900	0.887	54.37	8.10
Max	64,000	363,000	73,506	40	0.956	0.957	100	348
Min	0	36	0	0	0.715	0.376	0	0
Total	2,234,235	34,819,062	9,452,808	3,172	n.a.	n.a.	n.a.	53144
Total/3	744,745	11,606,354	3,150,936	1,057	n.a.	n.a.	n.a.	17,715

Source: adapted from Silva *et al.* 2000

Results

The overall modeled relationship (N=6563, Adj. R^2=0.50, p<0.01) and all variables of the original unrestricted model were statistically significant (p<0.05) and of the expected sign except the time trend and the “Land Gini”, which were statistically insignificant by conventional standards. “Land Gini” and “Cattle Gini” are highly correlated (0.87), explaining the lack of power in one of the variables. Reformatting the time trend variable into three dummy variables and deleting the intercept made them statistically significant but indistinct from one another. As a result, the time trend was left out of subsequent estimations and an intercept term was included.

As expected, the White test revealed heteroskedasticity in the estimated relationship. The White corrective procedure generated statistically consistent results with the original estimation, except that the "Number of Cattle" variable was reduced to critical level of significance ($p<0.25$). Subsequent testing indicated that heteroskedasticity was still a concern.

Since the source of heteroskedasticity was most likely in either the "Area" or the "Number of Cattle" variable, an estimation weighted by "Area" was undertaken. In this estimation, all variables were highly statistically significant and some 92 percent of the variability in the dependent variable was explained. Heteroskedasticity was detected, however, while the White correction reduced the "Number of Cattle" and "Number of People" variables to borderline statistical insignificance, heteroskedasticity remained a concern in the White-corrected Area-weighted estimation.

The model was re-estimated by weighting the series with "Number of Cattle" and "Area." The estimated relationship explained 93.8 percent of the variability in the dependent variable, cultivated pasture, and resulted in a high degree of significance in all descriptive variables. Correction for heteroskedasticity reduced the estimated statistical power of "Number of People" and "Number of Cattle" to insignificance ($p<0.33$ and $p<0.19$, respectively). Although heteroskedasticity remained a concern, the "Number of Cattle"- and "Area"-weighted, White-corrected, estimated relationship is used for interpretation based upon the strength of its predictive relationship with the dependent variable (Table 2).

Table 2: Wealth and deforestation in the Brazilian Pantanal, Regression results.

Cultivated Pasture (ha) =	Coefficient	Std. Error	t-Statistic	Prob.
Intercept	2449.19	3636.45	0.67	0.5006
Area (ha)	0.22	0.03	7.01	0.0000
$Area^2$ (1000 ha^2)	-0.0019	0.00	-7.34	0.0000
$Area^3$ (100,000 ha^3)	0.0000004	0.00	6.60	0.0000
Cattle (#)	0.18	0.14	1.31	0.1914
$Cattle^2$ (1000s)	-0.02	0.00	-3.28	0.0010
$Cattle^3$ (100,000s)	0.00037	0.00	6.10	0.0000
Land Gini	14855.73	8572.96	1.73	0.0832
Cattle Gini	-17110.19	9293.32	-1.84	0.0656
State (0,1)	-1406.47	705.93	-1.99	0.0464
Subregion (0,1)	2030.97	703.49	2.89	0.0039
Native Pasture (%)	-6872.97	1047.88	-6.56	0.0000
People (#)	13.17	13.59	0.97	0.3326
Tractors (#)	226.19	80.82	2.80	0.0051
R-squared	0.94		F-statistic	6514.768
Adjusted R-squared	0.94		Prob F	P<0.0000

Note: White corrected, area and cattle weighted.

Cattle and Land Wealth

Evaluated at the mean values for the dataset, an increase in the size of a parcel by 100 ha implies a 21.88 ha increase in deforestation for cultivated pasture. An increase of 100 head of cattle implies a 17.53 ha increase in cultivated pasture. Notwithstanding the lack of statistical significance and the high rate of correlation between the variables, a 1% increase in the concentration of land wealth implies an increase of 148.55 ha of cultivated pasture, while a similar increase in cattle wealth implies a 171.10 ha decrease in land deforested for cultivated pasture. Potentially, it may be interpreted that the joint effect of a 1% increase in wealth concentration implies a 22.55 ha decrease in deforestation pressure for cultivated pasture.

Location

Presence in the northern state of Mato Grosso, rather than Mato Grosso do Sul, implies 1,406 ha fewer of cultivated pasture. Ranches in the north are substantially smaller than those located in the south on average, potentially explaining this result. Location in the Pantanal wetland rather than the Planalto highlands implies a 2031 ha increase in cultivated pasture. Planalto ranches are more often used for fattening cattle, requiring intensification of the feeding operation, rather than the extensive management predominant in the cow-calf operations of the Pantanal. As a result, Planalto lands are more commonly planted in row crops than in pasture for forage.

Productive Inputs

Notwithstanding the fact that the White correction left the coefficient on "number of people" insignificant by conventional standards, an increase in available labor on a parcel implies greater deforestation pressure. The presence of an additional tractor, a potential proxy for intensification or capitalization of the ranching enterprise, implies a 264 ha increase in cultivated pasture. A one percent increase (53 ha, when evaluated at the mean) in the proportion of the total parcel in native pasture, a substitute for cultivated pasture, implies a 68.73 ha decrease in deforestation pressure for cultivated pasture. Potentially, this may be interpreted to imply that native pasture provides about 20% greater economic returns than cultivated pasture due to productivity differences as well as establishment and maintenance costs.

Environmental Kuznets Curve

Rather than the expected quadratic ("inverted U") shaped relationship, a cubic polynomial, or "N shaped," relationship between deforestation and land and cattle wealth is revealed in this estimation. Results were somewhat stronger in describing the relationship between land wealth and deforestation pressure than cattle wealth and deforestation. The turning points in the relationships are found at 5,216 and 30,857 cattle and 70,525 and 281,453 hectare parcels (Table 3). Some 6119 parcels, accounting for more than ½ of the total cattle, have fewer cattle than the first turning point. More than 6500 parcels, comprising more than 90% of the total land area have less land than the first turning point, indicating that the great majority of operations are increasing deforestation pressure. Some 437 operations, constituting about 45 percent of the total stock of cattle, are found in stage two of the EKC curve, where deforestation pressure is expected to diminish. However, only 26 operations and 8% of the land are in stage two, if the land wealth results are used for interpretation. Only one parcel exceeds the second size threshold and seven report more cattle than the second cattle turning point, where deforestation pressure is expected to increase again (Table 3). In support of the proposed hypothesis, these results imply that relatively smaller operations are more closely associated with deforestation for implanting pasture than are larger operations. However, contrary to the original hypothesis, results indicate that very large operations are also more likely associated with higher levels of deforestation pressure than are large operations. Results also indicate that the wealth threshold at which deforestation is expected to decline is far from modest relative to the average land and cattle wealth in the region.

Table 3: Regression results, Cattle and land above and below EKC thresholds

Stage of EKC Curve	Cattle Wealth Turning Points (#)	Parcels with Cattle (#)	% of total cattle	Land Wealth Turning Points (ha)	Land in Parcels (ha)	% of total area
Stage 1	<5,216	6119	51.4	<70,525	6536	90.6
Stage 2	5,217-30,857	437	44.9	70,526-281,453	26	8.3
Stage 3	>30,858	7	3.7	>281,454	1	1.0

Discussion

The environmental Kuznets curve (EKC) hypothesis proposes that there is an inverted U-shape relation between environmental degradation and income per capita. However, the body of published research provides limited insight into the causes that make the pollution curb downward after particular income levels because only income factors are traditionally included as explanatory variables (de Bruyn *et al.* 1997; Grossman and Krueger 1996). As a result of this potential omitted variable bias, evidence of an EKC has been taken to imply that economic growth will eventually redress the environmental impacts of the early stages of economic development.

Results point to a relationship between wealth indices and deforestation pressure in the Brazilian Pantanal. However, policy prescriptions do not fall out of the model as easily as descriptive information. Since the topic of the EKC is pollution, usually a productive externality, economic solutions including public policy are expected to play a part in the relationship. Demand-driven environmental policy, or induced innovation, is more likely to derive from a relatively wealthy populace interested in welfare enhancing activities other than income generation. In addition, higher average incomes do not, in and of themselves, correlate with greater demand for environmental policy. Higher average income coupled with relative parity in political power has been shown to correlate with such demands.

Moreover, indirect stakeholders (local, regional, national and international) may have more concern (greater unrequited demand) about Pantanal deforestation than local cattle ranchers do. At the local level, downstream effects on fishing and tourism would need to be internalized to rancher's decision-making through policy to economically rationally change deforestation behavior. Further, increased cattle prices should increase deforestation pressure assuming that cattle ranchers approach profit-maximizing behavior. On the other hand, increased tourism and sustainable harvest of extractive forest products should decrease deforestation pressure. Interestingly, decreased seasonal flooding fomented by a hotly contested dredging project should decrease regional deforestation pressure. This analysis can hope to inform local decision-making by better describing the relationship between deforestation and cattle ranching. However, appropriate policy prescriptions require a great deal more information than can be provided through such an analysis.

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