Decentralization and Regional Convergence: Evidence from Night-time Lights Data

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December 15, 2018

Abstract

The proponents of decentralization argue that it improves economic growth by increasing government efficiency and accountability. However, the critics argue that decentralization increases regional inequality by increasing the differences in institutional capacities and socio-economic endowments across regions. The empirical evidence is mixed and is based mostly on developed countries due to lack of income data at lower administrative regions. This paper fills that gap by analyzing the impact of decentralization on regional convergence using first and second administrative regions data from a global sample of developed and developing countries. We construct a panel dataset from 1992 to 2010 using intensity of night-time lights captured by U.S. Air Force satellites to proxy for local economic performance. We combine lights data with a new database of fiscal, political, and administrative decentralization derived from actual laws that are institutionalized and circumscribed. We find that decentralization hinders regional convergence between first as well as second subnational regions within a country. These impacts are larger for developing countries. The results are economically meaningful, statistically significant, and robust to alternative specifications.

JEL Codes: H77, O10, O47, R11.
Keywords: Decentralization, convergence, economic growth, economic inequality, night lights.

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1 Introduction

In the last few decades, more than 70 countries have implemented some form of decentralization reform by giving subnational governments power to tax, spend, legislate, and elect government officials within their jurisdiction. Decentralization has been at the center of institutional reforms not only in developed countries, but also in many developing and transition economies in Africa, Asia, and Latin America (Garman, Haggard and Willis, 2001; Bardhan, 2002; Hooghe, Marks and Schakel, 2010). This momentum is expected to continue as subnational movements, national governments, and multilateral organizations often praise the benefits of decentralized governments (Burki, Perry and Dillinger, 1999; The World Bank, 2000).

One of the primary stated objectives of decentralization is to improve economic growth. Decentralization can improve economic growth by increasing the effectiveness and efficiency of the public sector, by fostering competition among regional governments, and by better matching resources and preferences of communities and governments (Teibout, 1956; Oates, 1993; Weingast, 1995; Qian and Weingast, 1997; Ezcurra and Pascual, 2008). These "market preserving" theories are supported by empirical findings for developed countries (Akai and Sakata, 2002; Fisman and Gatti, 2002; Gemmell, Kneller and Sanz, 2013; Sobel, Dutta and Roy, 2013). However, there is very little empirical evidence to support such reforms in developing countries.

A major argument against decentralization is the belief that it can inhibit growth in poorer regions, creating an even larger disparity between richer and poorer regions. Decentralization can increase regional inequality through various channels. First, limited state capacity and weaker endowments in poorer regions can lead to lower infrastructure spending in schools, roads, and electricity. Second, richer regions can provide comparable public goods at a lower average tax per resident than poorer regions, which makes poorer regions less attractive to businesses and investments. Third, governments in poorer regions are more prone to elite capture than governments in richer regions or national governments (Prud'Homme, 1995; Bardhan and Mookherjee, 2005).[1] Fi-

[1]The elite capture is used to describe situations in which political and economic elites misappropriate resources

nally, decentralization can limit the redistributive role of the central government, further worsening regional disparity (Meltzer and Richard, 1981).

Thus, whether decentralization causes regional convergence is ultimately an empirical question. Yet, due to lack of comparable data, quantifying the impact of decentralization from actual country experience has proved elusive, especially in developing countries.

This paper fills that gap by analyzing whether decentralization promotes or hinders convergence between a country's rich and poor regions using a sample of 74 developed and developing countries across the world. We find strong evidence of unconditional within-country convergence across the world, using both first-level and second-level subnational data.[2] However, we find that decentralization slows down the speed of such regional convergence. These results are statistically significant and economically meaningful in the case of developing countries, whereas the estimates are mostly statistically insignificant for the high-income countries. For instance, calculations based on the coefficients from our preferred specifications (Table 3 Panel A) suggests that if the decentralization index of a country changes from the lowest possible value to the highest possible value, the growth rate of a region that is halfway to the country frontier (i.e., country's richest region) would decrease by more than 6 percent (from 7% to 1%). The estimates from other specifications also suggest that decentralization slows down the speed of regional convergence towards zero.

We also analyze the impact of changes in different components of decentralization such as fiscal autonomy, institutional depth, policy autonomy, and political representation on regional convergence. The sub-component analysis reinforces our baseline findings that decentralization substantially slows down the regional convergence in the developing countries, but it does not affect the convergence process in the high-income countries. There is some heterogeneity in the magnitude of convergence coefficients across different components of decentralization, but one pattern stands out: the majority of the estimates for the developing countries are statistically significant,

and public funds.

[2] To put into perspective, first subnational government for the United States are the states and second subnational government are counties.

but almost none of the estimates for the high-income countries are statistically significant.

We find that decentralization hinders not only within-country regional convergence but also within-first-subnational division regional convergence. In fact, the convergence coefficients of within-first-subnational division are larger than within-country convergence coefficients. This suggests that the growth of first subnational regions in developing countries is mostly driven by the growth of a few second subnational regions within that first subnational region.

There are various challenges in estimating the actual impact of decentralization. First, subnational government data on economic activity do not exist in most of the developing countries. Second, existing measures of decentralization such as expenditures going through the subnational budgets or revenues raised by subnational governments do not accurately reflect the true measure of fiscal decentralization. For instance, using existing measures of decentralization, countries such as Sweden, Norway, Finland, and Denmark, where subnational governments spend and tax according to national laws, appear equally decentralized as countries such as Germany and the United States, where subnational governments enjoy genuine autonomy. Third, since most of the convergence literature uses country-level data, they are unable to mitigate endogeneity problems tied to omitted variables and reverse-causality (Ebel and Yilmaz, 2002; Thornton, 2007; Hooghe et al., 2016; Martinez-Vazquez, Lago-Peñas and Sacchi, 2017).

Our paper addresses all of these challenges, contributing to two strands of literature: decentralization and convergence. First, to circumvent the subnational data unavailability problem, we create a proxy for subnational income per capita by combining night-time lights data captured by U.S Air Force Satellite with georeferenced subnational population data from the Gridded Population of the World database. There are various advantages of using satellite data to measure economic activity: it provides data for a large number of countries, makes data immune to manipulation by national or subnational governments, and makes data highly comparable across countries since the differences in fiscal or statistical capacity across countries do not affect data quality. Due to these advantages, satellite data have been used extensively to measure economic activity both at the national level and the subnational level (see Donaldson and Storeygard (2016) for an excellent survey of such studies). However, Lessmann and Seidel (2017) is the only study we are aware of that uses satellite data to analyze regional convergence.[3] The previous literature on the effects of decentralization has been limited to country-level analysis (Xie, Zou and Davoodi, 1999; Akai and Sakata, 2002; Sobel, Dutta and Roy, 2013) or regional analysis of high-income economies (Thornton, 2007; Baskaran and Feld, 2013; Gemmell, Kneller and Sanz, 2013; Sorens, 2014).[4] However, there are very few studies on developing countries (See Gadenne and Singhal (2014) for a recent survey of decentralization in developing economies). Moreover, they are all individual country cases such as Bagchi (2003) on India, Bonet (2006) on Colombia, Hill (2008) on Indonesia and Philippines, and Zhang and Zou (1998) and Liu, Martinez-Vazquez and Wu (2017) on China. Thus, our primary contribution is to expand the literature on the impact of decentralization to include a large number of developing countries.

Second, we contribute to the decentralization literature by using newly available data on decentralization, the Regional Authority Index, which improves previous measures used in the literature in two important ways (Hooghe et al., 2016; Sorens, 2015). First, it provides a comprehensive picture of decentralization by measuring it across dimensions such as fiscal autonomy, borrowing autonomy, institutional depth, policy autonomy, and representation. Second, it measures decentralization more accurately since this measure is derived from actual laws that are institutionalized and circumscribed, and are collected from documents such as constitutions, laws, executive orders, statutes or other written documents that are publicly available.[5] There are few studies (Fan, Lin and

[3] Our study differs from Lessmann and Seidel (2017) in two major ways. First, they focus on providing the evidence of regional convergence whereas we examine the role of decentralization in facilitating regional convergence. Second, their unit of observation is a country whereas our unit of observation is a subnational region.

[4] There is another strand of literature that studies the impact of decentralization on country level measure of regional disparity such as the Gini coefficient or the coefficient of variation. These studies also mostly focus on developed countries due to the lack of data (Canaleta, Arzoz and Garate, 2004; Lessmann, 2009; Rodriguez-Pose and Ezcurra, 2010)

[5] Following a different approach, Thornton (2007) and Baskaran and Feld (2013) use disaggregated data on the sources of tax revenue to create a more accurate measure of decentralization (e.g., own-source subnational revenue as a share of total national revenue). Unfortunately, due to data limitations their sample is limited to the OECD countries.

Treisman, 2009; Rodriguez-Pose and Ezcurra, 2010; Hammond and Tosun, 2011; Sorens, 2014) that use a more comprehensive measure of decentralization like ours, however, Sorens (2014) is the only study that studies the impact of decentralization on regional convergence. Thus, we contribute to the decentralization literature by expanding it to include measures other than fiscal decentralization.

Third, we combine national data on decentralization with subnational data on per capita income, which allows us to significantly mitigate the endogeneity problems tied to omitted variables and reverse-causality that plague country-level convergence literature. First, we augment the conventional convergence model by including country fixed effects as well as the growth of a country's frontier region as independent variables. This allows us to control for the time-invariant country characteristics as well as country's overall growth performance and potentially the omitted factors that exert mutual influence on the country's growth and decentralization tendencies. Second, we use region's distance-to-country-frontier to capture region's relative development level rather than its initial income level since the region's distance-to-country-frontier is mostly independent of the country's development level or growth rate. Thus, we argue that it is unlikely that country-level decentralization reforms are prompted by higher regional growth rate, conditional on country-fixed effects and frontier region's growth (Aghion, Howitt and Mayer-Foulkes, 2005; Che and Spilimbergo, 2012).

The rest of the paper is organized as follows. In section 2, we discuss the data collection process and their sources. In section 3, we present our empirical model for testing the effect of decentralization on regional convergence. We present our findings in section 4 and robustness of the baseline results in section 5. Finally, in section 7, we conclude the paper.

2 Data

We study the effect of decentralization on regional convergence of administrative regions at first and second subnational government for 74 countries from 1992 to 2010. Comparable data on income per capita at the subnational level are scarce. Hence, we construct an annual panel dataset of economic activity and economic activity per person at the second subnational level by combining satellite data on night-time lights with georeferenced data on population. We combine these data with country-level measures of decentralization from Regional Authority Index (RAI) compiled by Hooghe et al. (2016) and Regional Autonomy in Developing Democracies dataset compiled by Sorens (2015).

The night-time lights data is recorded by the satellites from the United States Air Force Defense Meteorological Satellite Program (DMSP) using Operational Linescan System sensors. Each satellite observes every location on the planet every night at some instant between 8:30 PM and 10:00 PM local time. The data is then processed by the scientists at the National Oceanic and Atmospheric Administration's (NOAA) National Geophysical Data Center (NGDC) before releasing it to the public. The scientists process the data to remove observations for places where the earth's surface is obscured by the cloud so that the human-made lights are properly recorded. They also remove the places experiencing the bright half of the lunar cycle, the summer months when the sun sets late, auroral activity (the northern and southern lights), and forest fires. These restrictions remove intense sources of natural light, leaving mostly human-made light. Finally, data from all orbits of a given satellite in a given year are averaged over all valid nights to produce a satellite-year dataset. It is this dataset that is distributed to the public (Henderson, Storeygard and Weil, 2012).[6]

Each satellite-year dataset is a grid reporting the intensity of lights for every 30 arc-second output pixel (approximately 0.86 square kilometers at the equator) between 65 degrees south and

[6]The data is available to download at https://ngdc.noaa.gov/eog/dmsp/downloadV4composites.html

75 degrees north latitude. The exclusion of high-latitude zones affects about 10,000 people or 0.0002 percent of the world's population. We further exclude pixels from regions that produce intense night-time lights due to gas flares.[7]

The intensity of light at each pixel is recorded as an integer between 0 (implying no detectable light) and 63 (implying maximum detectable light). The lights data is top-coded at 63, which affects a small fraction of pixels (0.1 percent), generally in rich and dense areas.[8] The de facto sensor settings vary over time across satellites and with the age of a satellite, so that comparisons of raw digital numbers over the years can be problematic. However, as suggested by Henderson, Storeygard and Weil (2012), we can control for such issues with year fixed effects. For years with multiple satellite readings, we calculate simple averages across satellites within pixel-years. We then aggregate the data at the second administrative region using the map from the Global Administrative Areas (GADM) database.[9] We add 1 to the recorded night-time lights data in all of the second-subnational regions. There are two reasons for doing so. First, the night-time lights of 0 do not necessarily mean there is no presence of human-made light. It only means that no human-made light is detectable by the satellite from outer-space. It is possible there is at least some economic activity in the region when night-time lights data reading is 0. Second, our outcome variable is measured in the log, hence avoiding a value of zero allows us to take the log of all of the observations. The dependent variable then is the total night-time lights intensity ($Light_{ict}$) for region i in country c at time t.

[7] Gas flaring is a practice of burning the natural gas produced as a byproduct in the process of producing petroleum. If there is gas flaring, it emits intense light. Thus, we remove the pixels where the GADM database has flagged gas flaring.

[8] At first glance, one may suspect that this censoring limits the variation in lights data in rich and dense areas and the lights per capita of these regions are mostly driven by population data. However, our unit of observation is second subnational regions and only a small fraction of grids are top-coded even in the most dense regions. For instance, Only a few grids in New York county are top-coded. When aggregating at second subnational level, the top-coded grids do not significantly drive lights per capita of the regions. Besides, there are only a few regions that are potentially affected by the censoring. Moreover, we trim the data to remove top and bottom 1% based on the regional growth rate. So, if a region is heavily affected by the censoring, the trim would most like remove the region as the region is likely to have a big negative growth rate. Hence, the censoring is unlikely to affect the outcome of the paper.

[9] GADM is a spatial database of the location of the world's administrative boundaries and is available at http://www.gadm.org/. We use version 2.8, which was released in November, 2015.

We obtain population information at the subnational level from the Gridded Population of the World (GPW) database developed by the Center for International Earth Science Network (CIESIN) at Columbia University. The GPW data are constructed using population census tables from various subnational levels (such as city and region). We use GPW v4 as the primary population database and supplement it with GPW v3 for the years 1990 and 1995.[10] CIESIN provides population data for every fifth year, so we linearly interpolate data for missing years. Hence, our study includes lights per capita data on $45,280$ level 2 subnational regions within a total of $2,709$ level 1 regions from 140 countries for years between 1992 and 2013.[11]

To measure decentralization at the country level, we use the Regional Authority Index (RAI) compiled by Hooghe et al. (2016) and Regional Autonomy in Developing Democracies dataset compiled by Sorens (2015). The Hooghe et al. (2016) RAI data is available for 81 countries from 1950 to 2010. We add 8 countries from Sorens (2015)'s update of the Hooghe et al. (2016) data, giving us 89 countries in total.[12]

Most of the studies in the literature use tax and expenditure data from the International Monetary Fund (IMF)'s Government Financial Statistics (GFS) to construct a measure of fiscal decentralization. First of all, as explained in Dziobek, Mangas and Kufa (2011) and Gadenne and Singhal (2014), there are significant gaps in the coverage of IMF data, especially in the case of developing countries. Moreover, expenditures going through the subnational budgets or revenues raised by subnational governments do not accurately reflect the true measure of fiscal decentralization, the authority that a subnational governments exercise in its territory. For instance, using existing measures of decentralization, countries such as Sweden, Norway, Finland, and Denmark, where

[10] For details, see http://sedac.ciesin.columbia .edu/data/collection/gpw-v.

[11] The numbers are after removing top and bottom 1% or the data based on regional growth rate in order to remove outliers from the sample.

[12] We could use 8 out of 17 countries from Sorens (2015) that are not in Hooghe et al. (2016). Sorens (2015)'s data are on the subnational level with different naming convention than ours, but it does not have data on subnational population, hence making it difficult to aggregate the data to create a measures of decentralization following Hooghe et al. (2016) approach. We use 8 of the countries because they only have one subnational level, so we can use the index as country aggregate.

subnational governments spend and tax according to national laws, appear equally decentralized as countries such as Germany and the United States, where subnational governments enjoy genuine autonomy (see Ebel and Yilmaz (2002); Hooghe et al. (2016)). Thus we use decentralization measures from Regional Authority Index (RAI) compiled by Hooghe et al. (2016) and Regional Autonomy in Developing Democracies dataset compiled by Sorens (2015), which measures the authority of regional governments across fiscal, political, and administrative dimensions, hence providing a better measure of decentralization.

There are two components of the RAI: self-rule and shared-rule. Self-rule measures regional government's authority within its jurisdiction and shared-rule measures its influence on the central government. For our study, we use self-rule as the measure of decentralization. Self-rule measures authority of the regional government across five dimensions.[13] They are (i) institutional depth, which encodes the extent to which a regional government can make autonomous policy decision; (ii) policy scope, which tracks the authority over policy within its jurisdiction; (iii) fiscal autonomy, which encodes the authority to set the rules for taxation (rate and base) and spending in its jurisdiction; (iv) borrowing autonomy, which encode the capacity of a regional government to independently borrow in financial markets; and (v) representation, which encodes the autonomy of a regional government in selecting legislative and executive bodies in its jurisdiction.

The value for institutional depth and borrowing autonomy range from 0 to 3 and the value for policy scope, fiscal autonomy, and representation range from 0 to 4. Thus, the regional self-rule measure we use in the baseline analysis ranges from 0 to 15, where 0 indicates a highly centralized system and 15 indicates a highly decentralized system.[14] These regional self-rule scores are then aggregated at the country level to generate the country level measure of self-rule.[15] We normalize

[13] Sorens (2015) measure of self-rule does not include borrowing autonomy, hence, we create two different self-rule measures, one including and the other one excluding the borrowing autonomy. For baseline specifications, we use the measure excluding borrowing autonomy as it gives us a larger sample size. The result using all five components of decentralization is very similar and is presented in the robustness section.

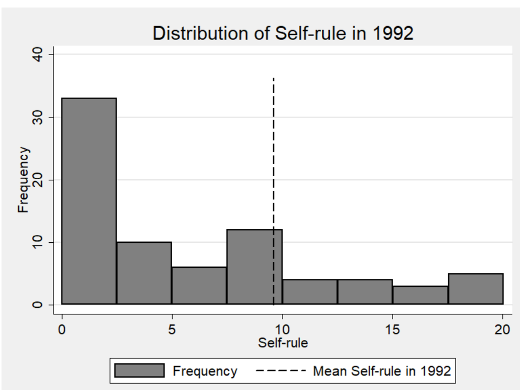
[14] The self-rule measure including all five components ranges from 0 to 18 for each regional tier and individual regional governments in a country.

[15] Hooghe et al. (2016) aggregate the regional self-rule scores in three steps. First, they calculate a score for each

the indices to be between 0 and 1, with 0 being the minimum level of decentralization and 1 being the maximum.[16]

Based on the self-rule measure, the most decentralized countries in our sample are the United States, Belgium, Germany, Italy, and Spain, while the least decentralized countries are Albania, Costa Rica, Croatia, Czech Republic, El Salvadore, Estonia, Latvia, Lithuania, Slovakia, and Slovenia. Figure 1 displays the distribution of self-rule scores in 1992. As illustrated in the figure, most of the country's self-rule score is towards the lower tail of the distribution, indicating a low level of decentralization in 1992. Many countries in our sample experience some level of decentralization over the sample period. The countries with the biggest change in self-rule are listed in Table 1.

Figure 1: Distribution of Self-Rule in 1992



Notes: The histogram presents the distribution of self-rule measure for 69 countries in 1992. The vertical dashed line is the mean value of self-rule in 1992.

Table 1: Countries with Biggest Change in Self-Rule

Country	Change in Self-Rule
Indonesia	14
South Korea	10
Croatia	9
Czech Republic	9
Greece	9
Slovak Republic	8
Bolivia	8
Paraguay	7
Italy	7
Finland	6

Notes: The table lists the countries with biggest change in self-rule from 1992 to 2010.

We obtain a regional panel of 74 countries from 1992 to 2010 after the merging of the cleaned version of night-lights per capita data with the decentralization data.[17]

standard and non-standard regions in a regional tier. Second, they weight scores by population. If a tier is composed of regions with different scores, a score for that tier is calculated by weighting each region's score by its share in the national population. Third, they sum the weighted regional scores for each tier. Thus, in a few cases, the self-rule measure at the country-level exceeds 15 when using the four components or 18 when using five components of self-rule. See Hooghe et al. (2016) for details.

[16]When normalizing, we divide by the maximum value of the actual country-level self-rule rather than 15 in our baseline specifications or 18 when including borrowing autonomy.

[17]15 countries that have data on decentralization are excluded from the analysis because they do not have second subnational regions. They are mostly small islands and excluding them do not affect the outcomes significantly.

3 Empirical Framework

In this section, we outline the empirical framework we use to analyze the role of decentralization on regional convergence. We are interested in learning whether or not poor regions of a country catch up with the frontier regions of the country, which is called a β-convergence in the growth literature. To do so, we first introduce a few variables. We define *Frontier region*, which is the region that has the highest lights per capita among all regions within a country in a given year. Then, we define *Distance*, which is the log difference in lights per capita between a region and the frontier region of a respective country. The *Distance* measures how far a region is from the *Frontier region* and is expressed as,

$$Distance_{ict} = ln(Light_{ict}) - ln(Light_{ct}^{frontier}) \tag{1}$$

where, $Light_{ict}$ is the total lights per capita for region i of country c at year t, and $Light_{ct}^{frontier}$ is the total lights per capita for the *Frontier region* of country c at year t.

The growth rate of lights per capita in region i of country c at time t is expressed as,

$$\Delta Y_{ict} = ln(Light_{ict}) - ln(Light_{ict-1}) \tag{2}$$

The baseline specification we use to study the effect of decentralization on β-convergence is then given by,

$$\begin{gathered} \Delta Y_{ict} = \beta_0 + \beta_1 Distance_{ict-1} + \beta_2 Decentralization_{ct-1} \\ + \beta_3 Distance_{ict-1} * Decentralization_{ct-1} + \beta_4 \Delta Y_{ct}^{frontier} + \lambda_c + \delta_t + e_{ijt} \end{gathered} \tag{3}$$

where $Decentralization_{ct-1}$ is the measure of decentralization, $Distance_{ict-1} * Decentralization_{ct-1}$ is the interaction term, and $\Delta Y_{ct}^{Frontier}$ is the growth rate of frontier region. λ are country fixed effects that control for time-invariant country characteristics such as geography, and δ are year fixed effects that control for unobservables specific for the year, as well as variation in data due to different satellite settings.[18] The primary coefficient of interest is β_3 as it indicates whether decentralization promotes convergence (i.e., negative β_3) or hinders convergence (i.e., positive β_3).

The endogeneity problem due to omitted variables and reverse-causality that plague country-level convergence regressions is reduced by combining national data on decentralization with sub-national data on per capita income. First, we include country fixed effects as well as the growth of a country's frontier region as independent variables. This allows us to control for the time-invariant country characteristics as well as country's overall growth performance and potentially the omitted factors that exert mutual influence on a country's growth and decentralization tendencies. Second, we use region's distance-to-country-frontier to capture region's relative development level rather than its initial income level since the region's distance-to-country-frontier is mostly independent of the country's development level or growth rate. Thus, we argue that it is unlikely that country-level decentralization reforms are prompted by higher regional growth rate, conditional on country-fixed effects and frontier region's growth.[19]

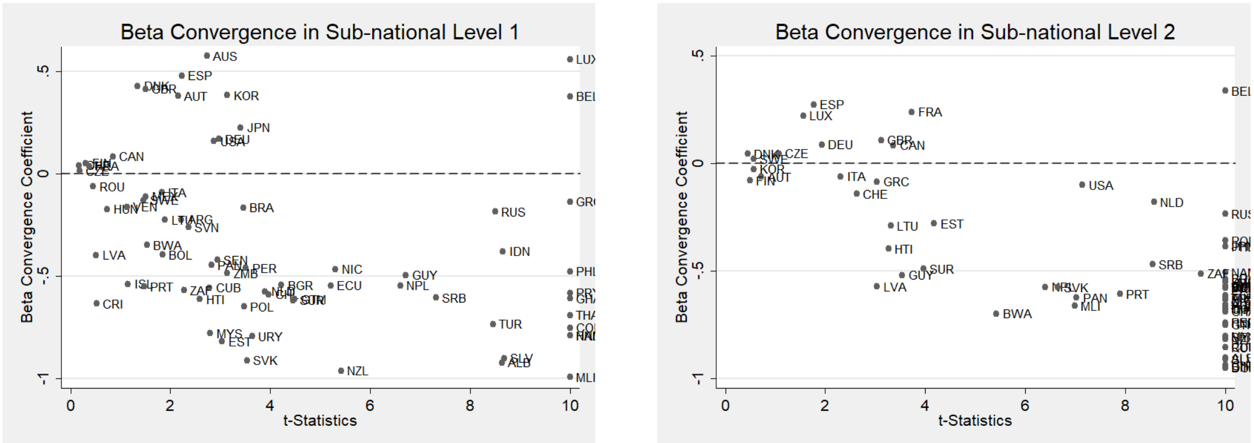
4 Results

4.1 Regional Convergence

Figures 2a and 2b present within-country convergence graphs using data on first and second sub-national levels respectively. The vertical axis plots the beta coefficients obtained from regressing

[18] We do not use regional fixed effects in our specifications because using regional fixed effects gives us the speed that each region converges to its own steady-state, instead of converging to the country frontier.

[19] A well-known econometric issue that occurs in a panel regression with a large number of countries and a small number of years is that when the lagged dependent variable is included in the regression, the fixed-effect estimate is inconsistent due to the correlation between the lagged dependent variable and the error term (Nickell, 1981). The typical bias in dynamic panels is much less of an issue in our case since we use regional data but we estimate the equation with only country-level fixed effects. Thus, if N is the number of regions in a country and T is the number of years in the sample. The inconsistency is to the order of $1/(T * N)$, which would be less than $1/10,000$ in our specification with the smallest N, instead of being $(1/T)$, which would be $1/34$ in the same specification if we used country-level dynamic model.



(a) First Subnational level

(b) Second Subnational level

Figure 2: Within-Country Convergence from 1992 to 2010 around the World

The variable on the vertical axis is the beta coefficient of regression capturing the average growth rate of night-time lights per capita on initial night-time lights per capita for individual countries in the sample of 74 countries, and the variable on the horizontal axis is the coefficient's t-statistics.

regional growth rate of per capita night-lights between 1992 and 2010 on per capita night-time lights in the year 1992 for individual countries and the horizontal axis plots the coefficient's t-statistics. These coefficients measure unconditional within-country convergence since we do not use any other controls in the regression. These figures demonstrate strong convergence across regions in most of the countries around the world.[20] Most of the estimates are negative and statistically significant at the conventional level, demonstrating a systematic tendency for regions that start with lower economic activity (measured here by night-time lights per capita) in 1992 to grow more rapidly over the next two decades compared to the regions that start with higher economic activity in 1992. However, there are some countries, especially high-income countries that experience regional divergence in our sample period, especially when using subnational level 1 data.[21] Thus, we analyze the regional convergence tendencies for the full sample as well as the sample of high-income countries and developing countries next.

[20]The graphs include the 74 countries in our sample. Graphs for 140 countries are in supplementary materials, and the results are similar.

[21]This finding is similar to Lessmann and Seidel (2017) where they also find that about a quarter of the countries experience regional divergence.

Table 2 presents the formal analysis of the graphs above using first and second subnational level data for the sample of 74 countries that have data on decentralization.[22] Column 1 presents the analysis on the full sample of countries, column 2 presents the analysis on the sample of high-income countries, and column 3 presents the analysis on the sample of developing countries.[23] Panel A presents the analysis using first subnational level data, and panel B presents the analysis using second subnational level data. The dependent variable for all of the regressions is the regional growth rate per capita. All specifications include country and year fixed effects, and none of them include region fixed effects or any other controls for regional characteristics, hence, the coefficients on lagged value of log of lights per capita (L.Log Light Per Capita) are the coefficients of within-country unconditional convergence.[24] The estimates range from -0.09 to -0.06, which are quite large and economically meaningful. For instance, a convergence coefficient of -0.08 implies that a region that is halfway to the frontier region grows 5.5 percent faster than the frontier region $(0.08 * ln(2))$. Even though we find regional convergence in all specifications, the estimates for the developing countries are larger and robustly significant compared to the developed countries. Thus, we conclude that there is stronger and robust regional convergence in the developing countries compared to the high-income countries.

In the next subsection, we examine the impact of decentralization on the speed of regional convergence. Since backward regions tend to catch up with frontier regions regardless of policies, the hope then is that decentralization speeds up the convergence process. However, we find that decentralization hinders convergence in developing countries.

[22] We also analyze the sample of all 140 countries in the supplementary materials and the results are similar.

[23] Country classifications are based on the World Bank's classification. We classify all the countries that are not in the high-income group as developing countries. Developing countries consist of upper-middle-income countries, lower-middle income countries, and three low-income countries.

[24] Analysis excluding year fixed effects for the sample of 140 countries in the supplementary materials show that the results are qualitatively similar with slightly larger coefficients quantitatively.

Table 2: Within-Country Convergence

	Full Sample	High-income Countries	Developing Countries
Panel A: First Subnational Level			
L.Log Light Per Capita	-0.0808***	-0.0723*	-0.0806***
	(0.0157)	(0.0411)	(0.00913)
Number of countries	74	38	36
Number of observations	25,747	11,808	13,939
Panel B: Second Subnational Level			
L.Log Light Per Capita	-0.0882***	-0.0645**	-0.0919***
	(0.0169)	(0.0246)	(0.0202)
Number of countries	74	38	36
Number of observations	554,757	237,924	316,833

Notes: The outcome variables in all specifications is subnational level growth rate of lights per capita. Columns 1 uses all countries with requisite data, columns 2 uses high-income countries with requisite data and columns 3 uses developing countries with requisite data. All regressions include country fixed effects and year fixed effects. Panel A presents analysis using first subnational level data and panel B presents analysis using second subnational level data. The standard errors, in parenthesis, are clustered at the country level.

* $p < .1$, ** $p < .05$, *** $p < .01$.

4.2 Decentralization and Regional Convergence

Table 3 shows the results for the baseline specification (equation 3). Column 1 is the analysis on the full sample of countries, column 2 is on the sample of high-income countries, and column 3 is on the sample of developing countries. Panel A presents the analysis using first subnational level data, and panel B presents the analysis using second subnational level data. The dependent variable is the regional growth rate per capita in each of the regressions. Each regression includes country fixed effects and year fixed effects.[25] The distance from the frontier region is given by $L.DistancePC$, the per capita growth rate of the frontier region of each country is given by $GrowthFrontierPC$, and the measures of decentralization used (i.e., Self-rule) is given by $L.Selfrule$.[26] The interaction terms of distance with measures of decentralization are the coefficients of interest, which indicates the impact of decentralization on the speed of convergence. We

[25] The analysis excluding year fixed effects is presented in the supplementary materials. The results are qualitatively similar with slightly larger coefficients quantitatively.

[26] We use self-rule measure that excludes borrowing autonomy in the baseline specifications because by excluding borrowing autonomy we can increase the sample of countries with all requisite data to 74.

call them the convergence coefficient from now on.

The coefficient on the variable $L.Distance$ is negative and statistically significant in almost all of the specifications. A negative coefficient implies that farther a region is from the frontier, higher its growth rate, reinforcing the idea that regions with the lower initial level of economic activity tend to grow faster in the absence of decentralization.

The convergence coefficients are positive and significant for the full sample, indicating that decentralization impedes regional convergence. When we divide the sample into high-income countries and developing countries, we find that the estimates are positive and significant at the 5 percent or better level for the developing countries. However, the estimates for the developed countries are significant at the 10 percent when using first subnational level data and insignificant at the conventional level when using second subnational level data. The coefficients range from 0.09 to 0.11, with coefficients of developing countries being slightly larger than that of the full sample.

These findings indicate that decentralization hinders regional convergence. The effect is larger and always significant at the conventional level for the sample of developing countries, while they are not robust for the high-income countries. To analyze how economically significant these estimates are, we can look at the effect on the growth rates for certain regions compared to the frontier region of the country when the value of self-rule changes. To illustrate, in the full sample (column 1), the convergence coefficient of 0.0918 implies that if the decentralization index of the country changes from the lowest possible value (i.e., 0) to the highest possible value (i.e., 1), the growth rate of a region that is halfway to the country frontier would decrease by more than 6 percent. For the full sample the difference in growth rate between the region and the frontier region of the country changes from about 7 percent to about 1 percent when decentralization index changes from 0 to 1. The sample of developing countries using first subnational level data show similar effect of decentralization.

These findings are in line with the studies that find the detrimental effect of decentralization on developing countries such as Zhang and Zou (1998); Davoodi and Zou (1998); Liu, Martinez-Vazquez and Wu (2017). Based on the findings for the different samples, it appears that developing countries drive the divergence effect of decentralization. We reach this conclusion because the effect is larger for the sample of developing countries compared to that of the full sample and the estimates for the high-income countries are not robust.

The implication of this analysis is substantial, especially in developing countries, as we find that regions which are relatively behind in development level tend to grow slower, and hence lag further behind, than a relatively more developed region within a country.

4.3 Components of Decentralization and Regional Convergence

In this section, we study how individual components of decentralization (i.e., fiscal autonomy, institutional depth, policy autonomy, and representation) affect regional convergence.[27] The results are presented in Table 4.[28] Panel A presents results for analysis using first subnational level data and panel B presents results for analysis using second subnational level data. Column 1 presents results for the full sample, column 2 presents results for the sample of high-income countries, and column 3 presents results for the sample of developing countries.

For the full sample, we find that almost all of the components have a significant impact on convergence. The convergence coefficients on the institutional depth, policy autonomy, and representation are all positive, range from 0.05 to 0.15, and significant using both first and second subnational level data. Whereas, fiscal autonomy (0.09) is positive and significant using second subnational level data only.

The sub-component analysis reinforces the findings from the analysis of the overall decentralization index that there is no robustly significant impact of decentralization on high-income

[27] For consistency, we exclude borrowing autonomy from the analysis as we use self-rule measure without borrowing autonomy in the baseline analysis.

[28] To save space, we only present estimates of the convergence coefficients from regressions that include year fixed effects. The specifications excluding year fixed effects yield similar results, both quantitatively and qualitatively

Table 3: Decentralization and Within-Country Convergence

	Full Sample	High-income Countries	Developing Countries
Panel A: First Subnational Level			
L.Distance PC	-0.109***	-0.124*	-0.101***
	(0.0129)	(0.0645)	(0.0120)
Frontier Growth PC	0.440***	0.492***	0.359***
	(0.0647)	(0.0837)	(0.0782)
L.Selfrule	0.156***	0.0870	0.170**
	(0.0560)	(0.140)	(0.0690)
L.Selfrule x Distance PC	0.0918***	0.112*	0.0855**
	(0.0293)	(0.0581)	(0.0322)
Number of countries	74	38	36
Number of observations	25,570	11,703	13,867
Panel B: Second Subnational Level			
L.Distance PC	-0.126***	-0.0983**	-0.136***
	(0.0272)	(0.0436)	(0.0321)
Frontier Growth PC	0.0627	0.0641*	0.293***
	(0.0715)	(0.0341)	(0.0546)
L.Selfrule	0.214	0.0740	0.294
	(0.227)	(0.231)	(0.295)
L.Selfrule x Distance PC	0.0942**	0.0814	0.108**
	(0.0374)	(0.0676)	(0.0418)
Number of countries	74	38	36
Number of observations	552,089	235,703	316,386

Notes: The outcome variables in all specifications is subnational level growth rate of lights per capita. Column 1 uses all countries with requisite data, column 2 uses high-income countries with requisite data and column 3 uses developing countries with requisite data. All regressions include country fixed effects and year fixed effects. Panel A presents analysis using first subnational level data and panel B presents analysis using second subnational level data. The standard errors, in parenthesis, are clustered at the country level.

* $p < .1$, ** $p < .05$, *** $p < .01$.

countries. In the sample of high-income countries, we do not find a significant effect of any of the components of decentralization when using second subnational level data. Institutional Depth, Policy Autonomy and Representation are statistically significant when first subnational data are used, but only at 10% significance level.

In the case of developing countries, the result is more nuanced but provides evidence that all components of decentralization substantially reduces regional convergence. We find that fiscal autonomy and representation have the robust impact on regional convergence. The estimated coefficients range from 0.07 to 0.12 and are significant at the conventional level using both first and second subnational level data. The institutional depth and policy autonomy indicators also suggest that decentralization hinders convergence, but the estimates are not robustly significant. The coefficient on institutional depth (0.104) is significant using first subnational data only, and policy autonomy (0.126) is significant using second subnational level data only.

4.4 Decentralization and within First Subnational Region Convergence

In this section, we extend our analysis on the effect of decentralization to study if decentralization promotes or hinders convergence between the poor and rich regions within each first subnational level division of a country. To do so, we use second subnational level data and add first subnational level region fixed effects to the baseline regression. Thus, we can interpret the coefficient on the interaction between distance and measures of decentralization as the impact of decentralization on within first subnational level regional convergence. Note that we also modify the variable *Distance*, which now represents distance to the frontier second subnational level region within a first subnational level region. Specifically, *Distance* is now defined as,

$$Distance_{ijct} = ln(Light_{ijct}) - ln(Light_{jct}^{Frontier}) \tag{4}$$

Table 4: Components of Decentralization and Within-Country Convergence

	Full Sample	High-income Countries	Developing Countries
Panel A: First Subnational Level			
Fiscal Autonomy	0.00735	-0.0562	0.105**
	(0.0913)	(0.100)	(0.0387)
Institutional Depth	0.147***	0.213*	0.104***
	(0.0309)	(0.119)	(0.0436)
Policy Autonomy	0.0688***	0.103*	0.0448
	(0.0253)	(0.0522)	(0.0367)
Representation	0.101***	0.145*	0.0677**
	(0.0239)	(0.0840)	(0.0270)
Number of Countries	74	38	36
Number of Observations	25,570	11,703	13,867
Panel B: Second Subnational Level			
Fiscal Autonomy	0.0886*	0.0666	0.114*
	(0.0492)	(0.0698)	(0.0586)
Institutional Depth	0.0837*	0.126	0.0687
	(0.0429)	(0.0874)	(0.0533)
Policy Autonomy	0.0996**	0.0515	0.126**
	(0.0454)	(0.0382)	(0.0612)
Representation	0.0500*	0.0543	0.0648**
	(0.0279)	(0.0615)	(0.0303)
Number of Countries	74	38	36
Number of Observations	552,089	235,703	316,386

Notes: The outcome variables in all specifications is subnational level growth rate of lights per capita. The coefficients reported are the convergence coefficients (coefficients of the interaction term between the decentralization measure used and the distance measure). Column 1 uses all countries with requisite data, column 2 uses high-income countries with requisite data and column 3 uses developing countries with requisite data. All regressions include country fixed effects and year fixed effects. Panel A presents analysis using first subnational level data and panel B presents analysis using second subnational level data. The standard errors, in parenthesis, are clustered at the country level.

* $p < .1$, ** $p < .05$, *** $p < .01$.

where $Light_{jct}^{Frontier}$ is the light per capita of frontier second subnational level region in first subnational level region j. The impact of decentralization on within first subnational region convergence is then give by,

$$\Delta Y_{ijct} = \beta_0 + \beta_1 Distance_{ijct-1} + \beta_2 Decentralization_{ct-1}$$
$$+\beta_3 Distance_{ijct-1} * Decentralization_{ct-1} + \beta_4 \Delta Y_{jct}^{Frontier} + \beta_5 \Delta Y_{ct}^{Frontier} \quad (5)$$
$$+\gamma_{jc} + \lambda_c + \delta_t + e_{ijct}$$

where $Distance_{icjt-1}$ is the distance to the frontier second subnational level region within a first subnational level region and $Decentralization_{ct-1}$ is the measure of decentralization. The coefficient on the interaction term $Distance_{icjt-1} * Decentralization_{ct-1}$ is the coefficient of primary interest as it indicates whether decentralization promotes within first subnational level regional convergence (i.e., negative β_3) or hinders convergence (i.e., positive β_3). γ_{jc} is the first subnational level region fixed effects, λ_c is the country fixed effects, and δ_t is year fixed effects. We control for the first subnational region growth by including growth of frontier region within each of the first subnational regions, $\Delta Y_{jct}^{Frontier}$. In some specifications, we also control for the country growth by including growth of first subnational level frontier region of the country, $\Delta Y_{ct}^{Frontier}$.

Table 5 presents the results. The results are similar to the baseline study. The convergence coefficients are positive and significant in the full sample and the sample of developing countries, but not significant at the conventional level for the high-income countries.

These findings suggest that decentralization hinders not only within-country convergence but also within-region convergence. The convergence coefficients are larger than in the analysis of within-country convergence for both the full sample and the sample of developing countries. Taken together, the results from within-country and within-region convergence suggest that the growth of first subnational level regions in developing countries is mostly driven by the growth of a few second subnational level regions within that first subnational level region. Since these within-region convergence estimates are larger than within-country convergence estimates from our baseline results, it also implies that the lack of regional convergence is more pronounced at the local level.

Table 5: Decentralization and Within First Subnational Region Convergence

	Full Sample		High-income Countries		Developing Countries	
L.Distance PC	-0.144***	-0.144***	-0.0956**	-0.0953**	-0.157***	-0.157***
	(0.0353)	(0.0354)	(0.0449)	(0.0446)	(0.0426)	(0.0424)
Level 2 Frontier Growth PC	0.584***	0.594***	0.547***	0.550***	0.597***	0.576***
	(0.0664)	(0.0620)	(0.125)	(0.126)	(0.0530)	(0.0506)
L.self rule	0.148	0.158	-0.118	-0.112	0.261	0.247
	(0.145)	(0.139)	(0.140)	(0.137)	(0.205)	(0.205)
L.Selfrule x Distance PC	0.151***	0.151***	0.0977	0.0973	0.162**	0.162**
	(0.0560)	(0.0561)	(0.0741)	(0.0738)	(0.0660)	(0.0656)
Level 1 Frontier Growth PC		-0.0425		-0.0119		0.0873*
		(0.0357)		(0.0173)		(0.0440)
Number of countries	74	74	38	38	36	36
Number of observations	552,089	552,089	235,703	235,703	316,386	316,386

Notes: The outcome variables in all specifications is second subnational level growth rate of lights per capita. Columns 1 and 2 illustrate results for all countries with requisite data, Columns 3 and 4 illustrate results for high-income countries with requisite data and Columns 5 and 6 illustrate results for developing countries with requisite data. All specifications include country, year, and first subnational level region fixed effects. The standard errors, in parenthesis, are clustered at the country level.

* $p < .1$, ** $p < .05$, *** $p < .01$.

5 Robustness Tests

To probe the robustness of our main results, we perform a series of tests. First, we estimate regional convergence using the traditional approach that compares regional growth with country average instead of the frontier region's growth. Second, we estimate the baseline model by controlling for, as well as removing, level 1 regions that include country capitals. Third, we estimate baseline regression excluding one country at a time to study if any particular country is driving the result. Fourth, we conduct additional robustness tests which include analyzing regional convergence using the data on decentralization from Hooghe et al. (2016) only, using four-year averages of our panel data, comparing differences in convergence coefficients between high-income countries and developing countries using alternative definitions of high-income countries, and augmenting the baseline specification to include important control variables from the cross-country growth literature.

5.1 Convergence Towards Country Average

In this section, we study the impact of decentralization on convergence using a traditional approach that compares regional growth with country average instead of the frontier region's growth. The specification is as follows.

$$\begin{aligned} Growthdiff_{ict} &= \alpha_0 + \alpha_1 * Lightdiff_{ict-1} + \alpha_2 * Decentralization_{ct-1} \\ &+ \alpha_3 * Decentralization_{ct-1} * Lightdiff_{ict-1} + \epsilon_{ijt} \end{aligned} \tag{6}$$

where $GrowthDiff$ is the growth differential between a region and the country where it is located,

$$Growthdiff_{ict} = \big(ln(Light_{ict}) - ln(Light_{ict-1})\big) - \big(ln(Light_{ct}) - ln(Light_{ct-1})\big) \tag{7}$$

and $Lightdiff$ is the log difference in the level of night-time lights per capita between a region and the country it is located in,

$$Lightdiff_{ict} = ln(Light_{ict}) - ln(Light_{ct}) \tag{8}$$

In this specification, the impact of business cycles is eliminated from the series by subtracting the country-level growth rate. The coefficient of interest is denoted by α_3, which measures the effect of decentralization on regional convergence. If $\alpha_3 < 0$, it implies faster convergence and if $\alpha_3 > 0$, it implies slower convergence or divergence due to decentralization.[29]

Table 6 presents the results. Panel A presents the analysis using first subnational level data and panel B presents the analysis using second subnational level data. Column 1 presents the result for the full sample, column 2 presents the result for the sample of high-income countries, and column 3 presents the result for the sample of developing countries. The variable *Light diff* is log difference of light per capita between a region and country as defined in equation 8. The interaction term between *Light diff* and decentralization measure are the coefficients of interest as they indicate the role of decentralization in the speed of convergence. The coefficients on *Light diff* are mostly negative and significant, suggesting higher growth in regions with lower initial lights per capita than the country's lights per capita.

The coefficients of convergence are positive and significant for the full sample and the sample of developing countries using both first and second subnational level data. The magnitudes of coefficients inform us how regional growth differential changes as the index for decentralization increases, at different values of the initial lights per capita differences. The magnitude of 0.0761 in column 1 indicates that for a region with initial lights per capita 50 percent lower than country average, if the decentralization index of the country changes from the lowest possible value to the

[29]Following our baseline specifications, we do not include regional level fixed effects because the speed of convergence when the regional fixed effects are present is the speed that each region converges to its own steady-state, instead of converging to the country average.

highest possible value, the predicted growth of the region would decrease by more than 5 percent.

The coefficients on the sample of high-income countries are not significant, and hence the effects are inconclusive. These findings support the results from our baseline specifications that the decentralization has a detrimental impact on the convergence process in the sample of developing countries. Also, these results suggest that the choice of our baseline specification does not drive our findings.

Table 6: Decentralization and Within-Country Convergence Towards Country Average

	Full Sample	High-income Countries	Developing Countries
Panel A: First Subnational Level			
L. Diff in GDP	-0.0927***	-0.0890	-0.0936***
	(0.0117)	(0.0603)	(0.00999)
L.Selfrule	-0.0140*	-0.0341**	-0.00294
	(0.00800)	(0.0134)	(0.0117)
L.Selfrule x Light Diff	0.0761***	0.0761	0.0676**
	(0.0276)	(0.0548)	(0.0294)
Number of countries	74	38	36
Number of observations	25,570	11,703	13,867
Panel B: Second Subnational Level			
L. Diff in GDP	-0.138***	-0.105**	-0.150***
	(0.0329)	(0.0502)	(0.0392)
L.Selfrule	0.0242	-0.0257	0.0900**
	(0.0246)	(0.0361)	(0.0353)
L.Selfrule x Light Diff	0.127**	0.110	0.136**
	(0.0526)	(0.0826)	(0.0576)
Number of countries	74	38	36
Number of observations	552,089	235,703	316,386

Notes: The outcome variables in all specifications is the growth differential between a region and the country it is located in. Column 1 uses all countries with requisite data, column 2 uses high-income countries with requisite data and column 3 uses developing countries with requisite data. Panel A presents analysis using first subnational level data and panel B presents analysis using second subnational level data. The standard errors, in parenthesis, are clustered at the country level.

* $p < .1$, ** $p < .05$, *** $p < .01$.

5.2 Controlling for Country Capitals

In this section, we estimate the baseline specification while controlling for level 1 regions with country capitals, and removing them entirely. The purpose of the exercise is to mitigate any endogeneity issue that may still exist due to government policies being mostly driven by special federal or capital districts. This can be an issue in the developing countries where the capital cities or districts are large and generate significant share of national income. It is likely that government's policies in these countries are driven by the growth of these regions. For instance, in cases like Buenos Aires in Argentina, the region accounts for large share of population and national income. Therefore, national policies potentially react to the development of those regions. The countries are likely to change their federal policies if those regions develop differently compared to the rest of the country. In order to mitigate the issue, we conduct two tests. First, we control for level 1 regions where the country capitals are located by adding a dummy variable for the regions. Second, we remove those regions entirely from the analysis.

The reasons for controlling for, and removing, level 1 regions with country capital instead of level 2 regions are two folds. First, a lot of country capitals are themselves a level 1 region. Second, in lot of countries, capital city is the level 2 region itself. In those cases, neighboring level 2 regions could exert similar influence on national policies. Also, the approach is more conservative than removing level 2 regions and hence, should mitigate the potential issue of endogeneity more.

Table 7 presents the results of the tests. To save space, we only report convergence coefficients of each test. Column 1 presents the convergence coefficients from the analysis that controls for level 1 regions with country capital. Column 2 presents the convergence coefficients from the analysis that excludes those regions from the sample. Row 1 presents the analysis on the full sample of countries, row 2 on the sample of high-income countries, and row 3 on the sample of developing countries. Panel A presents the analysis using first subnational level data, and panel B presents the analysis using second subnational level data. Each regression includes country fixed effects and year fixed effects.

Results are similar to the baseline analysis. Convergence coefficients for the full sample and the sample of developing countries are positive and significant, indicating detrimental effect of the decentralization on regional convergence. For the sample of high-income countries, the coefficients are again not robust. The findings alleviate the concern that the major capital cities that influence national policies cause endogeneity problem and potentially bias the results.

Table 7: Decentralization and Within-Country Convergence

	Control for Capital Regions	Remove Capital Regions
Panel A: First Subnational Level		
Full Sample	0.0846***	0.0889**
	(0.0295)	(0.0366)
High-income Countries	0.112*	0.153*
	(0.0595)	(0.0763)
Developing Countries	0.0800**	0.0822**
	(0.0308)	(0.0329)
Number of Countries	74, 38, 36	74, 38, 36
Number of Observations	25570, 11703, 13867	24320, 11022, 13298
Panel B: Second Subnational Level		
Full Sample	0.0940**	0.0999**
	(0.0374)	(0.0396)
High-income Countries	0.0813	0.0896
	(0.0680)	(0.0729)
Developing Countries	0.108**	0.114**
	(0.0418)	(0.0447)
Number of Countries	74, 38, 36	74, 38, 36
Number of Observations	552089, 235703, 316386	530638, 222507, 308131

Notes: The outcome variables in all specifications is subnational level growth rate of lights per capita. The coefficients reported are the convergence coefficients (coefficients of the interaction term between the decentralization measure used and the distance measure). Column 1 is the analysis that controls for level 1 regions where country capitals are located and column 2 is the analysis excluding those level 1 regions. All regressions include country fixed effects and year fixed effects. Panel A presents analysis using first subnational level data and panel B presents analysis using second subnational level data. In both panels, row 1 uses all countries with requisite data, row 2 uses high-income countries with requisite data, and row 3 uses developing countries with requisite data. The standard errors, in parenthesis, are clustered at the country level. Number of Countries and Number of Observations indicate number of countries and number of observations for the full sample, the sample of high-income countries, and the sample of developing countries, respectively.

* $p < .1$, ** $p < .05$, *** $p < .01$.

5.3 Leave-one-out Estimations

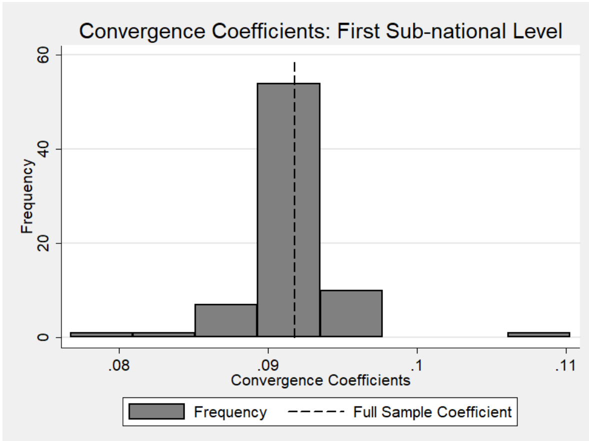
In this section, we test if any one particular country drives our baseline estimates by running the baseline regression excluding one country at a time. Figures 3a and 3b present the results using first and second subnational level data respectively. Since there are 74 countries in our sample, we run the experiment 74 times, yielding 74 leave-one-out convergence coefficients. We present these coefficients using a histogram, and we include the estimates from our baseline specifications for comparison. The horizontal axis of the histogram denotes the value of convergence coefficients and the vertical axis denotes the frequency for each of the coefficients. The vertical dashed line gives the convergence coefficient from the baseline model. The distribution of the convergence coefficients, using both first and second subnational level data, is concentrated near the baseline coefficient (0.0918 using first subnational level data and 0.0942 using second subnational level data), with less than 0.02 deviation of all leave-one-out estimations from the baseline results. It suggests that removing any one country from the baseline analysis does not significantly change the coefficient. Hence, we conclude that any one particular country is not driving our baseline results.

5.4 Additional Robustness Tests

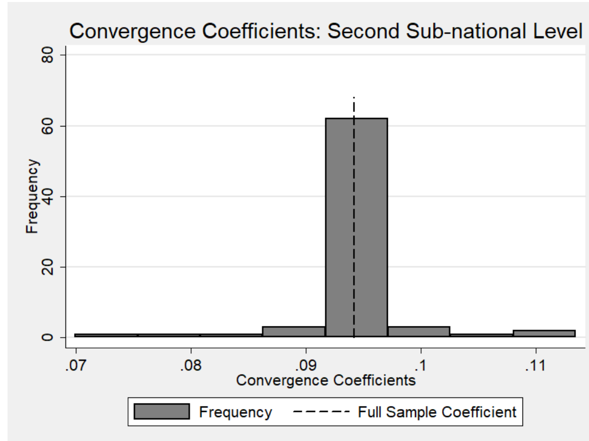
In this section, we run a series of additional tests to establish the robustness of our baseline results.

First, we estimate regional convergence using the data on decentralization from Hooghe et al. (2016) only, which also include data on borrowing autonomy of subnational government, but covers only 66 countries. Since the self-rule measure now consists of all five components, including borrowing autonomy, we call it self-rule 5.

Second, we run the analysis by collapsing the yearly data into four-year averages. Thus, each observation X_t is a four-year average of the values of X in the baseline model. Since our original night-time lights data covers the time span of 1992 to 2013, collapsing the data into four-year aver-



(a) First Subnational level



(b) Second Subnational level

Figure 3: Convergence Coefficients using Leave-one-out Estimators

The histogram presents the distribution of convergence coefficients from running 74 separate regressions, excluding one country at a time. The horizontal axis of the histogram denotes the value of the convergence coefficients and the vertical axis plots their frequency. The vertical dashed line gives the convergence coefficient from the baseline model.

ages results in five time periods spanning 1992 to 2011.[30] There are two advantages of taking such averages. First, the convergence coefficients capture the long-run patterns of regional convergence, and second, it eliminates the impact of the business cycle on regional convergence. The obvious disadvantage is the loss of sample size, which is quite significant here as we are reduced to five time periods.

Third, we run the baseline regression on high-income countries and developing countries using alternative definitions of high-income countries. First, we classify countries as high-income countries and developing countries based on the World Bank's analytical classification using 1992 as the base year. Under this classification, a country is classified as a high-income country if its gross national income (GNI) per capita is greater than USD 7,620 in 1992, otherwise, it is classified as a developing country. Second, we classify a country as a high-income country if it one of the members of the OECD, otherwise it is classified as a developing country.

[30]Note that we have data on decentralization up to 2010, thus, we use a three-year average of self-rule for years 2008 to 2010, instead of limiting our sample period to 2007. Given that the aggregate self-rule index has low year-on-year changes, a three-year average and a four-year average should be very similar.

Fourth, we add some important control variables from the cross-country growth literature in our baseline specification. These variables are investment as a share of GDP, average years of schooling, trade as a share of GDP, a dummy indicating whether a country is an oil producer or not, and a dummy indicating whether a country is a small region or not. We classify a country as a small region if it has population less than 500,000. They are mostly small islands. Controlling for small regions also controls for any errors in satellite light observations that may have been caused by possible glare from oceans and lights from other natural sources. We use lagged values of all variables, except for the dummies for oil producing countries and small regions.

Table 8 presents the results of these robustness tests. To save space, we only report convergence coefficients of each test. Column 1 presents the convergence coefficients using self-rule 5 measure of decentralization instead of self-rule measure used in the baseline analysis. Column 2 presents results from analysis using four-year average data. Columns 3 and 4 present results from the analysis for high-income and developing countries using two alternative definitions of high-income countries. In columns 3, countries are classified as high-income based on the World Bank's classification in the year 1992 and in column 4, countries are classified as high-income if they are members of the OECD. Column 5 presents results from analysis including additional controls mentioned above. Row 1 presents the analysis on the full sample of countries, row 2 on the sample of high-income countries, and row 3 on the sample of developing countries. Panel A presents the analysis using first subnational level data, and panel B presents the analysis using second subnational level data. Each regression includes country fixed effects and year fixed effects.

The results strongly support our findings from the baseline analysis. On the one hand, all of the convergence coefficients are positive and significant for the full sample and the sample of developing countries with one exception in the case of developing countries when using four-year averages of second subnational level data.[31] On the other hand, all of the convergence coefficients

[31] Note that for columns 3 and 4, analysis on the full sample would be the same as in the baseline analysis, so they are not reported here.

for the high-income countries are not robust as they are insignificant at the conventional level when second subnational level data are used, and when significant using first subnational level data, they are significant only at 10% significance level.

The robustness tests presented in this section support our findings in the baseline analysis. There is a strong and robust evidence to support that the decentralization hinders regional convergence in developing countries, while the findings on developed countries are not robust.

Table 8: Additional Robustness Tests of Within-Country Convergence

	Self-rule 5	Four-year Average Data	Income Group in 1992	OECD vs Non-OECD	Additional Controls
Panel A: First Subnational Level					
Full Sample	0.0913***	0.0629***			0.0949***
	(0.0252)	(0.0148)			(0.0294)
High-income Countries	0.123*	0.0424*	0.280	0.109*	0.112*
	(0.0695)	(0.0241)	(0.197)	(0.0632)	(0.0649)
Developing Countries	0.0831**	0.0512**	0.0928***	0.101***	0.0912**
	(0.0321)	(0.0219)	(0.0279)	(0.0321)	(0.0339)
Number of Countries	66, 38, 28	74, 38, 36	26, 48	34, 40	73, 38, 35
Number of Observations	24531, 11703, 12828	7153, 3280, 3873	7524, 18046	10688, 14882	25260, 11514, 13746
Panel B: Second Subnational Level					
Full Sample	0.0942**	0.0555*			0.0882**
	(0.0466)	(0.0286)			(0.0383)
High-income Countries	0.0878	0.0785	0.108	0.0241	0.0176
	(0.0691)	(0.0555)	(0.0939)	(0.0471)	(0.0408)
Developing Countries	0.108**	0.0446	0.110**	0.152***	0.114**
	(0.0511)	(0.0300)	(0.0427)	(0.0490)	(0.0426)
Number of Countries	66, 38, 28	74, 38, 36	26, 48	34, 40	73, 38, 35
Number of Observations	546378, 235703, 310675	154118, 66095, 88023	167256, 384833	223700, 328389	548782, 233108, 315674

Notes: The outcome variables in all specifications is subnational level growth rate of lights per capita. The coefficients reported are the convergence coefficients (coefficients of the interaction term between the decentralization measure used and the distance measure). Column 1 is the analysis using Self-rule 5 measure, column 2 is the analysis using four-year average data, column 3 is the analysis using year 1992's income classification to distinguish between high-income and developing countries, column 4 is the analysis using OECD membership to distinguish between high-income and developing countries, and column 5 is the analysis with additional controls included. All regressions include country fixed effects and year fixed effects. Panel A presents analysis using first subnational level data and panel B presents analysis using second subnational level data. In both panels, row 1 uses all countries with requisite data, row 2 uses high-income countries with requisite data, and row 3 uses developing countries with requisite data. The standard errors, in parenthesis, are clustered at the country level. Number of Countries and Number of Observations indicate number of countries and number of observations for the full sample, the sample of high-income countries, and the sample of developing countries, respectively.

* $p < .1$, ** $p < .05$, *** $p < .01$.

6 Discussion on the Detrimental Effect of Decentralization in the Developing Countries

There are various channels through which decentralization can hinder regional convergence on the developing countries. We provide some possible explanations in this section. First, developing countries are less likely to have effective equalization program to assist regions with lower level of growth. Also, those regions have limited state capacity, weaker endowments and smaller tax base compared to richer regions. Hence, their average tax rates are likely to be higher, which leads to lower infrastructure spending and lower level of external investments in the regions. Second, we find that the fiscal autonomy has detrimental effect on developing countries. The measure does not tell us the composition of subnational government's spending between current spending, capital spending and welfare spending. It may be the case that the subnational governments in developing countries are spending more on current and welfare category rather than capital spending. Excessive spending in wrong category can lead to lower growth of the regions even though they are more autonomous. This possibility is also pointed out by Davoodi and Zou (1998). Third, local governments in developing countries are more prone to elite capture than those of the high-income countries, hence, misappropriation of public funds by special interest groups are more likely in poor regions of the developing countries. Fourth, human capital in the developing countries are generally lower than that of the high-income countries. Hence, officials in local governments of developing countries are likely to be less skilled. So, a centralized system may be more beneficial where central government can utilize expertise of the few skilled government officials for policy making. Fifth, the efficiency gains of decentralization may not materialize in developing countries in practice as local governments may not be as responsive to preferences of the residents. This may occur when local government officials are not elected by local residents or the local residents are too poor to "vote with their feet".

7 Conclusions

In this paper, we attempt to understand how decentralization affects regional convergence using a global sample of countries. The theoretical prediction as well as the empirical estimation in the extant literature provides an ambiguous answer: decentralization can either cause convergence or divergence of subnational economies. Decentralization can improve economic growth by increasing the effectiveness and efficiency of the public sector, by fostering competition among regional governments, and by better matching resources and preferences of communities and governments. However, decentralization can also inhibit growth in more impoverished regions due to their limited state capacity, weaker endowments, and a higher incidence of elite capture, and due to the limited redistributive role of central government in a decentralized economy that can lead to an even larger disparity between richer and poorer regions.

We use data on night-time lights intensity at the regional level to proxy for local economic activity (or GDP) and Regional Authority Index's self-rule and its components to measure decentralization. The use of night-time lights data allows us to cover a large number of developing countries in our sample, which was not possible before. The use of self-rule and its components as measures of decentralization provides a broader measure of decentralization as it allows us to study a wide range of fiscal, political, and administrative authority of subnational regions.

Although our analysis fills an important gap in the literature, there are some limitations of our study. For instance, although night-time lights data allows us to cover a large number of developing countries, it is an imperfect proxy for regional income. We are also unable to fully explore the channels through which decentralization hinders convergence in developing countries, but not in developed countries. Does the link operate via the differential provision of public goods, via elite capture at the subnational level, or via less redistributive role of the central government?

We study within-country as well as within first subnational level convergence and find that decentralization hinders the convergence process in developing countries. For instance, we find that when the decentralization index of the country changes from the lowest possible value (i.e., 0) to the highest possible value (i.e., 1), the convergence rate of a region that is halfway to the country frontier slows down by about 7 percent to about 1 percent. We find that decentralization hinders not only within-country convergence but also within first subnational region convergence. In fact, the convergence coefficients of within first subnational region analysis are larger than within-country convergence analysis. It suggests that the growth of first subnational level regions in developing countries is mostly driven by the growth of a few second subnational level regions within that first subnational level region.

We also analyze the impact of changes in different components of decentralization such as fiscal autonomy, institutional depth, policy autonomy, and political representation on regional convergence. The sub-component analysis reinforces the findings from the analysis of the overall decentralization index that decentralization severely reduces the convergence process in developing countries but decentralization has no statistically significant effects on high-income countries.

We conclude by noting that the methods and data used in this paper can be applied to study the impact of various phenomena such as structural reforms, democratic reforms, trade openness, and globalization on regional inequality and convergence.

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A Decentralization and Within-country Convergence Analysis

The following 74 countries are in our analysis

High Income: Argentina, Australia, Austria, Belgium, Brunei, Canada, Chile, Croatia, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Italy, Japan, Latvia, Lithuania, Luxembourg, Netherlands, New Zealand, Norway, Poland, Portugal, Russia, Slovakia, Slovenia, South Korea, Spain, Sweden, Switzerland, United Kingdom, United States, Uruguay, Venezuela

Upper Middle Income: Albania, Bosnia and Herzegovina, Botswana, Brazil, Bulgaria, Colombia, Costa Rica, Cuba, Dominican Republic, Ecuador, Malaysia, Mexico, Namibia, Panama, Paraguay, Peru, Romania, Serbia, South Africa, Suriname, Thailand, Turkey

Lower Middle Income: Bolivia, El Salvador, Ghana, Guatemala, Guyana, Honduras, Indonesia, Nicaragua, Philippines, Senegal, Zambia

Low Income: Haiti, Mali, Nepal