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The spatial curse of natural resources

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Abstract

What are the macroeconomic implications of having a resource-rich neighbour? The voluminous literature on the curse of natural resources exclusively focuses on "domestic" effects; that is, how resource intensity in country *i* affects country *i*'s development. Still, there are good reasons to believe that the effects of natural resources can spread across the borders. This paper is a first attempt at understanding how the resources located in country *j* affect the income dynamics of its neighbour country *i*. Using a standard spatial econometrics approach, a measure of neighbourhood resource intensity is constructed for each of 147 countries. This measure, together with domestic resource intensity and a set of controls to account for the role of geography, culture, and institutional quality, is used as an explanatory variable in income and growth regressions. The main finding is that neighbourhood resource intensity reduces domestic income and growth, while domestic resource intensity has generally no negative effect. Interestingly, the negative spatial effect of natural resources becomes statistically less significant (and possible even insignificant) when neighbourhoods are characterized by higher income and better institutions. This in turn provides some ground for interpretation and policy recommendations.

Key words: spatial resource curse, income regressions, growth regressions

JEL Codes: O11, O13, O40, C31

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1. Introduction

Since the seminal contributions of Gelb (1988) and Auty (1993), the resource curse hypothesis has undergone careful empirical scrutiny and a number of recent papers conclude that resource intensity does not necessarily hamper development.[1] This paper departs from the conventional debate on the macroeconomic effects of natural resources by studying the resource curse hypothesis in a spatial context: what is the effect that natural resources located in country *j* have on the income dynamics of its neighbour country *i* ? Evidence from a cross-sectional dataset suggests that: (i) domestic income and growth decrease as resource intensity in the neighbourhood increases, (ii) this negative spatial effect of resources tends to become statistically less significant (or even insignificant) when neighbour countries are richer and/or institutionally more developed, and (iii) after controlling for resource intensity in the neighbourhood and other variables, domestic resource intensity does not significantly reduce domestic income and growth

The initial wave of research on the curse hypothesis used growth regressions of the type popularized by Barro (1991) to show that economies with a high ratio of natural resource exports to GDP tend to have low growth rates (Sachs and Warner 1999, Gylfasson et al. 1999, Sachs and Warner, 2001). This result has subsequently been challenged on different grounds. For one thing, it would appear that natural resources are not good or bad *per se*, but instead that their effect is conditional on some other factors, such as the quality of domestic institutions (Mehlum et al. 2006, Snyder, 2006, Andersen and Aslaksen, 2008, Collier and Hoeffler, 2009, Boschini et al. 2013), country's degree of ethnic fragmentation (Hodler, 2006), and the quality of country's disease environment (Carmignani and Chowdhury, 2012). For another, the findings from growth regressions tend to be quite sensitive to changes in the specification of the model and in the empirical definition of resource intensity (see, for instance, Stijns, 2005, Brunnschweiler, 2008, Brunnschweiler and Bulte, 2008, Alexeev and Conrad, 2009). The traditional view on the disruptive effect of natural resources has instead received new support from recent work by Arezki and Van der Ploeg (2011), Sala-i-Martin and Subramanian (2012), and Bhattacharyya and Collier (2014) who indicate that resource intensity distorts policy choices. Finally, a separate, but complementary line of research looks at how resource intensity can potentially affect human and social development (Bulte et al. 2005, Costantini and Monni, 2008, Gylfason, 2008, Carmignani and Avom, 2010, Carmignani, 2013).

The common denominator of all these papers is that they focus on the "domestic" effect of natural resources, meaning that they look at the impact of natural resources located in country *i* on country *i*'s development. To the best of the author's knowledge, no previous paper has studied the "spatial" effect of resource intensity;

[1] See inter alia, Brunnschweiler (2008), Brunsschweiler and Bulte (2008), Alexeev and Conrad (2009), Beny and Cook (2009), Weber (2013).

that is, the effect that resources located in country *j* have on country *i*'s economy. Yet, one can think of several mechanisms through which the effect of natural resources could spread across countries. Because of the uneven geographical distribution of natural resources, resource-rich and resource-poor countries often co-exist in the same neighbourhood. However, for a resource-poor country having a resource-rich neighbour might be a disadvantage. The resource-rich neighbour is likely to attract a disproportionate share of foreign investment, leaving its resource-poor neighbour with limited opportunities for external finance. Similarly, regional infrastructures such as motorways, ports, and airports could develop in a way that favours the resource-rich country at the expense of its neighbours. Also, a resource-poor country with weak institutions could be destabilized by conflict occurring in a resource-rich neighbour over the control of natural resources. On the other hand, one can also think of instances where the spatial effect of resources could be positive rather than negative. If natural resources foster domestic growth, then the resource-rich country could become a regional driver of development, for instance by financing development projects in the context of regional cooperation initiatives or by opening up new markets for neighbours' exports. Overall, the theoretical prediction about the sign (and size) of the spatial effect is ambiguous and hence the matter is worth investigating empirically.

This paper is a first attempt at understanding the spatial effect of resource intensity. Following a standard approach in spatial econometrics, a measure of "resource intensity in the neighbourhood"[2] is constructed using geographic information system (GIS) data on land borders. This measure is then added to the right hand side of income and growth regressions together with a measure of domestic resource intensity and several other controls. The regressions are estimated by ordinary least squares (OLS) and instrumental variables. Estimates are obtained for the full sample of all countries as well as various sub-samples characterized by more homogenous values of resource intensity and/or other controls. Overall, the evidence from both income and growth regressions are that the spatial effect of resources is negative. This result is generally robust to changes in model specification and estimation approach. The strength of the spatial effect of natural resources does not seem to depend on the initial values of domestic or neighbourhood resource intensity. However, it does seem to depend on the stage of economic and institutional development in the neighbourhood. This latter finding is more evident in income regressions. Lastly, domestic resource intensity does not appear to have any significant negative effect on either income or growth.

The rest of the paper is organized as follows. Section 2 presents the econometric model and deals with specification, measurement, and estimation issues. Results are reported in Section 3. Section 4 provides some discussion, policy recommendations,

[2] For the sake of brevity, this will be referred to as "neighbourhood resource intensity" in the rest of the paper.

and directions of future research. Variables definition, data sources, and summary statistics are reported in the Appendix.

2. Econometric model

2.1 Specification

A simple specification to test the spatial effect of natural resources is as follows:

$$(1)\ \ y_{2005,i} = \beta_0 + \beta_1 y_{1970,i} + \beta_2 r_{1970,i} + \beta_3 r_{1970,N} + \boldsymbol{c}'\boldsymbol{x_i} + \varepsilon_i$$

where *i* denotes a generic country in the sample and *N* denotes its neighbourhood, y_{2005} and y_{1970} are the level (in logs) of real per-capita GDP in 2005 and 1970 respectively, *r* is a measure of resource intensity (at the beginning of the sample period, i.e. 1970), $\boldsymbol{x}$ is a vector of control variables for country *i* and ε is a random disturbance. The βs and the ***c***s are the coefficients to be estimated; β_2 captures the effect of domestic resource intensity and β_3 represents the effect of neighbourhood resource intensity; that is, the spatial effect of natural resources.

Under the restriction $\beta_1 = 0$, model (1) is an income equation of the type generally estimated in the recent macro-development literature.[3] When β_1 is unrestricted, instead, model (1) becomes a standard growth regression. The income equation might be preferable as differences in long-run economic performance relevant to welfare are captured better by income levels than growth rates. Moreover, the low persistence of growth rates over time means that cross-country differences in growth rates are mostly transitory and hence that long-run differences in levels are the interesting fact to explain. However, most of the existing literature on the macroeconomic effects of natural resources uses growth equations. Therefore, in an effort to be as comprehensive as possible, this paper will estimate both the restricted and the unrestricted version of equation (1). As it turns out, results are quite similar across the two specifications.

The set of controls $\boldsymbol{x}$ is parsimoniously specified to represent three fundamental determinants of economic development: geography, institutional quality, and culture. The two proxies for geography are country *i*'s distance from the equator (*latitude*) and a dummy variable for landlocked countries. Latitude is generally used to capture climatic conditions that can have an impact on productivity and health: greater distance from the equator is assumed to have a positive impact on income and growth. Landlockedness instead is likely to be an obstacle to development as it reduces the

[3] See, for instance, Hall and Jones (2001), Acemoglu et al. (2001), Rodrik et al. (2004), Glaeser et al. (2004), Nunn (2008), Battacharrya, (2009), Alexeev and Conrad (2009), Carmignani and Chowdhury (2012), and Nunn and Puga (2012)

extent to which a country can integrate into the global economy and benefit from the circulation of ideas and knowledge.

Measuring culture is a rather challenging task. While country surveys of values and beliefs now provide a useful source of information, their coverage of developing countries is still limited, at least for the purpose of estimating a cross-country regression like (1). Therefore, cruder, but more widely available indicators have to be used in this paper. One such indicator is country's degree of ethnic fragmentation. Rivalries between ethnic groups are a source of conflict and mistrust. This implies that more ethnically fragmented countries have less social capital and this is likely to hamper their development process. Another useful indicator is the proportion of population speaking English. In a world where English is the global language of trade, science, business, and communication, a larger fraction of English speaking population can facilitate the mixing between local and foreign cultures, thus leading to forms of diversity and pluralism that recent work has found to be instrumental to long-term development.[4]

Institutional quality is measured by an index of institutional checks and balances from Beck et al. (2002). Several alternative indicators are also available, including the measure of protection against the risk of expropriation popularized by Acemoglu et al. (2001), various indices of quality of the polity available from the Polity IV database, the indicators of governance quality assembled by Kaufmann et al. (2010), and the measure of contract intensive money computed by Clague et al. (1999). However, it turns out that when these other measures are used in place of the index of checks and balances, estimation results are qualitatively unchanged.

Two final remarks on the specification of the controls are in order. First, all the controls are either time invariant or measured at the beginning of the period of observation (i.e. 1970 or immediately afterwards), so to reduce the risk of reverse causality. This however might not completely eliminate the endogeneity of a variable like institutional quality. As discussed below, instrumental variables will be used to account for this residual endogeneity. Second, there are of course other variables in addition to those listed above which could affect income or growth. However, the purpose of this paper is not to maximize the R^2 of the regression, but to examine whether resource intensity in the neighbourhood has any effect on the domestic economy. Therefore, what really matters is that the specification does not omit variables that jointly drive income or growth in country *i* and resource intensity in the neighbourhood of country *i*. This is unlikely to be the case for some standard proximate determinants of growth like the domestic rate of investment, government expenditure, and trade openness. As a matter of fact, when included as regressors in model (1), these proximate determinants do not affect the results on neighbourhood

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[4] See Alesina and La Ferrara (2005), Ottaviano and Peri (2006), Ager and Bruckner (2011)

resource intensity.[5] The omission of "neighbourhood" variables might instead have more significant consequences and for this reason, in the sensitivity analysis, the specification will be extended to include the average levels of per-capita income and institutional quality in the neighbourhood. As discussed in the next section, these variables produce significant conditional effects; that is, the strength of the spatial effect of natural resources depends on income and institutional quality in the neighbourhood. Finally, in order to allow for regional differences in the pace of economic development, a set of regional dummy variables (for Latin America, Asia, Africa, and Eastern Europe) are added to the specification.

2.2 Measurement issues

Estimating equation (1) requires an empirical definition of resource intensity for both the domestic country *i* and its neighbourhood *N*. This in turn involves two issues: (i) measuring resource intensity and (ii) determining the neighbourhood of a country. With respect to the first issue, several approaches have been explored in the literature. Early contributions used export-related measures of natural resources, such as the share of country's primary commodity exports in GDP or in total exports. These measures might however provide an inaccurate representation of country's actual endowment of natural resources. To see why, consider that the export structure of a country depends on its stage of economic development. Less advanced countries, which tend to have a lower GDP, export more of their resources, while developed countries consume more of their resources domestically. Therefore, for given initial endowment of resources, export-related measures are likely to be higher for developing countries. This also implies that when used to estimate a regression like (1), export-related measures bias the estimation results, artificially creating a resource curse effect. To overcome these limitations, subsequent research has made use of more direct measures of endowments or production. For instance, Sala-i-Martin et al. (2004) present measures of hydrocarbon deposits and mining output per-capita. Similarly, Alexeev and Conrad use data from the BP Statistical Review (2005) to construct measures of the value of oil output. World Bank (1997 and 2005) reports some estimates of the monetary value of natural resource stock for a broad sample of countries. These data have been used in several recent papers,[6] but they are not immune from criticisms. In particular, for countries where reserves data are not available, the World Bank computes natural assets value by multiplying current resource rents by twenty. However, rents are affected by economic policies and outcomes, implying that in an equation like (1) natural assets measures are endogenous to income. A similar point can be made for the adjusted net savings data reported by World Bank (2007).

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[5] These results are available from the author upon request.
[6] Gylfason (2001), Ding and Field (2005), Hodler (2006), Stijns (2006), Brunnschweiler (2008), Brunnschweiler and Bulte (2008), Arezki and van der Ploeg (2010), Carmignani and Chowdhury (2012).

In a recent contribution, Normann (2009) develops a measure that minimizes the risk of endogeneity. She estimates stocks of natural resources in 1970 by adding past production to the level of reserves estimated in 2002, so that any resources not mapped or included in stocks in earlier periods but present and mapped subsequently are included. With this approach, the only residual source of endogeneity is that past production depends on technology, whose availability in turn depends on economic performance. However, as noted by Van der Ploeg and Poelhekke (2010), even a very economically successful country that employs the most advanced technologies will produce no resources if there are no natural assets in its subsoil. The fact that natural assets are randomly distributed across countries then means that Normann's measure is essentially exogenous to economic outcomes. Drawing on these considerations, $r_{1970,i}$ is set equal to Normann's estimated stock of oil, coal, gas and mined minerals divided by total GDP in 1970.

Having settled the first measurement issue, the second issue – defining the neighbourhood – can be approached by drawing on tools from the spatial econometrics literature. Let *M* be the total number of countries in the sample. In general, resource intensity in the neighbourhood of country *i* is defined as the weighted sum of domestic resource intensity in the *M* countries:

$$(2)\ r_{1970,N} = \sum_{j=1}^{M} w_j r_{1970,j}$$

where *j* is a generic country different from the domestic country *i* and w_j is a non-negative weight. For computational purposes, it is convenient to normalize weights such that $\sum_{j=1}^{M} w_j = 1$. The problem of defining the neighbourhood then amounts to choosing a value for w_j.

A first option is to include in the neighbourhood of country *i* only countries that are contiguous to country *i*. In this case contiguous means that country *i* and country *j* share a border. Alternatively, the neighbourhood of country *i* can be defined to include all countries (contiguous or not) that fall within a certain distance from country *i* (e.g. 1000 km radius from country *i*). Conceptually, both options have their merits and disadvantages. Operationally, the second option generates results that are quite sensitive to the distance radius chosen to determine the neighbourhood. In fact, in the specific case of this paper, different choices of radius do not affect the essence of the results on the spatial effects of resources. Still, estimated coefficients quite sharply change when changing the radius. For this reason, the next section reports resulted obtained from a definition of neighbourhood based on contiguity. Results obtained from definitions of neighbourhood based on different choices of radius are available upon request.

In conclusion, w_j in equation (2) is computed as:

$$(3)\ w_j = \frac{l_{i,j}}{\sum_j l_{i,j}}$$

where $l_{i,j}$ is the length of the land border between country i and country j. This definition implies that resource intensity in country j is weighted by the relative length of its land border with country i. Therefore, countries that do not share a land border with country i are excluded from the neighbourhood. It might be objected that countries sharing a sea border with country i should also be considered as neighbours of that country. However, sea borders could lead to a counter-intuitive definition of neighbourhood for those countries that have overseas territories. For instance, if contiguity were defined using sea borders, then the neighbourhood of the United States would include countries like Japan, Samoa, New Zealand, Tonga, and the Netherlands. With such a vast and dispersed neighbourhood, the economic interpretation of results would become much more ambiguous.

2.3 Estimation

Given the definition of neighbourhood resource intensity given in equations (2) and (3), equation (1) can in principle be estimated by OLS if the other independent variables are effectively exogenous. As noted previously, all variables are time invariant and/or measured at the beginning of the sample period, which should prevent endogeneity due to reverse causality. However, one cannot exclude possible endogeneity of institutional quality and per-capita GDP due to omitted variables. To account for this potential residual endogeneity of institutional quality, instrumental variables estimates will also be reported in the next section. This brings up the question of finding appropriate instruments for institutional quality. Two approaches can be followed. One is to identify a suitable source of exogenous variation in institutional quality; that is, an exogenous variable that is correlated with institutional quality and that affects income or growth only through its effect on institutional quality. The alternative is to apply an estimation procedure that internally generates instruments. Both approaches are considered below.

In the comparative development literature, some of the most commonly used instruments for institutional quality are: country's legal origins, ethnic fragmentation, share of population speaking English (or a European language), settler's mortality rate, and share of population at risk of malaria (or share of population living in temperate areas). In the case of regression (1), ethnic fragmentation and share of population speaking English are already included as controls and hence cannot be used as instruments. Also, data on settler's mortality rate are available for a relatively small number of countries, which would imply a considerable loss of degrees of freedom in estimation. This leaves legal origins and malaria risk as two possible external instruments to be used. Legal origins are represented by two dummy variables, one that takes value 1 if country's law originates from the French Civil Code and one that takes value 1 if country's law originates from the Socialist/soviet law. For malaria risk, rather than the share of population that live with risk of malaria transmission, which might still be endogenous to per-capita income, the malaria ecology index of Kiszewski et al. (2004) is used (see also Sachs, 2003 for a discussion).

In general, external instruments that satisfy the fundamental properties of orthogonality and relevance required for estimates to be valid are often difficult to find. A methodological alternative is to apply an estimation procedure that automatically generates internal instruments. Arellano and Bond (1991), for instance, design an estimator procedure where lagged values of the endogenous variables are efficiently used as instruments. This procedure however requires panel data and therefore it cannot be applied to a purely cross-sectional equation like model (1). Lewbel (2012) proposes a method to identify structural parameters in regression models with endogenous regressors that does not require repeated measurements. With this method, identification is achieved by having regressors that are uncorrelated with the product of heteroskedastic errors. This is a feature of models where error correlations are due to an unobserved common factor, which is exactly the type of potential residual endogeneity that characterizes equation (1). These heteroskedasticity-based instruments can then be used as single instruments for the exogenous variables or to supplement existing external instruments.

Given that candidate external instruments are available, the pragmatic approach taken in this paper is to present three sets of instrumental variables estimates: one obtained from external instruments (legal origins and malaria ecology) only, one obtained from Lewbel's internally generated instruments only, and one obtained from using both external and internally generated instruments. Each set of estimates will be accompanied by a battery of diagnostics to test the strength and exogeneity of the chosen instruments. The Kleibergen-Paap LM and Wald F statistics are tests of underidentification and weak identification, respectively. For the LM statistic, the null hypothesis is that the equation is under identified. Standard p-values are reported together with the statistic and a rejection of the null indicates that the model is identified. For the Wald statistic, critical values are not tabulated and the general rule of thumb is that the statistic should be greater than 10 for weak instruments not to be a problem.[7] The Hansen J statistic is a test of over identifying restrictions. The joint null hypothesis of the test is that instruments are uncorrelated with the error term and that the excluded instruments are correctly excluded from the estimated equation. A non-rejection of the null therefore suggests that the instruments are valid.

[7] When errors are iid, then the test of weak identification is based on the F version of the Cragg-Donald Wald statistic. Critical values for this statistic are reported by Stock and Yogo (2002, 2005). However, when errors are not iid, the Cragg-Donald statistic is no longer valid and the Stock and Yogo critical values cannot be automatically applied to the Kleibergen-Papp Wald F statistic. The rule of thumb goes back to Staiger and Stock (1997)

3. Results

3.1 Baseline

Baseline estimates for the income regression (i.e. $\beta_1 = 0$) are reported in Table 1. Estimation is by OLS in columns I-IV and by instrumental variables in the remaining columns. In Column 1, ***c*** is also restricted to be zero, so that the only regressors are the constant term, domestic resource intensity, and neighbourhood resource intensity. The evidence points to a negative and significant spatial effect of natural resources while the domestic effect is not different from zero. Adding regional dummies (column II) and controls for geography and culture (column III) does not alter this central result. It is worth noting that the coefficients of all the controls have the expected sign and are rather precisely estimated. The inclusion of institutional quality (column IV) does not produce any qualitative change with respect to the effect of neighbourhood resource intensity. However, it does make the coefficient of domestic resource intensity statistically significant at the 10% confidence level. Furthermore, the coefficient of the English speaking population variable is now no longer significant, thus suggesting that this variable is probably collinear with institutional quality. The instrumental variables estimates shown in the remaining columns of Table 1 are qualitatively very similar to the OLS results and confirm the existence of a “spatial curse” of natural resources (but not a traditional curse). The diagnostics reported at the bottom of the table suggest that instruments perform reasonably well, even if the relatively low Wald F statistics might be indicative of a weak identification problem; that is, a situation where the correlation between institutional quality and its instruments (external and/or internal) is not too strong.

Table 2 reports the same baseline estimates as Table 1, with the difference that now β_1 is not restricted to be zero. This means that model (1) is estimated as a growth regression. The estimated value of β_1 is strongly significant, but also smaller than one, in line with the hypothesis of conditional convergence embedded in the neo-classical theory of growth. The estimated coefficients of all the other variables retain their sign as in Table 1, but they are less precisely estimated and several of them fail to be significant at usual confidence levels. Nevertheless, the negative spatial effect of natural resources continues to be different from zero, at least at the 10% level, while the effect of domestic resource intensity is never significant. This finding therefore confirms that there is an important spatial dimension to the curse of natural resources. Interestingly, external instruments seem to provide stronger identification of the estimating equation than the heteroskedasticity-based instruments.

All of the above results are robust to the exclusion of very high values (i.e. top 10%) of domestic and neighbourhood resource intensity. Moreover, when the sample is split on the basis of values of domestic and neighbourhood resource intensity, the pattern of estimated coefficients is unchanged and neighbourhood resource intensity continues to be negative and significant at the 5% confidence level and domestic resource intensity is positive, but statistically insignificant. These results suggest that the spatial effect is linear in the degree of neighbourhood resource intensity and does not depend on the degree of domestic resource intensity. However, a more systematic analysis of the possible interactions between domestic and neighbourhood resource intensity would be an interesting avenue for future research.

3.2 Extensions

With the exception of the dummy variables for continents, the regression model estimated in the Tables 1 and 2 only controls for domestic factors. However, it might be argued that other spatial dynamics might contribute to shaping the effect of neighbourhood resource intensity. This could happen in two ways. First, the average stage of economic and/or institutional development in the neighbourhood might affect domestic income or growth and simultaneously be correlated with neighbourhood resource intensity. If this is indeed the case, then the omission of these other spatial dynamics from the estimating equation could bias the estimate of β_2. The direction of this bias is difficult to establish a priori, but if one believes that a more economically and institutionally advanced neighbourhood would facilitate domestic development, then the model would underestimate the negative effect of neighbourhood resource intensity. Second, in the same way as the domestic effect of natural resources on income and growth might be conditional on a factor like domestic institutional quality, the effect of neighbourhood resource intensity might depend on the stage of economic and institutional development in the neighbourhood. Intuitively, if countries in the neighbourhood have better institutions or higher income, then the fact that they are also resource rich should be less of a problem for the domestic country. In other words, the potential for a spatial curse of natural resources should be smaller in economically and institutionally advanced neighbourhoods.

To test the relevance of these hypotheses, Table 3 reports a number of extensions of the baseline estimates of the income regression. In column I, the set of regressors includes two additional spatial variables: neighbourhood income per-capita and neighbourhood institutional quality. Similarly to neighbourhood resource intensity, these variables are defined as the weighted average of domestic income per-capita and institutional quality in the countries that share a land border with country *i*. Column I shows OLS estimates, but instrumental variables are very similar. The coefficients of the two new spatial variables are largely insignificant at usual confidence levels while the size and statistical significance of the coefficient of neighbourhood resource intensity are substantially the same as in Table 1 (see column V). Hence, it appears that the inclusion of neighbourhood income and neighbourhood institutional quality as control variables does not alter the strength of the spatial effect of natural resources.

In Columns II and III the baseline model is estimated on two separate sub-samples: rich neighbourhoods (column II) and high institutional quality neighbourhoods (column III). These sub-samples are identified from values of the neighbourhood income and neighbourhood institutional quality variables. The sample in Column II only includes observations such that neighbourhood income is above its sample median and the sample in Column III only includes observations such that neighbourhood institutional quality is above its sample median. The effect of neighbourhood resource intensity remains negative, but the coefficient is no longer statistically different from zero. To some extent, this might be due to the decline in the number of observations, which reduces the precision of estimates. However, the sub-samples of poorer and less institutionally advanced neighbourhoods have a similar number of observations, but the coefficient of neighbourhood resource intensity is negative and strongly significant. This suggests that there is indeed quite a relevant difference in the spatial effect of natural resources between the two sub-samples: when the neighbourhood consists of countries with higher income and better institutions, resource intensity in the neighbourhood is less of a curse (or even ceases to be a curse). Conversely, the positive effect of domestic resource intensity becomes statistically stronger when neighbourhoods are richer and/or have better institutions. Instrumental variable estimates confirm these results for both sub-samples (Columns IV for rich neighbourhoods and Column V for neighbourhoods with good institutions). As it can be seen, the instrument diagnostics are particularly good, including the Wald F statistics which is now well above ten.

Table 4 reports the same extensions as Table 3, but for a version of model (1) where β_1 is not restricted to be zero. Similarly to what is observed for the income regression, the inclusion of the two spatial variables for income and institutional quality does not significantly alter the negative effect of neighbourhood resource intensity (see Column I). However, unlike the income regression, the coefficients of both neighbourhood income and neighbourhood institutional quality are significant. Interestingly, the one of neighbourhood income is negative, suggesting some form of crowding-out in regional development. This is another issue that will deserve more attention in future work. Turning to the estimates by sub-samples, it is now unclear to what extent economic and institutional development in the neighbourhood condition the effect of neighbourhood resource intensity on growth. On the one hand, the OLS estimates (Columns II and III) suggest that in richer and more institutionally advanced neighbourhoods, the negative spatial effect of resource intensity ceases to be significant, as it was the case with the income regressions of Table 3. On the other hand, the instrumental variables estimates (Columns IV and V) tell a somewhat different story, with the coefficient of neighbourhood resource intensity that remains negative and statistically significant, albeit at the 10% only. Another difference from the income equation results is that in the growth regressions, the coefficient of domestic resource intensity never passes a zero restriction test.

All in all, the extensions considered in this subsection produce two bits of evidence. First, the sign and strength of the effect of neighbourhood resource intensity on domestic growth and income are not altered by the addition of neighbourhood income and neighbourhood institutional quality as controls. Second, the negative effect of neighbourhood resource intensity becomes statistically weaker (and possibly even insignificant) when neighbourhoods are characterized by higher income and better institutions. However, this decrease in the statistical significance of the coefficient β_3 is more evident in income regressions than in growth regressions.

4. Discussion and conclusions

This paper investigated the spatial dimension of the curse of natural resources. Using a standard spatial econometrics approach, a measure of neighbourhood resource intensity was constructed for a large sample of countries. This measure was then included as a regressor in income and growth regressions. The model also included a measure of domestic resource intensity and a set of controls to account for the role of institutions, geography, and culture. The regression was estimated by OLS and instrumental variables to account for the possible endogeneity of institutional quality. In order to assess the impact that other spatial dynamics might have on the spatial effect of natural resources, measures of per-capita GDP and institutional quality in the neighbourhood were added to the baseline regression. The model was also separately re-estimated on sub-samples of rich and more institutionally advanced neighbourhoods.

The key results of this exercise can be summarized as follows. The effect of neighbourhood resource intensity on domestic income or growth is negative and statistically significant. This finding points to the existence of a "spatial curse of natural resources". However, the statistical significance of this spatial curse declines (and possibly vanishes) when the neighbourhood is characterized by higher levels of per-capita income and/or institutional quality. This decline in statistical significance is more evident in income regressions. After controlling for the effect of neighbourhood resource intensity, domestic resource intensity generally has no significant effect on income and growth. There is however some evidence that domestic resource intensity has a positive effect on income when the neighbourhoods are richer and have better institutions.

To the best of author's knowledge, this is the first paper that looks at the spatial effect of natural resources. The finding that the curse lies in the neighbourhood rather than at home raises a number of policy considerations and opens up various avenue of future research, some of which have been already highlighted in the previous sections. From a policy perspective, it will be important to understand the transmission mechanisms of the spatial curse. The finding that the curse is statistically less significant when neighbourhoods are richer suggests that the problem is essentially one of unequal distribution of opportunities: when in proximity of a resource-rich country, then factors like foreign direct investment and infrastructure development will disproportionately benefit this country at the expense of the others. Another complementary transmission mechanism is probably regional stability and security. In less institutionally developed neighbourhoods, resource intensity is destabilizing in the sense that the fight over the control of these resources can more easily spread across the borders and hence adversely affect the development of the entire region. The finding that the neighbourhoods with better institutions produce a less significant (or even insignificant) spatial curse is consistent with this interpretation. In both cases (unequal distribution of opportunities and regional instability), the fundamental challenge for a country surrounded by resource-rich neighbours is to avoid being crowded-out. While there are policies that should be implemented domestically, for instance to make the country attractive to foreign investment or to prevent the spread of conflict from neighbour countries, the spatial dimension of the problem inevitably calls for regional responses. One such response is the introduction of a system of fiscal transfers to finance the development of regional infrastructures in the context of regional cooperation agreements. These agreements (which have become particularly popular among developing countries in Africa) can also play an important role in conflict prevention and peace keeping, thus contributing to stabilization of peace in the region.

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Appendix: Variables description, sources, and summary statistics

Name	Definition	Source	Mean	Std. deviation
Log per-capita GDP	Log of GDP per capita at constant prices in 2005 and in 1970	World Development Indicators	8.77 (2005) 8.26 (1970)	1.25 (2005) 1.091 (1970)
Neighbourhood resource intensity	Weighted average of domestic resource intensity in the neighbourhood of country *i*. The neighbourhood includes all countries that share a land border with country *i*. For each neighbour *j*, weights are equal to l_{ij}/l_i, where $l_{i,j}$ is the length of the land border between country *i* and country *j* and l_i is the total length of country *i*'s land border.	Author's calculations from data in Normann (2009) and GIS information.	47.92	147.91
Domestic resource intensity	Value of stock of coal, oil, gas, and minerals to GDP in the early 1970s	Normann (2009)	40.95	167.11
Latitude	Distance of capital city from the equator	La Porta et al. (1999)	.253	.176
Landlocked country	Dummy variable taking value 1 if the country is landlocked	Sala-i-Martin et al. (2004)	.170	.376
Ethnic fragmentation	Probability that two randomly selected individuals do not belong to the same ethnic group.	La Porta et al. (1999)	.359	.305
English speaking population	Fraction of total population speaking English	Rodrik et al. (2004)	.076	.240
Institutional quality	Index of checks and balances in 1970; higher values denote tighter checks and balances	Beck et al. (2002)	3.83	2.03
Neighbourhood per-capita GDP	Weighted average of log per-capita GDP in 1970 in the neighbourhood of country *i*. Neighbourhood and weights are defined as for the variable Neighbourhood resource intensity.	Author's calculations from World Development Indicators data	6.383	3.062
Neighbourhood institutional quality	Weighted average of institutional quality in 1970 in the neighbourhood of country *i*. Institutional quality is measured by the index of checks and balances of Beck et al. (2002), neighbourhood and weights are defined as for the variable Neighbourhood resource intensity.	Author's calculations from data in Beck et al. (2002)	2.745	1.694
Legal origins	Dummy variable taking value 1 if country's law originates from the French civil code	La Porta et al. (1999)	.510	.501
	Dummy variable taking value 1 if country's law originates from the Socialist/Soviet law	La Porta et al. (1999)	.075	.264
Malaria Ecology	Index of how favourable the ecology of a country is to malaria transmission	Earth Institute, Columbia University	4.33	6.94

List of countries (full sample):

Afghanistan, Albania, Algeria, Angola, Argentina, Australia, Austria, Bahamas, Bahrain, Bangladesh, Barbados, Belgium, Belize, Benin, Bolivia, Botswana, Brazil, Brunei Darussalam, Bulgaria, Burkina Faso, Burundi, Cambodia, Cameroon, Canada, Cape Verde, Central African Republic, Chad, Chile, China, Colombia, Comoros, Republic of Congo, Costa Rica, Cuba, Cyprus, Denmark, Djibouti, Dominica, Dominican Republic, Democratic Republic of Congo, Ecuador, Egypt, El Salvador, Equatorial Guinea, Ethiopia, Fiji, Finland, France, Gabon, Gambia, Ghana, Greece, Guatemala, Guinea, Guinea-Bissau, Guyana, Haiti, Honduras, Hong Kong, Hungary, Iceland, India, Indonesia, Iran, Iraq, Ireland, Israel, Italy, Cote d'Ivoire, Jamaica, Japan, Jordan, Kenya, Korea, Kuwait, Lao PDR, Lebanon, Lesotho, Liberia, Libya, Luxembourg, Macao, Madagascar, Malawi, Malaysia, Maldives, Mali, Malta, Mauritania, Mauritius, Mexico, Mongolia, Morocco, Mozambique, Namibia, Nepal, Netherlands, New Zealand, Nicaragua, Niger, Nigeria, Norway, Oman, Pakistan, Panama, Papua New Guinea, Paraguay, Peru, Philippines, Poland, Portugal, Qatar, Romania, Rwanda, Samoa, Saudi Arabia, Senegal, Seychelles, Sierra Leone, Singapore, Solomon Islands, South Africa, Spain, Sri Lanka, Sudan, Suriname, Swaziland, Sweden, Switzerland, Syrian Arab Republic, Tanzania, Thailand, Togo, Tonga, Trinidad and Tobago, Tunisia, Turkey, Uganda. United Arab Emirates, United Kingdom, United States, Uruguay, Vanuatu, Venezuela, Vietnam, Zambia, Zimbabwe

Table 1. Baseline income regressions

	I	II	III	IV	V	VI	VII
Neighbourhood resource intensity	-.0017*** (.0006)	-.0009* (.0005)	-.0009* (.0005)	-.0010** (.0005)	-.0009** (.0005)	-.0009** (.0005)	-.0009** (.0005)
Domestic resource intensity	.0004 (.0007)	.0005 (.0004)	.0002 (.0002)	.0003* (.0002)	.0002 (.0002)	.0002 (.0002)	.0002 (.0002)
Latitude	..	..	2.622*** (.7170)	1.804** (.749)	1.9554** (.8843)	1.9682*** (.7591)	2.0198*** (.7541)
Landlocked country	..	..	-.6762*** (.2157)	-.5164*** (.1820)	-.5355*** (.1732)	-.5365*** (.1738)	-.5406*** (.1744)
Ethnic fragmentation	..	..	-.6130* (.3604)	-.7750** (.3685)	-.7172** (.3763)	-.7131** (.3423)	-.6963** (.3437)
English speaking population	..	..	.6529*** (.2416)	.0606 (.2401)	.1394 (.2703)	.1453 (.2570)	.1691 (.2383)
Institutional quality	..	..	..	.2427*** (.0501)	.2001** (.1009)	.1969** (.0830)	.1841*** (.0685)
Kleibergen-Papp LM stat (p.val)	..	..	..	..	19.250 (.0002)	12.496 (.2532)	30.966 (.0034)
Kleibergen-Papp Wald F stat					7.893	2.072	4.502
Hansen J statistics	..	..	..	..	3.741 (.1540)	5.164 (.8197)	10.029 (.6134)
N. of Observations	147	147	132	120	119	119	119

Dependent variable is log per-capita GDP in 2005. Continent dummy variables not included in column I. Model in columns I-IV are estimated by OLS. Models in columns V to VII are estimated by 2SLS. In column V instruments are legal origins and malaria ecology. In column VI, Heteroskedasticity-based instruments are used. In column VII all instruments (heteroskedasticity-based, legal origins, and malaria ecology) are used. Estimates of the constant term and continent dummies are not reported. Heteroskedasticity robust standard errors reported in brackets.

Table 2. Baseline growth regressions

	I	II	III	IV	V	VI	VII
Log per-capita GDP in 1970	.9593*** (.0551)	.9057*** (.0663)	.8387*** (.0788)	.7538*** (.0959)	.7838*** (.0917)	.7462*** (.0973)	.7462*** (.0938)
Neighbourhood. resource intensity	-.0011*** (.0004)	-.0008** (.0004)	-.0006* (.0004)	-.0007* (.0004)	-.0006* (.0003)	-.0006** (.0003)	-.0006* (.0003)
Domestic resource intensity	-.0002 (.00012	-.0000 (.0001)	.0001 (.0002)	.0002 (.0001)	.0001 (.0002)	.0002 (.0001)	.0002 (.0001)
Latitude			.7079 (.4664)	.4299 (.5295)	.5408 (.5599)	.3855 (.5156)	.4598 (.5079)
Landlocked country			-.2216 (.1454)	-.1793 (.1438)	-.1834 (.1370)	-.1825 (.1357)	-.1829 (.1361)
Ethnic fragmentation			-.4903** (.2281)	-.5425** (.2525)	-.4744* (.2781)	-.5584** (.2538)	-.5183** (.2538)
English speaking population			.0748 (.1377)	-.1149 (.1563)	-.0401 (.1908)	-.1345 (.1867)	-.0894 (.1784)
Institutional quality				.1360*** (.0457)	.0877 (.0895)	.1485** (.0723)	.1194* (.0691)
Kleibergen-Papp LM stat (p.val)					17.659 (0.0005)	16.002 (.1411)	30.287 (.007)
Kleibergen-Paap Wald stat					7.327	4.572	5.159
Hansen J statistic					.043 (.9789)	7.065 (0.7193)	6.974 (.903)
N. of Observations	147	147	132	120	119	119	119

Dependent variable is log per-capita GDP in 2005. Continent dummy variables not included in column I. Model in columns I-IV are estimated by OLS. Models in columns V to VII are estimated by 2SLS. In column V instruments are legal origins and malaria ecology. In column VI, Heteroskedasticity-based instruments are used. In column VII all instruments (heteroskedasticity-based, legal origins, and malaria ecology) are used. Estimates of the constant term and continent dummies are not reported. Heteroskedasticity robust standard errors reported in brackets.

Table 3. Income regressions with other spatial dynamics

	I (full sample)	II (rich neighbourhoods)	III (good institutions neighbourhoods)	IV (rich neighbourhoods)	V (good institutions neighbourhoods)
Neighbourhood resource intensity	-.0011** (.0005)	-.0006 (.0005)	-.0008 (.0006)	-.0006 (.0004)	-.0008 (.0005)
Domestic resource intensity	.0003 (.0002)	.0154** (.0073)	.0004* (.002)	.0155** (.0067)	.0003* (.0002)
Latitude	1.9793*** (.7273)	2.4557** (1.0518)	.2382** (1.1795)	2.4373*** (.9341)	2.457** (1.0650)
Landlocked country	-.5192*** (.1806)	-.2243 (.1939)	-.4538* (.2528)	-.2035 (.1715)	-.4616** (.2295)
Ethnic fragmentation	-.7448** (.3685)	-.5510 (.4381)	-.8214* (.4649)	-.5677 (.3907)	-.7696* (.4280)
English speaking population	.0369 (.2661)	.3332 (.3825)	-.2778 (.2076)	.3034 (.3432)	-.2504 (.1864)
Institutional quality	.2350*** (.0491)	.1323* (.0762)	.0560 (.0857)	.1938** (.0769)	-.0005 (.1019)
Neighbourhood per-capita GDP	-.0471 (.0374)				
Neighbourhood institutional quality	.0962 (.0786)				
Kleibergen-Papp LM stat (p.val)				22.340 (.030)	21.976 (.041)
Kleibergen-Papp Wald F statistic				17.693	19.141
Hansen J statistic (p.val)				13.233 (.352)	16.527 (.1683)
Observations	120	61	61	61	61

Dependent variable is log per-capita GDP in 2005. Continent dummy variables included in all regressions. Model in columns I-III are estimated by OLS. Models in columns IV and V are estimated by 2SLS using external instruments (legal origins and malaria ecology) and heteroskedasticity-based instruments. Estimates of the constant term and continent dummies are not reported. Heteroskedasticity robust standard errors reported in brackets. *, **, *** denote statistical significance at 10%, 5%, and 1% confidence level respectively.

Table 4. Growth regression with other spatial dynamics

	I (full sample)	II (rich neighbourhoods)	III (good institutions neighbourhoods)	IV (rich neighbourhoods)	V (good institutions neighbourhoods)
Log GDP per capita in 1970	.7758*** (.0959)	.7299*** (.0948)	.5933*** (.1193)	.73330*** (.0840)	.5929*** (.1055)
Neighbourhood resource intensity	-.0008** (.0003)	-.0005 (.0003)	-.0007 (.0004)	-.0006* (.0003)	-.0007* (.0004)
Domestic resource intensity	.0001 (.0001)	.0048 (.0035)	.0002 (.0002)	.0049 (.0032)	.0002 (.0002)
Latitude	.6512 (.5098)	1.2227** (.5962)	1.1126 (.7881)	1.2088** (.5182)	1.0938* (.7176)
Landlocked country	-.1813 (.1403)	-.0344 (.1385)	-.1915 (.2458)	-.0237 (.1246)	-.1896 (.2157)
Ethnic fragmentation	-.4916** (.2461)	-.2906 (.3098)	-.6755* (.3757)	-.2974 (.2758)	-.6891** (.3396)
English speaking population	-.1318 (.1757)	.2477 (.3202)	-.2020 (.1447)	.2331 (.2773)	-.2091* (.1253)
Institutional quality	.1224*** (.0442)	.1532** (.0627)	.0515 (.0924)	.1824*** (.0692)	.0661 (.0822)
Neighbourhood per-capita GDP	-.0662*** (.0229)				
Neighbourhood institutional quality	.1465*** (.0465)				
Kleibergen-Papp LM stat (p.val)				22.127 (.051)	22.597 (.005)
Kleibergen-Papp Wald F statistics				19.128	31.144
Hansen J statistic (p.val)				12.127 (.517)	8.336 (.8211)
N. Observation	120	61	61	61	61

Dependent variable is log per-capita GDP in 2005. Continent dummy variables included in all regressions. Model in columns I-III are estimated by OLS. Models in columns IV and V are estimated by 2SLS using external instruments (legal origins and malaria ecology) and heteroskedasticity-based instruments. Estimates of the constant term and continent dummies are not reported. Heteroskedasticity robust standard errors reported in brackets. *, **, *** denote statistical significance at 10%, 5%, and 1% confidence level respectively.