How much long-run economic growth happens at the country level? *

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Abstract

Policy and academic discussions of economic growth usually focus on country-level outcomes and determinants. But how much of the variation in long-run growth really happens at the country level? To answer this question, we collect data on growth at the national level (from standard sources), or at the provincial level (from Gennaioli et al. (2014)), and decompose it into variation due to province, country-level or supra-national factors. Using national growth rates, we find that 2/3 of long run growth is due to country effects and the remaining 1/3 is explained by supra-national factors. In our dataset of provincial growth rates, 1/2 of long run growth is national, 1/5 is provincial and the rest is supra-national. Moreover, year dummies show significant variation, suggesting important non-national effects coming from global cycles or global secular shifts in growth. Consistent with a growing literature, our results suggest that many of the deep determinants of growth (for example institutions, geography or culture) may vary at sub-national or supra-national levels, and the importance of the nation-state for economic growth has been overstated.

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1 Introduction

The vast majority of analysis of long-run economic growth occurs at the country level, in both policy and academic discussions. For example, the cross-country economic growth literature (going back at least to Barro (1991)), is almost entirely at the country level.[1] The World Bank, IMF and other international bodies produce reports for each country. In part this is inevitable because data on growth and its covariates (capital stocks, human capital accumulation etc) are collated by national statistical authorities. Moreover, sovereignty is at the national level, so naturally governments demand reports and analysis at the that level.

But the focus on countries is also function of a deeper premise: that long-run growth occurs in an economic sense at the national level. If economic policies or institutions are determined at a national level and affect economic growth, then one would expect growth to also vary primarily at the national level. The institutions literature, for example, finds that there is substantial variation in institutions like protection of property rights across countries, which then feeds through to variation in national economic growth (Acemoglu et al. (2001), Acemoglu et al. (2002); Acemoglu and Johnson (2005)). In contrast, if variation in institutions also occurred within countries, then we would expect to find the national level relation between growth and institutions to be only part of the story. For example, Acemoglu and Dell (2010) found significant differences in productivity levels within countries attributed to local institutions and policies. Dell (2010) documented evidence of a colonial-era regional demarcation inside of Peru having lasting institutional and development effects, while Berger (2009) got a similar result for a colonial demarcation inside of Nigeria. Alternatively, if institutions vary mostly at the supra-national regional level (for example, between Europe and Africa), then the cross-country relationships between institutions and growth could actually be driven by supra-national regional differences rather than national differences.

Despite the traditional focus on countries, there is a recent literature which suggests that many of the deep determinants of growth tend to vary at levels other than the nation state. For example, Michalopoulos and Papaioannou (2013) argue that precolonial ethnic institutions, which vary within countries and across national borders, are highly correlated with current economic development in Africa. Moreover, Michalopoulos and Papaioannou (2014) find that economic development does not generally vary at national borders in Africa within ethnic homelands.

More generally, other deep determinants of economic growth can vary across sub-regions, nations and also continents. For example, Nunn (2008) shows that African countries that exported more

[1] The cross-country growth literature did find continent effects (most commonly a statistically significant dummy for sub-Saharan Africa), but this was usually treated as a nuisance effect reflecting omission of country-level factors (e.g. ethnic diversity as in Easterly and Levine (1997)). Sala-I-Martin et al. (2004) found dummies for Latin America and Sub-Saharan Africa to be one of the most robust variables in the entire cross-country growth literature.

slaves had worse subsequent economic performance. At the same time, Nunn and Wantchekon (2011) find a negative relation between interpersonal trust and slave exports at a sub-national level. Moreover slave exports over 1500-1900 were largely confined to particular supra-national regions of Africa, rather than being a general world-wide phenomenon. A large literature both stresses culture as a determinant of development outcomes and also emphasizes that culture can both vary within nations and spread across supranational regions (Bisin and Verdier (2010), Fernandez and Fogli (2009), Guiso et al. (2010), Guiso et al. (2013), Licht et al. (2007), Nunn (2012), Tabellini (2008),Tabellini (2010)). Geographical determinants of development, such as crop suitability (Hibbs and Olsson (2004), Easterly (2007), Easterly and Levine (2003), Engerman and Sokoloff (1994)), distance to waterways (Ashraf and Galor (2011), Ashraf and Galor (2013)), or malaria incidence (Sachs and Malaney (2002)), vary both within countries, between countries and across continents. Spolaore and Wacziarg (2009), Comin et al. (2010), Putterman and Weil (2010), Chanda et al. (2014), and Easterly and Levine (2015) discuss the long-run historical dissemination of institutions and technology as spreading through closely related ethnic groups and diasporas that do not neatly divide at national boundaries.

More generally, a large recent literature stresses the importance of history (even very ancient history) in determining development outcomes (Nunn (2009), Spolaore and Wacziarg (2013)). Different groups' very long history with statehood, institutions, or technology affects their outcomes today, again in a way that will not necessarily correspond to the national boundaries that did not even exist until relatively recently – and even more so because many national boundaries are artificial colonial or postwar creations (Alesina et al., 2011).

In this paper we test the extent to which per capita long-run economic growth varies at the supra-national or sub-national level, rather than at the national level. We remain agnostic on the reasons supra and sub-regions might be important by taking a variance decomposition approach. As foreshadowed above, a key challenge is that most growth data is collected at the national level. In the first part of the paper, we use the standard national growth data to investigate the extent to which national economic growth varies at the national or supra-national level. Specifically, we decompose variation in growth at the country level into a supra-national region-specific effect, a country-specific effect (after controlling for regional variation), time-specific effects and independent identically distributed (iid) noise.[2]

Although supra-national country groupings need not be geographically connected (e.g. institutions of the United States have more in common with those of the UK than Mexico), defining

[2]As different growth databases sometimes produce different results (Easterly and Pennings, 2015), we replicate our results with four commonly-used databases (Penn World Tables 6.1 and 7.1, the World Development Indicators (WDI), and Maddison's growth data), with the WDI and PWT 7.1 results reported in the body, and other growth datasets reported in the appendix.

a supra-national region without geographical constraints is difficult due to the almost countless possible combinations. Moreover, many potential grouping of countries are endogenous to past economic growth, with a trivial example being the OECD or World Bank income groupings. As such we take a conservative approach of combining countries into five geographically-based "supra-national regions" defined by the UN - Africa, Americas, Asia, Europe and Oceania – and then into 21 "mid-level regions".[3] Our results are robust to using other similar regional country grouping produced by the World Atlas, the World Health Organization, Eco regions, or World Bank geographic regions. As the growth share explained by regions weakly increases in the number of regions, we take our results to be a lower bound on the true influence of supra-national factors in explaining growth.

In the second part of paper, we do a full decomposition of growth at the sub-national, national, and supra-national level using Gennaioli et al. (2014) new dataset on per-capita growth at the provincial level. These data allow us to estimate the importance of country factors separately from province level ones. Unfortunately, provincial growth data is missing for much of Africa, and also might suffer from measurement error. To cross-check the accuracy of our results, we also decompose variation in growth rates for provinces using night-time light intensity (Henderson et al., 2012).

Methodologically, we perform the variance decomposition using random-effects panel econometric methods.[4] As outlined in Easterly and Pennings (2015), the variance of average growth rates can be substantially upward biased when the average is calculated over a small number of years or if the iid error variance is large. Monte Carlo simulations suggest that our methods produce close to the true variance shares.

Our first main result is that, on average, 1/3 of the variation of long run national growth happens at a supranational level, with the remaining 2/3 explained by factors at country level. If the supra-national level regions are whole continents, the share of variation at these macro regions is slightly lower (about 1/4), and if they are mid-level regions it is higher (about 1/2). Specifically, the standard deviation of long-run growth explained by country and province level factors is around 1% per year whereas the standard deviation of growth at the supra-national region level is around 0.64% for whole continents or 0.9% per year for mid-level macro regions (e.g. West Africa). Given that we are not able to separate country from province level factors using country level data, we run a second set of estimates using province level data to do so.

The result of the mentioned exercise is that the fraction of long-run provincial level growth

[3] As shown in Easterly and Pennings (2015) the variance of the average growth is substantially upward biased when the average is taken over only a few units (in their case leader spells). The same problem will appear here if regions only include a few countries. We try to avoid this by having a large number of countries in each region.

[4] Specifically, the bias is largest for the lowest level variance component (country or province effects) so we estimate these using the random-effects methodology. For higher level variance components (supra-national for example) we calculate the variance of estimated dummy variables.

explained by countries is around 1/3-1/2 (1/3 if controlling for mid-level regional factors, 1/2 if controlling for continental factors). Around 20% of variation of long-run growth at the province level is due to province-specific factors, though estimates vary somewhat depending on the methodology used. Specifically, the standard deviation of long-run provincial growth across countries is around 0.7% per year, 0.6% at the supra-national level and 0.45% at the provincial level.

Results using growth in lights intensity instead of provincial GDP growth (to correct for measurement error and include more African data) are broadly similar. On average across methods and samples, the overall country share of long run growth is slightly higher (1/2-2/3 rather than 1/3-1/2), the supra-national share is slightly lower and the provincial share about the same. However the lights data are very noisy, and results vary across methods, so these numbers must be interpreted with caution.

Finally, we find that the most important factor explaining overall variation in national and provincial level annual growth is iid noise: probably a combination of temporary shocks ("luck") and measurement error. Specifically, around 90% of variation in total national or provincial growth is iid noise, with country-level trends only explaining around 2-3% of total growth variation. This confirms that many of the key findings of Easterly et al. (1993) and Hausmann et al. (2005) extend to more recent data, and also apply at the provincial level. Persistent country-level factors explain almost none of the total variation in growth, most of which is noise, measurement error, or "luck" such as commodity price shocks. While we do not focus on the iid noise, it is another reminder that an additional annual observation on a country's growth contains very little information on that country's long run growth potential.

Another "nuisance" result is the importance of year dummies in explaining total variation of growth. The standard deviation of of the year dummies is 1-2%, at least as large as long-run variation in growth across countries. This can be interpreted as global variation in growth rates that reflects both short-run global cycles (such as the crisis of 2008 and after) and longer-run changes (such as the boom in global growth in the 1950s and 1960s, and the slowdown in the 1970s and 1980s). This is an important result since failing to appreciate global shifts reflected in year dummies can also lead to misattribute to nations what is really global. For example, discussions of the secular US growth slowdown sometimes fail to mention that there was a global slowdown and not just a US slowdown.

Taken together, our results suggest that the importance of the national state for economic growth has been overstated in the academic literature and also in policy discussions. At least half of variation in long-run growth occurs at levels other than the nation-state: either supra-national grouping of a number of countries (e.g. Western Africa, South-East Asia or South America), or occurs at the provincial level within countries. These results are consistent with the long-run drivers of growth such as institutions, history, culture, or geography varying substantially at both sub-national and supra-national level. Our results imply that, data allowing, researchers and policy makers should also pay greater attention to non-national factors when trying to explain economic growth.

The rest of the paper is as follows: Section 2 describes a simple model that guides our empirical exercise, Section 3 describes the data, Section 4 discusses methodology. The results are presented in Section 5 (national growth data) and Section 6 (province-level growth data). Section 7 presents an extension using night-time lights, Section 8 tests the relevance of our choice of supra-national regions and Section 9 concludes.

2 Model

Assume a world economy populated by continuum of supranational regions of measure one. Each region r has a continuum of countries (measure one), and every country i is composed by a continuum of provinces of measure P_i. A province h located in country i, region j has access to the following production function,

$$y_{hij,t} = A_{hij,t} \left(k_{hij,t}\right)^{\alpha} \tag{1}$$

Where α is the capital output elasticity, $y_{hij,t}$ represents the GDP per capita in province h, country i, region j, at year t. Moreover, $A_{hij,t}$ and $k_{hij,t}$ are province h total factor productivity and capital-labor ratio, respectively. To keep things as simple as possible we assume that province specific TFP growth is given by the following equation:

$$A_{hij,t+1} = \mu_h \cdot \mu_i \cdot \mu_j \cdot g \cdot A_{hij,t} \tag{2}$$

Where g denotes a world technology growth rate. In turn, μ_h, μ_i and μ_j are province, country and region specific components, respectively. These terms are introduced to take into account the fact that deep determinants of economic growth might vary across provinces, countries or regions. We assume that the log of each component has a null average, in particular,

$$\int log(\mu_\omega) d\omega = 0 \quad \omega = h, i, j$$

Given that we focus our analysis on long periods of time, we assume that capital and labor are perfectly mobile within the boundaries of each country. This assumption means that the marginal product of capital across provinces in the same country should be equalized, implying the following,

$$k_{hij,t} = [a_{hij,t}]^{\frac{1}{1-\alpha}} \, k_{ij,t} \tag{3}$$

Where $k_{ij,t}$ represents the total capital stock in country i in region j, and $a_{hij,t}$ is the relative TFP level of province h with respect to the average TFP in country i. That is,

$$k_{ij,t} \equiv \int_{P_i} k_{hij,t} dh$$

$$a_{hij,t} \equiv \frac{A_{hij,t}}{A_{ij,t}} \quad \text{where } A_{ij,t} \equiv \left[\int_{P_i} A_{hij,t}^{\frac{1}{1-\alpha}} dh \right]^{1-\alpha}$$

Following the Solow model, we assume that the capital stock evolves according to the following expression,

$$k_{ij,t+1} = s_i \cdot A_{ij,t} \cdot k_{ij,t}^{\alpha} \tag{4}$$

where s_i represents an exogenous country specific savings rate. Note that for simplicity we are assuming full capital depreciation and no population growth.[5]

What is the country long run growth rate according to this model? Taking log differences in equation (4) we get,

$$log \left[\frac{k_{ij,t+1}}{k_{ij,t}} \right] = log \left[\frac{A_{ij,t}}{A_{ij,t-1}} \right] + \alpha \cdot log \left[\frac{k_{ij,t}}{k_{ij,t-1}} \right] \tag{5}$$

Taking averages over a long period of T years, and using the fact that in the long run capital and output grow at the same rate, we get that the average per capita output growth $\bar{g}_{ij}$ is approximately given by,

$$\bar{g}_{ij} \approx \frac{1}{1-\alpha} \frac{1}{T} \sum_{t=1}^{T} log \left[\frac{A_{ij,t}}{A_{ij,t-1}} \right] \tag{6}$$

Therefore, using the definition of $A_{ij,t}$ and equation (2) we get the following expression for the average GDP growth rate,

$$\bar{g}_{ij} \approx \frac{1}{1-\alpha} \left[\tilde{g} + \tilde{\mu}_j + \tilde{\mu}_i + \tilde{\mu}(P_i) \right] \tag{7}$$

Where the tildes indicate that a variable is expressed in logarithms, that is, $\tilde{x} = log(x)$. The country specific growth in (7) has four terms: (i) a global growth component $\tilde{g}$, (ii) a region factor

[5] Removing this assumption does not affect our conclusions.

$\tilde{\mu}_r$ that is affected by deep determinants of economic growth at a regional level, (iii) a country effect $\tilde{\mu}_c$ that represents country specific determinants, and (iv) a within country variation term $\tilde{\mu}(P_i)$ that affects country level growth rates mainly through the largest or most productive provinces. The last term, $\tilde{\mu}(P_i)$, is a log of a weighted average of province components[6].

Equation (7) tells us that country level growth rates depend not only on deep determinants that happen at a global, regional and country level, but also on a within country variation term $\tilde{\mu}(P_i)$. This might be surprising given that we assumed that the simple average of log province level components is null, that is, $\int \tilde{\mu}_h dh = 0$. The reason why province factors play a role is that what matters for country growth rates is the weighted average of province level components. This weighted average is not equal to zero as long as there is a certain degree of heterogeneity across provinces. This is because provinces with higher $\tilde{\mu}_h$ are those who get higher weights over a long periods of time and, as a consequence, the weighted average tends to be higher than zero.

Equation (7) also highlights a potential problem of using country GDP growth rates to measure the importance country components of growth. Note that $\bar{g}_{ij}$ can be divided in two terms according to their cross-sectional variability: one that varies across supra-national regions and another across countries. The region-varying term corresponds to the regional component of growth ($\tilde{\mu}_r$). In turn, the country term is not only affected by country level factors ($\tilde{\mu}_i$) but also depends on the within country variation term ($\tilde{\mu}(P_i)$). Hence, any variance decomposition using country level data has the potential problem of overstating the importance of country determinants of growth ($\tilde{\mu}_i$), as the country variance might be contaminated by $\tilde{\mu}(P_i)$.

Given that we use province level data in the empirical part, we also need to get an expression for average province growth rates from the model. Combining (1), (2) and (3) we get,

$$\frac{y_{hij,t+1}}{y_{hij,t}} = \left[\frac{A_{ij,t+1}}{A_{ij,t}}\right]^{\frac{-\alpha}{1-\alpha}} \left[\frac{y_{ij,t}}{y_{ij,t-1}}\right]^{\alpha} \left[\mu_h \cdot \mu_i \cdot \mu_j \cdot g\right]^{\frac{1}{1-\alpha}} \tag{8}$$

Taking logs in (8) we find,

$$log\left[\frac{y_{hij,t+1}}{y_{hij,t}}\right] = \left(\frac{-\alpha}{1-\alpha}\right) log\left[\frac{A_{ij,t+1}}{A_{ij,t}}\right] + \alpha log\left[\frac{y_{ij,t}}{y_{ij,t-1}}\right] + \left(\frac{1}{1-\alpha}\right)\left[\tilde{\mu}_h + \tilde{\mu}_i + \tilde{\mu}_j + \tilde{g}\right] \tag{9}$$

Averaging over T years (with large T) and using (7) we find,[7]

[6] It is the average of the log of $\tilde{\mu}(P_i, t)$ over a given number of years, where $\tilde{\mu}(P_i, t)$ is a weighted geometric average of province level components at year t for country i. Specifically, $\tilde{\mu}(P_i, t) \equiv \left[\int_{P_i} \left[\mu_h \cdot \frac{A_{hij,t}}{A_{ij,t}}\right]^{\frac{1}{1-\alpha}} dh\right]^{1-\alpha}$

[7] Note that for a large T it is straightforward to see that $\left(\frac{-\alpha}{1-\alpha}\right)\sum_{t=1}^{T-1} log\left[\frac{A_{ij,t+1}}{A_{ij,t}}\right] + \alpha \sum_{t=2}^{T} log\left[\frac{y_{ij,t}}{y_{ij,t-1}}\right] \approx 0$

$$\bar{g}_{y_{hij}} \approx \frac{1}{1-\alpha}\left[\tilde{g} + \tilde{\mu}_h + \tilde{\mu}_i + \tilde{\mu}_j\right] \tag{10}$$

Where $\bar{g}_{hij}$ is the long run province level GDP growth rate and $\tilde{\mu}_h$ is the log province component. Notice that, according to the model, by using province level data we can potentially identify the importance of province level determinants of growth and separate them from country level factors.

Our empirical analysis is be guided by equations (7) and (10), and aims to assess the importance of each component (region, country and province) using long run growth rates at country and province level.

3 Regional Definitions and Growth Data

The first step in analyzing the importance of supra-national regions for growth is defining which regional groups we are going to consider. Our main "macro region" definition comes from the UN with 5 regions listed at the top of Table 1. Results using other region definitions are fairly similar and are shown in Appendix A.2.[8] The advantage of the UN regions is that the UN also breaks the 5 macro regions down into 19 mid-level-regions, listed in the second row of Table 1.

Table 1: UN region definitions

Macro region	Asia	Europe	Americas	Oceania	Africa
Mid-level regions	Central Asia Eastern Asia S-Eastern Asia Southern Asia	Eastern Europe Northern Europe Southern Europe Western Europe	Caribbean Central America Northern America South America	Aus & N.Zealand Melanesia Micronesia Polynesia	Eastern Africa Middle Africa Northern Africa Southern Africa Western Africa

Our first dataset consists of an unbalanced panel of annual log growth in real GDP per capita from four commonly-used growth datasets (see Appendix A.1 for further information). Descriptive statistics are presented in Table 2. In the body of the paper we present results from the World Development Indicators (WDI) from the World Bank, with a usable sample of 204 countries covering the period 1961-2010.[9] Alternatively, we use Penn World Table's dataset (version 7.1)[10],hereon

[8] Specifically these are (i) World Atlas (WA) –Africa, Asia, Europe, North America, Oceania, and South America; (ii) World Health Organization (WHO) –Africa, Americas, Eastern Mediterranean, Europe, Southeast Asia, Western Pacific; (iii) Eco Region (ECO) –Afrotropical, Australasian, Indo-Malayan, Nearctic, Neotropical, Oceania, and Paleartic; and (iv) World Bank (WB) – Eastern Asia, Europe and Central Asia, Latin America and Caribbean, Middle East and North Africa, North America, South Asia, and Sub-Saharan Africa.

[9] See: `http://data.worldbank.org/data-catalog/world-development-indicators`

[10] See: `https://pwt.sas.upenn.edu/php_site/pwt71/pwt71_form.php`.

PWT7, has a slightly larger sample of 189 countries from 1950 to 2010. Results using PWT 6.1[11] and Maddison Project[12] are reported in Appendix A.2.

Some of the literature uses 5 year average growth rates rather than annual rates (e.g. Gennaioli et al. (2014)) to make results less sensitive to mis-measurement in particular years. We use annual growth rates because we are primarily interested in estimating trends over the whole sample rather than changes in growth rates (Gennaioli et al. (2014) look at convergence). 5 year averages can lead to a smaller sample in the case the first or 5th year of the 5 year period is unavailable.

In Section 6 we also consider growth at the sub-national level. The sub-national regions are taken from Gennaioli et al. (2014), and are provinces or states. Gennaioli et al. (2014) data are available for 83 countries and around 1500 sub-national regions, with good coverage for most of the world except for Africa (see Table 1 of their paper for a list of countries and years covered). In Section 7, we extend coverage to Africa using data on night-time lights.

Table 2: Descriptive Statistics

Datasets	Years	UN Macro regions	UN Macro Sub groups	Countries	Sub regions (Provinces)	Obs.	Avg. growth	SD
WDI	1961-2011	5	22	204	n.a.	7,913	1.85%	6.02%
PWT7	1951-2010	5	21	189	n.a.	8,692	1.97%	6.94%
PWT6	1951-2000	5	19	154	n.a.	5,668	1.87%	6.43%
Maddison	1951-2000	5	19	161	n.a.	8,850	1.85%	5.94%
Gennaioli etal	1950-2010	5	15	65	1252	28,125	2.37%	8.23%
(Excl. Outliers)						25,313	2.40%	4.30%

In practice, our sample is somewhat smaller than that in Gennaioli et al. (2014), for two reasons: (i) for many countries there are gaps in GDP which make it hard to calculate annual growth, (ii) the sub-national growth data is extremely volatile: the variance of provincial growth is 80% larger than WDI country-level data. The first problem drops the usable sample to 65 countries and 1252 provinces. To get around (ii), we drop the top and bottom 5% outliers, which reduces the sample size to 25313 observations (we do not drop outliers for country-level GDP growth as they are not as volatile). Omitting outliers is a common practice with growth empirics. Our reason for doing so is our judgment that an extremely high positive or negative growth rate is much more likely to be measurement error than a real phenomenon. Dropping outliers reduces the standard deviation of provincial-level per capita GDP growth from 8.23% to 4.3%.[13]

[11]See: https://pwt.sas.upenn.edu/php_site/pwt61_form.php.

[12]See: http://www.ggdc.net/maddison/maddison-project/home.htm.

[13]Gennaioli et al. (2014) convert provincial GDP data into current PPP USD by multiplying the GDP share of the province by national USD PPP GDP. They then divide by provincial population to get GDP per capita. Regional

4 Methodology

In this section, we describe how we estimate the variance of different growth components. The method is very similar whether we are using country-level data or province-level growth data, though the province-level data requires the estimation of an additional province-level effect. We describe the country-level method first, and then the additions required for the province-level growth data.

4.1 Country level data

With regional definitions in hand we are able to perform a variance decomposition to estimate how much of the total variance of growth can be explained by different factors. We define the country level annual growth rate as the sum of long run growth rate and time varying factors τ_t and ϵ_{ijt},

$$g_{ij,t} = \bar{g}_{ij} + \tau_t + \epsilon_{ij,t} \tag{11}$$

Where $\bar{g}_{ij}$ represents the country long run growth rate, τ_t is included to take into account the fact that global growth varies over time, and $\epsilon_{ij,t}$ are normal iid shocks that can be interpreted as a mixture of transitory shocks to growth rates ("luck") and measurement error.

We can now plug (7) into (11)and get,

$$g_{ij,t} = \frac{1}{1-\alpha}\left[\tilde{g} + \tilde{\mu}_j + \tilde{\mu}_i + \tilde{\mu}(P_i)\right] + \tau_t + \epsilon_{ij,t} \tag{12}$$

Note that (12) has, in addition to the iid shock and time effects, two long run components that vary across regions ($\frac{1}{1-\alpha}\tilde{\mu}_j$) and countries ($\frac{1}{1-\alpha}(\tilde{\mu}_i + \tilde{\mu}(P_i))$). Renaming these two elements as r_j and c_i respectively, and setting $\bar{g} \equiv \frac{1}{1-\alpha}\tilde{g}$ we get the following model,

$$g_{ijt} = \bar{g} + r_j + c_i + \tau_t + \epsilon_{ijt} \tag{13}$$

$$\epsilon_{ijt} \sim N(0, \sigma_\epsilon)$$

We can actually estimate the model using region, country and time effects. Note, however, that we face an identification problem in that the supra-national region effects r_j and country effects c_i in Equation (13) are both time invariant. This means that we have two "individual effects".[14] We impose the condition that within each macro-region, the country effects are mean zero. This means that we can estimate the model with a random-effects GLS model, where r_j and τ_t are estimated

deflators are generally unavailable, so Gennaioli et al. (2014) deflate using national deflators.

[14] It is possible to increase the region effect r_j and reduce the country effect c_i for each country and keep growth unchanged.

using dummy variables for the particular supra-national region or year.[15] The estimated model includes the following assumptions,[16]

$$
\begin{aligned}
&g_{ijt} = \bar{g} + r_j + \tau_t + u_{ijt} \\
&u_{ijt} = c_i + \epsilon_{ijt} \\
&\epsilon_{ijt} \sim N(0, \sigma_\epsilon), \quad c_i \sim N(0, \sigma_c), \quad E\left(\epsilon_{ijt} c_i\right) = 0
\end{aligned} \tag{14}
$$

Using the independence assumption it easy to see that from the first two equations in (14):

$$
Var\left(g_{ijt}\right) = \sigma_r^2 + \sigma_\tau^2 + \sigma_c^2 + \sigma_\epsilon^2 \tag{15}
$$

Where σ_r^2 represents the variance of supra-national region effects, σ_τ^2 is the variance of time effects, σ_c^2 denotes the variance of country effects, and σ_ϵ^2 the iid shock variance.

As already noted the iid shock variance is very large and will generally dominate the variance decomposition. The time effects also have sizable variance. While we acknowledge these important results, which are not new findings, we also want to look at the components that reflect only permanent long run effects. Noting the lack of a time subscript, can also define “long run growth” as:

$$
g_{ij} = \bar{g} + r_j + c_i \tag{16}
$$

And the variance of long run growth as:

$$
Var\left(g_{ij}\right) = \sigma_r^2 + \sigma_c^2
$$

Hence, the country effects share of overall growth is:

$$
s_c = \frac{\sigma_c^2}{\sigma_r^2 + \sigma_\tau^2 + \sigma_c^2 + \sigma_\epsilon^2} \tag{17}
$$

And the country and supra-national regions shares(respectively) of long run growth are:

$$
s_c^{LR} = \frac{\sigma_c^2}{\sigma_r^2 + \sigma_c^2} \quad s_r^{LR} = \frac{\sigma_r^2}{\sigma_r^2 + \sigma_c^2} \tag{18}
$$

We know from our model that country effects c_i captures country-level determinants of growth along with province ones as long as the variance of $\tilde{\mu}(P_i)$ is different from zero. This is because the

[15] This method is closely related to the one employed in Easterly and Pennings (2015).

[16] We basically assume that $E(r_j c_i) = E(c_i) = 0$.

dispersion of long run national growth rates, controlling for supra-national factors, is affected by two different things: (i) the heterogeneity of province level factors, and (ii) country level determinants of growth. With country level data it is impossible to distinguish one from the other. Therefore, we should interpret the country shares coming from this exercise as representing an upper bound to the importance of country level determinants. We address this potential problem when we use province level data.

4.2 Biased estimation of the variance of individual effects (national growth data)

Following Easterly and Pennings (2015) estimates of $\sigma_r^2, \sigma_\tau^2, \sigma_c^2$ will be upward biased if they are calculated using a simple sample variance of estimated dummy variables. This is because the model will attribute the squared sample mean of the errors to variation in the components $\sigma_r^2, \sigma_\tau^2, \sigma_c^2$, which is a big problem if the error variance is large, or the number of observations per component is small. This is much larger problem for the lowest level variance component (σ_c^2) as the size of the bias is decreasing in the number of observations. Unbiased estimation of variance of individual effects is an important part of the GLS adjustment for random effects estimators. These estimators typically estimate the variance of the individual effect by subtracting off the bias term (see Easterly and Pennings (2015)). We estimate using two random effects procedures: the standard random effects estimator in Stata, and an estimator based on Baltagi and Chang (1994) that preforms better on unbalanced panels (our data are extremely unbalanced). In most cases, both estimators produce similar results. For upper level individual effects ($\sigma_r^2, \sigma_\tau^2$) the bias is small because the errors are being averaged over a large number of observations, so we can estimate $\sigma_r^2, \sigma_\tau^2$ quite accurately as the variance of estimated dummy variables.[17]

4.3 Monte Carlo results - country-level growth

To test how our proposed methodology performs we use Monte Carlo simulations. Specifically, we constructed 1,000 samples of the data generating process described by Equations (14), using the same dataset structure as WDI dataset and grouping regions according to the UN continental regional classification. We carried out our estimation method for each one of the samples, and computed summary statistics.

The Monte Carlo results are presented in Table 3. Panel A presents the results using Baltagi and Chang (1994) unbalanced panel correction (xtreg, sa in Stata), Panel B uses the Stata's default Random Effects estimator. We see that both methods do a good job fitting the data generating

[17] This would not be the case if there were only a small number of countries per macro region.

Table 3: MC Simulations with Country Growth Data

	SD country	SD region	SD year	SD iid
Generating process	1.16%	0.57%	1.52%	5.66%
Panel A: Batalgi and Chang unbalanced panel correction				
Mean	1.16%	0.53%	1.56%	5.66%
(SD)	(0.11%)	(0.18%)	(0.16%)	(0.05%)
Percentile 5	0.98%	0.25%	1.31%	5.59%
Percentile 95	1.34%	0.85%	1.83%	5.74%
Panel B: Standard RE				
Mean	1.10%	0.53%	1.56%	5.66%
(SD)	(0.12%)	(0.18%)	(0.16%)	(0.05%)
Percentile 5	0.90%	0.25%	1.31%	5.59%
Percentile 95	1.29%	0.85%	1.83%	5.74%
Panel C: Fixed Effects				
Mean	1.51%	0.53%	1.56%	5.66%
(SD)	(0.08%)	(0.18%)	(0.16%)	(0.05%)
Percentile 5	1.38%	0.25%	1.32%	5.59%
Percentile 95	1.64%	0.84%	1.83%	5.74%

process. The estimation of supra-national region, year and iid error standard deviations are identical in both methods. However, the unbalanced panel corrected estimation does a slightly better job estimating the country standard deviation.[18]

4.4 Province-level model and Monte Carlo results

The model for sub-national province level growth is very similar to that for country-level growth. We now use (10) and add time effects τ_t and iid shocks $\epsilon_{hij,t}$ to define province annual growth rates,

$$g_{hij,t} = \frac{1}{1-\alpha}\left[\tilde{g} + \tilde{\mu}_j + \tilde{\mu}_i + \tilde{\mu}_h\right] + \tau_t + \epsilon_{hij,t}$$

We have three different components of long run growth that vary at region, country and province level. Now the country varying factor c_i corresponds to country level determinants of growth

[18] One worry that the small size of the upward bias of the region effects depends on the true size of the region effects. Monte Carlo simulations (not reported) show that when there are no true region effects we will still find a region SD of 0.2%. However, because the bias disappears quite quickly, the large region effects found in the rest of the paper cannot be justified by the bias.

only ($\frac{1}{1-\alpha}\tilde{\mu}_i$). Moreover, there is a new province-level element that is explained by province deep determinants of growth ($\frac{1}{1-\alpha}\tilde{\mu}_h$), we call these province level effects p_h.

The estimation method is similar to before, except now the lowest level component is at the province level, so we reformulate the random effect model and incorporate the province effects rather than country effect in the combined error term u_{hijt}.

$$
\begin{aligned}
g_{hijt} &= \bar{g} + r_j + c_i + \tau_t + u_{hijt} \qquad (19)\\
u_{hijt} &= p_h + \epsilon_{hijt}
\end{aligned}
$$

As before, there are multiple time-invariant effects, so we need to assume that each lower-level effect is mean zero. We implement this in a two-step regression. First we run a Random Effects regression of provincial growth on macro-level region dummies (results are similar using OLS in the first stage). We calculate the variance of these macro dummies to estimate σ_r^2, which is almost unbiased because the number of observations for each region is large. We collect the residuals, and then estimate a random effects regression with country and time dummies. σ_τ^2 and σ_c^2 are calculated as the variance of the estimated dummies. The variance of the provincial effects σ_p^2, where potential biases are the most problematic, are backed out using the same random effects estimators as in the country-level growth case. Variance shares are calculated in an analogous way, though now the variation in total growth and also long-run growth also includes the variance of province effects σ_p^2.

Table 4: MC Simulations with Province-level Growth Data

	SD country	SD macro region	SD Province	SD year	SD iid
Generating process	0.76%	0.53%	0.25%	1.06%	4.07%
Panel A: Batalgi and Chang unbalanced panel correction					
MC simulation					
Mean	0.70%	0.50%	0.23%	1.06%	4.06%
(SD)	(0.09%)	(0.19%)	(0.09%)	(0.12%)	(0.02%)
Percentile 5	0.56%	0.21%	0.03%	0.86%	4.03%
Percentile 95	0.87%	0.83%	0.35%	1.27%	4.09%
Panel B: Standard RE					
MC simulation					
Mean	0.70%	0.50%	0.21%	1.06%	4.06%
(SD)	(0.09%)	(0.19%)	(0.15%)	(0.12%)	(0.02%)
Percentile 5	0.56%	0.21%	0.00%	0.86%	4.03%
Percentile 95	0.87%	0.83%	0.44%	1.27%	4.09%

We test our methodology by running a Monte Carlo simulation (results shown in Table 4) using the same two different random effects estimators as before. Both methods estimate the SD of the different variance components quite accurately, though estimates of σ_r^2, σ_c^2 and σ_p^2 are all slightly downward biased. The Baltagi and Chang estimator is marginally more accurate than the standard RE method.

5 Results with national growth rates

Table 5 presents the results from the estimation of Equations (14) using national growth rates from WDI and PWT7. Panel A presents results using Baltagi & Chang's random effect unbalanced panel correction (that has a more elaborate adjustment for small samples), though results are extremely similar to those using the standard RE estimates in Panel B. Columns (1), and (5) show the estimation of a simplified model without including time or region effects (all other specifications include both). Columns (2) and (6) present models where the supra-national regions are at the continental level, whereas Columns (3) and (7) present models where supra-national regions are at "mid-level" – for example Western Africa, Eastern Africa etc. Columns (4) and (8) average results from the two different supra-national regional definitions.

Averaging across all methods and datasets (Table 5, Panel C), our main result is that only around 2/3 of the variation in long-run national economic growth is explained by country effects, with the other 1/3 explained by effects at the supra-national level. If the supra-national level regions are whole continents, the share of country effects is slightly higher (about 3/4), and if they are mid-level regions it is slightly smaller (about 1/2). Note again that country effects in this stage are also affected by province level factors. Therefore, we should interpret the mentioned shares as upper bounds of the importance of national deep determinants of growth.

It should be emphasized that the standard deviation of long-run growth is only around 1.25%, much less than the estimated 5.7-6.7% standard deviation of the iid annual variation in growth. Another important temporal factor are the year dummies, with a standard deviation larger than long-run growth at about 1.5%. Because of the large variance of the iid term and the non-trivial variance in the year dummies, the country share of total annual variation in growth is tiny in all specifications – between 1 and 5%.

How variable is long-run growth at the country and supra-national level? The estimate of the country SD is around 1%, but varies from 0.85% to 1.3% depending on the specification. It is slightly lower using PWT7 growth data than WDI, and is smaller with mid-level region effects than continent effects.

Our methodology does not address the popular and important topic of convergence across countries, either worldwide or within supra-national regions. The tendency towards national convergence is simply one among many possible national determinants of growth. Even if all the country effects were due to convergence, the relatively small standard deviation of long run country growth suggests that for most countries, convergence is either slow or temporary.

The standard deviation of growth at the supra-national region level is around 0.64% for whole continents (ranging from 0.55%-0.72%), which is surprisingly high given there are only 5 macro-regions. The SD of growth is 0.9% per year for mid-level macro regions (e.g. West Africa), ranging from 0.86-0.96%. This suggests that a surprisingly large component of growth occurs at a level above the nation state, and may be driven by supra-nation regional variation in institutions, culture, geography or other factors. Results using other regional classifications or growth datasets are similar, and are shown in Appendix A.2.

6 Results with provincial growth rates

Table 6 presents the results from the estimation of Equations (19) using provincial growth rates from Gennaioli et al. (2014). Results are similar for most variance components using Baltagi and Chang's method (Panel A) or Standard RE (Panel B), except for the provincial SD (discussed further below).

Averaged across both methods (Table 6, Panel C), our main result is that on average only around 1/2 of the variation in long-run national economic growth occurs at the country level, with the other 1/3 explained by trends at the supra-national level and 1/6th explained at the provincial level. If the supra-national level regions are whole continents, the share of variation at the country level is slightly higher (about 56%), and if they are mid-level regions the share of long-run growth at the country level is smaller (about 35%). (As before, the standard deviation of long-run growth is only around 1%, which is much lower than the 4% standard deviation for iid annual growth variation - so country effects only explain around 2-3% of total annual growth variation.)

The estimate of the country effects SD is around 0.7%, down from 1% in results using national data in Table 5. This is mainly because country effects variability is not affected by province level determinants of growth when using province growth rates. The estimates range from 0.77% with continental regions effects vs 0.62% with mid-level regions. The standard deviation of growth at the supra-national level is around 0.5% for whole continents and 0.7% using mid-level regions (both slightly smaller than using national data).

Unfortunately different methods produce difference estimates of the province level SD: which could be between 0.25% (with Baltagi and Chang's Methodology) and 0.65% (with the standard RE). We slightly more confident with Baltagi and Chang's methodology as it is specifically in-

Table 5: Growth Decomposition (annual country-level per capita GDP growth, UN regions)

	WDI				PWT7			
	Baseline	Continent	Mid-level	Average	Baseline	Continent	Mid-level	Average
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Panel A: Batalgi and Chang unbalanced panel correction								
Std Deviation of Components								
Country (A)	1.33%	1.15%	1.07%	1.11%	1.14%	0.94%	0.84%	0.89%
	(0.14%)	(0.18%)	(0.18%)		(0.12%)	(0.13%)	(0.17%)	
Supra-National-Region (B)		0.55%	0.86%	0.71%		0.72%	0.96%	0.84%
		(0.12%)	(0.11%)			(0.11%)	(0.1%)	
Year (C)		1.52%	1.52%	1.52%		1.44%	1.44%	1.44%
		(0.12%)	(0.12%)			(0.1%)	(0.1%)	
iid Error (D)	5.66%	5.66%	5.66%	5.66%	6.70%	6.70%	6.70%	6.70%
	(0.29%)	(0.29%)	(0.29%)		(0.37%)	(0.37%)	(0.36%)	
Calculated Items:								
Total long run Std Dev (E) #	1.33%	1.27%	1.37%	1.32%	1.14%	1.18%	1.28%	1.23%
Total growth Std Dev (F) ##	5.81%	6.00%	6.02%	6.01%	6.80%	6.95%	6.97%	6.96%
Country Share of LR Var (G) *	100%	81%	61%	71.07%	100%	63%	43%	53.19%
Supra-Nat. Share LR Var (H) **	-	19%	39%	28.93%	-	37%	57%	46.81%
Country Share of Total Var (I) ***	5%	4%	3%	3.42%	3%	2%	1%	1.64%
Time Eff Share of Total variation (J)	-	6%	6%	6%	-	4%	4%	4%
iid Share of Total variation (K)	95%	89%	88%	89%	97%	93%	92%	93%
Panel B: Standard RE								
Std Deviation of Components								
Country (A)	1.23%	1.10%	1.04%	1.07%	1.22%	1.06%	0.95%	1.01%
	(0.22%)	(0.32%)	(0.33%)		(0.15%)	(0.16%)	(0.22%)	
Supra-National-Region (B)		0.55%	0.86%	0.71%		0.72%	0.96%	0.84%
		(0.12%)	(0.11%)			(0.11%)	(0.1%)	
Year		1.52%	1.52%	1.52%		1.44%	1.44%	1.44%
		(0.12%)	(0.12%)			(0.1%)	(0.1%)	
iid Error	5.66%	5.66%	5.66%	5.66%	6.70%	6.70%	6.70%	6.70%
	(0.29%)	(0.29%)	(0.29%)		(0.37%)	(0.37%)	(0.37%)	
Calculated Items:								
Total long run Std Dev (E) #	1.23%	1.23%	1.35%	1.29%	1.22%	1.28%	1.35%	1.32%
Total growth Std Dev (F) ##	5.79%	5.99%	6.01%	6.00%	6.81%	6.97%	6.98%	6.98%
Country Share of LR Var (G) *	100%	80%	59%	69.69%	100%	68%	49%	58.95%
Supra-Nat Share LR Var (H) **	-	20%	41%	30.31%	-	32%	51%	41.05%
Country Share of Total Var(I) ***	5%	3%	3%	3.18%	3%	2%	2%	2.08%
Time Eff Share of Total variation (J)	-	6%	6%	6%	-	4%	4%	4%
iid Share of Total variation (K)	95%	89%	89%	89%	97%	92%	92%	92%

Panel C: Averages across methods & datasets ###			
	Continent	Mid-level	Average
Country Share of LR Var	73%	53%	63%
Supra-Nat Share LR Var	27%	47%	37%

Notes: National annual real GDP pc growth # $E = sqrt(A^2 + B^2)$; ## $F = sqrt(A^2 + B^2 + C^2 + D^2)$;
*$G = A^2/E^2$; **$H = B^2/E^2$; *** $I = A^2/F^2$; ### Average of corresponding numbers in PWT7, WDI Panel A & B
Bootstrapped Standard Errors in parentheses.

Table 6: Growth Decomp. (province-level growth, UN regions)

	Continent (1)	Mid-level (2)	Average (3)
Panel A: Batalgi and Chang unbalanced panel correction			
Std Deviation of Components:			
Country (A)	0.77%	0.62%	0.70%
	(0.03%)	(0.03%)	
Supra-National Region (B)	0.51%	0.70%	0.61%
	(0.04%)	(0.04%)	
Sub-National Region (P)	0.25%	0.25%	0.25%
	(0.12%)	(0.12%)	
Year (C)	1.06%	1.06%	1.06%
	(0.03%)	(0.03%)	
iid Error (D)	4.07%	4.06%	4.07%
	(0.05%)	(0.05%)	
Calculated Items:			
Total long run Std Dev (E) #	0.96%	0.97%	0.96%
Total growth Std Dev (F) ##	4.31%	4.31%	4.31%
Country Share of LR Variance (G) *	65%	41%	52.90%
Supra-Nat. Share LR Variance (H) **	28%	52%	40.36%
Sub-nation share LR Variance (I) ***	7%	7%	6.75%
Country Share of Total Variation (J) **	3%	2%	2.63%
Time Eff Share of Total variation (K)	6%	6%	6.05%
iid Share of Total variation (L)	89%	89%	88.96%
Panel B: Standard RE			
	Continent	Mid-level	Average
Country (A)	0.78%	0.62%	0.70%
	(0.03%)	(0.03%)	
Supra-National Region (B)	0.50%	0.70%	0.60%
	(0.04%)	(0.04%)	
Sub-National Region (P)	0.65%	0.66%	0.66%
	(0.10%)	(0.10%)	
Year (C)	1.06%	1.06%	1.06%
	(0.03%)	(0.03%)	
iid Error (D)	4.07%	4.06%	4.07%
	(0.05%)	(0.05%)	
Calculated Items:			
Total long run Std Dev (E) #	1.13%	1.14%	1.14%
Total growth Std Dev (F) ##	4.36%	4.35%	4.35%
Country Share of LR Variance (G) *	47%	29%	38.42%
Supra-Nat. Share LR Variance (H) **	20%	37%	28.46%
Sub-nation share LR Variance (I) ***	33%	33%	33.12%
Country Share of Total Variation (J) **	3%	2%	2.62%
Time Eff Share of Total variation (K)	6%	6%	5.93%
iid Share of Total variation (L)	87%	87%	87.23%
Panel C: Averages across methods & datasets ###			
	Continent	Mid-level	Average
Country Share of LR Variance	56%	35%	46%
Supra-Nat Share LR Variance	24%	45%	34%
Sub-Nat. Share LR Variance	20%	20%	20%

Notes: Province level real GDP PC growth, top and bottom 5% outliers dropped. # $E = \sqrt{A^2 + B^2 + P^2}$; ## $F = \sqrt{A^2 + B^2 + C^2 + P^2 + D^2}$; $*G = A^2/E^2$; $**H = A^2/F^2$. Bootstrapped SEs in parentheses.

tended for unbalanced panels , and the province level dataset is very unbalanced (although our MC simulation found no difference in performance between the two methods).

7 Extension: provincial growth using night time lights data

A major limitation of the provincial dataset is that some countries do not publish province GDP figures regularly. In fact, the dataset from Gennaioli et al. (2014) has few African countries with available province-level annual growth rates. In order to address this issue, we perform a cross check using night time light intensity. As noted by Henderson et al. (2012), light intensity is highly correlated with GDP per capita at a national level.[19] Further, one important advantage of using lights in this analysis is that we can measure their intensity in any region of the world. The data come in satellite images covering the whole planet, and this allows us to crop them in any regional breakdown we wish. The down side of the lights growth data is that it seems likely to include larger measurement errors than the GDP growth data, as we discuss below.

We use the data from National Oceanic and Atmospheric Administration (NOAA) website.[20] Every image is composed by pixels with values corresponding to different levels of light intensity. In particular, the brightness in every pixel is measured in a scale from 0 (no light) to 63. We divide every image into provinces and compute the light intensity by taking the average across all pixels inside its boundaries. Since we are interested in growth rates, we will work with annual log growth rates instead of levels.

Table 7 shows the descriptive statistics of our dataset. As is clear from the table, annual lights growth data are remarkably dispersed, much more so than provincial GDP growth data. The full sample has a coefficient of variation of around 6, whereas the previously used GDP country level datasets (WDI, PWT7) have coefficients around 3. This high dispersion seems very likely to reflect considerable measurement error. We drop outliers to deal with this potential problem. Specifically, we run our estimations dropping 2 different sets of tail observations: top-bottom 5% and 15%.

The larger omission of the top and bottom 15 percent is meant to address the apparently more severe problem of outliers in the lights data compared to the GDP data. For example, the 95th percentile of the provincial GDP growth dataset is 5.5 times the average GDP growth rate, while the 95th percentile of the lights growth dataset is around 10 times the average lights growth. Even the 85th percentile of the lights data is 5 times the mean. We could conclude that the lights growth variable is simply so prone to extreme values and measurement error as to be unusable for our purposes. At the very least, the results have to be interpreted with great caution. We present the

[19] Following Henderson et al. (2012), we use light intensity per pixel rather than light intensity per capita because provincial population data are missing for many sub-national regions.

[20] http://ngdc.noaa.gov/eog/dmsp/downloadV4composites.html

results anyway for whatever information they provide.

How high is the correlation between lights and province GDP growth? The answer depends on the frequency we are considering. Figure 1a shows a scatter plot of province GDP growth rates and lights growth rates excluding province and year fixed effects. On the other hand, Figure 1b plots average light and province GDP growth rates for the period 1993-2010 .

As shown in Figure 1, annual lights and GDP growth rates are not significantly correlated. The linear fit between these two variables is basically flat. However, lights do a much better job predicting growth in the long run. When we regress long run average province growth rates on lights growth we get a statistically significant coefficient of 0.21. This number is consistent with the elasticities estimated by Henderson et al. (2012) that range from 0.17 to 0.3.

Figure 1: Lights and GDP per capita growth

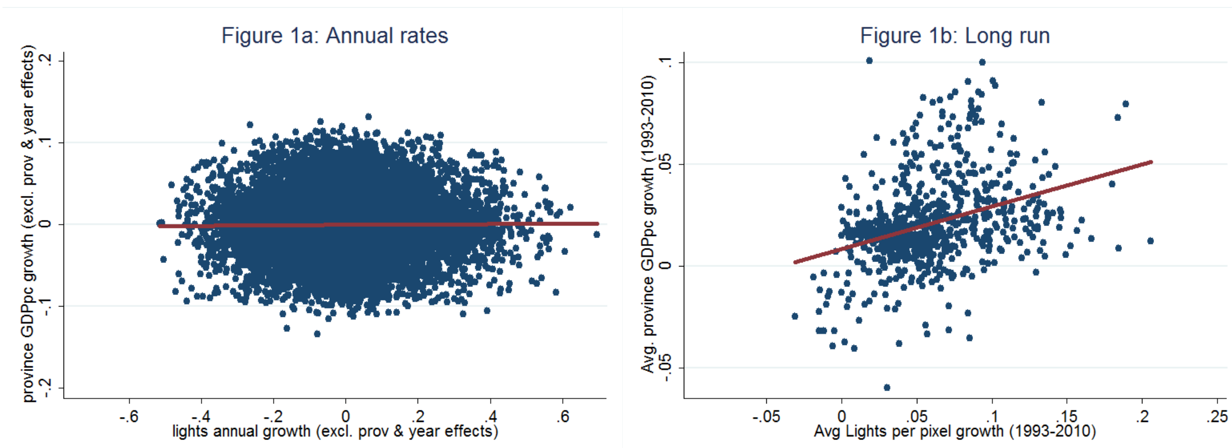


Table 7: Lights Growth Data (1993-2012)

Samples	UN Macro regions	UN Macro Sub groups	Countries Countries	Sub regions (Provinces)	Obs.	Avg. ann. growth	SD
Annual growth in light intensity							
Full sample	5	21	201	3252	61,335	5.71%	35.82%
Dropping top-bottom 5%	5	21	201	3154	55,203	4.74%	18.47%
Dropping top-bottom 15%	5	21	201	3137	42,935	3.99%	10.55%
GDP per capita growth predicted from lights (GDPpc growth = 0.009+0.21*Lights Growth)							
Full sample	5	21	201	3252	61,335	2.10%	7.52%
Dropping top-bottom 5%	5	21	201	3154	55,203	1.90%	3.88%
Dropping top-bottom 15%	5	21	201	3137	42,935	1.74%	2.22%

Given that we are focusing on long run growth rates, we think that lights are useful to perform a robustness check of our previous results using province GDP growth rates. With that aim, we translate annual lights growth rates into predicted province GDP growth using the estimated coefficients from the long run regression. We run our random effects variance decomposition using these predicted values. The results are reported in Table 8.

The results using light intensity are broadly consistent with the previous findings, though results do vary a little across methodologies. In Table 8 Panel C, we see that the country share in long run growth is 60%; supra-national regions explain 16% and the remaining 24% is explained by provinces. Compared to the results in Table 6, we see that countries become slightly more important (perhaps because electricity grids are usually national), whereas supra-national regions have a lower share. When we use mid-level supra-national regions the country share is around 50%, but when we use whole continents the country share is around 70%.

Consistent with our previous findings, the long run growth standard deviation (around 0.37%-0.78%) is much lower annual total standard deviation (2.2%-3.9%). As a consequence, the country long run share only represents a share of 1 or 2% of total annual variation.

Unfortunately, we still find different province standard deviations with different methodologies. Batalgi and Chang method (Panel A) yields very low province standards deviations (0-0.05%), while Stata's default standard random effects methodology (Panel B) produces higher provincial standard deviations (0.35-0.5%). The standard RE results are at least suggestive confirmation of the provincial GDP growth results that there is some sub-national variation in growth rates, again reducing the exclusive emphasis on national determinants of growth.

8 Robustness: UN Continents vs. Other Supra-National Regions

The reason why we use provinces as a different unit of analysis is simply related to the datasets we employ in this paper. However, as mentioned above, there is not an obvious choice for a supra-national breakdown. A priori, there are almost infinite groupings of countries that might explain part of the country/province GDP per capita variance. A natural question is then: Is the UN supra-national breakdown sensible? In other words, is it really capturing regional deep determinants of growth? In this section we try to answer that question by running a quasi placebo test.

Mathematically, any regional breakdown will yield a positive variance share in our methodology. This implies that any random regional breakdown will explain part of the variance of country/province growth rates. Therefore, a simple way of testing the relevance of UN continents and sub-regions is to compare the Supra-National standard deviations shown in tables 5 and 6 with those computed using random regions.

Table 8: Growth Decomp. (province-level growth inferred from lights, UN regions)

	Dropping top-bottom 5%			**Dropping top-bottom 15%**		
	Continent	Mid-level	Average	Continent	Mid-level	Average
	(1)	(2)	(3)	(4)	(5)	(6)
Panel A: Batalgi and Chang unbalanced panel correction						
Std Deviation of Components:						
Country (A)	0.54%	0.46%	0.50%	0.35%	0.31%	0.33%
Supra-National Region (B)	0.19%	0.34%	0.26%	0.11%	0.20%	0.15%
Sub-National Region (P)	0.00%	0.00%	0.00%	0.05%	0.05%	0.05%
Year (C)	2.12%	2.12%	2.12%	0.97%	0.97%	0.97%
iid Error (D)	3.22%	3.22%	3.22%	1.98%	1.98%	1.98%
Calculated Items:						
Total long run Std Dev (E) #	0.57%	0.57%	0.57%	0.37%	0.37%	0.37%
Total growth Std Dev (F) ##	3.90%	3.90%	3.90%	2.23%	2.23%	2.23%
Country Share of LR Variance (G) *	89%	65%	77%	90%	70%	80%
Supra-Nat. Share LR Variance (H) **	11%	35%	23%	8%	28%	18%
Sub-nation share LR Variance (I) ***	0%	0%	0%	2%	2%	2%
Country Share of Total Variation (J) **	2%	1%	2%	2%	2%	2%
Time Eff Share of Total variation (K)	30%	30%	30%	19%	19%	19%
iid Share of Total variation (L)	68%	68%	68%	78%	78%	78%
Panel B: Standard RE						
Std Deviation of Components:						
Country (A)	0.54%	0.46%	0.50%	0.35%	0.31%	0.33%
Supra-National Region (B)	0.20%	0.35%	0.27%	0.11%	0.20%	0.15%
Sub-National Region (P)	0.52%	0.52%	0.52%	0.36%	0.36%	0.36%
Year (C)	2.12%	2.12%	2.12%	0.97%	0.97%	0.97%
iid Error (D)	3.22%	3.22%	3.22%	1.98%	1.98%	1.98%
Calculated Items:						
Total long run Std Dev (E) #	0.78%	0.78%	0.78%	0.51%	0.51%	0.51%
Total growth Std Dev (F) ##	3.94%	3.94%	3.94%	2.26%	2.26%	2.26%
Country Share of LR Variance (G) *	49%	36%	42.39%	47%	36%	42%
Supra-Nat. Share LR Variance (H) **	7%	20%	13.19%	4%	14%	9%
Sub-nation share LR Variance (I) ***	44%	44%	44.41%	49%	49%	49%
Country Share of Total Variation (J) **	2%	1%	1.65%	2%	2%	2%
Time Eff Share of Total variation (K)	29%	29%	29%	18%	18%	18%
iid Share of Total variation (L)	67%	67%	67%	76%	76%	76%
Panel C: Average Across Methods						
	Continent	Mid-level	Average			
Country Share of LR Variance	69%	52%	60%			
Supra-Nat Share LR Variance	8%	24%	16%			
Sub-Nat. Share LR Variance	24%	24%	24%			

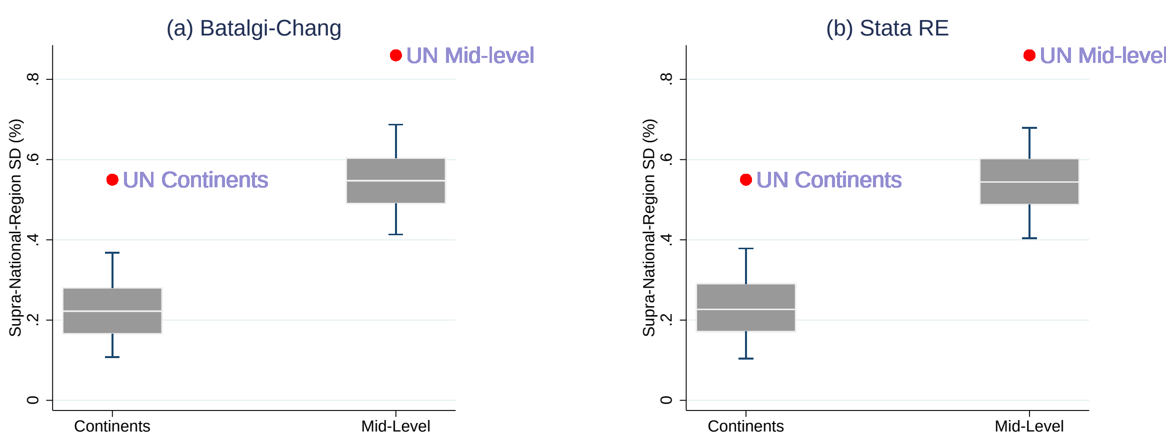
Notes: Province level real GDP PC growth, top and bottom 5% outliers dropped # $E = sqrtA^2 + B^2 + P^2$; ## $F = \sqrt{A^2 + B^2 + C^2 + P^2 + D^2}$; $*G = A^2/E^2$ $**H = A^2/F^2$. Bootstrapped SEs in parentheses.

With that aim we run 1,000 different estimations with randomly determined supra-national regions. We use country level data from WDI and adjust the region sampling such that the relative size of regions is similar to that of the UN breakdown on average. The distribution of Supra-National standard deviations is described in the box plots in figure 2.[21]

Figure 2 also highlights the supra-national standard deviations obtained using UN regions with red dots. The figure shows that for both estimation methods, UN regions and sub-regions have a significantly higher standard deviation compared to the distribution median (0.55 vs 0.23% for UN continents, 0.86 vs 0.54% for UN sub-regions). In fact, the UN standard deviations lie outside the whiskers' ends implying that they are higher than the percentile 95 of the distribution (around 0.38% for UN Continents and 0.69% for Mid-Level for both methods). Taking into account that the upward bias of our regional estimates is low (see Table 3), these results show that there is a statistically significant difference between our estimates and those computed using random regions.

We believe that this result supports the idea that regional deep determinants of long run economic growth are correlated with the location in different continents or sub-regions. Nevertheless, we remain agnostic about what specific deep determinant is most important at a macro regional level (i.e. geography, institutions, culture, etc.) mainly because our methodology does not provide information in that aspect.

Figure 2: Simulation Supra-National SD Box plots



[21] In these box plots the higher and lower end of whiskers represents the percentile 95 and 5, respectively.

9 Conclusions

In the past decade the macro development literature has moved away from an almost exclusive emphasis on national factors such as economic policies or institutions towards a broader consideration of factors such as history, culture, geography – which can vary at units either larger or smaller than nations. It is also possible that institutions can themselves vary more at the supra-national or sub-national level than was previously appreciated in the cross-country literature. (See references in introduction).

This paper is a simple exercise in documenting the significant variation in growth rates that occurs at both supra-national and sub-national levels, reducing the share of long-run growth variation attributed to national determinants.

The previous emphasis on national growth variation was partly determined by data availability and partly by the needs of national policymakers for advice on raising country growth rates. New data available at the sub-national level corrects the first reason for only emphasizing nations. The second reason for the national emphasis still exists. Academic research should not be constrained by the needs of policymakers. In any case, the record of cross-country empirics informing national growth-promoting policies is widely acknowledged as disappointing.

The picture of growth and development as happening at many levels – sub-national, national, and supranational – is useful in itself for a richer understanding of the historical, cultural, technological determinants of development. It also helps us appreciate the role in development of the uneven yet important movements of institutional and technological ideas, cultural values, and whole peoples within and across country borders. This paper is another modest step towards such an enhanced understanding.

A Appendix

A.1 Data Sources

PWT6 and PWT7 Growth Data We use two versions of PWT data 6.1 and 7.1, over the sample 1950-2000 and 1950-2010, respectively. https://pwt.sas.upenn.edu/php_site/pwt_index.php. Our GDP per capita variable is rgdpl: Real GDP per capita (Constant Prices: Laspeyres). We generate growth rates as $growth_t = ln(rgdpl_t) - ln(rgdpl_{t-1})$ for every year t.

WDI Data We use GDP at constant 2000 dollars (NY.GDP.MKTP.KD) and total population (SP.POP.TOTL) to define GDP per capita. With the calculated GDP per capita we compute the growth rates as $growth_t = ln(GDPpc_t) - ln(GDPpc_{t-1})$ for every year t.

We also use the variable "GDP per capita growth (annual %)" (NY.GDP.PCAP.KD.ZG) to complete missing data. With these annual growth rates we compute log growth rates doing, $growth_t = ln(1 + wdigrowth_t)$.

Maddison Data We downloaded Angus Maddison (from 1950 to 2010) Statistics on Per Capita GDP from http://www.ggdc.net/maddison/oriindex.htm. We generate annual growth rates as $growth_t = ln(GDPpc_t) - ln(GDPpc_{t-1})$ for every year t.

Provincial-level GDP Data Data from Gennaioli et al. (2014) (appendix on Rafael La Porta's website), unbalanced panel of annual growth rates, dropping the top and bottom 5% outliers. Gennaioli et al. (2014) convert provincial GDP data into current PPP USD by multiplying the GDP share of the province by national USD PPP GDP. They then divide by provincial population to get GDP per capita. Regional deflators are generally unavailable, so Gennaioli et al. (2014) deflate using national deflators.

Night-time lights Data Data from National Oceanic and Atmospheric Administration (NOAA) website. http://ngdc.noaa.gov/eog/dmsp/downloadV4composites.html. The images are divided using shapefiles from Global Administrative Areas (GADM) Database website: https://www.gadm.org.

A.2 Results using Maddison and PWT6 Data, and other supra-national regions

Table 9: Growth Decomposition (annual country-level per capita GDP growth, UN regions)

	PWT6				**Maddison**			
	Baseline	Continent	Mid-level	Average	Baseline	Continent	Mid-level	Average
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Panel A: Batalgi and Chang unbalanced panel correction								
Std Deviation of Components								
Country (A)	1.37%	1.00%	0.77%	0.89%	1.14%	1.06%	0.99%	1.03%
	(0.18%)	(0.20%)	(0.26%)		(0.11%)	(0.13%)	(0.15%)	
Supra-National-Region (B)		0.92%	1.25%	1.09%		0.54%	0.83%	0.69%
		(0.13%)	(0.11%)			(0.10%)	(0.10%)	
Year (C)		1.20%	1.20%	1.20%		1.62%	1.62%	1.62%
		(0.10%)	(0.10%)			(0.12%)	(0.12%)	
iid Error (D)	6.19%	6.19%	6.19%	6.19%	5.60%	5.60%	5.60%	5.60%
	(0.31%)	(0.31%)	(0.32%)		(0.26%)	(0.26%)	(0.26%)	
Calculated Items:								
Total long run Std Dev (E) #	1.37%	1.36%	1.47%	1.41%	1.14%	1.19%	1.29%	1.24%
Total growth Std Dev (F) ##	6.34%	6.45%	6.47%	6.46%	5.71%	5.95%	5.97%	5.96%
Country Share of LR Variance (G) *	100%	54%	28%	41%	100%	79%	59%	69%
Supra-Nat. Share LR Variance (H) **	-	46%	72%	59%	-	21%	41%	31%
Country Share of Total Variation (I) ***	5%	2%	1%	2%	4%	3%	3%	3%
Panel B: Method - Standard RE								
Std Deviation of Components								
Country (A)	1.31%	0.94%	0.54%	0.74%	1.17%	1.09%	1.03%	1.06%
	(0.30%)	(0.34%)	(0.17%)		(0.11%)	(0.12%)	(0.15%)	
Supra-National-Region (B)		0.92%	1.25%	1.09%		0.54%	0.83%	0.69%
		(0.13%)	(0.11%)			(0.10%)	(0.10%)	
Year		1.20%	1.19%	1.20%		1.61%	1.62%	1.62%
		(0.10%)	(0.10%)			(0.12%)	(0.12%)	
iid Error	6.19%	6.19%	6.19%	6.19%	5.60%	5.60%	5.60%	5.60%
	(0.31%)	(0.31%)	(0.32%)		(0.26%)	(0.26%)	(0.26%)	
Calculated Items:								
Total long run Std Dev (E) #	1.31%	1.32%	1.36%	1.34%	1.17%	1.22%	1.32%	1.27%
Total growth Std Dev (F) ##	6.33%	6.44%	6.45%	6.44%	5.72%	5.95%	5.98%	5.97%
Country Share of LR Variance (G) *	100%	51%	16%	33%	100%	80%	61%	70%
Supra-Nat. Share LR Variance (H) **	-	49%	84%	67%	-	20%	39%	30%
Country Share of Total Variation (I) ***	4%	2%	1%	1%	4%	3%	3%	3%
Panel C: Averages across methods & datasets ###								
		Continent	Mid-level	Average				
Country Share of LR Variance		66%	41%	53%				
Supra-Nat Share LR Variance		34%	59%	47%				

Notes: National annual real GDP pc growth # $E = sqrt(A^2 + B^2)$; ## $F = sqrt(A^2 + B^2 + C^2 + D^2)$;
*$G = A^2/E^2$; **$H = B^2/E^2$; *** $I = A^2/F^2$; ### Average of corresponding numbers in PWT6, Maddison Panel A & B
Bootstrapped Standard Errors in parentheses.

Table 10: Growth Decomposition (annual country-level per capita GDP growth,other regions)

	WDI				**PWT7**			
	WA	WHO	ECO	WB	WA	WHO	ECO	WB
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Panel A: Batalgi and Chang unbalanced panel correction								
Std Deviation of Components								
Country (A)	1.16%	1.20%	1.19%	1.21%	0.94%	0.98%	0.90%	1.01%
	(0.18%)	(0.17%)	(0.25%)	(0.17%)	(0.13%)	(0.14%)	(0.20%)	(0.14%)
Supra-National-Region (B)	0.57%	0.57%	0.75%	0.57%	0.73%	0.67%	0.74%	0.66%
	(0.12%)	(0.12%)	(0.15%)	(0.12%)	(0.10%)	(0.11%)	(0.13%)	(0.11%)
Year (C)	1.52%	1.52%	1.58%	1.52%	1.44%	1.44%	1.49%	1.44%
	(0.12%)	(0.12%)	(0.15%)	(0.12%)	(0.10%)	(0.10%)	(0.12%)	(0.10%)
iid Error (D)	5.66%	5.66%	5.74%	5.66%	6.70%	6.70%	6.90%	6.70%
	(0.29%)	(0.29%)	(0.34%)	(0.29%)	(0.37%)	(0.37%)	(0.45%)	(0.37%)
Calculated Items:								
Total long run Std Dev (E) #	1.29%	1.33%	1.41%	1.34%	1.19%	1.19%	1.17%	1.21%
Total growth Std Dev (F) ##	6.00%	6.01%	6.12%	6.01%	6.96%	6.96%	7.15%	6.96%
Country Share of LR Variance (G) *	81%	82%	72%	82%	62%	68%	60%	70%
Supra-Nat. Share LR Variance (H) **	19%	18%	28%	18%	38%	32%	40%	30%
Country Share of Total Variation (I) ***	4%	4%	4%	4%	2%	2%	2%	2%
Panel B: Standard RE								
Std Deviation of Components								
Country (A)	1.11%	1.13%	1.20%	1.14%	1.04%	1.09%	1.05%	1.12%
	(0.32%)	(0.30%)	(0.36%)	(0.29%)	(0.17%)	(0.17%)	(0.23%)	(0.17%)
Supra-National-Region (B)	0.57%	0.57%	0.75%	0.57%	0.73%	0.67%	0.74%	0.66%
	(0.12%)	(0.12%)	(0.15%)	(0.12%)	(0.11%)	(0.11%)	(0.13%)	(0.11%)
Year (C)	1.52%	1.52%	1.58%	1.52%	1.44%	1.44%	1.49%	1.44%
	(0.12%)	(0.12%)	(0.15%)	(0.12%)	(0.10%)	(0.10%)	(0.12%)	(0.10%)
iid Error (D)	5.66%	5.66%	5.74%	5.66%	6.70%	6.70%	6.90%	6.70%
	(0.29%)	(0.29%)	(0.34%)	(0.29%)	(0.37%)	(0.37%)	(0.45%)	(0.37%)
Calculated Items:								
Total long run Std Dev (E) #	1.25%	1.27%	1.42%	1.27%	1.27%	1.28%	1.28%	1.30%
Total growth Std Dev (F) ##	5.99%	6.00%	6.12%	6.00%	6.97%	6.97%	7.17%	6.98%
Country Share of LR Variance (G) *	79%	80%	72%	80%	67%	73%	67%	74%
Supra-Nat. Share LR Variance (H) **	21%	20%	28%	20%	33%	27%	33%	26%
Country Share of Total Variation (I) ***	3%	4%	4%	4%	2%	2%	2%	3%
Panel C: Averages across methods & datasets ###								
	WA	WHO	ECO	WB	Average			
Country Share of LR Variance	72%	76%	67%	77%	73%			
Supra-Nat Share LR Variance	28%	24%	33%	23%	27%			

Notes: National annual real GDP pc growth # $E = sqrt(A^2 + B^2)$; ## $F = sqrt(A^2 + B^2 + C^2 + D^2)$;
$*G = A^2/E^2$; $**H = B^2/E^2$; *** $I = A^2/F^2$; ### Average of corresponding numbers in PWT7, WDI Panel A & B
Bootstrapped Standard Errors in parentheses.

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