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The spatial econometrics of elephant population change

A note

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IMPRESSUM

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Abstract

While previous research found no other variable than corruption to have a negative impact on (the growth rate of) the African countries' elephant populations, we show that one further significant impact is exerted by what one might call neighbourhood effects. Elephants travel long distances, often crossing borders. Using spatial econometric tools, we find that elephant population changes in one country have a positive impact on elephants in neighbouring countries. Our results have possible policy implications, as they suggest that the spatial clustering of funds and of conservation efforts makes sense if the endangered species move across borders.

Keywords: Elephants, Spatial econometrics, Corruption and Ecology

JEL Classifications: Q20 and R15

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1 Introduction

The African Elephant compete with men for natural resources, and is a species much sought after by poachers. Hence at times its extinction was considered as likely, and the conservation of the African Elephant and its habitats is still on the political agenda. A traditional research task which is closely related is the estimation of the size of elephant populations. More recently there has also been a most interesting attempt to provide statistical evidence on the causes of elephant population changes. In Smith et al. (2003) it is shown that corruption has a negative impact on (the growth rate of) the African countries' elephant populations. They did not find significant control variables - e.g., the GDP per capita was insignificant. In this paper, we show that one further significant impact is exerted by what one might all neighbourhood effects.

Searching for new food and water resources, elephants travel long distances. Using GPS (Global Positioning System) techniques, elephants have been tracked who walked up to 55 km in 24 hours, covering an area of 20,000 km^2 in 500 days (Blake et al., 2003), though some elephants show less wanderlust (Galanti et al., 2000). In any case, they often cross political borders[1]. The nature of the resulting effects does not allow standard regression techniques to be applied. Hence, we use spatial econometric tools.

2 Hypotheses

Our basic idea is this: Elephants move, and they move across borders. This results in three possible links between elephant population changes in neighbouring countries:

First, if they move from country A to country B and do not return to A because they are poached in B, then the conditions in B have an impact on the elephant population growth rate in A.

A second mechanism linking A and B might be this: If elephants are poached, then food resources for elephants migrating from B increase, and that might keep these elephants from returning to A.

[1] Cf. the maps of known African elephant ranges in Blanc et al. (2003) or the case study by Okoumassou, Barnes and Sam (1998).

Third, it might be that elephants react to sustained poaching by crossing international borders - leading to increased populations in neighbouring countries.[2]

Whereas the first two hypotheses suggest a positive relation between elephant population changes of neighbouring countries, the third suggests a negative one, and it is not ex ante obvious what we will observe.

3 Method

In what follows, we mainly use the data from Smith et al. (2003), as provided on *Nature's* home page[3]. They report elephant population change rates for 1987 to 1994 in 20 African countries, with a minimum of -100 percent, a maximum of 62.7, and a median of -35.35. These 20 countries account for about 98 percent of the total African elephant population[4].

Unfortunately, we cannot estimate, by using simple OLS, the following regression equation:

$EPOPCH_i = a_0 + a_1 \cdot EPOPCH(N_i) + a_2 \cdot CPI_i$,

with $EPOPCH_i$ denoting country i's elephant population change, $EPOPCH(N_i)$ denoting the average of the population changes in the neighbouring countries, and CPI_i being corruption perception index. The regressand $EPOPCH_i$ has an impact on the explanatory variable $EPOPCH(N_i)$ as well as the latter on the former, which is why one speaks of "spatial autocorrelation". The error term is correlated with the explanatory variable $EPOPCH(N_i)$, hence OLS would lead to biased and inefficient estimates (Bao, 1999). In order to account for this problem properly, we need geographical information in addition to the elephant population data described above. Specifically, a distance weights matrix of the following type has to be used:

$$W_{ij} = \frac{1/w_{ij}}{\sum_j 1/w_{ij}}$$

Above w_{ij} is a measure of the distance between country i and country j. The variable W_{ij} is therefore a function of the inverse of the distance between country i and j. This inverse

2 We owe this observation to Robert J. Smith.

3 http://www.nature.com/nature/journal/v426/n6962/extref/nature02025-s1.pdf

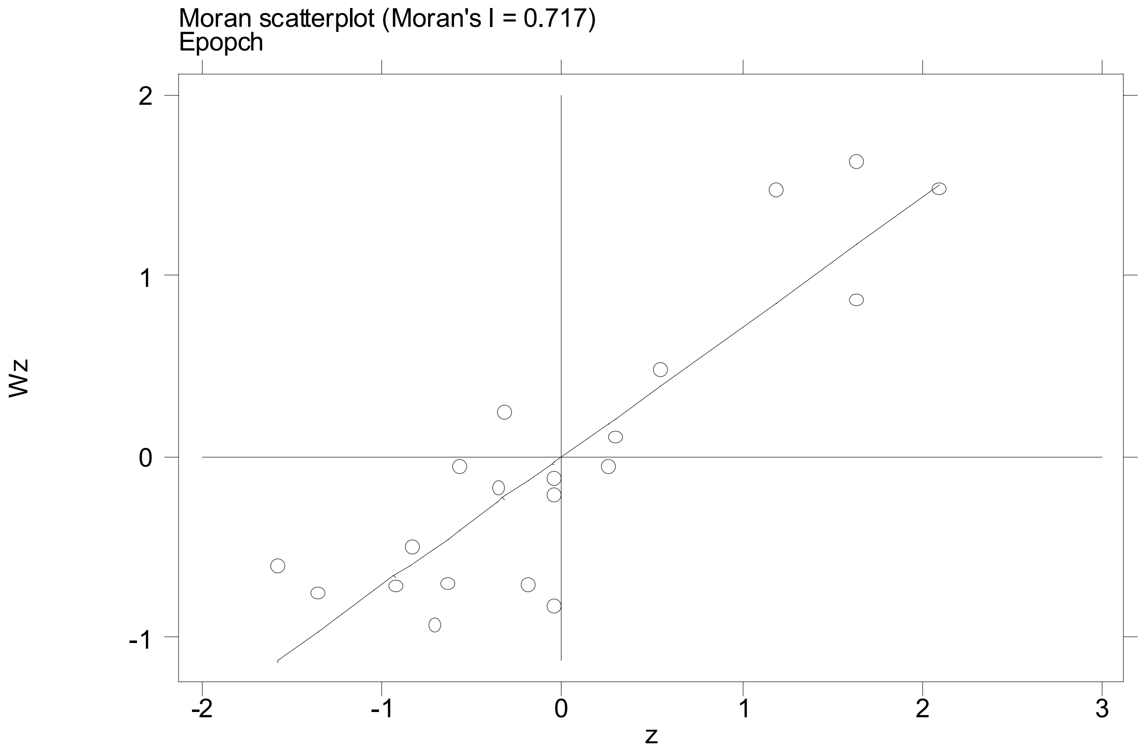
4 Calculated from Blanc et al. (2003). The countries included are: Botswana, Cameroon, Congo, Cote d'Ivoire, DRC (Zaire), Ethiopia, Gabon, Ghana, Kenya, Malawi, Mozambique, Namibia, Nigeria, Somalia, South Africa, Sudan, Tanzania, Uganda, Zambia and Zimbabwe.

distance measure is normalised with the sum of all such distances between country i and the other countries. This 'row-standardisation' makes it possible to construct weighted averages. In spatial econometrics analyses, the hypothesis is very often that a variable in one region will influence on a variable in another region as a negative function of the distance between the two regions. This is what the variable W_{ij} expresses. The distance variable, w_{ij}, can be constructed in different ways. Often geographical distance is used. Here we use contiguity between countries. That is, spatial spillovers are measured on the basis of neighbourhood between countries. Consider country j's elephant population change, $EPCH_j$ (normalised as deviations from the mean). For country i the variable

$$EPCH_i = \sum_j W_{ij} EPCH_j$$

denotes the weighted average of that country's neighbours' elephant population change.

Figure 1



In figure 1 we graph this variable against each countries' performance in the same variable. These plots are called Moran scatter plots. Observations in the northeast quadrant represent countries with both a relatively high elephant population change and neighbours who are similar in this respect. Likewise, the third quadrant shows countries with a below-the average elephant population change, and with neighbours who also do not seems to offer favourable conditions for this species. Clearly more dots are located in the first and in the third sector than in the other two, hence a simple regression has a positive slope.

A counterpart of the regression line is the so-called "Moran's I", the most common measure for spatial autocorrelation. Moran's I is 0.717 and significant at the 99 percent level.

This correlation is a *gross correlation* in the sense that we did not take into account how elephant population change is influenced by another variable - corruption. For example, what seemed to be positive neighbourhood effects might rather be a mere reflection of a spatial pattern of corruption. The spatial weight matrix W_{ij} can be used in regression-based explorations, i.e., when control variables are considered. There are two basic approaches on how to integrate spatial correlation into regression techniques, spatial lag models and spatial error models, but here we only use the former one, which has to be estimated by means of a maximum likelihood procedure (see, e.g., Anselin, 1992).

4 Results

Table 1 reports our main results. Beginning from the bottom of the table, the squared correlation and the variance ratio are two quasi R^2 statistics indicating that a relatively high percentage of the variance can be explained. Rho is the estimated coefficient of neighbourhood effects. It is positive and significant , hence controlling for corruption leaves the initial result about neighbourhood intact. However, corruption is also highly significant, but the coefficient has only half of the size that is estimated when we simply regress a elephant population change on corruption without considering neighbourhood effects, see table 2.

Table 1
Effects of corruption and neighbourhood on elephant population change

	Coef.	Std. Err.	z	P>|z|
cpi	13.49251	4.986211	2.71	0.007
constant	-55.72711	19.99991	-2.79	0.005
rho	.6404541	.1406262	4.55	0.000

Wald test of rho=0: chi2(1) = 20.742 (0.000)
Likelihood ratio test of rho=0: chi2(1) = 10.993 (0.001)
Variance ratio = 0.664 Squared corr. = 0.783

Table 2
OLS regression of elephant population change on corruption

Epopch	Coef.	Std. Err.	t	P>|t|
cpi	27.33386	6.062594	4.51	0.000
constant	-121.0664	21.37114	-5.66	0.000

N = 20, R^2 = 0.53

As a final check whether our results make sense, we have also applied methods described above to the change in natural forest cover in the same countries. As forests don't migrate across borders, we should not observe neighbourhood effects for forests. And indeed we don't (rho is clearly insignificant in table 3).

Table 3
Effects of corruption and neighbourhood on change in forest cover

	Coef.	Std. Err.	z	P>|z|
cpi	.0938317	.0645974	1.45	0.146
_cons	-.816207	.2841509	-2.87	0.004
rho	.2447276	.242802	1.01	0.313

Wald test of rho=0: chi2(1) = 1.016 (0.313)
Likelihood ratio test of rho=0: chi2(1) = 0.937 (0.333)
Variance ratio = 0.121
Squared corr. = 0.165

The result of table 3 also helps us to rule out the possibility that elephant populations are declining in neighbouring countries because of the fact that corruption levels are spatially autocorrelated, so countries that do not spend enough on anti-poaching strategies tend to share borders. While it is true that corruption is spatially autocorrelated (see Appendix 1), this mechanism is not strong enough to lead to spatial autocorrelation for forest cover. Furthermore, if our main result was due to spatial autocorrelation of corruption levels, controlling for the average level of corruption in the neighbouring countries, avneicpi, should lead to regression results which are substantially different from those reported in table 1. Yet this is not the case, see table 4. (With r = 0.35, the correlation between cpi and avneicpi is not so strong that multicorrelation would be a big problem.)

Table 4
Effects of corruption, neighbourhood and neighbouring corruption on elephant population change

	Coef.	Std. Err.	z	P>|z|
cpi	12.43573	4.890303	2.54	0.011
avneicpi	7.413634	4.394885	1.69	0.092
_cons	-81.30833	25.89923	-3.14	0.002
rho	.5708323	.1539477	3.71	0.000

Wald test of rho=0: chi2(1) = 13.749 (0.000)
Likelihood ratio test of rho=0: chi2(1) = 8.518 (0.004)
Variance ratio = 0.724
Squared corr. = 0.799

5 Conclusion

We find a marked positive correlation between elephant population growth rates between neighbouring countries. Hence our results provide evidence that the first two mechanisms described in section 2 dominate over the third. Our results have possible policy implications, as they suggest that the spatial clustering of funds and of conservation efforts makes sense if the endangered species move across borders. Although our statistical results are new, this kind of policy implication is evidently intuitive, as attempts in this direction have been implemented recently. The Biodiversity Support Program - a consortium of the World Wildlife Fund, The Nature Conservancy and the World Resources Institute - not only stressed the importance of Transboundary Natural Resource Management Projects, it also acknowledges wildlife migratory routes leading across political borders are acknowledges as a rationale (Griffin et al., 1999). For the same purpose, the government of Tanzania did commit itself to cooperating with its neighbours in conserving trans-boundary ecosystems (Mpanduji et al., 2002). Our analysis suggests that these efforts are well-founded.

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Appendix

Table A-1
Spatial autocorrelation of corruption levels, controlling for gdp per capita

	Coef.	Std. Err.	z	P>|z|
gdpcap	.0002729	.0001423	1.92	0.055
_cons	1.069353	.5356313	2.00	0.046
rho	.585548	.1548737	3.78	0.000

Wald test of rho=0: chi2(1) = 14.295 (0.000)
Likelihood ratio test of rho=0: chi2(1) = 8.631 (0.003)
Variance ratio = 0.387
Squared corr. = 0.579