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The Natural Resource Curse and Fiscal Decentralization*

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Abstract

Natural resource abundance is a blessing for some countries, but a curse for others. We show that differences across countries in the degree of fiscal decentralization can contribute to this divergent outcome. Using a large panel of countries, covering several decades and various fiscal decentralization and natural resource measures, we provide empirical support for the novel hypothesis. We also study a model that combines political and market mechanisms, under a unified framework, to illustrate how natural resource booms may create negative effects in fiscally decentralized nations.

Keywords: Natural resources, economic growth, fiscal decentralization

JEL classification: Q32, Q33, O13, O18, H77

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1 Introduction

Since the influential works of Sachs and Warner (1997, 1999, 2001) the so-called *resource curse puzzle*, describing an inverse relationship between resource abundance and economic growth, has attracted considerable attention. Albeit facing criticism (e.g., Brunnschweiler and Bulte 2008), further studies have provided additional empirical evidence of this phenomenon as well as various potential explanations for its occurrence. Among these explanations (see van der Ploeg 2011 for a survey of the literature), authors have emphasized political factors, corruption, underdeveloped legal and financial systems, Dutch Disease mechanisms, or human-capital inhibiting institutions.

This paper contributes to this strand of the literature by further examining the type of institutions that can contribute to the above result. More specifically, we focus on the level of fiscal decentralization, a novel explanation. Fiscal decentralization comprises the financial aspects of devolution to regional and local governments, and it covers two main interrelated issues. The first is the division of spending responsibilities and revenue sources between levels of government. The second is the amount of discretion given to regional and local governments to determine their expenditure and revenues. The definition that we adopt concerns both issues, yet emphasizes the latter. Our main hypothesis is that fiscally decentralized economies are more vulnerable to the growth curse of natural resources than fiscally centralized ones.

Consider, for example, the case of Venezuela *versus* Botswana. Both are heavily endowed with natural resources, yet the former experienced negative growth rates in the period of 1970-1990, while the latter presented one of the highest positive growth rates during that time. According to the Fiscal Decentralization Indicators of the World Bank, the economy of Venezuela is highly fiscally decentralized whereas that of Botswana is the most centralized in the sample. Let us consider other resource abundant countries with an average share of mineral output in total GDP greater than 10 percent over the said period. Some of the most fiscally centralized ones include Azerbaijan, Chile, Indonesia, Malaysia and Norway; all of which performed (growth-wise) remarkably well in the periods investigated in our samples. Conversely, some of those that are most fiscally decentralized include Ecuador, Ethiopia, Iran, Mexico, and Zambia; all of which performed rather poorly during the same time frames.

We offer a theory that combines political and market mechanisms, under a unified analytical framework, to illustrate possible income-reducing effects that operate when natural resource booms hit fiscally decentralized nations. The political aspect builds on the notion that local governments, especially if poorer and in distant regions, can be less efficient at providing public goods and fall more easily prey of corruption (e.g., see Rodriquez-Pose and Ezcurra 2011).[1] If this is the case, resource windfalls will incentivize rent-seeking behavior of local, fiscally-autonomous, governments. In addition, the model also considers a market mechanism: a natural resource boom gives resource rich regions an advantage in the inter-regional fiscal competition over factors (borne by fiscal decentralization) which they exploit to attract capital from the rest of the economy.[2] This leads to a capital movement towards areas that are less productive because, as we show later, they benefit less from agglomeration externalities (e.g., see Ciccone and Hall 1996) and public infrastructure.[3] These two channels contribute to the potential drop in the nation's total output level.

The paper provides empirical evidence for the main hypothesis and key predictions of the model. We adopt the World Bank's Fiscal Decentralization Indicators to add a fiscal decentralization measure together with its interaction with resource share measures to the regressions. The analysis is performed under a cross-country framework which enables studying the full extent of the variation in fiscal decentralization. For the natural endowment, we employ a variety of aggregate measures such as primary rents, natural capital stock, as well as price-based measures, and also look at the individual effects of cropland, forest, pastureland, protected areas and sub-soil assets.

We start with Sachs and Warner's (1997) data and methodology. The time period is 1970-1990 over a sample of 51 countries. Results confirm the main hypothesis and show that the growth curse of natural resource amplifies in fiscally decentralized economies, and is mainly driven by sub-soil assets. These results hold when controlling for investment, openness, institutional quality, ethnicity, terms of trade, education, and interaction terms of ethnicity and institutional quality with the resource share proxy.

Departing from Sachs and Warner, we thereafter employ an extended sample of 73 countries over the period of 1972-2008 to test the same hypothesis through panel

[1] This does not mean that fiscal decentralization increases corruption nation-wide. Papers such as Fisman and Gatti (2002) actually find the opposite. What it implies is that corruption rises in fiscally autonomous regions where resource booms occur. We later reference papers that support this role.

[2] Raveh (2013) studies a similar market mechanism, termed the *Alberta Effect*. He, however, focuses on within-region effects, and does not consider agglomeration economies or public goods as inputs.

[3] Introduced by Marshall (1920), the concept of agglomeration economies refers to the positive externalities of economic integration at the local level, especially with respect to increased labor market pooling, shared inputs, and knowledge spillovers.

estimations, having largely the same controls as in the cross-sectional version, but in addition controlling for country and time fixed effects. The main result remains. By undertaking further checks, we conclude that the confirmation of our hypothesis is robust to using various fiscal decentralization and resource share measures, as well as to different estimation methods and time periods.

Several papers within the natural resource curse literature have investigated the institutional link. Lane and Tornell (1996) suggest that the existence of powerful groups in conjunction with weak institutions provide an explanation for the curse. Mehlum *et al.* (2006) provide additional evidence that the quality of institutions matter. Other authors like Caselli and Michaels (2013) and Brollo *et al.* (2012) offer empirical evidence indicating that the quality of institutions deteriorate as a response to oil windfalls; in particular, they show that local corruption levels increase. In addition, some papers looked into the type of institutions that matter for the said curse. Andersen and Aslaksen (2008) provide empirical evidence that point at the importance of constitutional arrangements. Hodler (2006) argues that natural resources cause conflict in ethnic fragmented societies that, in turn, weakens property rights. We contribute to this literature by studying an additional related institutional aspect: fiscal decentralization; to the best of our knowledge, this paper is the first to do so.

Our paper also relates to the debate on the effect of fiscal decentralization on economic growth. Since the seminal work of Tiebout (1956), a literature has emerged stressing the benefits of fiscal decentralization. For example, Oates (1972) and Qian and Roland (1998) argue that this can occur through a higher degree of discipline on local governments and more efficient resource allocation. Other authors, however, argue against those benefits. Fiscal decentralization may introduce harming distortions related to fiscal competition that can prompt a race-to-the-bottom in local taxes and welfare provision – Zodrow and Mieszkowski (1986) – or produce overinvestment in infrastructure – Keen and Marchand (1997). As Martinez-Vazquez and McNab (2003) conclude in their survey of the literature, the effect still remains an open question. We contribute to this ongoing debate by emphasizing the potential adverse effects of fiscal decentralization on welfare manifested through natural resource abundance; a channel that, to our best knowledge, has not been considered previously in this context.

The paper is structured as follows. Section 2 presents and analyzes the model. Section 3 provides the empirical evidence. Section 4 concludes.

2 Analytical Framework

To help organize the discussion, we now construct a simple framework that illustrates how fiscal decentralization can interact with natural resources to affect income. Specifically, we consider two potential channels that operate under a unified setting; one related to political factors, and another to the optimal choice of taxation across fiscally decentralized regions.

2.1 Regions and consumers

Assume that there are N small regions in a closed and fiscally decentralized economy, each with its own government, competing for the nation's capital stock. Regions possess the same production and preference structure. They can differ in the endowment of natural riches, capacity to generate public goods, and population density – characteristics that are taken as given. Region i's fixed population is denoted by L_i.

These assumptions deserve some comment. First, foreign capital inflows are potentially important for natural resource exploitation. Multinational firms, for example, finance their own activities, and are in charge of the exploitation of oil fields in many countries. This is, nevertheless, consistent with our closed-economy model because it treats income from natural riches as exogenous, as in for instance Caselli and Cunningham (2009).

Second, we abstract from the existence of a central government. As long as resource abundant regions benefit more from their natural resources compared to the resource poor ones, our results would go through. This has the underlying implication that resource abundant regions have some fiscal advantage due to the resources located in their territories, irrespective of any existing equalization payment schemes.[4]

Third, as Oates (1993), Prud'homme (1995) and Rodríguez-Pose and Gill (2005), among others, argue, differences in the capacity to generate public goods can be a

[4] This may happen directly due to the control of the tax base, or indirectly through revenue sharing and grants from the central government. In the former case, decentralization directly provides the regions some fiscal ownership over its resources; examples include Argentina, Canada, the United Arab Emirates and the United States, where subnational ownership over resources is constitutionally entrenched. Under revenue sharing and grants arrangements, on the other hand, the central government owns the natural riches, yet it may redistribute greater proportions of the revenues to natural-resource rich areas; examples now include Bolivia, Brazil, Colombia, Ecuador, Indonesia, Nigeria and Russia (see Brosio and Jimenez 2012 for Latin America, and Ahmad and Mottu 2002 for nations worldwide). In addition, notice that even in the most equalized federations some significant fiscal imbalance remains regardless of the equalization schemes (see Boadway 2006 for the case of Canada).

consequence of economies of scale in production, administration or even negotiation, so that a central government or bigger/richer regions might be more efficient at the provision of public goods. Inman and Rubinfeld (2000), and Storper (2005) also emphasize that local governments may fall more easily prey of elites or special-interest groups, and suffer from greater corruption.

Finally, the fixed-population assumption is made for simplicity. What is essentially required for the model results to hold is that labor is sufficiently less mobile than capital; specifically, when moving towards less agglomerated areas where natural resources are located. We further discuss and present supporting evidence for these latter claims regarding the lack of factor co-movement and systematic differences in agglomeration levels in Appendices A and B.[5]

Each individual is endowed with one unit of labor and one unit of capital that are inelastically supplied to the production sector. As return from the use of these inputs, the consumer obtains a wage payment (w_i) and an interest rate (r_i) that are allocated to the consumption of a private good (c_i) and to pay taxes levied on capital at rate τ_i. A representative individual derives utility (U_{pi}) from the consumption of this private good and from a public good G_i supplied by the government:

$$U_{pi} = \ln(c_i) + \ln(G_i/L_i), \tag{1}$$

where

$$c_i = w_i + r_i - \tau_i. \tag{2}$$

2.2 Governments

Regional governments are rent-seekers and fiscally autonomous. Region i's authorities tax capital (K_i) and use the region's natural input endowment (Z_i) to obtain rents (R_i) and finance the public good. The emphasis on capital taxation is made because of its relative importance in fiscally decentralized scenarios (see Newman and Sullivan 1988, and Wilson and Wildasin 2004), and is more specifically motivated by our focus on capital mobility.

The problem reduces to choosing τ_i, G_i and R_i to maximize their current utility (U_{gi}) that depends on the rents and the representative consumer's utility. For ease of

[5] Implicit in this is the assumption that capital is relatively highly mobile across regions within the same nation. Previous studies support this notion. In particular, Kalemi-Ozcan *et al.* (2010) show the strong fit of neoclassical models when considering a within-U.S. framework.

exposition, policymakers take as given all variables that are not directly under their control. More specifically, the government in region i solves:

$$\max_{\{\tau_i, G_i, R_i\}} \{U_{gi} = \mu_i \ln R_i + (1-\mu_i)U_{pi}\}, \quad \mu_i \in [0,1], \tag{3}$$

subject to

$$Z_i + \tau_i K_i = R_i + G_i, \tag{4}$$

$$U_{pi} \text{ given by (1)},$$

$$K_i, L_i, Z_i, w_i, r_i \text{ taken as given.}$$

The weighting coefficient μ_i can be interpreted as a region-specific rent-seeking parameter; we also use it to capture possible heterogeneity in the capacity of regions to provide the public good G_i. A higher value of μ_i implies that the government is more interested in its own consumption, either because of corruption or because of an inability to provide better public services. Expression (4) is a feasibility constraint that equates public revenues to public expenditures.

The first order conditions to this problem imply the following optimal choices:

$$\tau_i = \frac{1}{2-\mu_i}\left[w_i + r_i - (1-\mu_i)\frac{Z_i}{K_i}\right], \tag{5}$$

and

$$G_i = (1-\mu_i)(Z_i + \tau_i K_i). \tag{6}$$

The tax rate then falls with the natural endowment, and increases with income and μ_i. Government spending G_i, on the other hand, rises with tax revenues and natural resources, and falls with the intensity of the rent-seeking behavior of politicians μ_i. Another interesting implication of expression (5) is that for a sufficiently large value of the natural endowment, the region can fully finance public goods using natural riches, and then the optimal tax rate becomes a subsidy to private-goods consumption.

2.3 Production and equilibrium outcomes

Expressions (5) and (6) determine the control variables as implicit functions, because K_i depends on equilibrium prices and taxes. In order to know how tax rates and government spending reacts to changes in exogenous variables and parameters, we need to specify the production side of the model. We assume that there exist a large number of profit-maximizing firms of mass one that produce in region i's non-resource-extractive sector using labor and capital as inputs according to

$$Y_i = A_i K_i^{\alpha} L_i^{1-\alpha}; \tag{7}$$

where $\alpha \in (0,1)$; and A_i is the region-specific technology level which we discuss later.

Unlike labor, capital moves perfectly across regions until the rental price net of taxes (ρ_i) is equalized and the capital market clears. Market clearing requires that

$$\sum_{j=1}^{N} K_j = K; \tag{8}$$

where K is the nation's capital stock, taken as given.

To see how the region's capital stock reacts to changes in exogenous variables and parameters, we compute the tax rate, τ_i, and the net return to capital, ρ_i. Assuming that firms take prices as given, the first order conditions to the firms' profit maximization problem deliver

$$\tau_i = \frac{A_i}{2-\mu_i}\left(\frac{K_i}{L_i}\right)^{\alpha}\left(1-\alpha+\alpha\frac{L_i}{K_i}\right) - \left(\frac{1-\mu_i}{2-\mu_i}\right)\frac{Z_i}{K_i} \tag{9}$$

and

$$\rho_i = \frac{A_i}{2-\mu_i}\left(\frac{K_i}{L_i}\right)^{\alpha}\left[\left(1-\mu_i\right)\alpha\frac{L_i}{K_i} - (1-\alpha)\right] + \left(\frac{1-\mu_i}{2-\mu_i}\right)\frac{Z_i}{K_i}. \tag{10}$$

The last two equalities imply that, other things constant, both τ_i and ρ_i rise with A_i. The impact of μ_i, on the other hand, is positive on τ_i but negative on ρ_i. In addition, the RHS of expression (10) declines with K_i. Hence, because net returns are equalized across areas, a region with a higher μ_i or a lower A_i will attract less capital – the former effect is due to the larger tax rate charged, and the latter one to the smaller input productivity.

To see how the provision of public goods is affected, combine (6), (7), and the fact that inputs are paid their marginal productivity to get:

$$G_i = \frac{1-\mu_i}{2-\mu_i}\left\{A_i\left(\frac{K_i}{L_i}\right)^{\alpha}\left[\left(1-\alpha\right)K_i + \alpha L_i\right] + Z_i\right\}. \tag{11}$$

Government spending then falls with the intensity of politicians' rent-seeking, and increases with the productivity parameter – notice that this remains true even when taking into account equilibrium effects on capital.

2.4 Fiscal decentralization and the natural resource curse

A natural resource curse occurs if a resource windfall in one of the regions induces an economy-wide decrease in the output produced by the non-resource sector that more than offsets the gains that the newly discovered natural riches bring to the nation. In our model, this means that

$$\frac{\partial}{\partial Z_i} \sum_{j=1}^{N} (Y_j + Z_j) < 0. \tag{12}$$

Looking at expression (7) that gives non-resource sector output Y_i, the curse in our model can be seen as a consequence of a sufficiently large decrease in the weighted average of A_i across regions.

Let us consider that

$$A_i = A Y_i^{\lambda} G_i^{\beta}; \tag{13}$$

where β, λ are strictly positive. The effect of the output level Y_i on the region-specific productivity captures agglomeration externalities of the type emphasized by Ciccone and Hall (1996). The effect of G_i, in turn, reflects the contribution of public goods as inputs, either directly as infrastructure, or indirectly through their role, for example, in the human capital accumulation process. Both of these effects in expression (13) are potentially important for our analysis: natural resources are located in relatively low agglomerated areas (see Appendix A for evidence), and the impact of fiscal decentralization on growth is related to the capacity of regions to provide public goods.

Coming back to the question of when inequality (12) may hold, a region that enjoys a resource windfall will in principle tend to have a larger G_i – by (11) – and therefore a larger A_i. However, there are at least two channels in the model that can contribute to diminish A_i and deliver the negative sign in (12): one related to politics, and the other to the reallocation of capital among regions.

The political channel is related to forces that directly generate a lower provision of public goods. This could be the case if

$$\mu_i = \mu_i(Z_i), \tag{14}$$

and $\partial \mu_i / \partial Z_i > 0$; put differently, if a resource windfall intensifies the rent-seeking behavior of politicians. By expression (11), a higher rent-seeking parameter implies a lower G_i, leading to lower productivity (A_i) and output levels. If the reduction is sufficient, it will produce a natural resource curse.

This effect can be present, to some extent, regardless of the degree of fiscal decentralization. However, as discussed earlier a higher degree of fiscal independence contributes to making the curse more pronounced if local governments, specifically in poorer and less agglomerated regions, fall more easily prey of elites, special-interest groups, and corruption. Indeed, supporting empirical evidence are obtained by Brollo *et al.* (2012) and Caselli and Michaels (2013) who find that in Brazil, a fiscally decentralized nation, municipalities that enjoy resource windfalls become more corrupted, and do not increase the supply of public goods.

The second channel is a market mechanism. Expression (13) implies that multifactor productivity is a function of the regional level of economic activity and the supply of public goods. Therefore, the reallocation of capital towards geographical areas with weaker agglomeration externalities and, as a consequence, less government spending will contribute to generate the curse. This originates directly from fiscal decentralization. In particular, it is a consequence of the lower tax rate chosen by regions that enjoy the resource windfall, as seen through condition (9).[6] Another factor that can contribute to the negative effect is the input misallocation generated by the constant population assumption, which increases the disparity in capital-labor ratios across regions. In Appendix B, we carry out a calibration exercise that shows that the market mechanism is quantitatively able to cause the curse.

3 Empirical Evidence

This section provides empirical support for the main hypothesis of the paper; namely, that fiscally decentralized economies are more vulnerable to the growth curse of natural resources. It also tests the amplification mechanisms to which the theory has pointed out. Given that the fundamental findings on the curse are rooted in the seminal work of Sachs and Warner (1997), subsection 3.1 tests our hypothesis using their database and cross-sectional methodology. Later, subsection 3.2 departs from Sachs and Warner and undertakes panel estimations using an extended sample of countries and years covered.

[6] There is evidence that supports that better-endowed areas compete more aggressively and drain capital from their poorly endowed counterparts. For example, Cai and Treisman (2005) provides evidence for post-communist Russia, Raveh (2013) for U.S. states, and Yao and Zhang (2008) for a less developed nation like China. For general discussions on the importance, and occurence, of competition for production factors in fiscally decentralized nations see, for example, Qian and Roland (1998) and Li *et al.* (2000).

Finally, in subsection 3.3, we undertake various robustness checks.

A detailed description of all variables, their definitions, and sources, are given in Appendix C. Appendix D provides the nations included in each of the samples. Table 1 presents descriptive statistics for all variables employed in the paper.

3.1 Cross-section tests

We first employ Sachs and Warner's (1997) data, variables, and cross-sectional estimation methodology. Because of limitations in the fiscal decentralization data, the original sample reduces to a cross-section of 51 countries that covers the period of 1970-1990. Employing those numbers, we test the following model:

$$\hat{y}_i = \alpha_0 + \alpha_1 X_i + \varepsilon_i; \tag{15}$$

where i represents the country; $\hat{y}$ is average annual growth in real per capita GDP during the interval 1970-1990; X is a vector of controls that includes resource share, initial income, openness, investment, institutional quality, ethnicity, terms of trade, education, fiscal decentralization, interactions terms of the natural resource share with ethnicity, institutional quality, and fiscal decentralization, and a dummy for landlocked economies; ε_i is the disturbance. Our focus will be on the latter interaction term, which puts our hypothesis to test.

In their analysis, Sachs and Warner (1997) measured resource abundance as the GDP share of mineral output in 1970. One key concern in the resource curse literature is the potential endogeneity of this measure (van der Ploeg 2011). Therefore, in the benchmark cross-sectional framework, we follow Brunnschweiler and Bulte (2008) and Arezki and van der Ploeg (2011), and use the World Bank's (2006) measure of natural capital: the total stock of sub-soil assets, timber, non-timber forest resources, protected areas, cropland, and pastureland. This stock variable is arguably more exogenous to growth than Sachs and Warner's flow variables, because it captures an economy's amount of proven natural reserves rather than its capacity to produce or export them. Hence, in the analysis to follow to we use the GDP share of natural capital in 2000 as the resource share proxy.[7]

[7] Year 2000 is preferred because it gives the largest sample size, 51 countries. Results do not change qualitatively in case the numbers provided by the World Bank for 1995 and 2005 are employed instead. Results do not change either if we use Sachs and Warner's measure – the mineral output GDP share in 1970; estimates using this last proxy are provided in Table A1.

As for the fiscal decentralization measure, we follow Davoodi and Zou (1998), Oates (1985, 1993) and Zhang and Zou (1998), and employ the World Bank's *Fiscal Decentralization Indicators*, which are based on data from the International Monetary Fund's *Government Finance Statistics*.[8] Since the World Bank provides several of those measures, we use the one that most closely resembles the model's notion of fiscal decentralization, which is the degree to which sub-national governments fund their expenditures through their own revenue sources (*Vertical Imbalance*). The higher the indicator, the more independent sub-national governments are, implying that the country as a whole is more fiscally decentralized.[9]

Results appear in Table 2. Regression 1 replicates Brunnschweiler and Bulte's (2008) analysis with the addition of Mehlum *et al.*'s (2006) interaction term of institutional quality and resources, Hodler's (2004) interaction term of fractionalization and resources, and our proposed interaction term of fiscal decentralization and the resource share proxy (along with the fiscal decentralization variable). Results on the various controls replicate those presented in previous studies in terms of signs and occasionally significance, including those on the non-fiscal-decentralization interaction terms, which replicate Hodler's (2004) and Mehlum *et al.*'s (2006). Regression 1 confirms our main hypothesis: the estimated coefficient on the interaction of fiscal decentralization and resources is negative and significant, confirming our main hypothesis by showing that the negative growth effect of resources is transmitted through the decentralization channel.[10]

Given that the natural capital measure is an aggregation of various types of natural resources, we disaggregate it to its various components (namely, cropland, forest, pastureland, protected areas, subsoil assets) to better understand the source of this. Results appear in Regressions 2 to 6 in Table 2, where we use the GDP share of each

[8] In terms of coverage, indicators are only provided for countries that report expenditures at both the national and sub-national levels. Nonetheless, as reported by the World Bank, this coverage reflects a lack of reported data rather than few countries with local and provincial governments; also, this should not necessarily reflect differences in the degree of fiscal decentralization between countries included in the sample and those that are not – the sample ranges from highly decentralized countries to highly centralized ones.

[9] Given that Sachs and Warner's (1997) analysis starts at 1970, the fiscal decentralization measure collected for each country is the one closest to 1970, up to 1975 (to mitigate endogeneity concerns), so that countries that do not have such a measure available up to 1975 are not included in the sample. This limits the coverage of our cross-sectional sample to 51 countries.

[10] For all cases reported in Tables we have also estimated the regressions without incorporating any of the fiscal decentralization related variables, and with fiscal decentralization but without its interaction term. Results were similar for all variables.

component. In these cases interactions of the resource proxy with ethnicity and institutional quality are excluded to minimize multicollinearity. The main result holds only under the subsoil assets, being the triggering group for the overall average effect. Indeed, this is consistent with the focus minerals have taken in previous studies on the natural resource curse (e.g. Sachs and Warner 1997, Ross 2001).

To further strengthen our claim let us try to offer additional evidence in favor of the mechanisms that drive the model prediction that fiscally decentralized nations may not benefit from resource windfalls: inter-regional differences in agglomeration levels. In particular, smaller isolated areas can be less efficient in the production and provision of public goods, and subject to stronger corruption problems. This is the main source in the model of the negative effects induced by a resource windfall.

More specifically, we construct an agglomeration index based only on population density vis-a-vis urbanization levels. This measure divides each country's total non-urbanized area by its total area (both in square kilometers); where the calculation of non-urbanized areas follows the definition of non-urbanization provided by the United Nations, on per-country basis.[11] A higher value is interpreted as an indication of greater agglomeration differences. Importantly, the sample shows virtually zero correlation between this agglomeration measure and economic growth, which mitigates endogeneity related concerns.

The model prediction is that decentralized economies with a higher index are more vulnerable to the growth curse. We multiply the fiscal decentralization measure and the above index, and refer to the updated index as *potential vulnerability*. Results appear in Regression 9, and confirm those presented in Regression 1. This provides some validation to the underlying forces, implying that resource endowments may be hurting fiscally decentralized economies through the proposed channels.

Fiscal decentralization can also suffer from endogeneity problems. Previous studies show that fiscal decentralization has several determinants, the key ones being land area, level of democracy, and level of income, each affecting fiscal decentralization positively – see Arzaghi and Henderson (2005), Oates (1972), Panizza (1999), and Treisman (2006). Thus fiscal decentralization may in fact be endogenous to growth through an unobserved development factor; consequently, the positive association between income and fiscal decentralization could be creating an upward bias. We address this concern

[11] For detailed definitions see the Gridded Population of the World database of the Center for International Earth Science Information Network at Columbia University.

by taking an IV approach. In particular, we use the abovementioned determinant, land area, as instrument for fiscal decentralization. Consistent with the findings of previous studies, the logarithm of land area is positively correlated with our measure of fiscal decentralization ($\rho = 0.51$), as depicted in Figure 1. As for the exclusion restriction, some authors such as Alesina *et al.* (2005) discuss the potential endogenous nature of a country's land area and its influence on economic growth. Their work suggests that controlling for the degree of openness can minimize this influence; this is what we do. Our identification assumption is that, once controlling for the level of openness, land area affects growth solely through the fiscal decentralization channel.[12]

We follow Wooldridge's (2002) approach to instrumentation of endogenous interaction terms. In the first stage, we predict fiscal decentralization using the instrument and the exogenous explanatory variables of the regression. We then interact the predicted variable with the natural resource share proxy and use it in the second stage of the TSLS estimation. Results appear in Regressions 7 and 10. First stage results confirm the validity of the instrument, through the F-statistic and the coefficient of interest (being positive and significant). Second stage estimations, in turn, show that the key result remains: the coefficient on the interaction term of decentralization and resources is negative and significant in all cases.

3.2 Panel data analyses

The previous cross-sectional analyses, a-la Sachs and Warner, raise several concerns. First, the time period covered is limited (1970-1990). Second, the sample covers merely 51 countries. Last, the cross-sectional estimation methodology potentially gives rise to both omitted variable and endogeneity biases (van der Ploeg 2011). Departing from Sachs and Warner, we now employ an extended panel that covers the period 1972-2008 (in 9-year intervals) for 73 countries; the maximum number provided by the World Bank's Fiscal Decentralization Indicators.[13] The use of this panel allows addressing the above concerns.

[12] Regardless of any arguments over exogeneity, there were very little changes in the land area of the countries in our sample throughout the investigated period. In fact, the only countries in our sample that experienced such a change are Denmark, Philippines, and Spain, with the largest change being at a rate of only 0.07 percent over the period.

[13] This is an unbalanced panel, limited by data availability of the World Bank's Fiscal Decentralization Indicators. We use 9-year intervals to maximize sample size, while maintaining a relatively long time interval, consistent with the resource curse hypothesis; longer time intervals decrease sample size significantly.

We estimate the following model:

$$\hat{y}_{it} = \beta_0 + \beta_1 X_{it} + \varphi_i + \varepsilon_{it}. \tag{16}$$

The variables $\hat{y}_{it}$, X_{it} and ε_{it} are the same ones as in specification (15), for country i at date t, with the difference of excluding ethnicity and terms of trade as controls due to lack of data, as well as some additional measurement differences outlined below. Because the Hausman test strongly rejects (at the 1% level) the null hypothesis of an efficient random effects model, we take a fixed effects approach and include φ_i, denoting country fixed effects. This approach also mitigates potential omitted variable bias, alleviates concerns regarding potential multicollinearity by centering variables, and helps controlling for unobserved within-country constant phenomena, being a standard concern under the given framework. All variables are measured in the initial year of the corresponding time interval to reduce endogeneity concerns,[14] and are expressed in deviations from period means so that time fixed effects are also implicitly controlled for in all the corresponding regressions (e.g., see Caselli *et al.* 1996).

Not all the explanatory variables employed in these panel estimations are measured in the same way as in the cross-sectional analysis due to data limitations, though all our measures are standard in the economic growth literature (see Appendix B). Specifically, given its greater coverage, institutional quality is now measured by the Civil Liberties Index, which is commonly used as a proxy for institutional quality. Civil liberties, however, do not capture corruption levels that are essential for our analysis. Therefore, as a separate control, we follow Andersen and Aslaksen (2008) and consider the level of democracy as proxy for corruption, using data from the Polity-IV project dataset.[15] We include as well its interaction with the resource proxy to control for the heterogeneous effects across levels of corruption (but excluding the interaction with institutional quality, due to multicollinearity).

As for resource abundance, we also use a different measure, in an attempt to capture exogenous variations in resource shocks over time. This measure is constructed as follows: for each country, we take the GDP share of mineral rents in the earliest year available, and multiply it by the average international price index of mineral goods

[14] Nonetheless, we note that results are not sensitive to the alternative usage of average values.

[15] Note that the correlation between our proxies for corruption and institutional quality stands at approximately 0.5, affirming to some extent their distinct definitions, and motivating their concurrent inclusion in the regressions. Nonetheless, we note that all results hold if only one of them is included. In addition, we discuss multicollinearity related concerns separately in a later section.

(normalized to 2005) at time t.[16] Put differently, we keep the initial share of mineral production in GDP constant, but we weigh the share at each point in time with the corresponding level of mineral prices.

As presented in Figure 2, the relative international ranking in the GDP share of mineral output (having nations with no mineral output assigned a rank of 1) has changed little over time: countries that were largely mineral abundant at the beginning of the period (1972) appear to hold their relative ranking 36 years later ($\rho = 0.81$). Keeping the share of mineral production in GDP constant, hence, can still capture accurately the countries' relative position with respect to their mineral abundance over time. To the extent that changes in international mineral prices are exogenously driven and that initial mineral output is pre-determined, we argue that the variation we investigate is indeed exogenous since it is entirely triggered by changes in the international price of minerals.

Results appear in Regression 1 of Table 3. Results on convergence, openness, investment, institutional quality, democracy, education, decentralization and the interaction of resources with institutional quality are similar in sign, and occasionally in significance, to previous findings in the cross-section tests. Interestingly, the regression shows that our main result – a negative and significant coefficient on the interaction term between fiscal decentralization and resource share – holds in this case as well.

There is a debate in the literature on the nature of the link between fiscal decentralization and internal conflicts (Siegle and O'Mahony 2006). To the extent that fiscal decentralization may induce internal conflicts, the observed effect on growth may be driven through that channel. We test this hypothesis by adding an indicator for whether an internal armed conflict has taken place in the investigated time interval; this measure is retrieved from the Uppsala Conflict Data Program.[17] This exercise is undertaken in Regression 2 which shows that our main result on the interaction term of interest remains.

[16] Data retrieved from the World Bank. Mineral resources include: oil, natural gas, minerals, and coal. Rents are computed as unit rents times production, where a unit rent is the unit price less unit cost. The price measure is a general index that does not account for the different mineral shares of each country; prices of different minerals, however, exhibit strong co-movement.

[17] An internal armed conflict is defined as a contested incompatibility that concerns government and/or territory where the use of armed force between two parties, of which at least one is the government of a state, results in at least 25 battle-related deaths. The internal armed conflict occurs between the government of a state and one or more internal opposition group(s), without intervention from other states.

3.3 Additional robustness checks

Regressions 3 to 5 in Table 3 contain further robustness tests of our main hypothesis. Using the panel data, we begin by considering an output-based resource measure, which allows us to examine variations in resource discoveries and technology improvements (on top of price variations, as was done initially): the GDP share of primary rents. Regression 4 reproduces Regression 1 using this output-based measure. Results on all variables, including our interaction term, are similar in sign and significance.

Nevertheless, as was mentioned previously, this measure is potentially endogenous (motivating our use of the price-based measure in the baseline specification); thus, we take an IV approach and instrument it with the GDP share of mineral rents in $t-1$. We view this measure as a suitable IV, because it is highly correlated with our proxy ($\rho = 0.9$), and relatively exogenous to growth. Its exogeneity can be justified as follows: first, mineral rents are not dependent on an economy's capability to export, thus making it less correlated with development and growth; second, mineral rents in developing economies are usually extracted by multi-national firms that bring their own technology and production factors, making these rents relatively independent of unobserved development indicators; last, the lagged value is arguably more exogenous to growth in the following period. Estimation of the endogenous interaction term is carried out using the previously described procedure. Results are reported in Regression 5 of Table 3. First stage results validate the instrument, and the second stage ones confirm our main result.

Let us now test the hypothesis using a different fiscal decentralization measure, and in particular, the Kearney Decentralization Index (Arzaghi and Henderson 2005). Although there are several available decentralization indices, we adopt this one because of its larger time and country coverage: the index is available for 43 developing and developed countries over the years 1965-1995. The Kearney measure is a comprehensive index that covers nine distinct dimensions of fiscal decentralization. We adopt one of them: the Revenue Raising Authority dimension; it measures sub-national governments' formal authority to raise their own revenue through taxation, which resembles the model's notion of decentralization more closely.[18] Regression 3 of Table 3 replicates Regression 1 using the Kearney measure, the previously described price-based

[18] This component of the index assigns each country a number between zero and four, with four having the highest level of revenue raising autonomy and zero the least.

resource measure, and a panel that covers the period of 1965-2000 with 5-year intervals.[19] Results under these measure are similar to previous estimations; our main result, therefore, is robust to different decentralization variables.

We realize that throughout the panel analyses the fiscal decentralization measure remains potentially endogenous. Adopting a suitable IV with sufficient time variation is not straight forward. As an alternative, we turn to test the cross-sectional version of our panel employing the logarithm of land area as an instrument for fiscal decentralization. More specifically, we extend the previously used Sachs and Warner's cross-sectional sample to 2008, use the logarithm of land area as IV for fiscal decentralization, and employ the previously discussed natural capital measure as the resource share proxy. Regression 8 of Table 2 gives the outcome of this exercise for the period 1970-2008. Our main finding is once again confirmed. Although not presented, similar results arise when the time interval from 1990 to 2008 is used instead.

To this point we considered maximized cross-country samples that include both developed and developing economies. Often times, however, the natural resource curse hypothesis refers specifically to developing economies (Auty 1993). Let us test, therefore, whether our result holds for developing economies. Hence, we divide our samples into high and non-high income economies based on the earliest available classification provided by the World Bank starting at 1989, and estimate the basic specifications as in Regression 1 of Table 2 and Regressions 1 and 3 of Table 3, for each group separately.[20] Due to multicollinearity concerns when the sample is split, we exclude the interaction terms of the resource share measure with fractionalization and rule of law in the cross-sectional case, and the measure of democracy together with its interaction with the price-based resource measure in the panel cases. Results appear in Table 4. As can be seen, the main result is strongly apparent in the developing economies group, and weakly so in the developed one. This result also lends support to the political angle of the model, and its potential significance in the overall mechanism, given that corruption levels are higher and markets more imperfect in developing economies.

Given our empirical setting, using various standard country-level controls and inter-

[19] We adopt 5-year intervals in this case, again, to maximize the sample size (notice that the index is available in 5-year intervals as well). Nonetheless, results do not change qualitatively if 10-year intervals are adopted instead.

[20] See Appendix D for a list of economies included in each group. We note that results hold as well if the developed-economies group includes also the middle-income countries, leaving the developing-economies group with the low-income ones only.

action terms, one concern is that our main results may be plagued by multicollinearity. In the panel analyses this is addressed through the usage of a fixed effects framework that centers the variables. However, to address this further we estimate the benchmark regressions, namely Regression 1 of Table 2, and Regressions 1, 3 and 4 of Table 3, with the non-fiscal-decentralization related interactions excluded. Results appear in Table A2. The highest Variance Inflation Factor (uncentered) in all cases is 6.58, indicating multicollinearity levels are sufficiently low. In all Regressions the main result remains to hold in sign, significance, and magnitude, hence alleviating related concerns.

4 Conclusion

The question of why resource endowments lead to divergent outcomes continues to attract much interest among economists. This paper presented a novel answer to that question: countries with a high degree of fiscal decentralization are more vulnerable to the negative effects of natural resource windfalls. The new hypothesis also contributes to understanding the effects of fiscal decentralization on economic growth.

We explored a model that suggests possible channels through which fiscal decentralization and natural resource booms can interact to increase the probability of a natural resource curse. To support the theory, we have shown that natural resources are located in less agglomerated, sparsely-populated regions; areas in which we have argued that agglomeration externalities are weaker, and the growth-harming effects emphasized by the fiscal decentralization literature are more likely to arise. If this is the case, resource windfalls may incentivize rent-seeking behavior of local, fiscally-autonomous, governments – the political channel. In addition, natural riches can lead less agglomerated and efficient regions to cut taxes and attract capital from more productive areas – the market mechanism. These two channels can contribute to drop total output in the nation, following a natural resource boom.

The main hypothesis – that countries with a high degree of fiscal decentralization are more vulnerable to the natural resource curse – has been empirically tested and confirmed. First, we used the original Sachs and Warner's (1997) data set and method; then, an extended panel, in conjunction with the World Bank's Fiscal Decentralization Indicators. Finally, we have shown that results are robust to different resource abundance and fiscal decentralization measures, as well as to different estimation techniques and time periods.

The paper has, in general, remained agnostic about the contribution of each of the two mechanisms to our estimations – whether one is more important than the other. Yet results have shown that the interaction between fiscal decentralization and natural resources is driven mainly by developing nations. This suggests that political channels might be more significant than market mechanisms. Nevertheless, assessing more accurately the relative importance of each of them represents a promising avenue for future research. In addition, results may be sensitive to the specific periods and countries investigated. Future work should further test the results and analyze the suggested mechanisms using different data sets and case studies, as they become available.

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Table 1: Descriptive Statistics

A. Cross-sectional analysis

	Mean	Std. Dev.	Min.	Max.		Mean	Std. Dev.	Min.	Max.
Growth, 1970-1990	1.3	1.6	-3.09	5.7	Ethnicity	36.89	28.35	0	89
Growth, 1970-2008	3.4	3.1	-1.2	17.77	Terms of trade	-0.41	2.32	-4.69	7.38
GDP share of mineral output	0.04	0.08	0	0.37	Education	0.17	0.14	0.005	0.54
GDP share of natural capital	0.02	0.05	0.0001	0.38	Landlocked economies	0.13	0.34	0	1
Logarithm of initial income	8.65	0.86	6.76	9.95	Vertical Imbalance	67.15	23.94	7.02	99.8
Openness	0.5	0.45	0	1	Potential Vulnerability	62.47	24.75	3.96	99
GDP share of cropland	0.02	0.02	0.0001	0.104	GDP share of pastureland	0.006	0.008	0.0002	0.04
GDP share of forest	0.006	0.01	1E-05	0.06	GDP share of protected areas	0.006	0.01	3E-05	0.09
Investment	2.86	0.49	1.33	3.61	Modified Potential Vulnerability	9.63	4.31	0.97	20.6
Institutional quality	3.56	2.005	1	6	Logarithm of land area	12.65	1.97	6.54	16
GDP share of subsoil assets	0.005	0.01	0	0.05					

B. Panel analysis

Regressions 1, 2, 4, and 5; Table 3					Regression 3; Table 3				
	Mean	Std. Dev.	Min.	Max.		Mean	Std. Dev.	Min.	Max.
Growth, 1972-2008	2.13	2.75	-8.06	12.98	Growth, 1965-2000	2.14	2.98	-11.39	22.4
Price-based resource measure	1.81	8.48	0	120.4	Price-based resource measure	4.42	7.61	0	61.7
GDP share of primary rents	0.05	0.09	0	0.78	Logarithm of initial income	7.49	1.57	4.43	10.5
GDP share of mineral rents	0.03	0.08	0	0.78	Openness	0.39	0.24	0.05	1.92
Logarithm of initial income	8.75	1.25	4.91	11.4	Investment	24.75	8.81	1.34	58.3
Openness	0.71	0.42	0.02	3.24	Institutional quality	4.31	2.19	1	7
Investment	24.4	9.23	5.17	70.31	Education	5.45	2.95	0.13	12.7
Institutional quality	4.86	1.83	1	7	Kearney Decentralization Index	1.18	1.06	0	3.56
Education	7.17	2.82	0.57	12.7	Democracy	4.66	4.19	0	10
Democracy	5.93	4.11	0	10					
Vertical Imbalance	45.72	21.25	0.91	97.38					

Further descriptions and sources of all variables are outlined in the Appendix.

Table 2: Cross-country growth regressions, cross-section [Sachs and Warner (1997) database, period: 1970-1990, unless specified otherwise]

Panel A: Main and second stage results	Fiscal decentralization is 'Vertical Imbalance'								Fiscal decentralization is 'Potential Vulnerability'	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Dependent variable: Average annual growthin real per capita GDP, 1970-1990	(OLS)	(OLS)	(OLS)	(OLS)	(OLS)	(OLS)	(TSLS)	(TSLS, extending to 2008)	(OLS)	(TSLS)
Natural capital	10.72						17.27	6.23	7 .67	14.34
	(27.01)						(27.47)	(54.59)	(27.29)	(27.56)
Cropland		-6.68								
		(22.01)								
Forest			-30.37							
			(46.53)							
Pastureland				-150.36						
				(132.22)						
Protected areas					-1.5					
					(52.78)					
Subsoil assets						37.54				
						(30.89)				
Logarithm of initial income	-2.02***	-2.15***	-2.04***	-1.89***	-2.02***	-1.54***	-1.94***	-2.22***	-1.99***	-1.94***
	(0.38)	(0.41)	(0.38)	(0.38)	(0.39)	(0.36)	(0.34)	(0.45)	(0.37)	(0.34)
Openness	2.81***	2.12***	2.32***	2.22***	2.27***	1.99***	2.75***	5.09***	2.81***	2.75***
	(0.49)	(0.49)	(0.41)	(0.53)	(0.48)	(0.51)	(0.49)	(1.45)	(0.49)	(0.49)
Investment	0.07	0.02	0.17	0.21	0.24	1.05*	-0.26	1.16	-0.05	-0.22
	(0.45)	(0.48)	(0.49)	(0.56)	(0.55)	(0.53)	(0.39)	(0.85)	(0.42)	(0.39)
Rule of law	0.04	0.24	0.27	0.27	0.29	0.13	0.05	-0.43	0.05	0.05
	(0.21)	(0.19)	(0.19)	(0.19)	(0.21)	(0.18)	(0.19)	(0.44)	(0.2)	(0.19)
Ethnicity	-0.01	-0.009	-0.007	-0.01**	-0.01**	-0.01	-0.01	-0.04	-0.01	-0.01
	(0.007)	(0.006)	(0.006)	(0.01)	(0.01)	(0.006)	(0.007)	(0.03)	(0.007)	(0.007)
Terms of trade	0.16**	0.13*	0.13	0.13	0.18**	0.31***	0.16**	0.05	0.16**	0.16**
	(0.06)	(0.07)	(0.08)	(0.08)	(0.08)	(0.08)	(0.07)	(0.11)	(0.06)	(0.07)
Education	2.85**	2.06*	2.22*	2.54*	2.68**	1.99*	2.68**	4.43*	2.72**	2.69**
	(1.29)	(1.19)	(1.25)	(1.36)	(1.28)	(1.13)	(1.28)	(2.49)	(1.23)	(1.28)
Landlocked economies	0.22	-0.63	-0.29	-0.99**	-0.99*	-1.11**	0.41	0.19	0.28	0.39
	(0.45)	(0.59)	(0.38)	(0.49)	(0.54)	(0.43)	(0.51)	(0.91)	(0.45)	(0.49)
Ethnicity x Resource share	-0.62**						-0.71**	-1.06	-0.61**	-0.66**
	(0.27)						(0.26)	(0.68)	(0.27)	(0.29)
Rule of law x Resource share	7.84**						8.14**	18.32**	7.97**	7.89**
	(3.67)						(3.77)	(7.2)	(3.74)	(3.81)
Fiscal decentralization	0.008						0.002	-0.001	0.004	-0.001
	(0.01)						(0.01)	(0.03)	(0.01)	(0.01)
Fiscal decentralization x Resource type share	**-0.39*** **	**-0.34**	**-0.31**	**1.77**	**-0.25**	**-1.19*** **	**-0.46*** **	**-0.71** **	**-0.37*** **	**-0.43*** **
	(0.08)	**(0.33)**	**(0.53)**	**(1.37)**	**(0.6)**	**(0.38)**	**(0.1)**	**(0.27)**	**(0.09)**	**(0.09)**
Adjusted R-squared	0.7853	0.7238	0.7513	0.6956	0.708	0.7532	0.7733	0.6517	0.7827	0.7695
Observations	51	51	51	51	51	51	51	51	51	51

Panel B: First stage results

Regressions:	(7), (8)	(10)
Dependent variable:	Fiscal decentralization	Fiscal decentralization
Logarithm of land area	3.59***	4.93***
	(0.99)	(0.91)
Adjusted R-squared	0.7823	0.8146
F-statistic	17.2	21.16

Standard errors are robust and appear in parentheses for independent variables. Superscripts *,**, *** correspond to a 10, 5 and 1% level of significance, respectively. First stage regressions include all relevant variables. All regressions include an intercept. 'Resource type' refers to the specific type of natural resource examined in the regression. All resource-type variables are measured as GDP shares (source: World Bank 2006). For description and sources of variables, as well as a list of economies included in each regression, see Appendix.

Table 3: Cross-country growth regressions, panel data (OLS estimations, unless specified otherwise]

Panel A: Main and second stage results	Using the price-based measure as the resource share proxy			Using GDP share of primary rents as the resource share proxy	
Dependent variable: Average annual growthin real per capita GDP for sample period	(1)	(2)	(3) Kearney	(4)	(5) [TSLS]
Resource share	0.47	0.46	0.003	10.41	6.78
	(0.44)	(0.43)	(0.05)	(8.3)	(10.44)
Logarithm of initial income	-3.46***	-3.48***	-2.2*	-4.18***	-4.36***
	(1.23)	(1.23)	(1.2)	(1.24)	(1.28)
Openness	1.26	1.22	1.1	1.14	1.19
	(1.26)	(1.34)	(1.94)	(1.13)	(1.22)
Investment	0.38	0.39	2.32***	0.71	0.81
	1.2	(1.19)	(0.62)	(1.09)	(1.16)
Civil liberties	-0.58***	-0.58***	-0.22	-0.63***	-0.56***
	(0.18)	(0.19)	(0.19)	(0.18)	(0.19)
Democracy	-0.12	-0.12	-0.03	0.01	0.21
	(0.09)	(0.09)	(0.03)	(0.04)	(0.04)
Democracy x Resource share	-0.09	-0.09	-0.004	1.64	-0.59
	(0.06)	(0.06)	(0.01)	(1.24)	(0.89)
Education	0.39	0.34	0.85***	0.34	0.24
	(0.24)	(0.24)	(0.25)	(0.23)	(0.23)
Fiscal decentralization	-0.02	-0.02	-0.05	-0.002	-0.002
	(0.01)	(0.01)	(0.29)	(0.01)	(0.01)
Fiscal decentralization x Resource share	**-0.01*** **	**-0.01*** *	**-0.05*** *	**-0.4*** *	**-0.4*** *
	(0.006)	**(0.007)**	**(0.02)**	**(0.19)**	**(0.19)**
Internal armed conflicts		**-0.11**			
		(0.62)			
Adjusted R-squared	0.8034	0.8035	0.5859	0.7982	0.7987
Observations	207	207	232	207	207
Country fixed effects	Yes	Yes	Yes	Yes	Yes
Number of economies included	73	73	43	73	73

Panel B: First stage results	
Regressions:	(5)
Dependent variable:	GDP share of primary rents
GDP share of mineral rents in t-1	0.99***
	(0.06)
Adjusted R-squared	0.8877
F-statistic	71.04

Standard errors are robust, clustered by country, and appear in parentheses for independent variables. Superscripts *, **, *** correspond to a 10, 5 and 1% level of significance, respectively. In Regressions 1, 2, 4, and 5 the period covered is 1972-2008 in 9-year intervals, with the fiscal decentralization measure being 'Vertical Imbalance'; In Regression 3 the period covered is 1965-2000, in 5-year intervals, with the fiscal decentralization measure being the Revenue Raising Authority component of the Kearney Decentralization Index. First stage regressions include all relevant variables. All regressions include an intercept. All variables are expressed as deviations from period means so that time fixed effects are controlled for in all regressions. For description and sources of variables, as well as a list of economies included in each regression, see Appendix.

Table 4: Revisitng main results using restricted samples of developing and developed economies [OLS estimations]

Dependent variable: Average annual growth in real per capita GDP	Developing economies			Developed economies		
	Cross section (Table 2, Regression 1)	Panel (Table 3, Regression 1)	Panel (Table 3, Regression 3)	Cross section (Table 2, Regression 1)	Panel (Table 3, Regression 1)	Panel (Table 3, Regression 3)
	(1)	(2)	(3)	(4)	(5)	(6)
Resource share	11.82**	0.54	-0.03	-9.77	0.26	0.21**
	(4.24)	(0.74)	(0.05)	(107.337)	(0.32)	(0.08)
Logarithm of initial income	-2.48***	-2.95***	-1.94	-1.05*	-4.11***	-4.68***
	(0.33)	(1.39)	(1.22)	(0.57)	(1.16)	(1.31)
Openness	3.43***	0.001	1.21	2.21	3.88***	3.14
	(0.71)	(1.33)	(2.64)	(1.72)	(1.22)	(1.87)
Investment	-0.02	1.16	2.23***	0.63	-1.72	-0.59
	(0.67)	(1.56)	(0.62)	(0.69)	(1.29)	(1.37)
Rule of law	0.25			-0.28		
	(0.25)			(0.28)		
Ethnicity	-0.03***			0.01		
	(0.01)			(0.01)		
Terms of trade	0.16**			0.91		
	(0.07)			(0.35)		
Landlocked economies	-0.49			-0.46		
	(0.89)			(0.35)		
Education	-0.19	0.79*	1.14***	2.51*	-0.21	0.31
	(2.66)	(0.42)	(0.29)	(1.23)	(0.24)	(0.52)
Civil liberties		-0.69**	-0.14		-0.23	-0.43**
		(0.29)	(0.21)		(0.19)	(0.14)
Fiscal decentralization	0.02	-0.02*	0.01	0.02*	-0.01	-0.31
	(0.01)	(0.01)	(0.37)	(0.01)	(0.02)	(0.27)
Fiscal decentralization x Resource share	**-0.48*** **	**-0.01** **	**-0.04** **	**0.01**	**-0.02***	**-0.04**
	(0.13)	**(0.005)**	**(0.02)**	**(1.31)**	**(0.01)**	**(0.04)**
Adjusted R-squared	0.8272	0.7128	0.6417	0.8421	0.3802	0.358
Observations	30	120	161	21	94	74
Number of economies included	30	48	29	21	27	14

Standard errors are robust, clustered by country in Regressions 2, 3, 5, 6, and appear in parentheses for independent variables. Superscripts *, **, *** correspond to a 10, 5 and 1% level of significance, respectively. Regressions 1, 2, 3 (4, 5, 6) replicate Regression 1 of Table 2 and Regressions 1 and 3 of Table 3, respectively, using a restricted sample of developing (developed) economies; unlike the benchmark specifications, the interaction terms of the resource share measure with fractionalization and rule of law in the cross-sectional cases, and the measure of democracy together with its interaction with the price-based resource measure in the panel cases, are excluded, to avoid multicollinearity; this increases the sample in the panel cases, compared to that in the benchmark specifications. For description and sources of variables, as well as a list of economies included in each regression, see Appendix.

Figure 1: Fiscal decentralization and land area

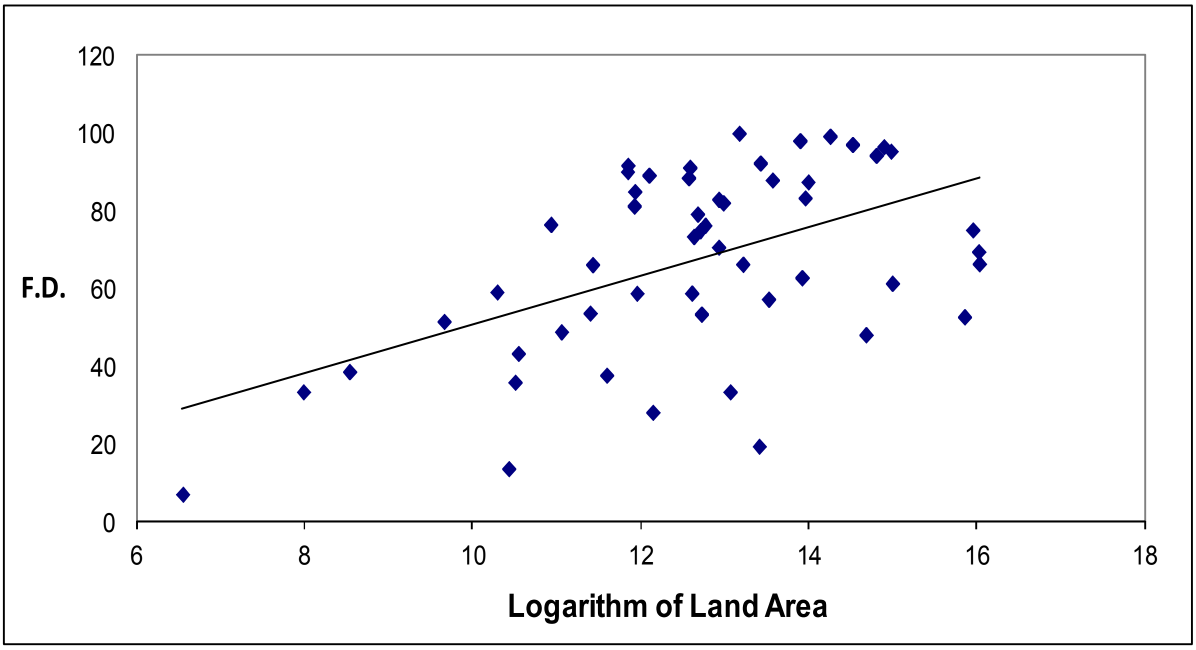


Figure presents the correlation between the logarithm of land area (source: World Bank Indicators) and the cross-sectional fiscal decentralization measure ('Vertical Imbalance'; source: World Bank Fiscal Decentralization Indicators).

Figure 2: Relative rank of resource dependence: 1972 VS. 2008

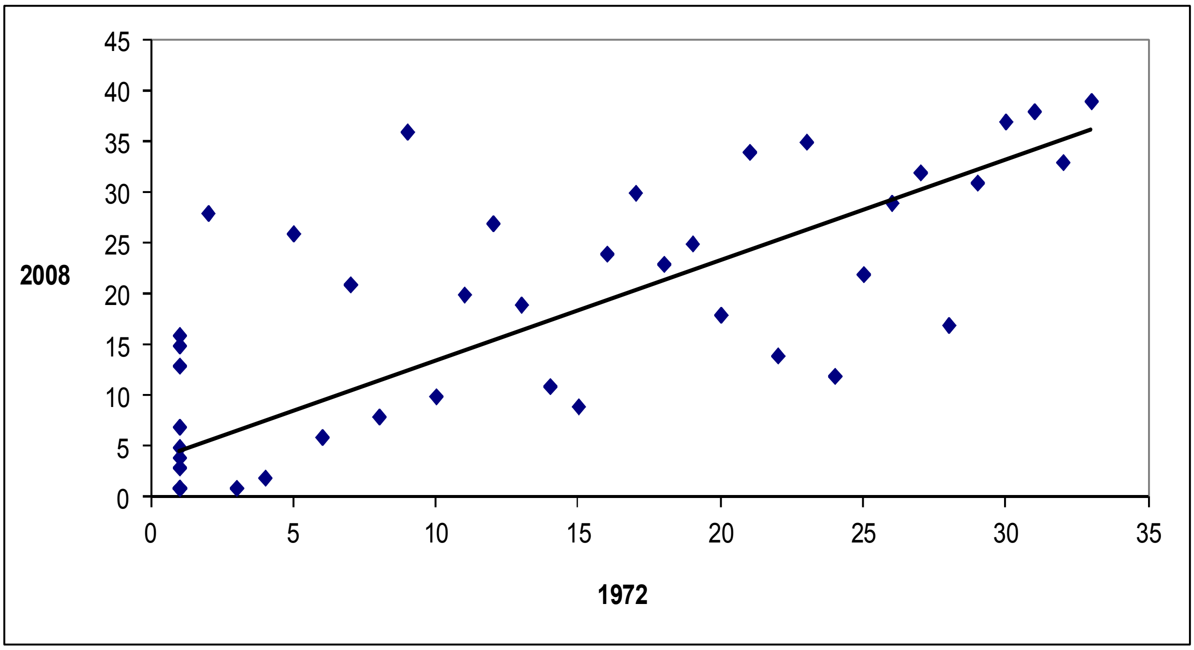


Figure presents the Spearman Correlation between the GDP share of mineral output in 1972 and that in 2008 (source: World Bank Indicators); ρ=0.81.

A Natural resources and Agglomeration

A main foundation of the theory is that natural resources locate in less agglomerated regions. In this Appendix, we offer evidence that confirms it.

Let us focus, for example, on the agglomeration index computed by Ciccone and Hall (1996) for the 48 contiguous U.S. states in 1988. It measures the intensity of labor, human and physical capital relative to physical space, and is expressed as a number between one and two. The estimated agglomeration index is lowest for Montana, a resource rich state, and highest in the District of Columbia, a resource poor area. Figure A1 shows that there is a clear negative correlation between the resource endowment and agglomeration ($\rho = -0.72$) within that group.

Figure A2 presents similar state-level graphs using population density to capture agglomeration for Australia, Brazil, Canada, Germany, India, Malaysia, Russia, and United Arab Emirates.[21] Even though population density is a narrower concept than agglomeration, the two variables are highly positively correlated. In the Figure, we can see that all these nations show similar negative relationships between population density and resource abundance, implying that at regional levels resources indeed locate in non-agglomerated areas.

B The Quantitative Version of the Model

As mentioned, there is empirical evidence that supports that $\partial\mu_i/\partial Z_i > 0$, that is, the political channel. Only partial evidence are available, however, for the market one. We tackle this issue in this Appendix, albeit indirectly, carrying out a calibration exercise that shows that the market mechanism is quantitatively able to cause the curse. We also discuss the role of the lack of labor mobility in the result, and provide evidence that supports our approach.

In order to focus exclusively on the market mechanism, we abstract from the rent-seeking behavior of politicians and from the role of public goods as inputs; that is, we take $\mu_i = \beta = 0$. In addition, we slightly modify production function (7) to make it closer to the one proposed by Ciccone and Hall (1996). In particular, expression (7) becomes:

$$Y_i = A_i \left(K_i^{\alpha} L_i^{1-\alpha}\right)^{\nu}; \tag{17}$$

where $\nu \in (0,1)$ proxies the income share of non-land inputs in non-extractive industries.

To make the quantitative analysis more relevant, we also relax some of the exogeneity assumptions made for ease of exposition in the government's problem. In particular, we let politicians internalize the agglomeration externality and the effect of the tax rate

[21] Data retrieved from the central statistical agencies of each federation. We plot correlations for the earliest year for which data is available at the state level. Australia: 1990; Brazil: 1995; Germany: 1991; Canada: 1984; Malaysia: 2005; Russia: 2004; India: 1980; United Arab Emirates: 2000.

on the firm's demand for capital. Finally, we weigh the impact of public goods on U_{pi} by a factor γ, which allows calibrating the size of the public sector to the data.

B.1 Solutions

Policymakers take as given the net return to capital ρ, which is equalized across regions. From technology (17), they also know that demand for capital and labor provided by the first order conditions of the firms' problem are given by

$$w_i = (1-\alpha)\nu \frac{Y_i}{L_i}, \tag{18}$$

and

$$r_i = \rho_i + \tau_i = \alpha\nu \frac{Y_i}{K_i}, \tag{19}$$

respectively. Incorporating the modifications proposed, and employing expressions (1),(4),(7), (13) and (19), the government's problem (3) can be rewritten as

$$\max_{\tau_i} \left\{ U_{gi} = \ln c_i + \gamma \ln \frac{G_i}{L_i} \right\}, \quad \gamma > 0, \tag{20}$$

subject to

$$G_i = \tau_i K_i + Z_i; \tag{21}$$

$$Y_i = A^{1/(1-\alpha\nu-\lambda)} \left[L_i^{1-\alpha} \left(\frac{\alpha\nu}{\rho + \tau_i} \right)^{\alpha} \right]^{\frac{\nu}{1-\alpha\nu-\lambda}}. \tag{22}$$

$$Y_i + Z_i = c_i L_i + G_i, \tag{23}$$

The first order condition to the above problem obtains

$$\frac{C_i}{G_i} = \frac{1}{\gamma} \left(1 + \frac{1}{1-\alpha\nu-\lambda} \right) = \phi; \tag{24}$$

where $C_i = c_i L_i$. Substituting conditions (21) and (23) into (24), we can write the optimal capital tax rate as

$$\tau_i = \frac{\rho - \alpha\nu\phi\frac{Z_i}{K_i}}{\alpha\nu(1+\phi) - 1}. \tag{25}$$

When $Z_i > \rho K_i/(\alpha\nu\phi)$, the tax rate becomes negative, thus implying a subsidy.

In order to know how the tax rate reacts to changes in the variables and parameters that the region takes as exogenous, we can use expressions (19), (22) and (25) to get

$$\frac{(\rho+\tau_i)^{1-\lambda}}{\{\rho - [\alpha\nu(1+\phi)-1]\,\tau_i\}^{1-\alpha\nu-\lambda}} = \frac{A\left[(\alpha\nu)^{\alpha} L_i^{(1-\alpha)}\right]^{\nu}}{(\phi Z_i)^{1-\alpha\nu-\lambda}}. \tag{26}$$

This equality implicitly solves τ_i as a function of ρ and region-specific characteristics. When $1 - \alpha\nu - \lambda > 0$, the optimal value of τ_i is unique and decreases with the endowment Z_i, becoming zero for a sufficiently large value of Z_i.

Governments choose taxes according to (25), and the return to capital moves until the capital market clears – that is, condition (8) holds. At that point, the whole economy is in equilibrium, and the following non-arbitrage condition holds:

$$\rho = \alpha\nu\frac{Y_i}{K_i} - \tau_i = \alpha\nu\frac{Y_j}{K_j} - \tau_j. \tag{27}$$

B.2 Calibration

The model is calibrated to a representative average nation.[22] Let us start with the production function parameters. The productivity parameter A is normalized to 1. Gollin (2002) reports that labor shares are relatively similar across nations with an average of about 0.7; we then pick $\alpha\nu = 0.7$. There are few estimates of the share of land in non-extractive industries' value added. Probably the most compelling number is the one provided by Herrendorf and Valentinyi (2008), who estimate a land income share of Agriculture around 10 percent using 1997 U.S. input-output tables and purchaser prices. Hence, $\nu = 0.90$, and then $\alpha = 0.79$. Estimates of the agglomeration externality parameter are also scarce. To choose now a number, we follow Ciccone (2002) that finds an elasticity of labor productivity with respect to employment density of 4.5 percent in a sample of European nations – similar to the 4 percent estimated for the U.S. by Ciccone and Hall (1996). As a consequence, $\nu/(1-\lambda)$ equals 1.045, and $\lambda = 0.139$.

We allow the natural endowment to vary from *zero* to 15 percent of the natural-richest economy's income level; this means that Z_i varies from *zero* to 0.5 in our simulations. In turn, the value of the aggregate capital stock K is picked so as to generate, on average, a capital-output ratio of about 3 for economies that have a Z_i above the median; this approach agrees with country level data on capital stocks and natural resource rents provided by PWT 8.0 and World Bank, respectively. A value of 3 is also supported by evidence presented in Inklaar and Timmer (2013) using PWT 8.0 data; in particular, these authors find that the capital-output ratio is uncorrelated with GDP per capita levels across nations, with an average close to 3.

Agglomeration differences between resource abundant and resource scarce regions are proxied by population density figures. Density differences between resource-rich and resource-poor regions vary greatly across nations. For example, if we compare population density between the 10 most natural-scarce and the 10 most natural-abundant regions, the ratio of the former to the latter is 4.80 in Brazil, 4.52 in India and 1.78 in Russia. We choose an intermediate value of 2.5, and assign $L_i = 1$ and $L_j = 2.5$.

[22] When numbers for developed and developing economies were available, we did not find significant differences across countries in the values, except for within-country density differences. Resource-scarce and resource abundant economies showed also an additional difference with respect to the capital-output ratio, with the resource-rich having a slightly larger capital-output ratio on average. Nevertheless, our quantitative results were not sensitive to reasonable changes in either the capital-output ratio or density. Therefore, our findings apply to both developing and developed economies, as well as resource scarce and resource abundant nations.

Finally, the parameter γ, that is, the weight of public goods in consumer's utility function is calibrated to reproduce the share of the government spending in GDP, used as a proxy for the ratio $G/(C+G)$ in the model. Looking at the cross-country average from 2005 to 2009 provided by PWT 8.0, this number is about 18 percent, and its correlation with the income share of natural-resource rents is very low (-0.06). The 18 percent implies that γ equals 0.55.

B.3 Simulation results

We now present the results obtained in the simulations. Suppose that our model economy, composed of identical regions, starts without natural riches, and that, suddenly, there is a natural resource windfall in region i. Given that all other regions are identical, we can treat them as a unique economy, call it region j. We look at the equilibrium values of some key variables depending on the size of the shock.

Figure A3 presents results for four different parameterizations. The first row gives the benchmark calibration described in the previous section. The second row is obtained when the agglomeration externality parameter λ rises. In this case, the value of γ is also modified to maintain the share of the public good invariant, and then abstract from demand-side effects. In the third row, the capital share α falls, and is equivalent to making differences in the capital-labor ratio less important for the results. Finally, row 4 shows the effect of a decrease in the share of the public good in total income $G/(C+G)$.

The two columns in Figure A3 provide results for tax rates and income levels (vertical axes) as a function of the natural endowment variable Z_i (horizontal axis). Recall that, by assumption, region j does not own natural riches ($Z_j = 0$). More specifically, the LHS column gives results for the tax rates τ_i (taui, black line) and τ_j (tauj, grey line). The RHS column, in turn, shows the predicted values of income in region j (Y_j, solid grey line), income plus natural resource endowment in region i ($Y_i + Z_i$, black line) and income in the whole country ($Y + Z_i = Y_i + Y_j + Z_i$, dashed black line).

The qualitative effects on tax rates and regional income are the same across rows. In particular, when $Z_i = Z_j = 0$, tax rates in both regions coincide.[23] As the natural endowment rises in i, this region reduces pressure on taxpayers. Region j then responds in the opposite direction, rising its capital tax rate to be able to finance public goods, thus amplifying the capital outflow. Income in region j falls due to this, but increases in region i because of both the capital inflow and the natural resource discovery.

Quantitative findings and the effect on the nation's total income are, however, different across scenarios. Look at the dashed line in the RHS panels. In the benchmark economy (first row), the country's income falls as Z_i increases. The movement of capital

[23] Bucovetsky (1991) shows that in an asymmetric tax competition with population dfferences, the more populated region imposes higher tax rates. This exercise extends his analysis by showing that an agglomeration externality can possibly correct for that, as we observe that in equilibrium tax rates are equal despite having population differences.

from the resource poor region to the resource abundant one causes output loss, because the same unit of capital can produce more in the agglomerated region than in the non-agglomerated one.

The importance of the agglomeration externality can be shown by picking a larger value of λ. In particular, we increase λ from 0.139 to 0.25. As row two shows, this change makes the decrease in income larger as Z_i rises. The reason is that the impact of a larger Z_i on τ_i goes up, in absolute terms, with the agglomeration externality parameter (see expression (5)). Put differently, competition to attract capital becomes fiercer. The LHS chart also shows that the governments tax the extra output from the agglomeration externality at a higher rate. The reason now is the higher multifactor productivity related to the stronger externality.[24]

Rows three and four in Figure A3 represent two cases in which income levels in the country do not fall with natural riches. The first one (third row) is when the labor share is sufficiently low. This case illustrates the importance for the results of the lack-of-labor-mobility assumption. When the share of labor falls from 0.7 to 0.6 – thus α increases from 0.22 to 0.33 – the effect of a change in Z on economy-wide output becomes slightly positive. We find the same effect in row four, which gives results when the share of public goods in total income falls from 18 to 10 percent. A smaller government needs less taxes to finance itself and reacts less to changes in the natural endowment. In both cases, the ultimate reason for the lack of a negative impact on total income is that the tax rates in both regions do not react as much to changes in the natural endowment, Z.

B.4 Does labor follow capital everywhere?

As we have shown, the assumption that labor is immobile matters to obtain the natural resource curse result through the market mechanism. If labor were fully mobile, the agglomeration externality would cause all labor and capital to move to region i as soon as new natural riches are discovered, increasing the nation's welfare level. However, if population density is fixed, the externality is *de facto* not able to induce increasing returns. As a consequence, only a fraction of capital is reallocated, and then the externality serves to generate a stronger negative effect on tax rates and total income.

Nevertheless, what we need is not the complete lack of labor mobility. It can be easily deduced that it is sufficient for our results to go through (in addition to having the standard framework of diminishing marginal productivities) that capital and labor do not move together towards low-agglomerated resource abundant regions. In other words, the requirement is that resource rich and resource poor areas offer sufficiently different incentives to capital and labor. In what follows, we argue that the latter is a sensible assumption.

To start with, recall that the mere existence of different population densities in

[24] This is consistent with previous studies on tax competition and agglomeration. See Borck and Pfluger 2006.

a nation is inconsistent with agglomeration externalities in case labor was to follow job opportunities only. Besides the evidence on agglomeration externalities presented by Ciccone and Hall (1996), other authors also point out in the same direction. For example, Decressin and Fatas (1995) find that regional labor adjustments in Europe occur through a fall in the participation rate instead of through outwards migration.

Focusing more on resource poor versus resource rich regions, anecdotal evidence on unemployment also suggests the same conclusion. If labor moved following only job opportunities, unemployment rates should be equalized across economies. However, oil rich areas such as Aberdeen in the U.K., and North Dakota and North Slope Borough (Alaska) in the U.S. enjoy much lower unemployment rates than their respective national economies. According to the Office of National Statistics, the unemployment rate in Aberdeen on July 2010 was 2.2%, compared to 8.4% for Scotland. The above two U.S. areas display similar patters: unemployment rates on February/March 2012 in North Dakota and North Slope Borough were 3.1% and 5.5%, respectively; much lower than the 8.3% of the U.S..

Let us now look more directly at the relationship between changes in each of the two inputs and natural resources. More specifically, we look at the partial correlation between the growth in population density and the initial GDP share of the primary sector, and between the growth in investment and the initial GDP share of the primary sector, controlling for the initial values of the non-natural input measures (to account for potential convergence effects).

Following the above agglomeration example, we first examine the case of the U.S. in Figure A4. The upper panel depicts the residuals from regressing the average annual growth from 1977 to 2008 of population density on population density in 1977 against the residuals of the GDP share of the primary sector in 1977 on population density in 1977. Notice that the slope of the regression line gives the coefficient on the natural input measure in the regression of population density growth on natural resources and initial population density. This slope is negative and statiscally significant, giving some indication that population in resource abundant regions grows more slowly.[25] In Figure A5 we present results of a similar exercise for additional nations, yielding similar results.[26]

The bottom chart in Figure A4 undertakes the same, within U.S., analysis for the capital input. For the same time period, the panel depicts the residuals from regressing the growth of the GDP share of investment on the initial GDP share of investment against the residuals of the initial GDP share of the primary sector on the initial GDP

[25] This result is supported by Michaels *et al.* (2012) who find that since the late 19th century densely U.S. regions became more densely populated over time, compared to those regions with relatively low initial density levels.

[26] Results appear for Australia, Brazil, Germany, and India. Data retrieved from the central statistical agencies of each federation. We plot correlations for the maximized period for which data is available at the regional level. Australia: 1990-2009; Brazil: 1995-2008; Germany: 1991-2009; India: 1980-2008.

share of investment.[27] Now results are opposite: resource abundant regions attract on average more capital. That is, investment increases faster but population grows more slowly in regions with more resources. This is obtained while controlling for possible transitional effects caused by relatively low initial levels, and also for investment induced by output changes. In Figure A6 we present results of a similar exercise for additional nations, yielding similar results.[28]

This evidence provides support to the assumption that labor does not follow capital at least towards less agglomerated and more isolated areas where natural riches are mostly located. We could say that whereas capital only searches for financial returns, labor shows a preference for more agglomerated areas.

C List of Variables

C.1 Cross-sectional estimations

Source of variables in these tables is Sachs and Warner (1997), unless stated otherwise.

Growth (dependent variable). *Measure 1* (used in all regressions, with the exception of Regression 8 of Table 2): Average annual growth in real per capita GDP in the years 1970-1990. *Measure 2* (used in Regression 8 of Table 2): Average annual growth in real per capita GDP in the years 1970-2008 (source: World Development Indicators).

Logarithm of initial income. The log of real per capita GDP in 1970.

Resource share. *Measure 1* (used in all cross-sectional regressions, with the exception of those in Table A1): Share of natural capital in total GDP in 2000; natural capital is calculated as the sum of *cropland*, *forest*, *pastureland*, *protected areas*, and *subsoil assets* (source: World Bank 2006). *Measure 2* (used in Table A1): Share of mineral production in total GDP in 1970.

Cropland. Share of cropland in total GDP in 2000; cropland wealth is calculated as the net present value of the return to land, being the rents from cultivating crops (source: World Bank 2006).

Forest. Share of forest in total GDP in 2000; forest wealth is the sum of timber and non-timber forest wealth. The former is calculated as the present discounted value of rents from roundwoood and fuelwood production, whereas the latter is obtained as the present value of the returns from annual non-timber goods and benefits derived from services provided by forests (source: World Bank 2006).

[27] For the investment measure, we follow Papyrakis and Gerlagh (2007) and proxy it employing the GDP share of industrial machinery production, because BEA does not publish investment data at the state level.

[28] Results appear for Australia, Brazil, Germany, and India. Data retrieved from the central statistical agencies of each federation. We plot correlations for the maximized period for which data is available at the regional level. Australia: 1990-2008; Brazil: 1995-2005; Germany: 1991-2005; India: 1980-2005.

Pastureland. Share of pastureland in total GDP in 2000; pastureland wealth is calculated as the net present value of the return to land, being the rents from selling livestock products (source: World Bank 2006).

Protected areas. Share of protected areas in total GDP in 2000; protected areas are estimated as the opportunity cost of preservation i.e. the minimum of wealth derived from alternative uses of land such as growing crops and livestock (source: World Bank 2006).

Subsoil assets. Share of subsoil assets in total GDP in 2000; subsoil assets are calculated as the present value of rents from extraction of oil, natural gas, coal, and minerals (source: World Bank 2006).

Openness. The fraction of years over the period 1970-1990 in which the country is rated as economically 'open', according to Sachs and Warner (1997).

Investment. The log of the ratio of real gross domestic investment to real GDP, averaged over the period 1970-1989.

Institutional quality. The Rule of Law Index from the International Country Risk Guide, in 1982, expressed as a number between one and six, six presenting best institutional quality and one least.

Ethnicity. Measure of ethno-linguistic fractionalization; measures the probability that two randomly-selected people from a country will not belong to the same ethnic or linguistic group.

Terms of trade. The average annual growth rate in the log of the external terms of trade between 1970 and 1990. External terms of trade are defined as the ratio of an export price index to an import price index.

Education. Secondary school enrollment rate in 1970.

Landlocked economies. A dummy variable for landlocked economies.

Fiscal decentralization. *Vertical Imbalance:* The extent to which sub-national governments rely on their own revenue sources for their expenditures; it is measured in initial year, closest to 1970 in case data is available for one of the years in the 1970-1975 period; the indicator is a number between 0 and 100 – the closer it is to 100 the more fiscally independent sub-national governments are (source: World Bank Fiscal Decentralization Indicators).

Potential Vulnerability. The share of non-agglomerated (urbanized) area in total area in 2001 (source: Gridded Population of the World database, Center for International Earth Science Information Network at Columbia University) multiplied by the *Vertical Imbalance* measure.

Land area. The logarithm of land area in square Kilometers (source: World Bank Development Indicators).

C.2 Panel estimations

Note that Regressions 1, 2, 4, and 5 of Table 3 employ a panel that covers the period of 1972-2008 with 9-year intervals, whereas Regression 3 of Table 3 employs a panel that covers the period of 1965-2000, with 5-year intervals. Unless stated otherwise, variables are measured in the initial year of the corresponding time interval.

Growth (dependent variable). *Measure 1* (used in Regressions 1, 2, 4, and 5 of Table 3): Average annual growth in real per capita GDP in the years 1972-2008, in 9-year intervals (source: World Bank Development Indicators). *Measure 2* (used in Regression 3 of Table 3): Average annual growth in real per capita GDP in the years 1965-2000, in 5-year intervals (source: World Bank Development Indicators).

Logarithm of initial Income. The log of real GDP per capita (source: World Bank Development Indicators).

Resource share. *Measure 1:* Price-based measure; GDP share of mineral rents (from oil, natural gas, minerals, and coal) in earliest year available multiplied by the price index of mineral goods, normalized to 2005 (source: World Bank Development Indicators). Rents are computed as unit rents times production, where a unit rent is the unit price less unit cost. The price measure is a general index that does not account for the different mineral shares of each country; prices of different minerals, however, exhibit strong co-movements. *Measure 2:* GDP share of primary rents (source: World Bank Development Indicators). *Measure 3* (instrument, Regression 5 of Table 3): GDP share of mineral rents in t-1 (source: World Bank Development Indicators).

Openness. Share of total trade (exports and imports) in total GDP (source: Penn World Table 7.0).

Investment. The log of the ratio of real gross domestic investment to real GDP (source: Penn World Table 7.0).

Institutional quality. Civil Liberties Index, expressed as a number between one and seven, one representing best institutional quality and seven least (source: Freedom House).

Democracy. Democracy level, expressed as a number between zero and ten, ten representing the highest level and zero least (source: Polity-IV Project Dataset, Center for Systematic Peace).

Education. Average years of total schooling for population aged 15 and over (source: Barro and Lee 2010).

Fiscal decentralization. *Vertical Imbalance* (used in Regressions 1, 2, 4, and 5 of Table 3): The extent to which sub-national governments rely on their own revenue sources for their expenditures (source: World Bank Fiscal Decentralization Indicators). *Kearney Decentralization Index* (used in Regression 3 of Table 3): The Revenue-Raising component of the Kearney Decentralization Index, (available for the years 1965-1995) expressed as a number between zero and four with four having the highest level of revenue-raising autonomy and zero the least (source: Arzaghi and Henderson 2005).

Internal armed conflicts. An indicator for whether an internal armed conflict has taken place in the investigated time interval. An internal armed conflict is defined as a contested incompatibility that concerns government and/or territory where the use of armed force between two parties, of which at least one is the government of a state, results in at least 25 battle-related deaths. More specifically, an internal armed conflict occurs between the government of a state and one or more internal opposition group(s) without intervention from other states (source: Uppsala Conflict Data Program).

D List of Countries

D.1 Cross-sectional estimations

Australia, Austria, Belgium, Bolivia, Brazil, Canada, Chile, Colombia, Costa Rica, Denmark, Dominican Republic, Ecuador, Finland, France, West Germany, Greece, Guatemala, Honduras, India, Indonesia, Iran, Ireland, Israel, Italy, Kenya, Korea Republic, Malawi, Malaysia, Mexico, Netherlands, New Zealand, Nicaragua, Norway, Pakistan, Paraguay, Peru, Philippines, Portugal, Senegal, Spain, Sri Lanka, Sweden, Switzerland, Thailand, Trinidad and Tobago, Tunisia, United Kingdom, United States, Uruguay, Venezuela, Zambia. [Table A1 includes also Sudan].

D.2 Panel estimations

D.2.1 Regressions 1, 2, 4, and 5; Table 3

Albania, Australia, Austria, Belgium, Bolivia, Botswana, Brazil, Bulgaria, Canada, Chile, China, Colombia, Costa Rica, Czech Republic, Denmark, Dominican Republic, Ecuador, Estonia, Fiji, Finland, France, Gambia, Germany, Greece, Guatemala, Honduras, Hungary, India, Indonesia, Iran, Ireland, Israel, Italy, Kenya, Korea Republic, Latvia, Lithuania, Luxemburg, Malawi, Malaysia, Mauritius, Mexico, Moldova, Mongolia, Netherlands, New Zealand, Nicaragua, Norway, Pakistan, Panama, Papua New Guinea, Paraguay, Peru, Philippines, Poland, Portugal, Romania, Russian Federation, Senegal, Slovak Republic, Slovenia, Spain, Sri Lanka, Swaziland, Sweden, Switzerland, Thailand, Tunisia, Uganda, United Kingdom, United States, Uruguay, Zambia, Zimbabwe.

D.2.2 Regression 3; Table 3

Algeria, Argentina, Australia, Bangladesh, Brazil, Cameroon, Canada, Chile, China, Colombia, Ecuador, Egypt, France, Germany, Ghana, Great Britain, Greece, Hungary, India, Indonesia, Italy, Japan, Kenya, Korea Republic, Malaysia, Mexico, Mozambique, Nepal, Netherlands, Pakistan, Peru, Philippines, Poland, Romania, Russian Federation, Spain, Sri Lanka, Syria, Thailand, United States, Uganda, Venezuela, Zaire.

D.3 Developing/Developed Division

Division is made to high and non-high income countries, based on the earliest available classification of the World Bank (starting at 1989).

D.3.1 Cross-sectional estimations

Developing economies: Bolivia, Brazil, Chile, Colombia, Costa Rica, Dominican Republic, Ecuador, Guatemala, Honduras, India, Indonesia, Iran, Kenya, Korea Republic, Malawi, Malaysia, Mexico, Nicaragua, Pakistan, Paraguay, Peru, Philippines, Senegal, Sri Lanka, Sudan, Thailand, Trinidad and Tobago, Tunisia, Uruguay, Venezuela, Zambia, Zimbabwe. **Developed economies:** Australia, Austria, Belgium, Canada, Denmark, Finland, France, West Germany, Greece, Ireland, Israel, Italy, Netherlands, New Zealand, Norway, Portugal, Spain, Sweden, Switzerland, United Kingdom, United States.

D.3.2 Panel Estimations

Developing economies: Albania, Bolivia, Botswana, Brazil, Chile, China, Colombia, Costa Rica, Croatia, Czech Republic, Dominican Republic, Ecuador, Estonia, Fiji, Gambia, Guatemala, Honduras, India, Indonesia, Iran, Kenya, Korea, Latvia, Lithuania, Malawi, Malaysia, Mauritius, Mexico, Moldova, Mongolia, Nicaragua, Pakistan, Panama, Papua New Guinea, Paraguay, Peru, Philippines, Russian Federation, Senegal, Slovakia, Slovenia, Sri Lanka, Swaziland, Thailand, Tunisia, Uganda, Zambia, Zimbabwe. **Developed economies:** Australia, Austria, Belgium, Bulgaria, Canada, Denmark, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Israel, Italy, Luxemburg, Netherlands, New Zealand, Norway, Poland, Portugal, Romania, Spain, Sweden, Switzerland, United Kingdom, United States.

Table A1: Cross-country growth regressions, using the GDP share of mineral output as the resource share proxy [Cross-section, Sachs and Warner (1997) database, period: 1970-1990]

Panel A: Main and second stage results	Initial results	Fiscal decentralization is 'Vertical Imbalance'			Fiscal decentralization is 'Potential Vulnerability'	
Dependent variable: Average annual growth in real per capita GDP, 1970-1990	(1) (OLS)	(2) (OLS)	(3) (OLS)	(4) (TSLS)	(5) (OLS)	(6) (TSLS)
Resource share	-15.68*	-15.88	2.68	17.54	1.87	11.12
	(8.86)	(9.75)	(14.47)	(17.13)	(14.81)	(16.47)
Logarithm of initial income	-1.63***	-1.63***	-1.72***	-1.69***	-1.69***	-1.71***
	(0.38)	(0.39)	(0.38)	(0.35)	(0.38)	(0.36)
Openness	2.2***	2.18***	2.26***	2.28***	2.27***	2.24***
	(0.46)	(0.47)	(0.47)	(0.47)	(0.47)	(0.47)
Investment	0.59	0.62	0.84	0.16	0.72	0.24
	(0.37)	(0.55)	(0.51)	(0.41)	(0.49)	(0.41)
Rule of law	0.08	0.08	0.14	0.23	0.15	0.22
	(0.37)	(0.22)	(0.23)	(0.22)	(0.23)	(0.22)
Ethnicity	-0.01**	-0.01**	-0.01*	-0.01**	-0.01*	-0.01**
	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)
Terms of trade	0.21*	0.22*	0.15	0.13	0.15	0.14
	(0.11)	(0.11)	(0.12)	(0.12)	(0.12)	(0.12)
Education	2.06*	2.08*	2.27*	2.18*	2.14*	2.17*
	(1.2)	(1.2)	(1.16)	(1.14)	(1.18)	(1.16)
Landlocked economies	-0.49	-0.5	-0.48	-0.28	-0.43	-0.32
	(0.44)	(0.46)	(0.36)	(0.36)	(0.38)	(0.38)
Ethnicity x Resource share	0.02	0.02	0.006	-0.009	0.009	0.006
	(0.05)	(0.05)	(0.05)	(0.04)	(0.05)	(0.04)
Rule of law x Resource share	3.34	3.39	1.49	-0.64	1.33	-0.03
	(2.43)	(2.66)	(2.91)	(3.01)	(2.94)	(3.03)
Fiscal decentralization		0.0008	0.01	0.01	0.009	0.009
		(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Fiscal decentralization x Resource share			**-0.14****	**-0.25*****	**-0.13****	**-0.2****
			(0.06)	**(0.09)**	**(0.06)**	**(0.08)**
Adjusted R-squared	0.7155	0.7156	0.739	0.746	0.7366	0.7405
Observations	52	52	52	52	52	52

Panel B: First stage results

Regressions:	(4)	(6)
Dependent variable:	Fiscal decentralization	Fiscal decentralization
Logarithm of land area	4.52***	5.43***
	(1.31)	(1.16)
Adjusted R-squared	0.693	0.7364
F-statistic	12.46	16.73

Standard errors are robust and appear in parentheses for independent variables. Superscripts *, **, *** correspond to a 10, 5 and 1% level of significance, respectively. First stage regressions include all relevant variables. All regressions include an intercept. For description and sources of variables, as well as a list of economies included in each regression, see Appendix.

Table A2: Revisitng main results under reduced multicollinearity [OLS estimations]

Dependent variable: Average annual growth in real per capita GDP	Cross section (Table 2, Regression 1)	Panel (Table 3, Regression 1)	Panel (Table 3, Regression 4)	Panel (Table 3, Regression 3)
	(1)	(2)	(3)	(4)
Resource share	7.05**	0.45	8.63	0.01
	(3.01)	(0.43)	(9.79)	(0.05)
Logarithm of initial income	-2.08***	-3.75***	-4.16***	-2.25*
	(0.37)	(1.24)	(1.27)	(1.19)
Openness	2.28***	1.34	1.11	1.19
	(0.53)	(1.28)	(1.19)	(1.91)
Investment	0.53	0.59	0.7	2.33***
	(0.52)	(1.19)	(1.1)	(0.62)
Rule of law	0.19			
	(0.18)			
Ethnicity	-0.02***			
	(0.01)			
Terms of trade	0.16**			
	(0.07)			
Landlocked economies	-0.64			
	(0.5)			
Education	3.55**			
	(1.44)			
Civil liberties		-0.52***	-0.58***	-0.21
		(0.19)	(0.19)	(0.19)
Democracy		-0.001	0.01	-0.02
		(0.04)	(0.04)	(0.02)
Fiscal decentralization	0.01	-0.02	-0.002	-0.04
	(0.01)	(0.01)	(0.01)	(0.29)
Fiscal decentralization x Resource share	**-0.29*** **	**-0.02*** **	**-0.38** **	**-0.05*** **
	(0.11)	**(0.01)**	**(0.19)**	**(0.02)**
Adjusted R-squared	0.7327	0.6596	0.6591	0.5874
Observations	51	207	207	232

Standard errors are robust, clustered by country in Regressions 2, 3, 4, and appear in parentheses for independent variables. Superscripts *, **, *** correspond to a 10, 5 and 1% level of significance, respectively. Regressions 1, 2, 3, and 4 replicate Regressions 1 of Table 2, and Regressions 1, 4 and 3 of Table 3, respectively, with the exclusion of non-fiscal-decentralization related interactions; the highest Variance Inflation Factor (uncentered) in all cases is 6.58. For description and sources of variables, as well as a list of economies included in each regression, see Appendix.

Figure A1: GDP share of primary sector Vs. agglomeration in U.S. States

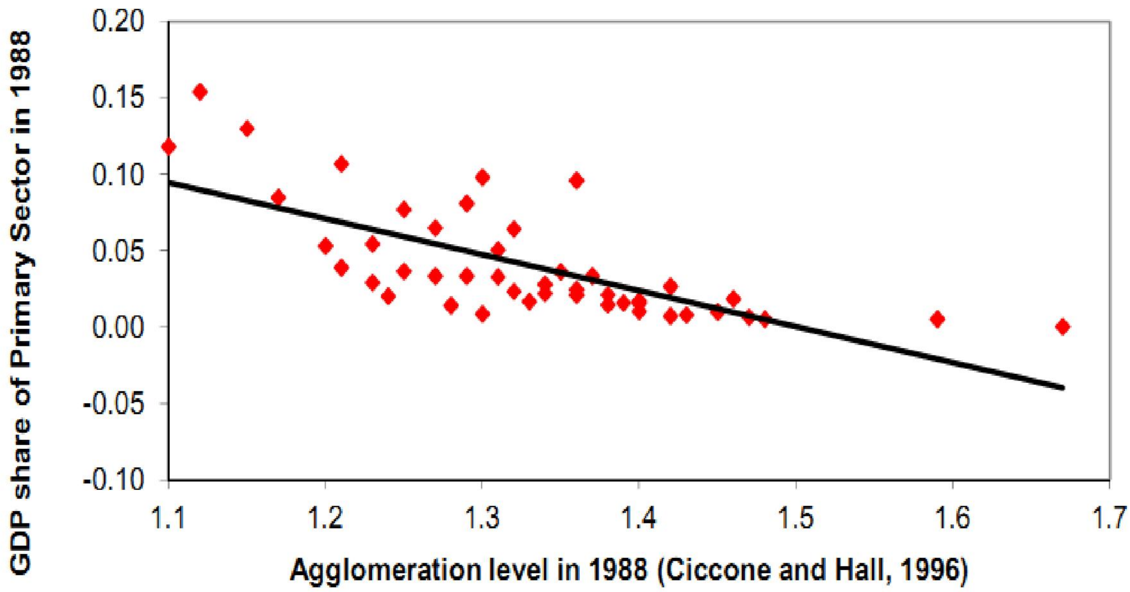
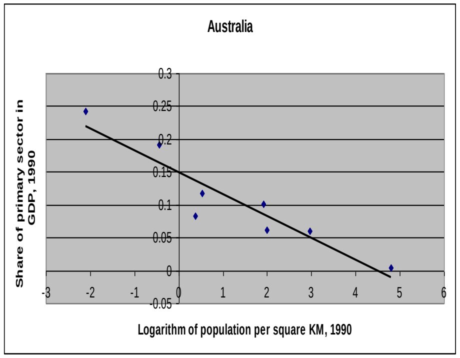
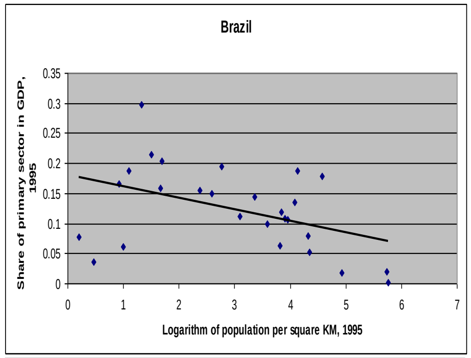
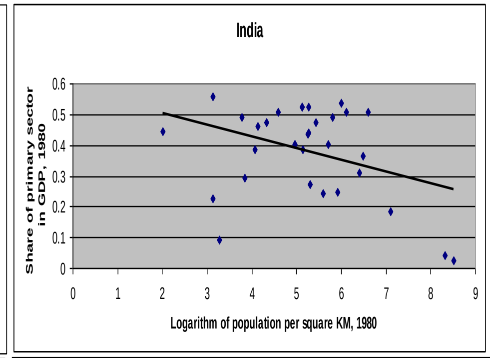


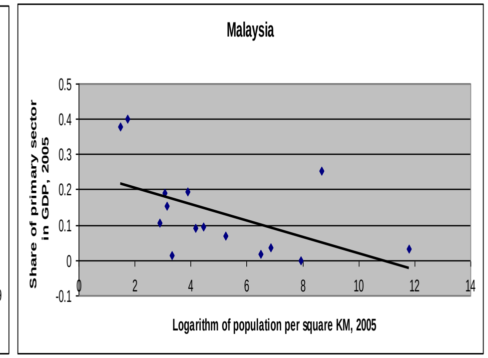
Figure presents the correlation between the Ciccone-Hall Agglomeration Index (1996) and the GDP share of the primary sector in 1988, for the 48 contiguous U.S. states (source: U.S. Bureau of Economic Analysis); ρ=-0.72.

Figure A2: Population density versus resource abundance







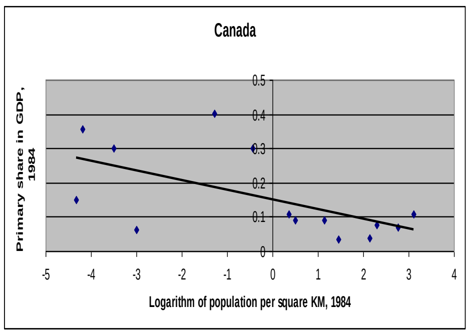


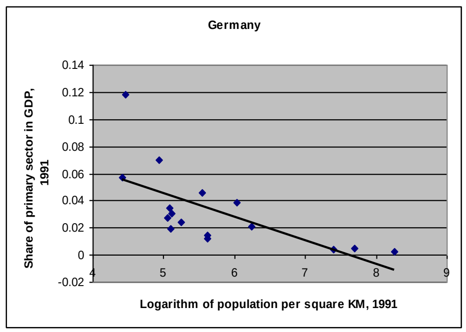
Resources = 0.1497 - 0.0333Agglomeration
R-squared = 0.8688 , p<0.00

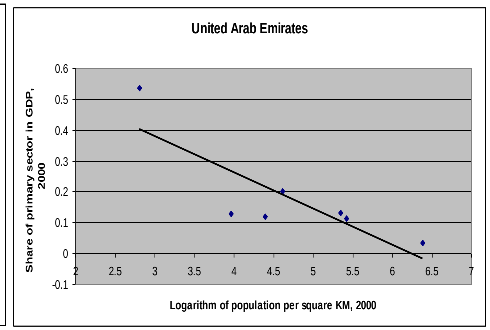
Resources = 0.1802 – 0.0189Agglomeration
R-squared = 0.1844 , p<0.02

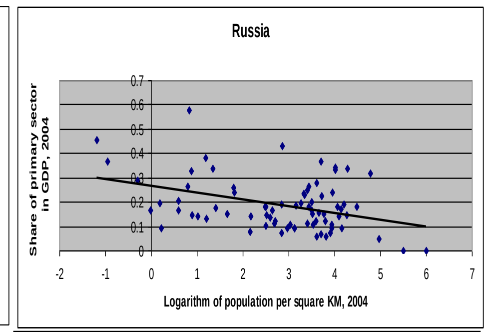
Resources = 0.7333 - 0.1175Agglomeration
R-squared = 0.6875 , p<0.02

Resources = 0.2531 - 0.0233Agglomeration
R-squared = 0.274 , p<0.04









Resources = 0.1322 - 0.0173Agglomeration
R-squared = 0.4366 , p<0.00

Resources = 0.151 - 0.0282Agglomeration
R-squared = 0.369 , p<0.02

Resources = 0.5784 - 0.0378Agglomeration
R-squared = 0.1326 , p<0.04

Resources = 0.2645 - 0.029Agglomeration
R-squared = 0.1468 , p<0.00

Figure presents correlation between state-level population-density and the GDP share of primary sector (each point representing a state within the respective federation). Data retrieved from the central statistical agencies of each federation.

Figure A3: Tax rates (left) and relative output levels (right) predicted by model

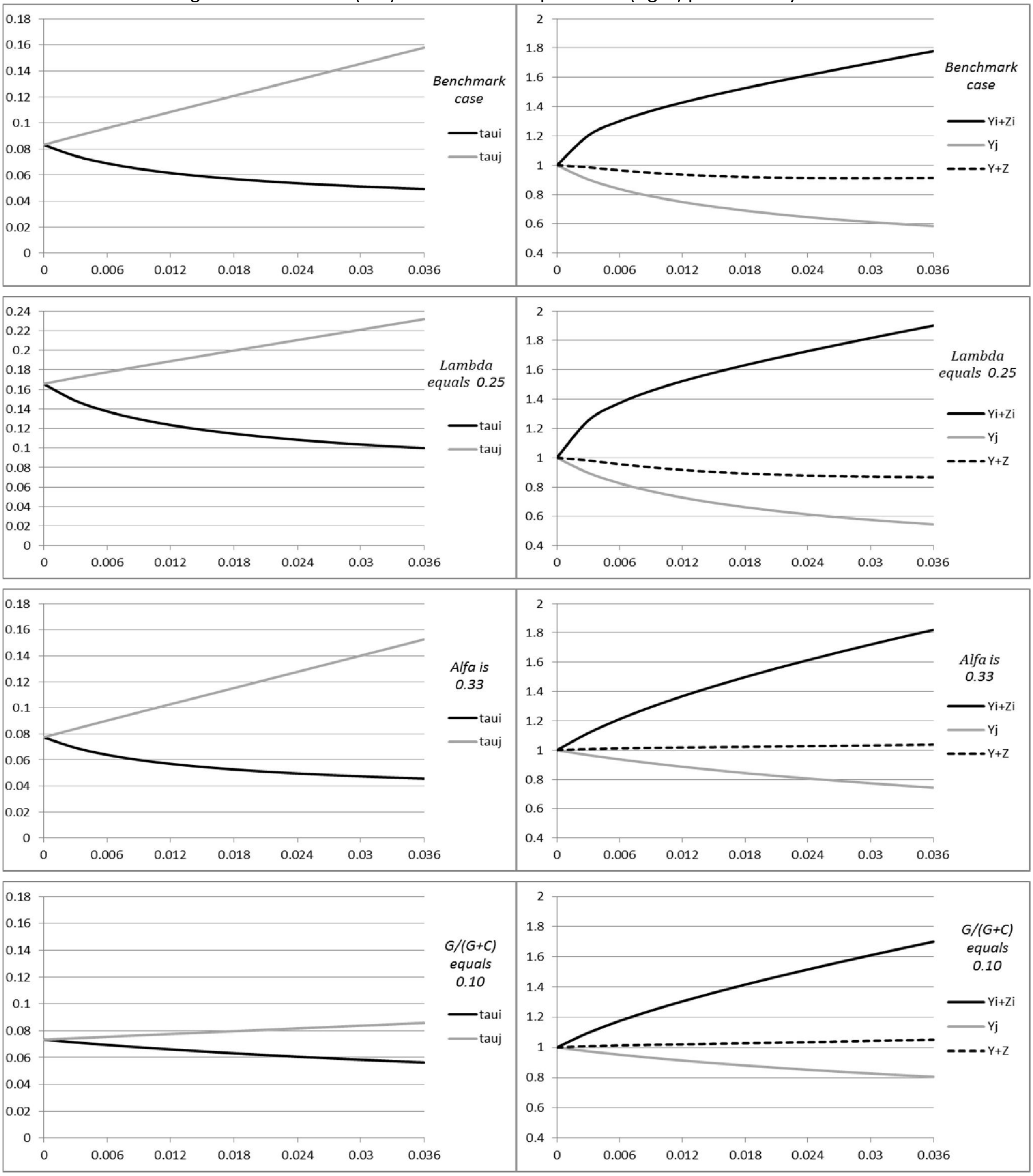


Figure presents results of the quantitative exercise. See Appendix B for further details.

Figure A4: Partial correlations of average annual input growth and initial natural resources: U.S. states

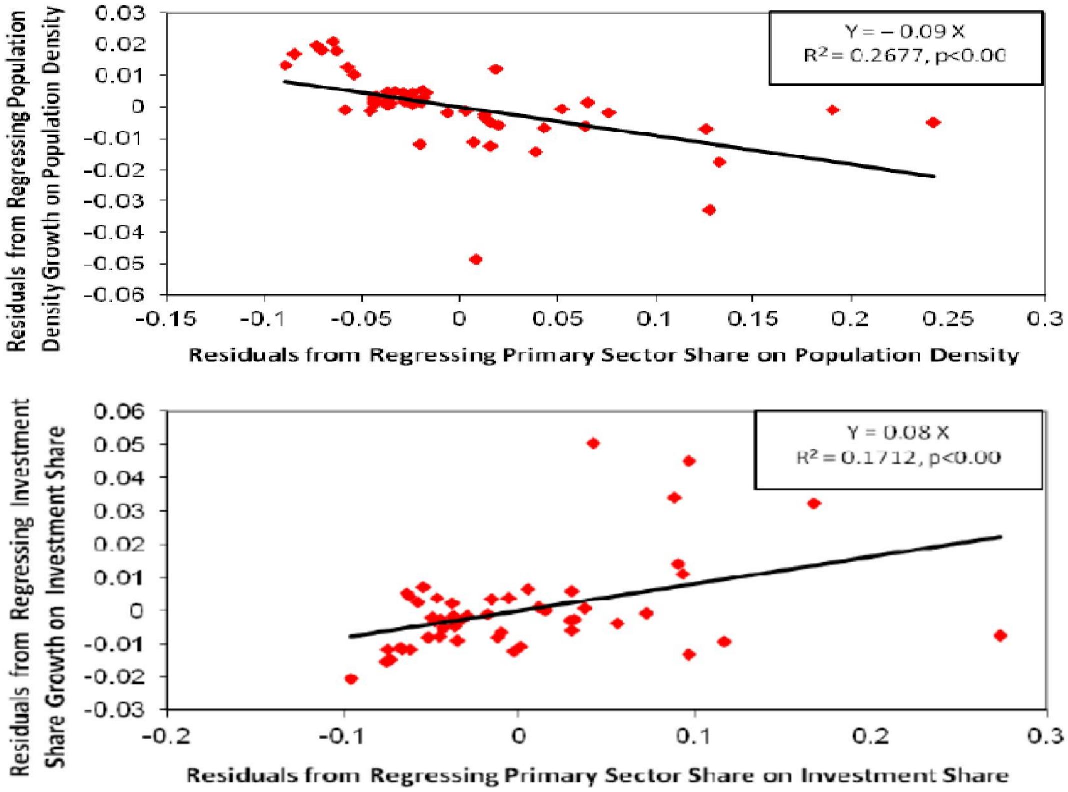
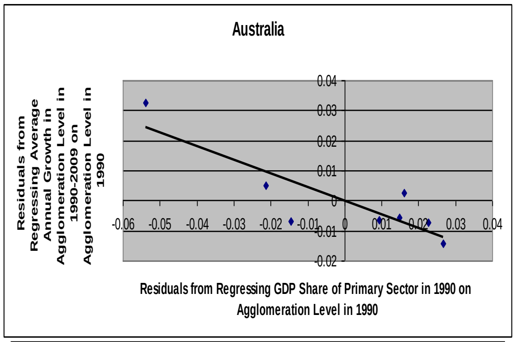
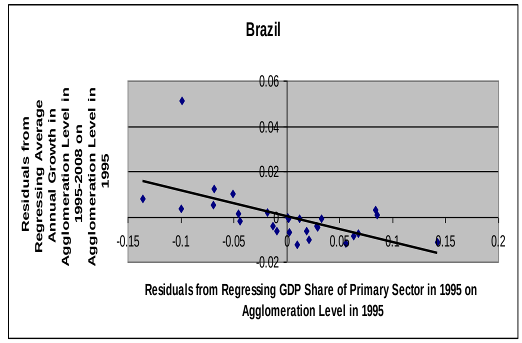


Figure presents the conditional correlation between average annual input growth and initial natural resources for U.S. states, 1977-2008, controlling for initial level of input growth (source: U.S. Bureau of Economic Analysis), where initial refers to 1977. The input represented in the top (lower) panel is population density (GDP share of investment), which proxies for labor (capital).

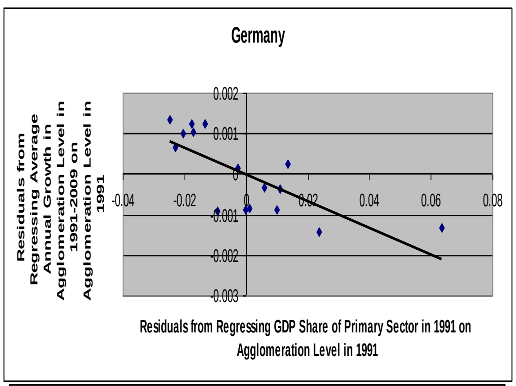
Figure A5: Partial correlations of state-level average annual population-density growth and initial natural resources: Additional countries



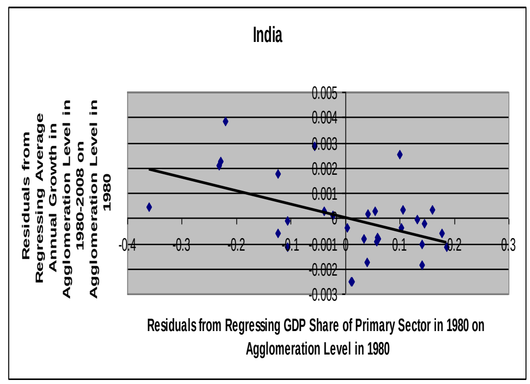
Y = – 0.45 X
R-squared = 0.7371, p<0.00



Y = – 0.11 X
R-squared = 0.3539, p<0.01



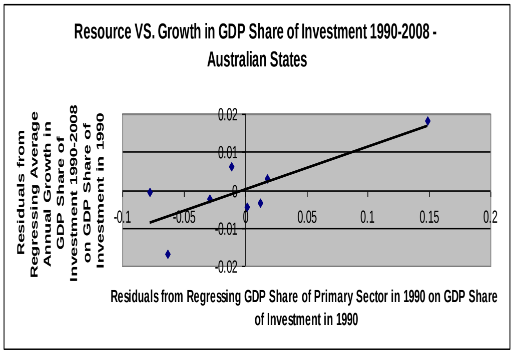
Y = -0.03 X
R-squared = 0.5561, p<0.00



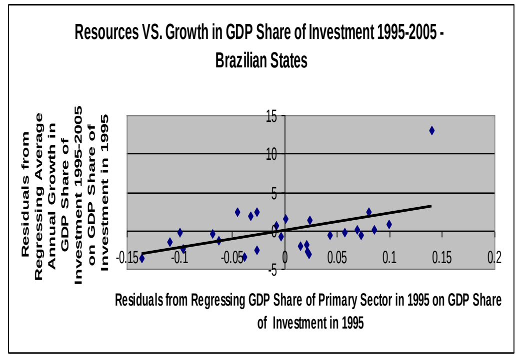
Y = -0.005 X
R-squared = 0.2233, p<0.00

Figure presents the conditional correlation between state-level average annual population-density growth and initial natural resources, controlling for initial level of input growth, where initial refers to initial year. Data retrieved from the central statistical agencies of each federation. We plot correlations for the maximized period for which data is available at the regional level.

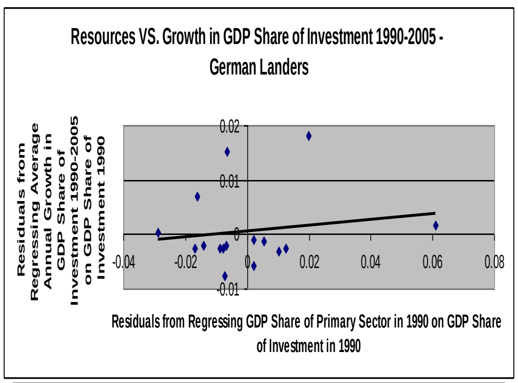
Figure A6: Partial correlations of state-level average annual investment growth and initial natural resources: Additional countries



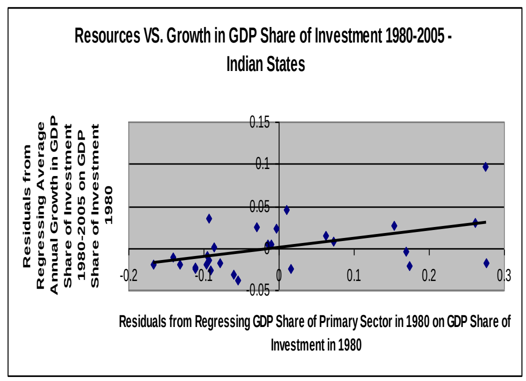
Y = 0.11 X
R-squared = 0.6258, p<0.01



Y = 22.7 X
R-squared = 0.2441, p<0.00



Y = 0.11 X
R-squared = 0.236, p<0.00



Y = 0.11 X
R-squared = 0.236, p<0.00

Figure presents the conditional correlation between state-level average annual investment growth and initial natural resources, controlling for initial level of input growth, where initial refers to initial year. Data retrieved from the central statistical agencies of each federation. We plot correlations for the maximized period for which data is available at the regional level.