Artificial States*

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March 2006

Abstract

Artificial states are those in which political borders do not coincide with a division of nationalities desired by the people on the ground. We propose and compute for all countries in the world two new measures of the degree to which states are artificial. One is based on measuring how borders split ethnic groups into two separate adjacent countries. The other measures how straight land borders are, under the assumption the straight land borders are more likely to be artificial. We then show that these two measures seem to be highly correlated with several measures of political and economic success.

1 Introduction

Artificial states are those for which political borders do not coincide with a division of nationalities desired by the people on the ground. Former colonizers or post-war agreements amongst victors regarding borders have often created monstrosities in which ethnic or religious or linguistic groups were thrown together or separated without any respect for peoples' aspirations. Eighty percent of African borders follow latitudinal and longitudinal lines and many scholars believe that such artificial (unnatural) borders, which create ethnically fragmented countries or, conversely, separate into bordering countries the same people, are at the roots of Africa's economic tragedy.[1] Not only in Africa but everywhere around the globe from Iraq to the Middle East failed states, conflict and economic misery often are very visible around borders left over by former colonizers, borders that had little resemblance to natural division of peoples.

There are three ways in which those who drew borders created problems. First they gave territories to one group ignoring the fact that another group had

*We thank Jean Marie Baland, Albert Bravo-Biosca, Patrick Florance and participants at the Harvard Development Lunch for useful comments.

[1] See Easterly and Levine (1997) for early econometric work on this point. Herbs (2000) and especially Englebert Tarango and Carter (2002) focus on the arbitrariness of African borders as an explanation of politico economic failures in this region. At the time of decolonization, new rulers in Africa made the decision to keep the borders drawn by former colonizers to avoid disruptive conflicts amongst themselves.

already claimed the same territory. Second, they drew boundaries lines splitting ethnic (or religious or linguistic) groups into different countries, frustrating national ambitions of various groups and creating unrest in the countries formed. Third they combined into a single country groups that wanted independence. The results can be disastrous. Artificial borders increase the motivation to safeguard or advance nationalist agendas at the expense of economic and political development. As George Bernard Shaw eloquently put it "A healthy nation is as unconscious of its nationality as a healthy man is unconscious of his health. But if you break a nation's nationality it will think of nothing else but getting is set again."

While the nature of borders has been mentioned in the poltical scence (especially) and economic literature, we are not aware of systematic work relating the nature of country borders to the economic success of countries. Our goal is to provide measures that proxy for the "naturalness" or "artificiality" of borders and relate them to economic and political development. We provide two measures never before used in econometric analysis of comparative development. One measure is relatively simple and captures whether or not an ethnic group is "cut" by a political border. That is, we measure situations in which the same ethnic group is present in two bordering countries. This measure accounts fairly precisely for one of the ways in which borders may be "wrong", namely when borders cut through groups' land leave them in separate countries. But it does not capture other ways in which borders may be "artificial"; for instance situations in which two ethnic groups are forced into the same country. We then provide a second measure, based upon the assumption that if a land border is close to a straight line it is more likely to be drawn artificially; if it is relatively squiggly it is more likely to represent either geographic features (rivers, mountains etc.) and/or divisions carved out in time to separate different people. Needless to say, the measure is not perfect, but much of our paper is about precisely discussing this measure and alternatives. It turns out that our two new measures are in fact not highly correlated, implying that they capture different aspects of the artificial nature of states.

After we have constructed our measures we explore how they are correlated with various standard measures of economic development such as per capita GDP, measures of institutional success such as freedom or corruption, and measures of quality of life and public services, such as infant mortality and education. Both measures of artificiality are correlated with several variables that measure politico-economic development. Artificial states measured by the two proxies described above, function much less well than non-artificial states. The correlation of our measures with measures of politico-economic success of various countries are fairly robust to controlling for climate, colonial past and the other traditional measures of ethnolinguistic fractionalization.

We also checked our measures' relationship to the occurrence of wars, domestic or international. Our results are just a first step towards further research. A measure of political instability and violence is indeed correlated with our measure of artificial states; however we do not find evidence of correlations between the number and intensity for wars fought by one country with our measures of artificial borders.[2] Future research needs to address these questions using data on bilateral conflicts around various types of borders.

Because borders can be changed, as Alesina and Spolaore (1997) emphasized, citizens can rearrange the borders of artificial states. Indeed this happens; once can consider the breakdown of the Soviet Union. In fact it is quite possible that as time goes by many currently straight borders will become squiggly as they are rearranged. Relatively newly independent countries have had "less time" than countries which have been never colonized to carve their borders as a result of an equilibrium reflecting how different people want to organize themselves. With specific reference to Africa, Englebert, Trango and Carter (2002) document several instances of border instability in Africa due to the artificial original borders. Even amongst never-colonized countries, tensions remain, for example the Basque independentist movement in Spain.

We are not aware of other papers that have attempted to consider formally (as opposed to narratively) the relationship of the shape of countries to economic development, however our paper is related to three strands of the literature. One strand is the recent work on the size of countries and its relationship with economic growth, as in Alesina and Spolaore (2003), Alesina Spolaore and Wacziarg (2000), and Alcala and Ciccone (2004), amongst others. Second, our work builds on the literature concerning the relationship between ethnolinguistic fractionalization and economic growth, as in Easterly and Levine (1997) , Alesina et. al. (2003), and several others. Our paper discusses one historical phenomenon that may have led to excess ethnic fractionalization. [3] Third, the role of former colonizers has also been widely studied (see Acemoglu, Johnson and Robinson (2001) Glaeser et al(2004)) but not specifically with regards to the importance of borders. Our paper specifies a new mechanism by which colonizers affected subsequent development. In many ways we bridge these three strands because we focus on how colonizers have created fragmented societies by drawing artificial borders.

The paper is organized as follows. In Section 2 we provide historical examples of artificial border-drawing. Section 3 describes our basic hypothesis, presents our measures of artificial borders, and discusses the properties of these measures. Section 4 investigates whether artificial states indeed perform less well than other states, by relating our measures of borders to various indicators of economic and political development. The last section concludes.

2 Examples of problematic borders

Examples of problematic borders abound. Macmillan (2002) in her analysis of the post World War I meeting at Versailles describes how the redrawing of borders around the world was decided based on compromises between the winning powers, with often little regard for preserving nationalities. American

[2] Other authors as well have not identified a simple way of relating ethnic conflicts and civil wars, see for instance Easterly and Levine (1997) and Fearon and Laitin (2003).

[3] For a recent survey of this literature see Alesina and La Ferrara (2005).

President Woodrow Wilson spoke often and eloquently in favor of a nationality principle, namely that political borders had to respect ethnic boundaries and respect nationality, but that principle was often ignored including by Woodrow Wilson himself. The book by Macmillan clearly documents, sometimes even in hilarious ways, how borders were drawn on maps with strikes of a pencil by the leaders of England, France and the US, ignoring the leg work of their experts and without even knowing the names of the ethnicities involved. Historians agree that the Treaty of Versailles created many problematic borders that planted the seeds for a very large number of future conflicts.

The past and current trouble in the Middle East at least in part originated from this kind of agreement between Western powers. Under the Sykes-Picot agreement between British and French during WWI, Northern Palestine would go to the French, Southern Palestine to the British, and Central Palestine including Jerusalem would be an allied Condominium shared by the two. After the war, the French agreed to give up any claims to Palestine in return for control over Syria. The British abandoned their protegee (Faisal) in Syria and offered him Iraq, cobbling together three different Ottoman provinces containing Kurds, Shiites and Sunnis. This set the stage for instability and the military coups that led to Saddam Hussein. In Lebanon, the French added Tripoli, Beirut and Sidon to the traditional Moronite area around Mount Lebanon, giving their Maronite Christian allies control of what were originally Muslim areas.

The partition of India and Pakistan is another famous example of artificial borders. The burning issue in the partition of 1947 was whether and how to award separate rights of national self-determination to Hindus and Muslims (the British ignored the national aspirations of smaller groups like the Sikhs, which would bring its own bitter consequences). The Congress Party of Gandhi and Nehru campaigned for independence for one unitary Indian state, including Hindus, Muslims, and Sikhs from Peshawar to Dhaka. Mohammed Ali Jinnah founded the Muslim League, which called for a separate state for Muslims: Pakistan. But since Hindus and Muslims were mixed together all over the subcontinent, how could one devise a plan to carve a Muslim nation out of India?

This intermixing was the result of a complex history that included the Muslim Mughal dynasty that the British Raj replaced. Until the last days of the Raj, there were Muslim princes ruling over majority Hindu princedoms and Hindu princes ruling over majority Muslim princedoms. The only areas with a Muslim majority were in the extreme northwest and the extreme northeast, separated by a thousand miles, and still containing large minority Sikh and Hindu communities.

In the Muslim Northwest Frontier Province (NWFP), ethnic Pathans were separated from their fellow Pathans in Afghanistan by the Durand Line, an arbitrary boundary between Afghanistan and British India laid down by a previous British bureaucrat. Peshawar, the capital of NWFP, was the traditional winter home of the Afghan kings. The Pathans preferred either an independent Pukhtoonwa uniting all Pathans or a Pathan-led Greater Afghanistan. At the time of Partition, NWFP had a Congress-allied government led by a charismatic advocate of nonviolence, Khan Abdul Ghaffar Khan (the "Frontier Gandhi)."

Back in British India, two other provinces of the future Pakistan were Sindh and Balochistan. Sindhi feudal landowners initially opposed the Pakistan idea and only later gave their grudging support under the naïve hope that Sindh would be largely autonomous. Balochi tribesmen (also divided from ethnic compatriots by a colonial boundary with Iran) preferred an independent Balochistan, which would lead to a secessionist attempt in the 1970s, met with murderous repression by the Pakistani state. As far as Punjab and Bengal, Congress leaders would not consent to hand them over to the Muslims. This meant that the British would partition the mosaic of Hindus and Moslems in each state (and Sikhs in the Punjab, which was a Sikh state at one point). The Unionist government in Punjab prior to partition backed neither the Muslim League nor Congress.

The unhappiest heir of the partition of 1947 is Pakistan. Jinnah complained that he got a "moth-eaten" Pakistan, with missing halves of Bengal and Punjab, little of Kashmir, some frontier territory, and two disjointed areas of West and East Pakistan. As late as 1981, only 7 percent of the Pakistani population were primary speakers of the supposed national language, Urdu. So to sum up, Pakistan wound up as a collection of Balochistan, NWFP, Sindh (all of whom entertained secession at various times), East Bengal (which successfully seceded in 1971 to become Bangladesh, although only after a genocidal repression by West Pakistani troops), mohajir migrants from India (many of whom regretted the whole thing), and West Punjab (which had its own micro-secessionist movement by the Seraiki linguistic minority).[4]

Besides the examples above, artificial borders were drawn during the colonial period and few borders changed after decolonization. Africa is the region most notorious for arbitrary borders. Historian Roel Van Der Veen (2004) points out that prior to the era of decolonization, states had to prove their control of a territory before being recognized by the international system. Virtually all new African states would have failed this test. With decolonization in Africa (and to some extent in other regions), the leading international powers changed this rule to recognize nations that existed principally on paper as the heir to a former colonial demarcation. As Van Der Veen put its, "letterbox sovereignty" was conferred upon whatever capital and whichever ruler the letters from the UN, the IMF, and the World Bank were addressed to. This left the new rulers more accountable to international organizations and leading industrial powers than to their purported citizens.[5] States consisted of little more than a few former independence agitators, the indigenous remnant of the colonial army, and a foreign aid budget. The new rulers of African states had no incentive to change a system of which they were the main beneficiaries, and hence the Organization of African Unity adopted a convention in the 1960s to treat colonial boundaries as sacrosanct (only rarely violated since). We refer to Englebert Tarango and Carter (2002) for have many more examples of problematic borders in Africa

[4] These examples are from Easterly (2006).

[5] Van De Veen (2004), p29

that lead to disputes, political instability and economic failures.

Latin America is a lesser known (and much earlier) example of artificial borders drawn by a colonial power, in this case Spain. The Spanish created administrative units (vice royalties, captaincies, audiencias, etc.) in the Americas that had virtually nothing to do with indigenous groups on the ground. For example, the various Mayan groups in southern Mexico, Guatemala, and what became other Central American states were split between units. The province of Upper Peru, which later became Bolivia, split the Quechuas between Bolivia and Peru, and combined the Quechuas with Aymaras in Bolivia. When independence arrived in the early 19th century, the new states were controlled by the European elites who formed states based on these colonial demarcations. In the words of one historian, "the new 'sovereign' states were often little more than a loose collection of courts, custom houses, and military units." (Winn 1992, p. 83). Although there were some wars that altered a few borders, today's Latin American states still correspond closely to Spanish colonial divisions.

3 Artificial states: hypotheses and measures

Our main hypothesis is that artificial states perform less well than non-artificial ones. Measure of performance may include indicators of economic and political development, education, health, public goods delivery, political instability and violence. Our goal is to provide a statistical content to the widely held view that countries which do not match nationalities well and which are a mix of ethnic or religious groups thrown together (or separated) artificially by former colonizers do not perform well.

The main difficulty is of course, to provide a measure of artificial states which is as much as possible based upon objective criteria rather than judgement calls. We will use two measures. The first measures the degree to which ethnic groups were split by borders, based upon a calculation for each pair of adjacent nations using detailed data of ethnic groups within nations from Alesina et al. (2003). The second measure is completely new, and the construction of this measure per se is, we hope, a significant contribution in itself; this is the fractal measure described below.

3.1 The fractal measure

The basic idea is to compare the borders of a country to a geometric figure. If a country looks like a perfect square with borders drawn with straight lines, the chances are these borders were drawn artificially. On the contrary, borders which are coast lines or squiggly lines (perhaps meant to capture geographic features and/or ethnicities) are less likely to be artificial. Squiggly geographic lines (like mountains) are likely to separate ethnic groups, for obvious reasons of patterns of communication and migration.

But how can we measure squiggliness? We first present the measure and then we discuss its properties and alternatives.

Fractal dimension is analogous to the typical concept of the dimension of an object, although, unlike the simple definition of dimension, the fractal dimension can be a fractional number. A point has a fractal dimension of zero, a straight line a fractal dimension of one, and a plane a fractal dimension of two. However, unlike with the traditional definition of dimension, as a line stops being perfectly straight and begins to meanders more and more, i.e. to become more and more squiggly, the fractal dimension increases. In the limit that a curve meanders so much that it essentially fills a whole page, then the fractal dimension becomes much closer to 2 than to 1. This is because the "line" is behaving more like a "plane".

Our measure is meant to capture how close a border is to a straight line which would have a fractal dimension of 1, versus a line so squiggly that fills a plane and has a fractal dimension of 2. In practice the fractal measure of actual borders is much closer to 1 than to 2 but there is variation. Figure 1 shows two countries, Sudan and France. Visually, they are quite different, as many of the borders of Sudan are very straight and those of France are quite squiggly. It will turn out that the fractal dimension for France is 1.0429 and that of Sudan is 1.0245, reflecting the fact that Sudan's borders are much closer to being straight lines (dimension 1.0000) than France's borders.

The fractal dimension can be calculated in several ways. We use the box-count method which is the most straightforward; (Peitgen, Jurgens and Saupe (1992), p 218-219). For this method, a grid of a certain size/scale is projected onto the border and the number of boxes which the border crosses is tallied. The scale of this grid is also recorded, as measured by the length of a side of one of the boxes in the grid. This gives a pair of numbers: box-count and box-size. The process is then repeated using grids with different box-sizes, each time recording both the box-size and the number of boxes that the border crosses. Given the pairs of data, box-size and box-count, the log-log plot of this data gives the fractal dimension as follows, where the negative of the slope B is the fractal dimension of the line:

$$\ln\text{ (box count)} = a + b * \ln\text{ (box size)}$$

Some intuition for this method can be gained by considering two extreme cases, a perfectly straight line and a line so wiggly that it covers a whole page (Figure 2a-2d). Figures2a and 2b show two different grids projected onto a perfectly straight line. The length of the side of a box or the "box size" in Figure 2a is twice that of Figure 2b and we can normalize the box sizes to 2 and 1, respectively. Counting the number of squares that the line crosses in each case, we get a box count of 24 for Figure 2a when the box size is 2, and a box count of 48 for Figure 2b when the box size is 1. Thus, for the straight line, the box count doubles (or increases by a factor of 2^1) when the box size is halved (or "increases" by a factor of 2^{-1}). Plotting ln(box count) versus ln(box size) yields a downward-sloping line with a slope of –1 (Figure 1g and Table 1

). Thus the fractal dimension for the straight line depicted in Figures 2a and 2b is determined to be 1. This makes sense because the fractal dimension is identical to our normal notion of dimension for perfectly straight lines, planes and other simple shapes.

Next consider Figures 2c and 2d, which show a line so squiggly that it covers the whole page. Here the box count is 176 when the box size is 2 (Figure 2c) and the box count is 704 when the box size is 1 (Figure 2d). Thus the box count quadruples (increases by a factor of 2^2) when the box size is halved ("increases" by a factor of 2^{-1}). In this case, the plot of ln(box count) versus ln(box size) yields a downward-sloping line with a slope of $2 / -1 = -2$ (Figure 2g and Table 1). Consequently, for this line, which is so squiggly that it fills the whole page, the fractal dimension is 2. This is identical to the standard notion of dimension in which a plane or a page has two dimensions.

The borders of countries will be in between these two extremes of a perfectly straight line with fractal dimension 1 and a very squiggly line which fills a whole page and has a fractal dimension of 2. Consider the somewhat less squiggly line in Figures 2e and 2f. Here, when we calculate the fractal dimension using the box counting method, we find that the box count increases from 54 (Figure 2e) to 130 (Figure 2f) when the box size is reduced from 2 to 1, respectively. Thus the box count is more than doubling when the box size is halved. But yet the box count is not quadrupling, as was the case with the very squiggly line (Figures 2c and 2d). We would thus expect that a plot of ln(box count) versus ln(box size) would have a slope that is steeper than -1 but not quite a steep as -2. In fact, when we do the calculation for this example, the slope is -1.267 (Figure 2g and Table 1). Based on this result, we would a sign a fractal number of 1.267 to this squiggly line. In practice the fractal dimension of most country borders is between 1.000 and 1.100. Squiggly borders have fractal dimensions closer to 1.100, while straighter borders have fractal dimensions closer to 1.000.

These examples use only two data points to determine the fractal dimension of a line form. In practice, when calculating the fractal dimension of country borders, we use twelve different box sizes. The smallest box size is the smallest possible, given the digital nature of our data. This smallest box size corresponds to about 0.001 of a degree latitude or longitude. In addition to this box size, which we normalize to 1, we also use grids with box sizes of 2, 3, 4, 6, 8, 16, 31, 64, 128, 256, and 512. As in the examples above, for each box size, we project a grid with that box size onto our country border. We then count the number of boxes that the border crosses, resulting in a data point of box count and box size. Using all twelve box sizes gives us twelve data points with which to regress ln(box count) on ln(box size). Recall that the general formula for the fractal dimension is given by

$$\ln \text{(box count)} = \text{(constant intercept)} - \text{(fractal dimension)} * \ln \text{(box size)}$$

Thus, we take the negative of the slope of the regression of ln(box count) on ln(box size) as the fractal dimension for the country.

It is useful to present an example, using the case of Colombia. Figure 3 shows our method for determining the fractal dimension for Colombia. The graph plots ln(box count) versus ln(box size) and has twelve points, corresponding to the twelve different box sizes. For each box size, we have projected a grid of that size onto the border for Colombia and counted the number of boxes that the border crosses. Taking logs of this data, we arrive at our twelve data points, representing the pairs of data, ln(box size) and ln(box count). Regressing ln(box count) on ln(box size) using these twelve data points gives the straight line pictured on the graph. This line has a slope of -1.0354. Using the equation above, we take the negative of the slope of the regression line as the fractal dimension. Thus the fractal dimension for Colombia is 1.0354. Finally, for the purposes of our analysis, we calculate a fractal index for each country, which is the log of the fractal dimension. Returning to our example, since the fractal dimension of Colombia is 1.0354, the fractal index for Colombia is $\ln(1.0354) = 0.0348$.

3.2 Properties

A measure of the straightness or squiggliness of country borders ideally exhibits several properties. One desirable property is scale-invariance, meaning the ideal measure should not differ systematically for large or small countries. Scale-invariance also means we should be able to apply our measure to a particular country and get consistent results regardless of the scale of the analysis for that country. Our measure is indeed scale invariant.[6]

A second desirable property of a "squiggliness" measure is the degree to which it measures larger-scale irregularities as opposed to smaller-scale irregularities. Small-scale deviations from a smooth curve or line may well be the result of how ethnic considerations or other local politics determined whether a particular parcel of land should be on one side of a border or another. Since we are interested in comparing borders where local and ethnic considerations were taken into account, with more "artificial" borders, we prefer our measure to focus on these small-scale irregularities, rather than measuring the overall shape of a country. Unlike measures such as this circumscribed/inscribed circle ratio, the fractal measure emphasizes the small-scale variation that we are interested in measuring.

We also prefer a measure that treats straight lines and very smooth but slowly curving lines as similar. Most arbitrarily-drawn borders are straight lines,

[6] To be precise our measure is not 100 percent scale invariant, but it is close to scale invarient. Analyzing a country when at differing degrees of being "zoomed in" or "zoomed out" may yield slightly different values for the fractal dimension. However, these numbers do not vary greatly for each county and the relative rankings of countries are maintained. More importantly, our measure allows us to consistently compare large and small countries. By using the same set of 12 box-sizes (as measured in degrees latitude and longitude) for each country, our analysis for each country is on the same "human" scale as for the other countries. By contrast other measures of compactness, such as the ratio of the area of a circumscribed and an inscribed circle for the country border, may differ systematically for large and small countries.

but we are also interested in a continuum of less-to-more-meandering borders, none of which are perfectly straight lines. Given this, it would be good to avoid a discontinuous change in our measure when moving from a rectangular shape to a smoothly curved shape. As it turns out, there is no discontinuity in the fractal measure, when moving from a perfectly straight line to a smooth curve.

Finally, and most importantly, we would like a measure which allows us to consider only part of the border at a time. In particular, we will disregard coastlines, since they are determined by nature and not by politics, and may be highly non-compact. The fractal measure can be applied to selected portions of the border, such as just the political boundaries. Most other measures of compactness must use the entire boundary, including coastlines. For instance other common compactness measures include: the ratio of the longest axis to the maximum perpendicular length; the ratio of the minimum shape diameter to the maximum diameter; various ratios among the area of the shape, the area of an inscribing circle and the area of a circumscribing circle; the moment of inertia of the shape; and the ratio of the area of the shape to the area of a circle with the same perimeter.[7] All of these measures require a closed shape in order to be calculated. Thus, our fractal measure exhibits several desirable qualities, and can be easily applied to the situation of country borders.

3.3 Partitioned groups and other measures

Our second new measure focus on the specific issue of borders cutting across an ethnic group and dividing it into two adjacent countries. This variable is defined as the percent of the population of a country that belongs to a partitioned group. In turn, a partitioned group is one that appear in two or more adjacent countries. One possible objection to this variable is mobility of people. If members of the same ethnic groups wanted to be together they could move into the same country. However mobility of people is often not free and many countries may prevent entry (or in some cases exit). We calculate the fractal variable for 144 non-island countries. Islands have no political boundaries, so they cannot have a political boundary fractal dimension. The partitioned variable is calculated for 131 countries, including 117 countries for which both indices are available.

The literature of ethno linguistic fractionalization has normally focused on one index of fractionalization, the Herfindhal index which captures the probability that two randomly drawn individuals from the population of the country belong to different groups.[8] The original index was based on a linguistic classification of groups from a Soviet source (Atlas Narodv Mira). It was originally used in the economic development literature by Mauro (1995) Easterly and Levine (1997) and it is if often referred to as the ELF (Ethnolinguistic fractionalization) index. Alesina and al. (2003) proposed another index that in addition to linguistic differences includes differences based on other characteristic such as skin color. They label it Fract but to avoid confusion we label it ELF1 in

[7]For more on this, see Niemi, Grofman, Carlucci, and Hofeller. (1990) and Flaherty, and Crumplin. (1992).

[8]Another index frequenlty used is a polarization index suggested by RRRR

the present paper. (See Alesina and al. (2003) for additional discussion of the construction of this variable.)

How do our new measures, FRACTAL and PARTITIONED, relate to each other and to the previously used index of fractionalization? Our fractal measure is meant to capture a much broader idea than ethnic fractionalization. However, artificial states as proxied by our measure may end up including different ethnic groups within the same political borders, and therefore there should be some correlation between the Herfindhal index of fractionalization and our fractal measure. Simlar consideration apply for the partioned variable.

Table 2 displays the correlation coefficients between the two measures of artificial borders and the more traditional measure of ethnolinguistic fractionalization. Several comments are in order. First note how the partition variable is positively correlated with the index of ethnic fractionalization, but the correlation is in the order of 0.5 so clearly these are "different variables". Given the way the two variables are constructed it is not surprising that they are positively correlated but they indeed capture different things. Second the fractal variable is correlated with the ELF and ELF1 measures (with the appropriate negative sign, less curvy borders is associated with more fractionalization), but the correlation is not very high especially with ELF, while it is -0.22 with ELF1. Third the correlation between our partitioned variable and our fractal variable is basically zero. This was frankly a surprise to us. It suggests artificial states are not easy to summarize with one measure. (For example, the partitioned variable captures only one of the problematic features of artificial states mentioned in the introduction.) We use both measures as providing independent information on "artificiality." Finally, ELF and ELF1 are highly correlated but are not statistically identical. In summary are two new measure are different from each other and are not very highly correlated with other measures previously used in the literature of ethnic fractionalization.

3.4 Data and sources

Data for determining the fractal dimension for each country's political boundary comes from the GIS (Geographic Information Systems) format data set World Vector Shoreline. This data set is the largest-scale digital data set of political boundaries available today. The data is based on work done by the U.S. military in the early 1990's. The non-coastline borders for each country are isolated using ArcGIS software[9]. This data is then changed to a raster (digitized) format and then to a "tif" format. With a few minor modifications, the software program ImageJ [10] calculates the box-count/ box-size data for twelve different box-sizes; the smallest box-size corresponds to the smallest scale of the raster data exported from GIS (approximately 0.001 degrees latitude or longitude). A fractal dimension is calculated for each country using this data, ranging from

[9] ArcGIS 9.0 Desktop software from ESRI; www.esri.com

[10] Available online at http://rsb.info.nih.gov/ij/download.html and at http://rsb.info.nih.gov/ij/developer/index.html

1.000 to 1.100. Finally, we take logs of the fractal dimension to achieve a fractal index, which ranges from 0 to 0.10.

4 Empirical results

4.1 Which states are "artificial"?

Table 3 lists our measures for all the countries in our sample. To illustrate which states are most artificial according to both measures, we took countries that were in the top third of PARTITIONED and in the bottom third of FRACTAL (the straightest borders). Given the weak correlation between the two measures, there were not that many countries in both – 13 to be exact. These "most artificial" states are Chad, Ecuador, Equatorial Guinea, Eritrea, Guatemala, Jordan, Mali, Morocco, Namibia, Niger, Pakistan, Sudan, and Zimbabwe. These examples accord with what we know of the historical process that led to formation of these states (some of it described above).

4.2 Economic and Political Success

We now turn to verifying whether these new measures of artificial states are correlated with economic and institutional success. We consider three groups of variables as left hand side variables. (See Table 3 for variable definitions and sources). First, the variables that measures economic or economic policy success: (log of) per capita income in 2002; an index of economic freedom in 2005 that measures adherence to a free market economic system; and an alternative index of economic freedom averaged over 1970-2002.[11] Second, we look at poltico-institutional variables: voice and accountability (which measure checks on power), political stability and violence, government effectiveness, regulatory quality, rule of law, and corruption. Third, we use quality of life and public goods delivery-related measures: infant mortality in 2001, literacy rate averaged over the period 1995 2002; measles immunization rate in 2002; immunization rate against DPT in 2002, percent of population with access to clean water, in 2000. [12] We choose these variables as representative of state performance in the core public goods areas of health, education, and infrastructure, selecting particular measures based on which ones have data available for a large sample of countries. All of these variable are clearly correlated with each other. Obviously

[11] We use the second measure as a robustness check on the first measure of economic freedom, since each is based on a complicated mix of indicators and may reflect some subjectivity. Given the uncertainty surrounding this measure, we also check robustness with respect to using a long period average of the second measure rather than just a single year, which may average out data errors and noise (while sacrificing our preferred approach of using the most recent datapoint available).

[12] Data on literacy is spotty, with different countries reporting different years over 1995-2002, so we average all available data over this period. Otherwise, the year given is the most recent for which data are widely available.

rich country have lower infant mortality, more clean water etc. Table 4 reports a correlation chart between all of these variables: the correlations are not all very close to 1 (or -1 depending on the variable definition). That is, this set of variables do capture different aspects of politico-economic development that are different from each other, so there is information provided by considering all of them.

Table 5 presents the basic univariate regressions of our measures of artificial states. Consider line one: the left hand side variable is the log of per capita GDP in 2002, and we report only the coefficient and the p-value of the single right hand side variable. (Obviously we include also a constant in the regression). Each line represents the same regressions with a different left hand side variable which is listed in the first column. We use all the observations available, and their number varies (from 84 to 144) in different regressions because of data availability on the left hand side variable. The dependent variables are divided in three blocs: economic variables, institutional variables and quality of life/public goods variables. Notice that because of how the right hand side variables are constructed, we expect the opposite sign in the first and second column. So for instance in the first line we expect a negative correlation of economic success measured as income per capita in countries where the partition variable assumes a lower value, and in countries where the measure of how straight borders are assumes a higher value. The coefficient in bold represents all the cases in which statistical significance (with the expected sign of course) is 5 percent or better; marginally significant coefficients at the 10 percent level or better are indicated with a "+" sign . Of the 28 coefficients in the first two columns, 20 are statistically significant (p-value of 5 percent or better) and three are borderline (p-value of 10% or better). Our two measures are not highly correlated with each other and in fact as discussed above, they capture different aspects of the nature of borders. For this reason there is no reason why they could not be used in the same regressions. In the third column, we use them both. In all regressions at least one is significant at the 5 percent level or better and in almost all regressions they are either both statistically significant at the five percent level or one is and the other is borderline significant.

Table 6 displays information on the size of the impact of these measures of artificial states, which is considerable. For the partitioned variable, going from the 75th most partitioned country to the 25th most partititioned country is associated with an increase of 83% in GDP per capita (0.832 log-points; Table 6, Column 2). Many of the other variables are also strongly affected, by around half of a standard deviation (Column 3). The impact of the fractal variable is smaller but still significant in size. Moving from the 75th most squiggly border to the 25th most squiggly border is associated with a 37% increase in GDP per capita. The other dependent variables are also affected by about a third of a standard deviation.

We now check whether these strong univariate correlations survive adding other exogenous variables to the right hand side. We begin with ethnic fractionalization to see whether our new measures add anything to traditional, previously-used measures of ethnic fractionalization. In Table 9 we add as a control in the right hand side the variable ELF, the "traditional" ethnolinguistic fractionalization variable used by Easterly and Levine (1997) and by many after them. In the case of our FRACTAL measure, the result suggests that in about half the regressions (6 out of 14) both variables are statistically significant; in one additional regression FRACTAL is marginal at the 10 percent level. In particular, for the institutional regressions, FRACTAL remains significant when controlling for ELF. For the other regressions, ELF is significant but FRACTAL is not. Consider now column 1. Here the variable PARTITIONED remains significant in 7 out of 14 regressions. For GDP per capita, PARTITIONED remains significant when controlling for ELF. Column 3 shows our results when we include both variables and control for ELF. Of the 28 coefficients on our artificial states variables (from the 14 regressions), 16 are significant at a the 5 percent level or greater and 9 are borderline significant, at the 10 percent level.

The next experiment concerns former colonial status. As we discussed in section 2 above, much of the problem of artificial states has to do with colonizers drawing borders which did not respect indigenous divisions. In fact, the FRACTAL index for former colonies is lower than for non-former colonies, with the index averages equal to 0.0335 and 0.0435 for these two groups respectively. This difference is significant at the 1% level. The overall standard deviation for the fractal index is about 0.02, so this is an important difference of about half a standard deviation between former colonies and non-colonies. Likewise, for the PARTITION variable, former colonies and non-colonies differ by 13.6 out of the 100 point scale; former colonies have higher proportions citizens from "partitioned" ethnic groups. This difference is also significant at the 1% level. But having been a colony or not may influence political and economic outcomes in many different ways, so it is important to check that controlling for colonial status does not change all the significance of our variables of interest. We do that in Table 8 where we add a dummy variable that assumes the value of 1 if the country has never been a colony. In column 1 note how 11 out of the 14 coefficients on the partition variable are now significant at the 5 percent level and all the other except one are borderline. For the fractal measure, however, only 1 out of 14 is and one is borderline. This show that it is difficult to identify separately the effect of colonial status and straight-line borders, since one led to the other. For the regressions with both variables, about half of the 28 coefficients are significant.

Another important exogenous factor that can explain economic and political success is geography and climate. Many geographic variables have been suggested in the literature. One of the most precise in capturing weather pattern is the variable climate defined as the percentage of a country's cultivatable land that is in the Koppen-Geiger Climate Zone A, which is a humid climate with no winter. This is a classical definition of what constitutes a tropical area. In Table 9 we add this variable to our regression. Our variables are generally quite robust, much more so than the ELF variable.

4.3 Other robustness checks

We consider a number of other possible explanations for our results, adding further controls that might otherwise have introduced a spurious correlation with our measures of artificiality of states. In order to keep the length of this paper manageable, we simply summarize the results here in the text. A separate appendix with the full results will be available on our web sites.

First, we include the index of ethnic fractionalization ELF1, from Alesina et al. (2003), in place of the control variable ELF. The results are slightly less strong, especially for the fractal measure, but the results for GDP and several health indicators remain strong. We then control for the percent of a country's land area that is desert. Borders may be more likely to be straight in deserts, and desert itself might influence our dependent variables of interest. However, controlling for desert leaves our results basically unaffected.

Another possible concern is to what extent our results reflect outcomes mainly in Africa. We have mixed feelings about introducing an African dummy variable into our regressions. On one hand, we are concerned that the Africa dummy is not truly exogenous because the decision to introduce an African dummy is influenced by the knowledge of poor outcomes in the endogenous variables in Africa (even the conventional definition of Africa as being countries below the Sahara has likely been influenced by the differing outcomes in North Africa and sub-Saharan Africa). On the other hand, it is clearly of interest to see whether our results are heavily influenced by the sub-Saharan African observations of very artificial borders and very poor outcomes. The results are definitely weakened by including the Africa dummy, which is always significant. The only result to survive with FRACTAL is for democracy (still significant at the 5 percent level). More of the results on PARTITIONED survive, with the result on per capita income level, literacy, measles immunization, and DPT immunization still significant at the 5 percent level, and corruption, clean water, and infant mortality still significant at the 10 percent level.

Finally, we control for two other important characteristics of countries that might be related to the nature of the borders (and thus possibly causing a spurious correlation with artificial borders): population density and the land area of the country. Population density is sometimes significant in our regressions, but leaves the results on PARTITIONED and FRACTAL basically unchanged. Land area is often significant and has some effect on the FRACTAL results, but little effect on the PARTITIONED results.

4.3.1 Borders and Wars

One type of variable is conspicuously missing in our analysis: wars, both international and civil. Our reason for not discussing it at length is that we found no effects of artificial borders on war. We did find an effect of artificial borders on a subjective measure of political instability and violence, as described above, but clearly it would be desirable to study the objective outbreaks of wars in addition to this variable.

The lack of an immediate and strong evidence of a correlation between borders and wars surprised us (although it echoes similar non-results in the literature on ethnic diversity and war). We are not ready to conclude that ethnic rivalries and border disputes are unrelated to wars: we believe that more work is needed. For international war, there is first of all the international system (mentioned for Africa in the introduction) that has tended to support existing borders no matter how artificial. These international conventions are more binding in some regions than others. Second, to study international wars properly, we need to study pairs of countries and to study to what extent the probability of war between them depends on whether the border dividing adjacent ones is artificial. There are clearly some examples of border wars arising from partition, such as Israel and its neighbors, India and Pakistan, and Eritrea and Ethiopia. To what extent these examples are validated by a systematic association requires a study that uses pairwise data on war outbreaks that is beyond the scope of this paper. For civil wars, a more detailed analysis would also require some attention to the nature of artificial states, especially finding some objective way of measuring whether previously hostile groups were combined into one state. The level of further work required for both civil and international war would unduly extend the length of this paper, so we plan a subsequent paper (not currently completed) in which we focus exclusively on artificial states and war.

5 Conclusions

The idea of "failed states" is a recurrent them both in newspapers and within academia. The borders of many countries have been the result of processes that have little to do with the desire of people to be together or not. In some cases groups who wanted to be separate have been thrown into the same political unit; others have been divided by artificial borders. Former colonizers have been mainly responsible for such mistakes, but the botched agreements after the two major wars of the last century have also played a role.

The main contribution of this paper is to provide two new measures meant to capture how "artificial" political borders are. One measure considers how straight land borders are, under the assumption that straight borders are more like to be artificial and less likely to follow geographic features or the evolution of hundreds of years of border design. The second measure focuses on ethnic or linguistic groups separated by borders. We have then investigated whether these variables are correlated with the politico-economic success of various countries, and we found that indeed they are. The general patterns of correlations that we presented in a battery of tables suggest that these two new measures do quite well in cross-country regressions in which other exogenous measures of geography, ethnic fragmentation and colonial status are controlled for. We have also explored the correlation of our measures of artificial borders with the occurrence of civil and international wars and our results are inconclusive. While we find correlations of our variables with measure of political instability and lack of democracy, we do not find a clear pattern of correlations with wars. Further research is needed on this point looking at bilateral data on wars, namely which country engaged in war with whom.

Probably the single most important issue that we have not addressed is that of migrations. One consequences of artificial borders is that people may want to move, if they can. Often movement of peoples is not permitted by various government but migration certainly occur. In some cases migrations that respond to artificial borders may be partly responsible for economic costs, wars, dislocation of people, refugee crises and a hots of undesirable circumstances. Thus, the need to migrate, created by the wrong borders may be one reason why artificial borders are inefficient. But sometimes the movement of people may correct for the artificial nature of borders. This dynamic aspects of movement of people and migrations, and changes of borders for that matter is not considered in this paper in which we consider a static picture of the world.

The bottom line in this paper is that the artificial borders bequeathed by colonizers were a significant hindrance to the political and economic development of the independent states that followed the colonies.

6 References

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Figure 1 – Artificial versus Organic boundaries – Sudan and France

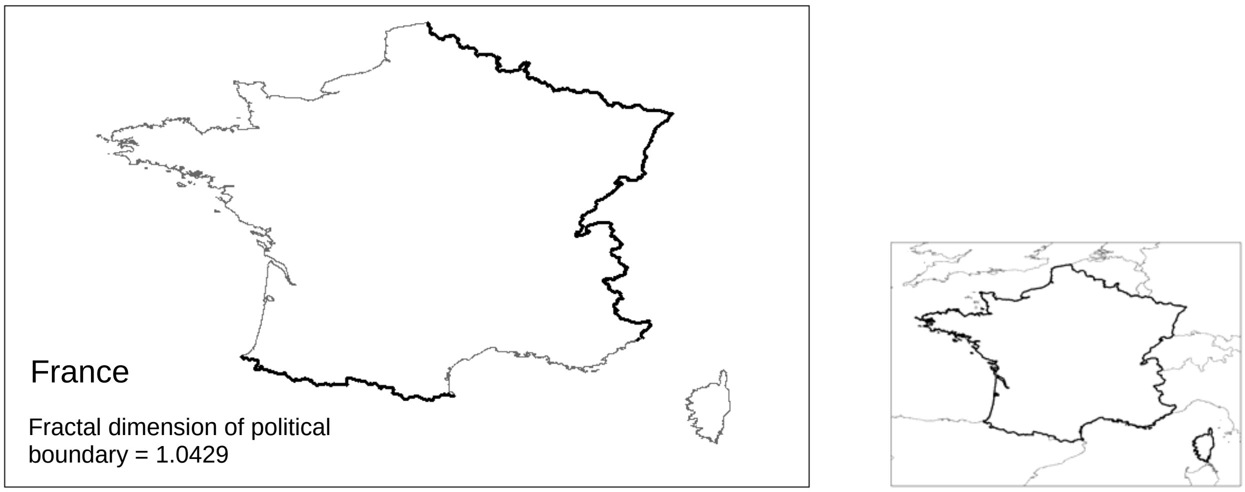

Figure 1a – France, with poltical boundaries highlighted at left

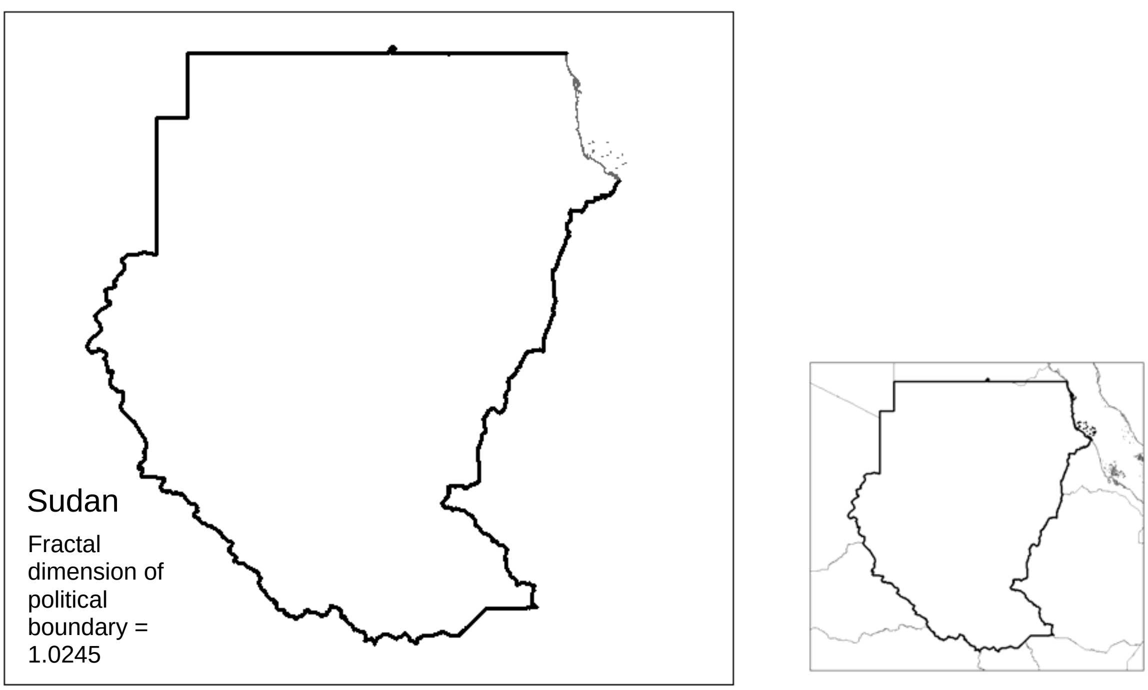

Figure 1b – Sudan, with poltical boundaries highlighted at left

<u>Figure 2a – 2d – Projections of two grids of different sizes onto Straight and Very Squiggly lines</u>

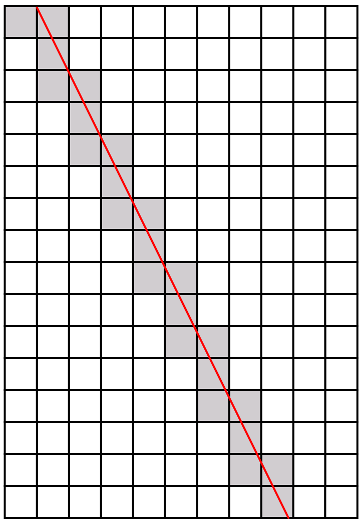

Figure 2a:
Box size = 2; Box count = 24

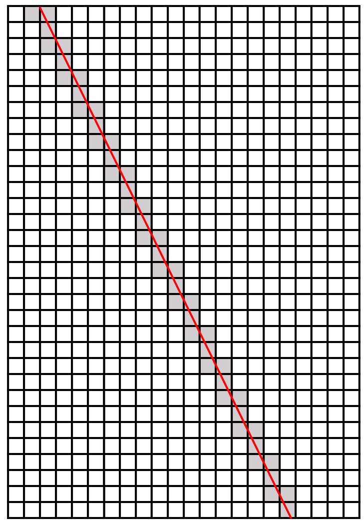

Figure 2b:
Box size = 1; Box count = 48

Straight line

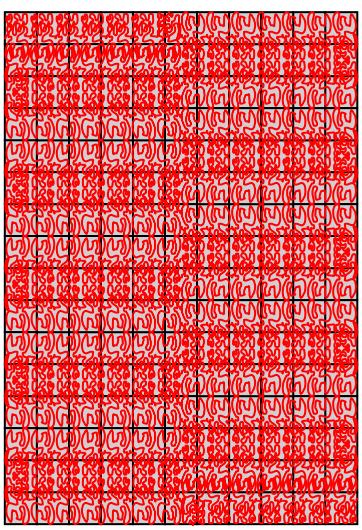

Figure 2c:
Box size = 2; Box count = 176

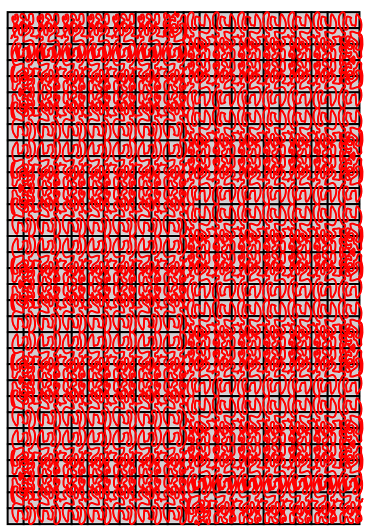

Figure 2d:
Box size = 1; Box count = 704

Very squiggly line
(fills the whole page)

Figure 2e – 2g – Projections of two grids of different sizes onto a Somewhat Squiggly line; Calculation of Fractal Dimension

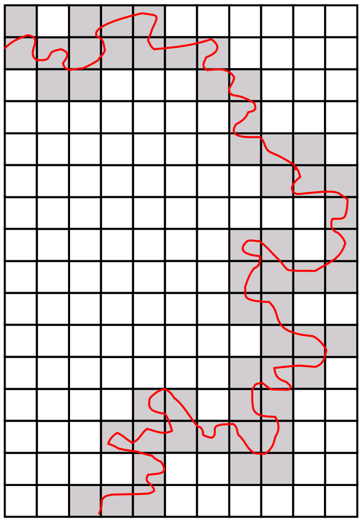

Figure 2e:
Box size = 2; Box count = 54

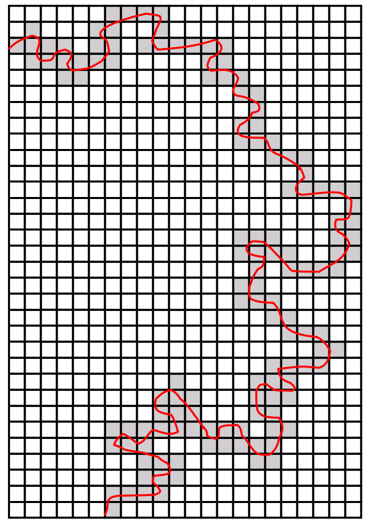

Figure 2f:
Box size = 1; Box count = 130

Squiggly line

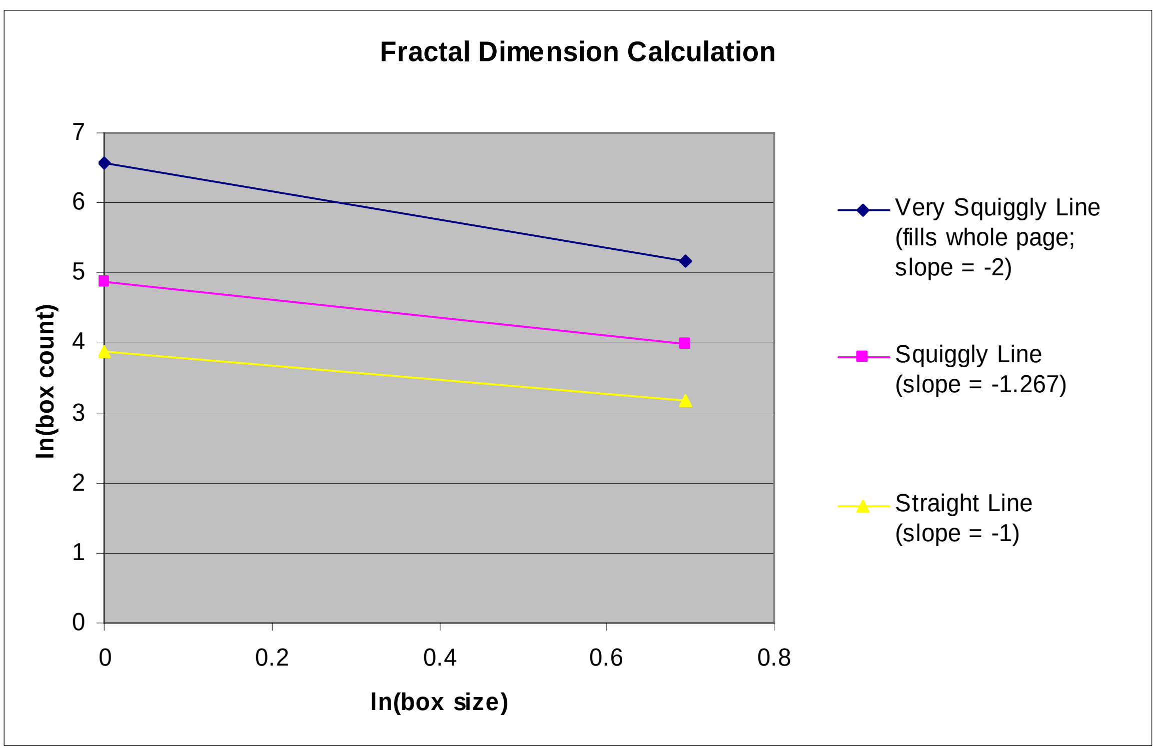

Figure 2g: Fractal Dimension Calculation

<u>Figure 3 – Calculation of the Fractal Dimension of Columbia's Border</u>

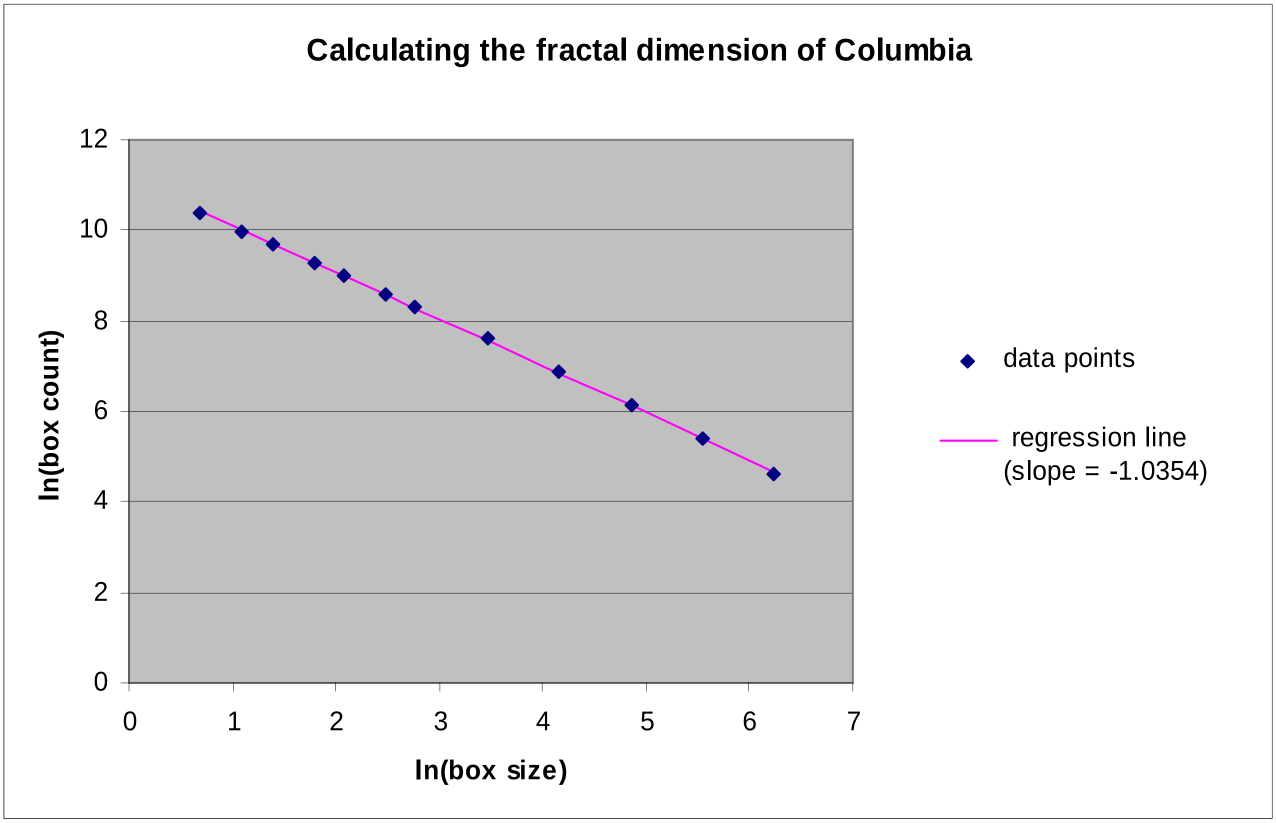

Table 1 – Fractal Dimension Calculation

Straight Line (Figures 1a and 1b)

box size	box count	ln (box size)	ln (box count)
1	48	0.000	3.871
2	24	0.693	3.178

Regression coeff:	Fractal Number:
-1.000	1.000

Very Squiggly Line (Figures 1c and 1d)

box size	box count	ln (box size)	ln (box count)
1	704	0.000	6.557
2	176	0.693	5.170

Regression coeff:	Fractal Number:
-2.000	2.000

Squiggly Line (Figures 1e and 1f)

box size	box count	ln (box size)	ln (box count)
1	130	0.000	4.868
2	54	0.693	3.989

Regression coeff:	Fractal Number:
-1.267	1.267

Table 2 – Correlations of various ethnic and artifical state measures

	Partitioned index	Basic fractal index	Ethnolinguistic fractionalization (elf) index - 1960	Alesina-Easterly fractionalization index
Partitioned index	1			
Basic fractal index	0.0554	1		
Ethnolinguistic fractionalization (elf) index - 1960	0.5245	-0.1001	1	
Alesina-Easterly fractionalization index (ADEKW 2003 paper)	0.5152	-0.2168	0.766	1

Table 3 – Data sources

Table 3: Variable definitions

code 3-letter World Bank country code

Ethnic/ variables	
partitionedc	Percent of population belonging to groups partitioned by a border
lnfractal905	log of basic fractal index (latest revision as of September 2005) based onWorld Vector Shoreline Dataset (GIS format)
lnsmallfractal	log of “small country” fractal index (used only in robustness checks)
elf60	Ethnolinguistic fractionalization, 1960 (as used in Easterly and Levine 1997)
frac	Ethnic fractionalization (from Alesina et al. 2003)
Political variables	
noncolonial	dummy =1 if never colonized by European power

Kaufmann-Kraay indices of institutions for 2004 (increase means better institutions):

voice democracy,	checks on power, accountability to population
polstab	political stability and violence
govteff	government effectiveness
regqual	regulatory quality
rulelaw	rule of law
corrupt	corruption
Economic variables	
lpcy2002	log per capita income in 2002 (Summers-Heston updated with World Bank per capita growth rates)
ief2005	Index of Economic Freedom, 2005 (increase means less freedom) from Heritage Foundation
efw19702002	Economic Freedom in the World, average 1970-2002, from the Fraser Institute
Quality of life and public goods variables	
infmort2001	Infant mortality rate in 2001 (WDI)
literacy9502	Literacy rate averaged over available data 1995-2002 (EDI)
measlesimm02	Measles immunization rate, 2002 (WDI)
dptimm02	Immunization rate against DPT, 2002 (WDI)
water2000	Percent of population with access to clean water, 2000 (WDI)
Geography variables	
cultca	percent of cultivated land in Koppen-Geiger climate zone A (humid climate with no winter) Source: Sachs (199X), Center for International Development, Harvard
cultcb	percent of cultivated land in Koppen-Geiger climate zone B (dry climate with no winter) Source: Sachs (199X), Center for International Development, Harvard Note: cultca and cultcb included separatly as controls
kg_a_bw, desert	Percent of total land area in Koppen_Geiger climate zone BW (desert) Source: Sachs (199X), Center for International Development, Harvard
areakm2	Total land area in kilometers squared Source: Sachs (199X), Center for International Development, Harvard
pdenpavg	Population density experienced by the typical citizen (population density of many small regions is totaled, but using the population of each region as a weight) Source: Sachs (199X), Center for International Development, Harvard

Table 4 – Correlations Among our Principle Dependent Variables

Econonic Variables	Log GDP per capita, 2002	Index of Econ Freedom, 2005 (higher = less free)	Economic Freedom in the World, avg 1970-2002
Log GDP per capita, 2002	1		
Index of Econ Freedom, 2005 (higher = less free)	-0.7078	1	
Economic Freedom in the World, avg 1970-2002	0.7431	-0.7494	1

Quality of Life Variables	Literacy rate, avg of available data 1995-2002	Percent pop with access to clean water, 2000	Infant mortality, 2001	Measles immuniz. rate, 2002	DPT immuniz. rate, 2002
Literacy rate, avg of available data 1995-2002	1				
Percent pop with access to clean water, 2000	0.5105	1			
Infant mortality, 2001	-0.7074	-0.6835	1		
Measles immunization rate, 2002	0.6743	0.5771	-0.6975	1	
DPT immunization rate, 2002	0.6666	0.6079	-0.7461	0.8956	1

Polticial Variables	Voice - checks on power	Political stability and violence	Government effectiveness	Regulatory quality	Rule of law	Corruption
Voice - checks on power	1					
Political stability and violence	0.7306	1				
Government effectiveness	0.7197	0.7858	1			
Regulatory quality	0.8147	0.8034	0.9092	1		
Rule of law	0.8035	0.8791	0.9315	0.9244	1	
Corruption	0.7412	0.7993	0.9564	0.8898	0.9496	1

Table 5 – OLS regressions with no controls

Dependent variables:		Coefficient on:	1	2	3
Economic variables	Log GDP per capita, 2002	PARTITIONED	**-0.021****		**-0.019****
			(0.000)		**(0.000)**
		FRACTAL		**11.49***	10.23$^+$
				(0.041)	(0.083)
	Index of Econ Freedom, 2005 (higher = less free)	PARTITIONED	**0.006***		**0.005***
			(0.013)		**(0.028)**
		FRACTAL		-6.12$^+$	**-7.54***
				(0.080)	**(0.031)**
	Economic Freedom in the World, avg 1970-2002	PARTITIONED	**-0.009***		**-0.008***
			(0.029)		**(0.037)**
		FRACTAL		5.70	9.80
				(0.369)	(0.142)
Political and governance variables	Voice - checks on power	PARTITIONED	**-0.01****		**-0.01****
			(0.003)		**(0.002)**
		FRACTAL		**13.16****	**14.66****
				(0.002)	**(0.002)**
	Political stability and violence	PARTITIONED	**-0.009****		**-0.01****
			(0.008)		**(0.001)**
		FRACTAL		5.79	7.26
				(0.199)	(0.151)
	Government effectiveness	PARTITIONED	**-0.01****		**-0.011****
			(0.002)		**(0.000)**
		FRACTAL		9.57$^+$	**11.46***
				(0.062)	**(0.042)**
	Regulatory quality	PARTITIONED	**-0.01****		**-0.011****
			(0.003)		**(0.000)**
		FRACTAL		**11.23***	**12.93***
				(0.016)	**(0.011)**
	Rule of law	PARTITIONED	**-0.011****		**-0.012****
			(0.001)		**(0.000)**
		FRACTAL		8.33$^+$	9.43$^+$
				(0.099)	(0.092)
	Corruption	PARTITIONED	**-0.011****		**-0.011****
			(0.001)		**(0.001)**
		FRACTAL		8.53	10.22$^+$
				(0.106)	(0.079)
Quality of life variables	Literacy rate, avg of available data 1995-2002	PARTITIONED	**-0.442****		**-0.441****
			(0.000)		**(0.000)**
		FRACTAL		**290.6***	**393.5****
				(0.029)	**(0.000)**
	Percent pop with access to clean water, 2000	PARTITIONED	**-0.261****		**-0.267****
			(0.000)		**(0.000)**
		FRACTAL		**238.0***	168.3$^+$
				(0.021)	(0.100)

Infant mortality, 2001	PARTITIONED	**0.702**** **(0.000)**		**0.774**** **(0.000)**
	FRACTAL		**-548.0**** **(0.001)**	**-556.5**** **(0.002)**
Measles immunization rate, 2002	PARTITIONED	**-0.317**** **(0.000)**		**-0.379**** **(0.000)**
	FRACTAL		94.8 (0.13)	110.2+ (0.061)
DPT immunization rate, 2002	PARTITIONED	**-0.323**** **(0.000)**		**-0.375**** **(0.000)**
	FRACTAL		**190.5**** **(0.009)**	**214.5**** **(0.006)**

P values in parenthesis; + * ** refer to significance at the 10%, 5% or 1% levels, respectively.

Columns 1, 2 and 3 refer, respectivly, to groups of regressions using PARTITIONED, FRACTAL, or both variables.

Table 6 – Impact of Partitioned and Fractal Variables

PARTITIONED index (high value ~ artificial state):
25th percentile = 33rd country = VNM (Vietnam): 2.8
75th percentile = 98th country = LVA (Latvia): 42.4

FRACTAL index (low value ~ artificial state):
25th percentile = 33rd country = Isreal (including WB border): 0.0498
75th percentile = 98th country = Dem Rep of Congo (Zaire): 0.0241

Dependent variable	Standard deviation of dependent variable	Impact of going from 25th to 75th percentile in the PARTITIONED Index (coeff * 39.6)	**Impact of PARTITIONED / std dev of dep variable**	Impact of going from 25th to 75th percentile in the FRACTAL Index (coeff * 0.0257)	**Impact of FRACTAL / standard deviation of dep. variable**
Log GDP per capita, 2002	1.141	0.832	**0.73**	0.374	**0.33**
Index of Econ Freedom, 2005 (higher = less free)	0.720	-0.238	**0.33**	-0.222	**0.31**
Economic Freedom in the World, avg 1970-2002	0.998	0.356	**0.36**	0.272	**0.27**
Voice - checks on power	1.000	0.396	**0.40**	0.393	**0.39**
Political stability and violence	1.000	0.356	**0.36**	0.181	**0.18**
Government effectiveness	1.000	0.396	**0.40**	0.324	**0.32**
Regulatory quality	1.000	0.396	**0.40**	0.355	**0.36**
Rule of law	1.000	0.436	**0.44**	0.282	**0.28**
Corruption	1.000	0.436	**0.44**	0.297	**0.30**
Literacy rate, avg of available data 1995-2002	21.180	17.503	**0.83**	7.132	**0.34**
Percent pop with access to clean water, 2000	20.601	10.336	**0.50**	7.012	**0.34**
Infant mortality, 2001	41.825	-27.799	**0.66**	-16.023	**0.38**
Measles immunization rate, 2002	17.049	12.553	**0.74**	2.851	**0.17**
DPT immunization rate, 2002	18.445	12.791	**0.69**	5.654	**0.31**

Table 7 – Controlling for ethno-linguistic fractionalization (elf60)

Dependent variables:		Coefficient on:	1	2	3
Economic variables	Log GDP per capita, 2002	PARTITIONED	**-0.016****		**-0.018****
			(0.003)		**(0.000)**
		FRACTAL		10.555	**16.284***
				(0.112)	**(0.010)**
		ELF60	**-0.013****	**-0.021****	**-0.01***
			(0.010)	**(0.000)**	**(0.046)**
	Index of Econ Freedom, 2005 (higher = less free)	PARTITIONED	0.003		0.003
			(0.358)		(0.365)
		FRACTAL		-6.47	-7.927$^+$
				(0.121)	(0.056)
		ELF60	**0.007***	**0.008****	**0.007***
			(0.018)	**(0.000)**	**(0.048)**
	Economic Freedom in the World, avg 1970-2002	PARTITIONED	-0.007		-0.008
			(0.196)		(0.106)
		FRACTAL		8.916	**15.517***
				(0.176)	**(0.018)**
		ELF60	-0.006	**-0.009****	-0.004
			(0.19)	**(0.002)**	(0.377)
Political and governance variables	Voice - checks on power	PARTITIONED	-0.008$^+$		**-0.01***
			(0.095)		**(0.029)**
		FRACTAL		**14.21****	**17.728****
				(0.008)	**(0.003)**
		ELF60	**-0.008***	**-0.01****	-0.006
			(0.046)	**(0.002)**	(0.168)
	Political stability and violence	PARTITIONED	-0.007		-0.009$^+$
			(0.146)		(0.060)
		FRACTAL		**11.88***	**16.01****
				(0.032)	**(0.009)**
		ELF60	**-0.009***	**-0.012****	-0.007
			(0.047)	**(0.001)**	(0.128)
	Government effectiveness	PARTITIONED	-0.008		-0.009$^+$
			(0.121)		(0.051)
		FRACTAL		**13.52***	**17.59***
				(0.040)	**(0.012)**
		ELF60	**-0.011***	**-0.013****	-0.009$^+$
			(0.020)	**(0.001)**	(0.066)
	Regulatory quality	PARTITIONED	-0.008		**-0.01***
			(0.101)		**(0.043)**
		FRACTAL		**14.55****	**17.94****
				(0.009)	**(0.005)**
		ELF60	**-0.009***	**-0.012****	-0.007
			(0.035)	**(0.000)**	(0.117)

	Rule of law	PARTITIONED	-0.008 (0.143)		-0.009$^+$ (0.074)
		FRACTAL		**13.40*** **(0.035)**	**16.74*** **(0.013)**
		ELF60	**-0.012**** **(0.008)**	**-0.014**** **(0.000)**	**-0.011*** **(0.034)**
	Corruption	PARTITIONED	-0.008 (0.125)		-0.008$^+$ (0.062)
		FRACTAL		**13.81*** **(0.026)**	**17.09**** **(0.007)**
		ELF60	**-0.013**** **(0.004)**	**-0.014**** **(0.000)**	**-0.011*** **(0.015)**
Quality of life variables and public goods delivery	Literacy rate, avg of available data 1995-2002	PARTITIONED	**-0.38**** **(0.000)**		**-0.396**** **(0.001)**
		FRACTAL		204.7 (0.254)	325.6$^+$ (0.051)
		ELF60	**-0.154*** **(0.032)**	**-0.271**** **(0.001)**	-0.128 (0.122)
	Percent pop with access to clean water, 2000	PARTITIONED	-0.173$^+$ (0.052)		-0.152$^+$ (0.067)
		FRACTAL		88.79 (0.538)	8.58 (0.948)
		ELF60	**-0.226**** **(0.006)**	**-0.27**** **(0.000)**	**-0.224**** **(0.005)**
	Infant mortality, 2001	PARTITIONED	**0.426*** **(0.032)**		**0.452*** **(0.024)**
		FRACTAL		-380.3$^+$ (0.068)	-497.8$^+$ (0.060)
		ELF60	**0.752**** **(0.000)**	**0.861**** **(0.000)**	**0.687**** **(0.002)**
	Measles immunization rate, 2002	PARTITIONED	**-0.27**** **(0.000)**		**-0.288**** **(0.000)**
		FRACTAL		-41.841 (0.602)	42.992 (0.634)
		ELF60	**-0.157**** **(0.009)**	**-0.297**** **(0.000)**	**-0.166*** **(0.012)**
	DPT immunization rate, 2002	PARTITIONED	**-0.206**** **(0.003)**		**-0.242**** **(0.001)**
		FRACTAL		99.039 (0.278)	188.871$^+$ (0.084)
		ELF60	**-0.276**** **(0.000)**	**-0.332**** **(0.000)**	**-0.255**** **(0.002)**

P values in parenthesis; $^+$ * ** refer to significance at the 10%, 5% or 1% levels, respectively.

Columns 1, 2 and 3 refer, respectivly, to groups of regressions using PARTITIONED, FRACTAL, or both variables.

Table 8 – Controlling for elf60 and former colonial status

Dependent variables:		Coefficient on:	1	2	3
Economic variables	Log GDP per capita, 2002	PARTITIONED	**-0.016****		**-0.016****
			(0.000)		**(0.000)**
		FRACTAL		5.918	7.406^{+}
				(0.324)	(0.095)
		ELF60	-0.003	**-0.014****	-0.002
			(0.481)	**(0.001)**	(0.654)
		NON-COLONIAL	**1.426****	**1.099****	**1.474****
			(0.000)	**(0.001)**	**(0.000)**
	Index of Econ Freedom, 2005 (higher = less free)	PARTITIONED	0.004		0.003
			(0.165)		(0.367)
		FRACTAL		-3.965	-3.546
				(0.269)	(0.305)
		ELF60	0.002	0.004^{+}	0.002
			(0.570)	(0.085)	(0.587)
		NON-COLONIAL	**-0.739****	**-0.607****	**-0.785****
			(0.000)	**(0.001)**	**(0.000)**
	Economic Freedom in the World, avg 1970-2002	PARTITIONED	-0.007^{+}		-0.006
			(0.086)		(0.150)
		FRACTAL		2.042	6.819
				(0.678)	(0.162)
		ELF60	0.002	-0.003	0.003
			(0.587)	(0.276)	(0.530)
		NON-COLONIAL	**1.133****	**1.145****	**1.228****
			(0.000)	**(0.000)**	**(0.000)**
Political and governance variables	Voice - checks on power	PARTITIONED	**-0.007***		**-0.008***
			(0.032)		**(0.0360**
		FRACTAL		10.40^{+}	10.67^{+}
				(0.053)	(0.0930
		ELF60	0	-0.005	0
			(0.988)	(0.124)	(0.952)
		NON-COLONIAL	**1.255****	**0.847****	**1.149****
			(0.000)	**(0.003)**	**(0.000)**
	Political stability and violence	PARTITIONED	-0.007^{+}		-0.007^{+}
			(0.065)		(0.081)
		FRACTAL		7.572	8.161
				(0.121)	(0.121)
		ELF60	-0.001	-0.006	0
			(0.849)	(0.115)	(0.923)
		NON-COLONIAL	**1.272****	**0.959****	**1.277****
			(0.000)	**(0.001)**	**(0.000)**

	Government effectiveness	PARTITIONED	**-0.008***		-0.007^{+}
			(0.043)		(0.073)
		FRACTAL		7.68	7.796
				(0.153)	(0.161)
		ELF60	-0.001	-0.005	-0.001
			(0.816)	(0.152)	(0.891)
		NON-COLONIAL	**1.526****	**1.30****	**1.594****
			(0.000)	**(0.000)**	**(0.000)**
	Regulatory quality	PARTITIONED	**-0.008***		-0.007^{+}
			(0.044)		(0.067)
		FRACTAL		**9.977***	9.814^{+}
				(0.040)	(0.077)
		ELF60	0	-0.006^{+}	0
			(0.912)	(0.075)	(0.954)
		NON-COLONIAL	**1.343****	**1.018****	**1.322****
			(0.000)	**(0.000)**	**(0.000)**
	Rule of law	PARTITIONED	**-0.007***		-0.006^{+}
			(0.048)		(0.099)
		FRACTAL		7.295	6.553
				(0.148)	(0.192)
		ELF60	-0.002	-0.006^{+}	-0.002
			(0.611)	(0.098)	(0.706)
		NON-COLONIAL	**1.576****	**1.358****	**1.658****
			(0.000)	**(0.000)**	**(0.000)**
	Corruption	PARTITIONED	**-0.007***		-0.006^{+}
			(0.045)		(0.089)
		FRACTAL		7.76	7.214
				(0.120)	(0.148)
		ELF60	-0.003	**-0.006***	-0.002
			(0.437)	**(0.045)**	(0.504)
		NON-COLONIAL	**1.533****	**1.346****	**1.608****
			(0.000)	**(0.000)**	**(0.000)**
Quality of life variables	Literacy rate, avg of available data 1995-2002	PARTITIONED	**-0.373****		**-0.388****
			(0.000)		**(0.001)**
		FRACTAL		202.8	318.8^{+}
				(0.259)	(0.060)
		ELF60	-0.135^{+}	**-0.273****	-0.112
			(0.080)	**(0.002)**	(0.200)
		NON-COLONIAL	5.712	-0.6	5.518
			(0.261)	(0.933)	(0.269)
	Percent pop with access to clean water, 2000	PARTITIONED	**-0.171***		-0.144^{+}
			(0.039)		(0.069)
		FRACTAL		71.76	-12.69
				(0.608)	(0.911)
		ELF60	**-0.173***	**-0.234****	**-0.171***
			(0.044)	**(0.003)**	**(0.043)**
		NON-COLONIAL	**10.19***	7.853	**11.105***
			(0.018)	(0.251)	**(0.013)**

Infant mortality, 2001	PARTITIONED	**0.421***		**0.404***
		(0.022)		**(0.035)**
	FRACTAL		-270.4	-325.6
			(0.185)	(0.201)
	ELF60	**0.566****	**0.719****	**0.536***
		(0.009)	**(0.000)**	**(0.015)**
	NON-COLONIAL	**-28.477****	**-24.45****	**-28.02****
		(0.002)	**(0.007)**	**(0.001)**
Measles immunization rate, 2002	PARTITIONED	**-0.27****		**-0.287****
		(0.000)		**(0.000)**
	FRACTAL		-50.00	38.08
			(0.549)	(0.660)
	ELF60	**-0.159***	**-0.286****	**-0.162***
		(0.018)	**(0.000)**	**(0.022)**
	NON-COLONIAL	-0.346	1.846	0.799
		(0.924)	(0.611)	(0.802)
DPT immunization rate, 2002	PARTITIONED	**-0.205****		**-0.23****
		(0.002)		**(0.002)**
	FRACTAL		62.04	146.4
			(0.489)	(0.157)
	ELF60	**-0.225****	**-0.284****	**-0.217***
		(0.008)	**(0.000)**	**(0.012)**
	NON-COLONIAL	**7.713***	**8.368***	**6.915***
		(0.046)	**(0.030)**	**(0.049)**

P values in parenthesis; + * ** refer to significance at the 10%, 5% or 1% levels, respectively.

Columns 1, 2 and 3 refer, respectivly, to groups of regressions using PARTITIONED, FRACTAL, or both variables.

Table 9 – Controlling for elf60, former colonial status and climate[1]

Dependent variables:		Coefficient on:	1	2	3
		PARTITIONED	**-0.015****		**-0.016****
			(0.000)		**(0.000)**
		FRACTAL		10.53^{+}	**10.76***
				(0.074)	**(0.013)**
	Log GDP per capita, 2002	ELF60	-0.002	**-0.013****	-0.001
			(0.562)	**(0.001)**	(0.835)
		NON-COLONIAL	**1.323****	0.694^{+}	**1.226****
			(0.000)	(0.053)	**(0.000)**
		CLIMATE	-0.456^{+}	**-0.813***	-0.531^{+}
			(0.064)	**(0.016)**	(0.062)
		PARTITIONED	0.004		0.004
			(0.193)		(0.282)
		FRACTAL		-6.333^{+}	-5.122
				(0.069)	(0.157)
Economic variables	Index of Econ Freedom, 2005 (higher = less free)	ELF60	0.001	0.003	0.001
			(0.722)	(0.149)	(0.799)
		NON-COLONIAL	**-0.709****	**-0.411***	**-0.68****
			(0.001)	**(0.049)**	**(0.001)**
		CLIMATE	0.196	**0.463***	0.239
			(0.318)	**(0.029)**	(0.280)
		PARTITIONED	-0.006		-0.006
			(0.103)		(0.115)
		FRACTAL		3.982	8.549^{+}
				(0.416)	(0.069)
	Economic Freedom in the World, avg 1970-2002	ELF60	0.002	-0.003	0.003
			(0.574)	(0.317)	(0.453)
		NON-COLONIAL	**1.195****	**0.98****	**1.103****
			(0.000)	**(0.000)**	**(0.000)**
		CLIMATE	-0.116	-0.273	-0.24
			(0.669)	(0.300)	(0.377)
Political and governance variables		PARTITIONED	**-0.007***		**-0.009***
			(0.032)		**(0.018)**
		FRACTAL		**12.59***	**13.83***
				(0.023)	**(0.038)**
	Voice - checks on power	ELF60	0.001	-0.004	0.001
			(0.871)	(0.216)	(0.681)
		NON-COLONIAL	**1.184****	**0.642***	**0.942****
			(0.000)	**(0.046)**	**(0.006)**
		CLIMATE	-0.193	**-0.56***	-0.448
			(0.464)	**(0.048)**	(0.119)
	Political stability and violence	PARTITIONED	-0.006^{+}		**-0.008***
			(0.078)		**(0.028)**
		FRACTAL		**11.51***	**12.24***
				(0.012)	**(0.015)**

		ELF60	0	-0.005	0.001
			(0.988)	(0.203)	(0.766)
		NON-COLONIAL	**1.17****	**0.637***	**1.009****
			(0.000)	**(0.039)**	**(0.001)**
		CLIMATE	-0.326	**-0.707***	-0.579^{+}
			(0.274)	**(0.016)**	(0.060)
	Government effectiveness	PARTITIONED	**-0.007***		**-0.008***
			(0.050)		**(0.026)**
		FRACTAL		**12.49***	**12.45***
				(0.011)	**(0.019)**
		ELF60	0	-0.004	0.001
			(0.933)	(0.299)	(0.759)
		NON-COLONIAL	**1.42****	**0.898****	**1.289****
			(0.000)	**(0.005)**	**(0.000)**
		CLIMATE	**-0.515***	**-0.916****	**-0.66***
			(0.048)	**(0.001)**	**(0.014)**
	Regulatory quality	PARTITIONED	-0.007^{+}		**-0.008***
			(0.061)		**(0.042)**
		FRACTAL		**12.95****	**12.53***
				(0.006)	**(0.021)**
		ELF60	0	-0.005	0.001
			(0.990)	(0.134)	(0.844)
		NON-COLONIAL	**1.314****	**0.762***	**1.144****
			(0.000)	**(0.012)**	**(0.000)**
		CLIMATE	-0.197	**-0.618***	-0.385
			(0.469)	**(0.028)**	(0.171)
	Rule of law	PARTITIONED	**-0.007***		**-0.007***
			(0.048)		**(0.031)**
		FRACTAL		**12.22****	**11.65***
				(0.009)	**(0.014)**
		ELF60	-0.001	-0.004	0
			(0.879)	(0.201)	(0.913)
		NON-COLONIAL	**1.428****	**0.951****	**1.324****
			(0.000)	**(0.002)**	**(0.000)**
		CLIMATE	**-0.581***	**-0.911****	**-0.722****
			(0.022)	**(0.000)**	**(0.005)**
	Corruption	PARTITIONED	-0.007^{+}		**-0.007***
			(0.053)		**(0.034)**
		FRACTAL		**12.28****	**11.65***
				(0.009)	**(0.019)**
		ELF60	-0.001	-0.005	-0.001
			(0.678)	(0.108)	(0.829)
		NON-COLONIAL	**1.418****	**0.97****	**1.317****
			(0.000)	**(0.002)**	**(0.000)**
		CLIMATE	**-0.531***	**-0.853****	**-0.628****
			(0.026)	**(0.001)**	**(0.009)**
Quality of life variables	Literacy rate, avg of available data 1995-2002	PARTITIONED	**-0.364****		**-0.39****
			(0.001)		**(0.001)**
		FRACTAL		212.6	**333.1***
				(0.268)	**(0.037)**

	ELF60	-0.144^{+}	**-0.272****	-0.109
		(0.068)	**(0.003)**	(0.197)
	NON-COLONIAL	8.2	-1.326	5.061
		(0.197)	(0.873)	(0.371)
	CLIMATE	4.773	0.359	-1.119
		(0.410)	(0.962)	(0.837)
Percent pop with access to clean water, 2000	PARTITIONED	**-0.163***		**-0.160***
		(0.039)		**(0.037)**
	FRACTAL		170.6	59.51
			(0.196)	(0.594)
	ELF60	**-0.163***	**-0.217****	-0.156^{+}
		(0.050)	**(0.003)**	(0.057)
	NON-COLONIAL	7.994^{+}	1.206	7.727^{+}
		(0.086)	(0.869)	(0.079)
	CLIMATE	-6.676	**-14.72***	-7.662
		(0.124)	**(0.014)**	(0.124)
Infant mortality, 2001	PARTITIONED	**0.409***		**0.419***
		(0.026)		**(0.026)**
	FRACTAL		-368.9^{+}	-385.2
			(0.051)	(0.100)
	ELF60	**0.555****	**0.69****	**0.512***
		(0.009)	**(0.000)**	**(0.016)**
	NON-COLONIAL	**-28.23****	-16.84	**-24.11****
		(0.008)	(0.109)	**(0.009)**
	CLIMATE	4.644	14.81	8.447
		(0.700)	(0.243)	(0.501)
Measles immunization rate, 2002	PARTITIONED	**-0.272****		**-0.295****
		(0.000)		**(0.000)**
	FRACTAL		0.707	72.339
			(0.993)	(0.384)
	ELF60	**-0.153***	**-0.272****	**-0.149***
		(0.017)	**(0.000)**	**(0.031)**
	NON-COLONIAL	0.142	-2.092	-1.449
		(0.971)	(0.630)	(0.700)
	CLIMATE	-3.197	-7.155	-4.856
		(0.465)	(0.193)	(0.283)
DPT immunization rate, 2002	PARTITIONED	**-0.202****		**-0.249****
		(0.004)		**(0.001)**
	FRACTAL		149.8^{+}	**224.2***
			(0.065)	**(0.030)**
	ELF60	**-0.21***	**-0.256****	**-0.187***
		(0.012)	**(0.000)**	**(0.025)**
	NON-COLONIAL	6.08	1.18	1.807
		(0.169)	(0.780)	(0.638)
	CLIMATE	-5.949	**-14.54***	**-11.04***
		(0.274)	**(0.018)**	**(0.047)**

P values in parenthesis; $^{+}$ * ** refer to significance at the 10%, 5% or 1% levels, respectively.

Columns 1, 2 and 3 refer, respectivly, to groups of regressions using PARTITIONED, FRACTAL, or both variables.

[1] Climate is measured as the percentage of cultivatable land in Koppen-Geiger Climate Zone A – humid weather with no winter