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Examining the Impact of Aging on Gross Domestic Product (GDP) Growth and Infrastructure Investment in India: A District-Level Study

Sahil Tekchandani

Claremont McKenna College

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Sahil Tekchandani

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Abstract

India, like many other countries around the world, has a rapidly aging population. Unlike most developed nations, however, India's economy is not growing quickly enough to adequately support the increase in old age population share. Using district-level data from the Indian Census and the International Crops Research Institute for the Semi-Arid Tropics, this study performs linear regressions to analyze the impact that aging has on GDP growth and infrastructure investment. GDP growth is examined in the primary, secondary, and tertiary sectors, while the focus of infrastructure investment is on roads and banks. The study finds that a higher old age share has a positive effect on GDP growth in the secondary sector, mixed effects on road growth, and a negative effect on bank growth. These findings display strong variation between districts and regions, highlighting the need for both local and national efforts to drive economic growth amidst the widespread aging trend.

Keywords: Aging population, GDP growth, Primary sector, Secondary sector, Tertiary sector, Infrastructure investment, Bank growth, Road growth

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I. Introduction

According to a report published by the United Nations earlier this year, the current population of people over 65 will more than double to reach 1.6 billion people worldwide by 2050 (United Nations 2023). Not only does the UN predict an absolute increase in elderly people, but by 2050 they expect that one in six people worldwide will be above 65. This aging trend is accelerating rapidly, fueled by a decrease in fertility and a rise in life expectancy, and will dramatically shape the social and economic landscape in many countries around the world. For example, a growing elderly population share may stymie the growth of the workforce and place pressure on pension systems, among many other potential effects. While populations are aging around the world, the trend has been shown to be especially concerning in India. India is a crucial entity to focus on, not only because of its massive population but also because of the unique challenge that aging poses to the Indian economy.

India's aging problem is unlike that of other countries, especially wealthier, developed ones. Looking at a comparison between the old-age dependency ratio and GDP per capita, as seen in Figure A1, it becomes clear that India is facing a rapidly aging population while its GDP remains relatively low. In comparison to three wealthier nations, the United States, Japan, and Germany, who were relatively wealthy fifty years ago and have all seen massive GDP growth in the past fifty years alongside its aging population, India's real GDP per capita has only grown to $1,936 in the same time period. Fundamentally, the aging problem facing India is financially riskier than that faced by wealthier countries. And, as India's old-age dependency ratio continues to grow, a lack of future GDP growth may pose serious troubles for maintaining elderly support and economic structure.

While India's aging issue is unique in the context of wealthier countries, the journeys of developing nations such as China and Brazil can provide context for what the future holds as India's old age share continues to grow. As shown by Figure A1, India is following a similar path to China before it experienced a steep rise in GDP per capita after its dependency ratio hit 10. Brazil, on the other hand, has seen its GDP per capita decrease in recent years as its dependency ratio rises. It is clear that Brazil and India are facing a far riskier aging predicament, as they are having to deal with an aging population amidst only minor GDP growth. Other developing countries such as Costa Rica and Indonesia, which are projected to have old-age dependency ratios of 41.6 and 27.3 by 2050 respectively, will likely face similar economic challenges to India as they too have a relatively low GDP per capita.

To further emphasize India's unique role in the global aging trend, it is critical to build an understanding of why GDP growth is both necessary to address India's aging but also potentially threatened by it. In India, as in other countries, elderly people consume more than they produce in economic output. However, this deficit is not met by public transfers such as welfare or social security. Regardless of how this deficit is financed, it poses a problem for the economy as the old-age share continues to grow. Still, the means of financing matters, as a push for greater social security would require the working population to increase economic output to provide for the growing old-age population. In India, public transfers only account for five percent of the old age deficit, and the main pension scheme that India has only provides a mere 200 rupees per month to elderly people who live in poverty (Ladusingh 2012).

Additionally, while Indian culture and tradition suggest that the elderly are taken care of by their kin, families spend more on their young than on elderly (Dommaraju 2015). Thus, a large portion of India's elderly population is forced into financial independence. As a result, in a

country where the majority of people work in the informal sector with no defined pension or retirement guidelines, a large share of elderly Indians are still working: in 2012, 38.9% of men, and 10.9% of women were employed. Within these numbers, 68% of men and 82% of women were working out of economic necessity (Dommaraju 2015). Additionally, 80.4% of elderly work in the primary sector, in industries such as agriculture, forestry, and fishing (Roy and Barua 2023). These statistics do not properly account for rural or destitute elderly, as they are often not part of aging studies. As the Indian economy shifts away from agriculture and other informal work that employs elderly people more than physically arduous or technologically demanding jobs in other sectors, many elderly Indians are struggling to find work to support their consumption habits (Vera-Sanso 2007).

This is precisely where GDP growth comes into the picture. In order to prevent massive elderly populations in India from falling into or remaining in poverty, the country must establish a strong social safety net that provides income to such people. However, building out a public safety net amidst a rapidly aging population requires GDP growth to expand the pool of economic resources available to provide people with sufficient income. This economic burden, in turn, falls on working-age people. As fertility rates in India continue to plummet, 25% higher than the global average in 1960 and 14% lower than the global average in 2021, the pool of new entrants into the workforce is undoubtedly shrinking. As financial need from the elderly is growing, and the relative pool of those who could help contribute to a more robust national welfare scheme is shrinking, the issue becomes clear.

Additionally, establishing a more robust social safety net requires effective taxation. In 2016, India's tax-to-GDP ratio was lower than that of developed nations such as the United States and United Kingdom, developing nations such as Mexico and South Africa, and the world

average (Ghuge and Katdare 2016). This low ratio is concerning, and serves as an indicator that India's tax policy is not capitalizing on income that is being generated in the economy. This becomes more clear when looking at India's current tax structure: in 2023, citizens earning less than 7 Lakhs Rupees, equivalent to around $8,500, do not have to pay any income taxes (Jaiswar 2023). However, the GDP per capita in India is only around $2,200, meaning that many earning well above the national average do not contribute any amount in taxes. While this lack of taxation is concerning, it can pave the way for political reform. The Indian government must reform its taxation policy to ensure that its relatively wealthier citizens are paying taxes in order to provide elderly support as the old-age dependency continues to rise.

This study seeks to fill a gap in the literature by honing in directly on the relationship between GDP growth and old age in India. I have conducted a district-level study to analyze the correlation between the percentage of people over 65 in a given district and that district's GDP growth over a six-year period between 2007-2013. I conducted this study with 229 separate districts in order to find geographical patterns and analyze where old age is making the largest economic impact. In assessing GDP growth, I looked at the primary, secondary, and tertiary sectors individually as well as GDP as a whole. Additionally, I also separately analyzed the impact of an aging population on the development of infrastructure such as roads and banks, using infrastructure growth as an additional metric to assess the impact of a growing elderly population.

This study found a positive significant effect of old age share on GDP growth in the secondary sector and a negative effect of old age share on road growth and bank growth in the period between 1991-2000. Additionally, a positive effect was found on road growth during the period between 2011-2015.

The rest of this paper will proceed as follows: Section II will discuss recent literature related to this topic and where this study fits in, Section III will analyze the data and highlight key trends in the summary statistics. Section IV will present the empirical results of this paper, Section V will discuss further research and policy implications, and Section VI will share concluding remarks on this study's findings.

II. Literature Review

In recent years, there has been much empirical focus on aging populations and their economic implications. Rajan, Sarma, and Mishra (2003) highlighted this trend in India, pointing at fertility declines and life expectancy increases as the main drivers behind the rapidly aging population. The authors' main contribution to previous literature was their projection for elderly population share. By dividing India into six major regions and using census data from 1991, they predicted a 12% elderly share in 2031 and a 17% share in 2051. Additionally, they found that the Southern and Western regions of India were expected to see the largest increases in old-age dependency. The in-country variation is significant, as some parts of India will face a greater challenge than others in adjusting. This disparity may actually signal optimism, however, as the Western and Southern parts of India are slightly wealthier than other regions and may be better suited to handle the economic challenges of an aging population.

This correlation between aging and the relative wealth of an area is not coincidental. As highlighted in Bloom, Canning, and Sevilla (2001), declining birth rates lead to less economic focus on the younger population through investments into areas such as health and education. This phenomenon, known as the demographic dividend, allows more attention to be placed on the working-age population in generating economic output. Areas that saw this age structure shift

earlier, such as countries like Japan in Southeast Asia, are now much wealthier than others who are still going through a transition in age structure. This is also the case in India; Aiyar (2001) found that states such as Maharashtra and Karnataka saw an increase in their per-capita income ranks relative to other states between 1971 and 1996, and Tekchandani (2023) shows that those two states had a relatively high old-age share in 1991. This indicates that there may be a pattern of older areas growing wealthy before younger areas.

Bhattacharya (2005) adds to this discussion by outlining some of the economic and social implications of an aging population. For example, the author addresses several concerns regarding policy that must be put in place to adapt to such a rapidly growing old population. He attacks the current pension and social security systems along with the lack of healthcare facilities, highlighting avenues of reform to caution against increasing poverty and sickness that may be inevitable if elderly people are not financially supported by the government. Others have also contributed to an understanding of the economic tendencies of elderly individuals, such as Dommaraju (2015) who found that over half of Indians continue to work after the age of 60, and Vera-Sanso (2007) who found that the majority of working elderly Indians continue to participate in the workforce out of financial necessity.

While many have studied the causes and effects of aging populations on the economy, fewer have looked specifically at GDP growth and even less have analyzed this relationship in India. Prskawetz et al. (2004) began to look into the relationship between age structure and growth in India, and Nagarajan, Teixeira, and Silva (2016) contributed to the intersection of aging and economic growth by presenting a framework through which the relationship can be understood. In their discussion, they focus on three key connections between aging and growth:

elderly people consuming more than they save, providing for elderly through public social expenditures, and ensuring that there is enough human capital to support economic growth.

Additional studies have examined some of the more macroeconomic trends and policy implications that come along with an aging population. Mason and Lee (2017) discuss how the sources of monetary support for elderly vary drastically in different regions of the world. The authors find that in the United States and Asia, a large portion of elderly support comes from labor income while in Europe the majority comes from public transfers.

Bloom (2008) also analyzes growth, but through the lens of behavioral responses to population aging. The author argues that as populations age, economies can continue to grow if countries encourage individuals to save more for retirement, participate more in the labor force, and immigrate from countries with a labor surplus to those with a labor deficit. If people were to work for longer given an understanding of average longevity, the economy might actually benefit. This is an important observation for India, where the economy is shifting from one based on agriculture to a more modern, urbanized economy utilizing technology that requires much less manual labor. This transition is taking place as the population is getting older, which might increase labor force participation rates.

Though the aforementioned authors clarify the theoretical connections between aging and economic growth, Pham and Vo (2021) take this one step further by quantifying the impact that a growing old age share has on economic growth. Using a quantile regression approach to study 84 different developing countries, the authors found that in the long term, having a larger share of population above 65 years is positively correlated with economic growth while youth age share was found to have a negative correlation with growth. However, this result is not as prevalent as the contrary, as most studies in this realm have shown a negative correlation between growth and

old age. For example, in a study conducted on the United States' population trends, Maestas, Mullen, and Powell (2022) found that from 1980-2010, each 10% increase in old age share decreased GDP per capita by 5.5% due to factors such as slow employment growth and labor productivity growth. Several others have also found this relationship to be negative, such as Bloom et al. (2015) and Narciso (2010) who focus on social security burdens and international capital flows respectively. The former author addresses the stresses that a larger elderly population places on the labor force to provide, and focuses on policy responses that might help alleviate these concerns. Narciso (2010) finds that both the current and future age structure of countries, as well as other demographic factors, have a crucial impact on foreign direct investment and foreign portfolio investment.

The discrepancy between Pham and Vo (2021) and Maestas, Mullen, and Powell (2022) may hint that a growing elderly share can benefit developing countries while hurting developed ones. One potential explanation for this phenomenon is the differences in age structures over time between developing and developed countries as outlined in Bloom, Canning, and Fink (2011). The authors explain that between 1950 and 2005, birth rates dropped at a much faster pace than population aging in developing countries. The population between 0-14 dropped from a 38% share to 31% while the population of 60+ only increased from a 7% share to 8%, resulting in a growth in the working-age population share. On the contrary, during the same period in developed countries, fertility rates declined and the population aged at nearly identical rates, resulting in only a minimal shift in the working-age share. A similar pattern is reflected in the predictions for 2005 to 2050, as the working-age share in developed countries is expected to drop by nearly 10%. Therefore, developing countries are likely able to capitalize on the demographic dividend outlined in Bloom, Canning, and Sevilla (2001) which allows them to concentrate on

the working-age population while developed nations have to dedicate more economic resources towards their elderly population.

With the clear connections between economic growth and aging populations, India faces a unique issue of a rapidly aging population alongside GDP growth that pales in comparison to other developed and developing nations. Thus, India will face the challenge of finding ways to boost GDP growth as the elderly population share continues to grow, as the country is not accumulating the wealth currently to support such a drastic shift in age structure.

This study adds to the current literature by highlighting the geographical aging pattern most prevalent in the South and West regions of India. The empirical analysis finds a positive significant effect of aging on GDP growth in the secondary sector and a negative effect on road growth and bank growth between 1991-2000. Meanwhile, a positive effect was found on road growth during the period between 2011-2015. These results will be explained further in the following sections.

III. Empirical Analysis

Data

The data in this study was obtained from two main resources: Indian state-level Census Data from 1991, 2001, and 2011, and district-level data from the International Crops Research Institute for the Semi-Arid Tropics. From the first source, I pulled age returns data to find the number of people at each age in every district. From the second, I found data on the number of banks, road length in kilometers, and GDP for each of the districts. One limitation here was that only 300 districts had available data, and within these 300 only 229 had data for all of the categories that I needed for statistical analysis. Within GDP, I pulled data from the primary,

secondary, and tertiary sectors. My motivation in doing this was to understand the breakdown in GDP between sectors in different districts. For example, the district of Salem in Tamil Nadu, which houses the large city of Salem, has a significant portion of its total GDP from the tertiary sector whereas a small rural district such as Shajapur in Madhya Pradesh generates a majority of its GDP in the primary sector. This is especially important for my analysis, as rural areas in India have the highest proportion of elderly working people relative to other areas.

The bank and road data I collected was available between 1966 and 2015, thus aligning with the age data from the census. However, the GDP data at the district level was only available between 2007 and 2013, with 2004 being the base year for the constant dollars. Therefore, my GDP analysis was limited, as I could only analyze the effect of the 2001 age data on the period of GDP growth between 2007 and 2013.

Descriptive Statistics

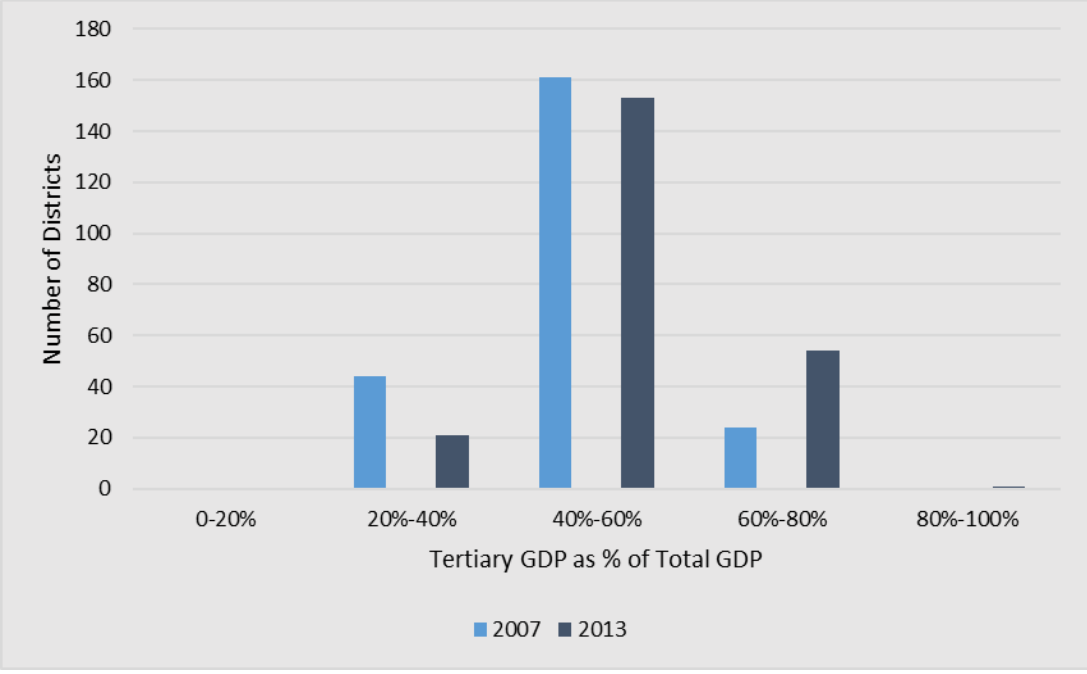
The summary statistics for all key variables are shown in Table A1. Out of the 229 districts analyzed in this study, the average starting real GDP per capita values in 2007 was 24,672 rupees. By 2013, the average rose to 40,716 for an average yearly increase of 10.84%. However, this data is skewed towards larger cities that experienced more total GDP per capita growth, as they have larger populations that contribute to greater economic output. These cities also house large businesses and corporations that generate significant wealth within the tertiary sector.

Within GDP per capita, I also analyzed the primary, secondary, and tertiary sectors. For this data sample, the average primary sector share of total GDP was 25.7% in 2007, dropping to an average of 21.7% in 2013. Likewise, the average secondary sector share dropped from 27% in

2007 to 25.5% in 2013, while the tertiary sector share average rose from 47.2% to 52.7%. This 5.5% average increase in the tertiary share as a component of total GDP reflects the trend towards industrialization and modernization in India, as the tertiary sector is growing rapidly while the primary sector is shrinking. This significant rise in the tertiary sector is displayed in Figure 1, while the decline in the primary sector is shown in Figure A2. Figure A10 paints a clear picture of what is happening in India, as rural areas in the Central and North regions have seen the largest decline in annual primary sector growth. Meanwhile, as shown in Figure A12, the tertiary sector has grown annually between 2007-2013 in just about every district.

This trend towards the tertiary sector reflects the idea that over recent years, even smaller suburban and rural districts that once only had agricultural industries have largely moved towards other sectors. According to a study from 2014, higher education in rural areas is leading more people to seek jobs outside of the agricultural industry. However, this demand is not being met by much job availability. Instead, educated workers seeking mobility within the labor market have had to turn to mostly male-dominated construction roles to escape the agricultural industry (Thomas 2014).

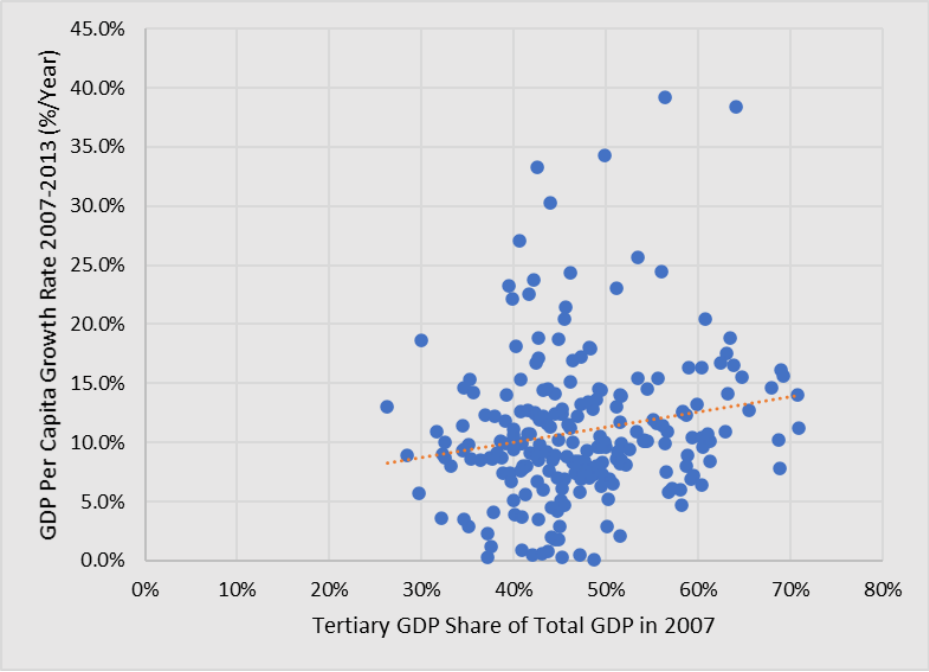
Figure 1: Tertiary GDP Share in 2007 and 2013



Source: International Crops Research Institute for the Semi-Arid Tropics, Author Calculations

Additionally, in 2007, over 140 of the 229 districts in this study had a primary sector share between 20-40%, and only 68 had a primary share lower than 20%. By 2013, this had changed drastically, as 110 districts had primary sector shares lower than 20%. On the other hand, in 2007, the tertiary sector represented 20-40% of total GDP for 44 districts, and 40-60% of total GDP for 161 districts. By 2013, only 21 districts had tertiary shares between 20-40%, while 153 had tertiary shares between 40-60% and 54 between 60-80%. Figure 2 also highlights the relationship between tertiary share and the total GDP per capita growth rates, displaying a low but positive correlation of 0.183 that indicates higher GDP per capita growth in districts that had larger tertiary shares in 2007.

Figure 2: Plot of Tertiary Share in 2007 Against GDP per Capita Growth Rate



Source: International Crops Research Institute for the Semi-Arid Tropics, Author Calculations

One explanation for the massive growth in the tertiary sector is the growth of banks. Among the 229 districts in this study, bank growth was most prevalent between 1991 and 2000, as banks grew at an average yearly rate of 37.83%. However, between 2001-2010, as well as 2011-2015, banks only grew at an average yearly rate of 4.14% and 1.26% respectively. This substantial growth in the first period is likely due to India relaxing its policies on foreign banks holding a presence in the country. Since 1991, more than 25 foreign banks have received full banking licenses in India. This commitment to expanding banking was further bolstered in 1997 under the WTO Financial Services Agreement, in which India committed to adding 12 foreign bank branches in each subsequent year (Panagariya 2004). This dramatic growth in banks during the 1991-2000 period is shown by Figure A4. While banks grew significantly in most districts, growth was especially prevalent in the largely rural North and Central regions. However, in the following period between 2001 and 2010, bank growth was dominated by a select few regions dispersed throughout the country, as displayed in Figure A5. Still, banks in rural India have grown rapidly and play a massive role in rural development and literacy growth. Since the Rural Regional Banks (RRB) Act was passed in 1976, the amount of banks in rural areas has grown immensely (Gautam and Kanoujiya 2022).

On the contrary, the strongest period of road growth was 2001-2010, where the amount of roads by kilometers grew at an average of 9.66%. Roads only grew at an average of 3.78% between 1991 and 2000, and at 1.25% between 2011 and 2015. The road growth during the 2001-2010 period is shown in Figure A8. It is clear here that road growth was most prevalent in rural Central India, where transportation was previously not accessible. Roads not only provide a metric to understand infrastructure investment, but are also a critical tool allowing mobility between districts and states. A 2017 study found that roads were one of the primary drivers in

growing agricultural income, which is the most important factor in "rural poverty alleviation" (Chatterjee 2017).

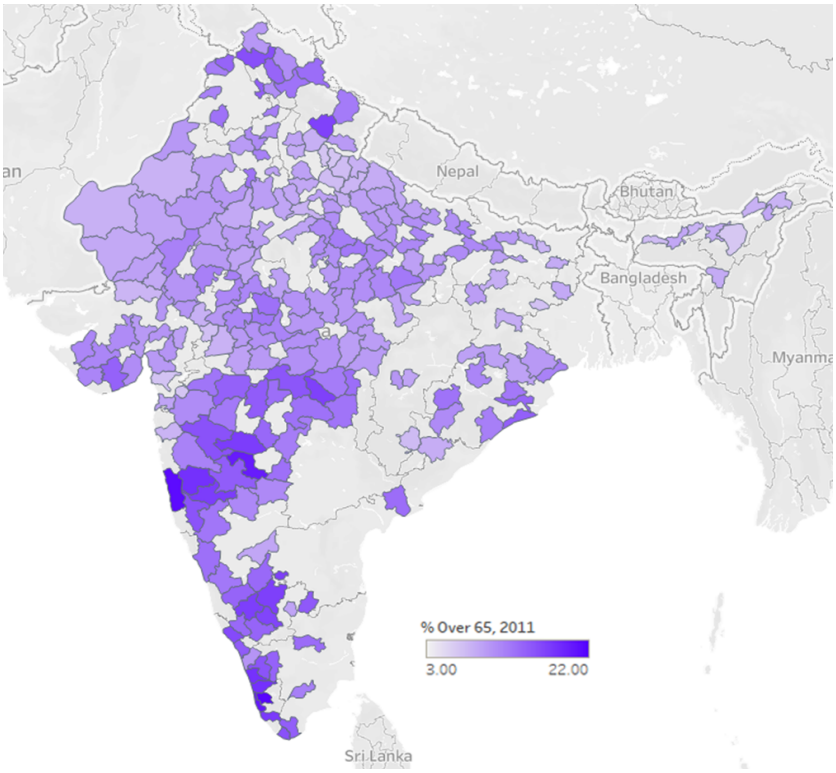
The reasoning behind the notion that bank growth peaked before road growth can be at least partially attributed to the fact that India started only its first National Highway Development Project in the late 1990s. This was in part an effort to imitate China, who had already established a strong highway infrastructure fueling its economic rise (Bathla 2022). In an effort to speed up road growth, the Indian government introduced the National Highways Authority of India (NAHI) in 1995. Its initial goal was to expand road infrastructure in primarily rural areas, which explains the massive growth in Central India during the 2001-2010 period. Thus, there is no concrete connection between the chronological staggering of road and bank growth other than the fact that the government prioritized growing banking earlier. Still, in both efforts, there was a key focus on first providing infrastructure to rural areas that were not previously integrated in the national economy.

Bringing the GDP, banks, and roads data back to the central importance of this study is the old age data. Based on availability, I calculated the percentage of people over 65 years old in each district in 1991, 2001, and 2011. The mean was 8.3% in 1991 with a range of 3.9% to 14.7%, 9.9% in 2001 with a range of 5.4% to 18.6%, and 11.4% in 2011 with a range of 6.5% to 21%. This data corresponds with the literature on the aging population in India, and while this study only represents a twenty year period of aging, the old age dependency ratio is expected to grow even faster in the coming decades. As shown below in Figure 3, the majority of elderly people tended to reside in the South and West regions of India in 2011, with strong presences in some Northern districts as well. This makes sense, as these two regions in India are home to the largest cities and a majority of the wealthy Indian population. These areas also have much more

modern infrastructure with regards to elderly care, banking, and transportation. Simply put, they are more ideal living spaces especially for those needing assistance or additional care.

Additionally, comparing age data to GDP growth, Figures A16 and A17 highlight the correlation between the old-age dependency ratio and GDP. Figure A17 explains the notion that those with a higher old-age dependency ratio in 2001 experienced a higher average GDP per capita growth during the 2007 to 2013 period, while Figure A16 displays a positive correlation between the old-age dependency ratio in 2001 and GDP per capita in 2007. Thus, not only were older districts in India wealthier to begin with, but they also grew at a higher rate over the studied period. While these positive correlations don't necessarily indicate causality, as older people may be concentrated in wealthy, high-growth areas, they nonetheless point to the idea that areas with a higher old-age population share experienced more growth than those with a lower one. The relationship between old age and GDP per capita growth will be expanded upon in the next section, both for total GDP and in the individual sectors.

Figure 3: Percentage of Population Over 65 in 2011



Source: Indian Census Data, Visual Made by Author

Empirical Model

For this study, I performed ten separate linear regressions. They serve to help understand the effect of old age population share on the development of roads, banks, and GDP per capita growth in each of the three sectors as well as total growth. As noted in the Data section, the GDP regressions were only done using old age data from 2001, as the GDP data is between 2007-2013 and thus the idea behind the regression is to understand how the percentage of old people in 2001 influenced growth in GDP throughout the latter portion of the decade and into the following decade. The road and bank regressions, however, are using old age data from 1991, 2001, and 2011. The GDP growth regressions were run using the form

(1) $$Y_i^t = \beta_0 + \beta_1 X_i^t + \beta_2 Z_i^t + \varepsilon_i^t$$

where *Y* represents the outcome variables average total GDP per capita growth rate, average primary GDP per capita growth rate, average secondary GDP per capita growth rate, and average tertiary GDP per capita growth rate between 2007 and 2013. *X* is the independent variable of the percentage of people over 65, or old age share, in a given district, *i* at time *t*, while *Z* is the control variable of GDP per capita level in 2007. This control is due to the fact that poorer areas tend to grow faster and "catch up" with wealthier areas.

Similarly, for the road and bank growth regressions, the equations take the form

(2) $$Y_i^t = \beta_0 + \beta_1 X_i^t + \varepsilon_i^t$$

where Y represents the outcome variables of average road growth rate and average bank growth rate during three separate time frames: 1991 to 2000, 2001 to 2010, and 2011 to 2015. X is the independent variable of the percentage of people over 65, or old age share, in a given district i at time t. For these regressions, no controls were used, as I found no literature regarding a "catch up" effect with either roads or banks.

These regressions present the foundation to understanding how the aging population in the 2000s correlates to the amount of road, bank, and GDP growth in the 229 sample districts. While this sample does not represent the entirety of India, the regressions should nonetheless help indicate which areas old age has the strongest impact in. Initially, I aimed to incorporate the Solow growth model into this study by controlling for the percentage of the population under 18, however the collinearity between the old age and young age variables (0.83) was too high to include the additional variable in the regression.

For each of the GDP regressions, I aimed to understand whether the percentage of people over 65 in a given district inhibits GDP per capita growth. I also analyzed whether old age share specifically inhibits growth in the primary, secondary, or tertiary sectors, controlling for a catch-up effect using the starting level of GDP per capita in 2007. For the bank and road regressions, I sought to understand whether the old age share in a given district discourages infrastructure investment. The next section will detail the findings from each regression and the statistical significance of old-age share on GDP, bank, and road growth.

IV. Results

Empirical Results

This study performs many linear regressions in order to analyze the impact old age population share has on the growth of banks, roads, and GDP per capita in the primary, secondary, and tertiary sectors.

The first regression I ran seeks to analyze the relationship between old age share in 2001 and the total GDP per capita growth rate between 2007 and 2013. I controlled for the GDP per capita in order to factor in the catch-up effect. Thus, I regressed the GDP per capita growth rate on the old age share in 2001 using GDP per capita in 2007 as a control. The results are shown in Table A2. While previous literature has found both positive and negative effects on the impact of old age share on GDP per capita growth, this regression found a small positive effect (0.329) for the GDP growth rate between 2007 and 2013. However, the positive correlation was not significant at the 95% confidence level. When the control variable was removed, the positive coefficient was slightly lower, but still not significant at the 95% confidence level. To further examine the lack of significance, I tested whether the outliers were causing a lack of power. Still, the positive coefficient remained without significance. One possible explanation for the lack of significance in the results can be seen in Figures A13 and A15. Looking at these maps, it becomes clear that the districts that aged the quickest are largely in the West region of India, while GDP growth was more spread out across the nation. There were certain hotspots of GDP growth, both total and within each sector, but overall a majority of districts experienced massive economic growth. Aging was far less scattered, as most districts that saw their population age dramatically were mostly concentrated in the South and West regions.

Similarly, the second regression sought to analyze the impact that old age share in 2001 had on the growth rate of the primary sector's share of GDP per capita during the period of 2007-2013. To analyze this, I regressed the growth rate of the primary sector on the old age share in 2001, controlling here for the starting level of primary sector GDP per capita in 2007. I hypothesized that the relationship would be negative, based on the massive decline of the primary sector during a period of aging. Additionally, it has been shown that wealthier areas tend to age faster, and these wealthier areas largely house economic activity in the tertiary and secondary sectors. Thus, I did not expect old age share to positively correlate with the growth in the primary sector. However, previous literature also suggests that an overwhelming majority of elderly people participating in the labor force in India work in the primary sector. This regression yielded a negative coefficient of -0.27, meaning that districts with a higher percentage of elderly are more likely to have a smaller primary sector. This result, displayed in Table A3, corresponds with the dramatic decline of the primary sector between 2007-2013 and the simultaneous aging trend in most districts. Still, the result was not significant at the 95% confidence level, even after accounting for outliers. Given the fact that the majority of elderly people tend to reside in the Southern and Western parts of India, I was curious to see if there was any internal migration of elderly people away from rural areas towards more urban districts. No pattern of this was found, thus returning to the understanding that aging corresponds with wealthier areas.

The third regression I ran investigated the impact that the old age share in a given district had on the growth of the secondary sector during the 2007-2013 period. Unlike the primary sector which saw an overwhelming decline, the secondary sector grew in many districts and became less prominent in only a handful of districts. Still, I hypothesized that because the secondary sector largely consists of manufacturing jobs, elderly people were less likely to take

on roles in this sector. Therefore, I expected to see a negative relationship between the variables. I regressed the growth rate of the secondary sector's GDP per capita between 2007 and 2013 on the old age share in 2001, controlling for the initial level of secondary GDP per capita in 2007. Contrary to my hypothesis, this regression yielded a positive coefficient of 0.798 significant at both the 95% and 99% confidence levels, as shown in Table A4. This finding also disagrees with literature explaining the impact of the expanding manufacturing sector on decreased elderly labor force participation rates (Dhar 2014). However, the result can be explained by looking at Figures A11 and A15, as it is clear that areas with large concentrations of elderly people in 2001 were also the areas in which the secondary sector grew between 2007 and 2013.

The final GDP regression I ran looked at the relationship between growth in the tertiary sector and the old age share. Again, the hypothesis here was not clear cut; the literature suggests that elderly are concentrated in wealthier areas, which tend to have a prominent tertiary sector. At the same time, previous literature also conveys the notion that elderly people have trouble working in the secondary and tertiary sectors in roles that can involve technical proficiency and digital literacy. It is important to note, however, that a lack of labor force participation in a given sector does not necessarily mean that elderly people would leave that area. In fact, elderly people may want to live in a district with a strong tertiary sector as it likely has better banking, healthcare, and transportation infrastructure. I regressed the growth rate of the tertiary sector on the old age share in 2001, controlling for the initial level of tertiary GDP per capita in 2007. This regression found a small positive effect of 0.129. This finding, displayed in Table A5, makes sense given the positive correlation between total GDP and tertiary sector GDP already established in this paper. This regression was not significant at the 95% confidence level, even after factoring in the impact of outliers.

My second major hypothesis in this study was that a strong presence of elderly individuals in a district would discourage infrastructure investment. As populations continue to age and the proportion of working age people shrinks, there is likely less need for added infrastructure. On the local level, a growing old age share could also reduce local savings, as consumption is higher than production for the majority of elderly people. And, elderly people are unlikely to participate in the manufacturing processes that facilitate bank and road growth, further leading to the prediction that a greater elderly share corresponds with lower rates of infrastructure growth. I conducted six regressions, three with the growth rate of banks as my dependent variable and three with the growth rates of roads over the periods of 1991-2000, 2001-2010, and 2011-2015. The results and interpretations of these regressions are detailed in the following paragraphs.

First, I looked at the impact of old age share on the growth rate of roads between 1991 and 2000. I regressed the growth rate of roads on the old age share in 1991, and found a negative effect of -0.395, as shown in Table A6. This regression indicates that districts with a larger old age share in 1991 saw less road growth in the following nine years. The regression was significant at the 95% confidence level. Similarly, I ran this regression with the road growth rates in both 2001-2010 and 2011-2015. For 2001-2010, using the old age share from 2001, I found a larger negative coefficient of -0.44, as displayed in Table A7, but the result was lacking significance. Finally, for 2011-2015, using the old age share from 2011, I found a small positive correlation of 0.06 (Table A8), significant at the 95% confidence level. This result runs contrary to my hypothesis on infrastructure investment. The significance of the road growth regressions can be explained by Figures A7 and A14. In the period between 1991-2000, the majority of road growth was taking place in the North region of India, while aging was mostly happening in the

West. However, during the 2011-2015 period, in which the regression constant was both significant and positive, the majority of road growth was in the West and the South, where populations were continuing to age at a rapid pace.

With bank growth, I also hypothesized that the presence of a large old age share would decrease investment into banking infrastructure. Similar to the road growth regressions, I regressed bank growth rates in 1991-2000, 2001-2010, and 2011-2015 on the corresponding old age shares in 1991, 2000, and 2011. For the 1991 regression, I found a strong negative coefficient of -3.95, meaning that the presence of old age in a given district greatly reduced the growth of banks in that district. The result was significant at the 95% confidence level, as shown in Table A9. This corroborates my hypothesis that old age discourages investment into banks. Although bank growth was most prominent in the 1991-2000 period, banking largely grew in areas without a strong old age presence. For the 2001-2010 and 2011-2015 regressions, I found negative coefficients of -0.44 and -0.06 respectively. However, these results, displayed in Tables A10 and A11 were not significant at the 95% confidence level, even after analyzing the impact of outliers.

With bank growth and old age, the significant result points to the possibility that the presence of elderly people takes away investments into banking infrastructure. However, the lack of significance in the other periods could be explained in part by the fact that districts that saw the most bank growth were not the same ones in which aging populations grew significantly. While districts in the North and West regions of India saw more bank growth than the rest of India, and the West was also subject to more of a rapid aging population, bank growth was ultimately a lot more spread out than aging was. This is also likely due to the fact that there was

a strong effort to grow banking in more rural parts of India, while the wealthier areas with cities, where more old people tend to reside, already had significant banking infrastructure.

V. Discussion

Though many of the results are not significant, this study confirms a positive correlation between old age and GDP growth in the tertiary and secondary sectors, and a negative correlation between old age and infrastructure investment with the exception of road growth in 2011-2015. This means that as India's population continues to age, there must be policies that facilitate ongoing infrastructure investment to drive economic growth. The understanding that a higher presence of elderly people correlates positively with GDP growth and negatively with infrastructure investment is not enough to fully grasp the aging problem in India, however, as there are a lot more factors to consider. For example, as the growth of the workforce continues to drop, there is a massive social security burden placed on working-age people. There are many more people who require social security, and less working to pay for this. Additionally, many Indians in rural areas still do not have adequate access or literacy to save money through banking institutions, and are not well supported by their families. Future research must analyze the implications of aging in the context of building out a robust social welfare system to protect the elderly and their families.

Beyond this study, there must be research done to understand how exactly the aging population in India is impacting the workforce. According to the Migration Policy Institute, India has the highest number of people emigrating with a postsecondary degree, and is now one of the top origin countries for United States immigrants (Singh 2022). While remittances to India remain high, and have continued to grow in the past ten years, it is clear that those theoretically

most qualified to contribute to the economy are leaving India for other opportunities. As the population continues to age and there are fewer people joining the workforce than before, emigration makes the issue even more pressing from an economic standpoint.

Additionally, work must be done to find an adequate method of providing elderly people with some income. As mentioned in Uppal and Sharma 2007, less than 11% of the Indian elderly population has any sort of pension. Today, the aging population and the benefits that the public pension system provides in India makes the current system financially insecure and potentially unstable in coming years (Goswami). There have been pushes for reform to the current pension scheme given the fact that the number of retirees is growing so quickly.

VI. Conclusion

As highlighted in this study, there is a negative and significant effect of old age on the growth of roads and banks between 1991-2000. Additionally, there is a positive and significant effect of old age on the growth of roads in 2011-2015. Meanwhile, there was no significance found in the positive correlation between the GDP per capita growth rate and the percentage of people over 65, except in the secondary sector. The results of the bank and road growth regressions, with the exception of road growth in 2011-2015, confirm my hypothesis that the presence of old age discourages investment into new infrastructure. The GDP regressions do not provide significant corroboration or refutation of my hypothesis, though the overall positive correlation between age and GDP growth in the secondary and tertiary sector point to the modernization that is taking place at a national level and especially in areas with a strong elderly presence. One possible limitation in this study was the sample size, given there was only district-level GDP and infrastructure data available for 229 districts. In the sample districts, it

was largely the case that the aging wave was taking place in cities in the West and South, confirming the predictions of Rajan, Sarma, and Mishra (2003), while GDP growth was more spread throughout the country.

Still, the elderly population is growing everywhere in India, not just in cities. In rural areas, where banks and roads are not as prevalent as in cities, districts may face the problem of maintaining output as more and more people leave the workforce and the fertility rate continues to decline. In cities with established infrastructure, elderly people will largely fare well, as they can still participate in the economy if they have any digital literacy.

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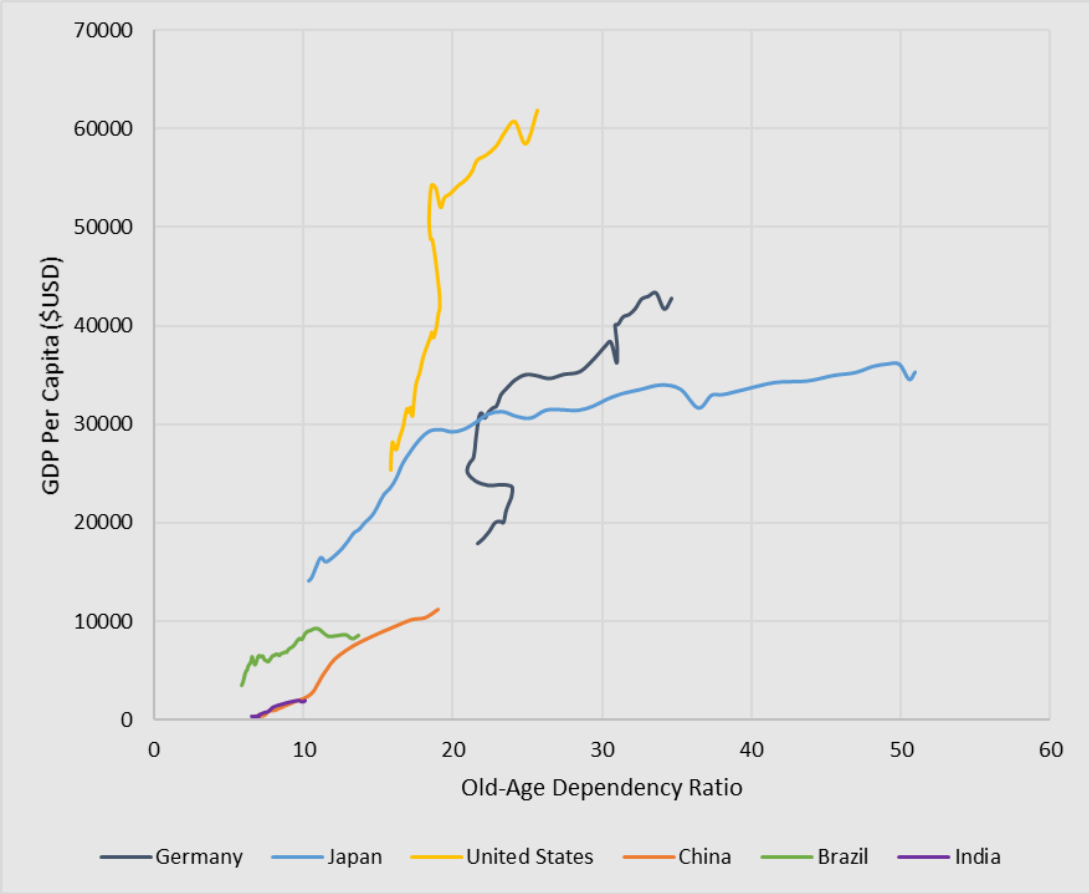
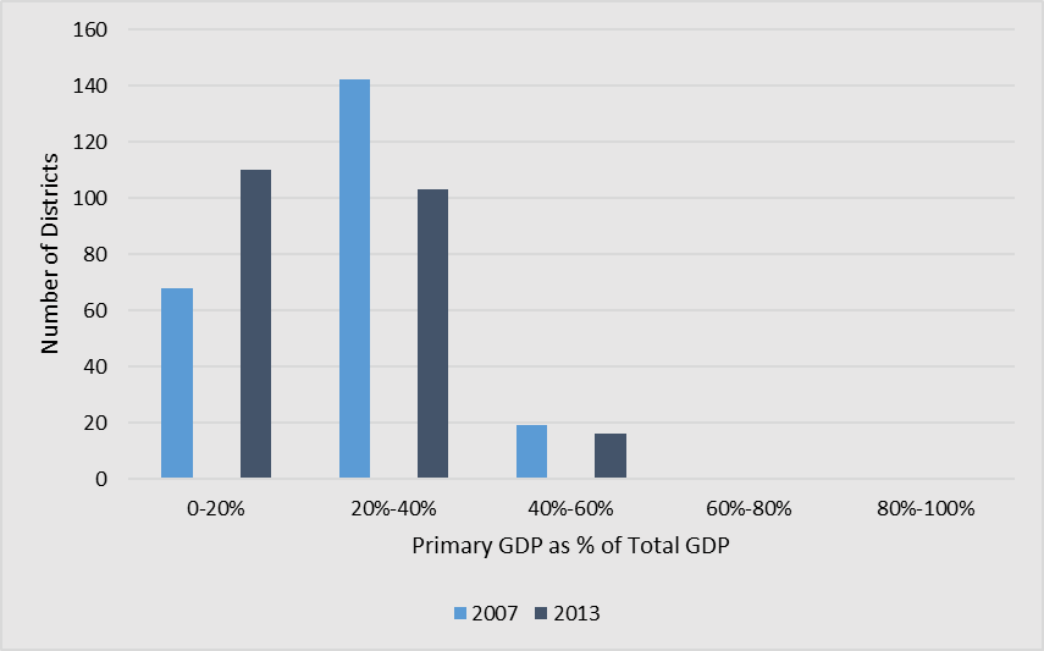
VIII. Appendix

Figure A1: Dependency Ratio v. GDP Per Capita



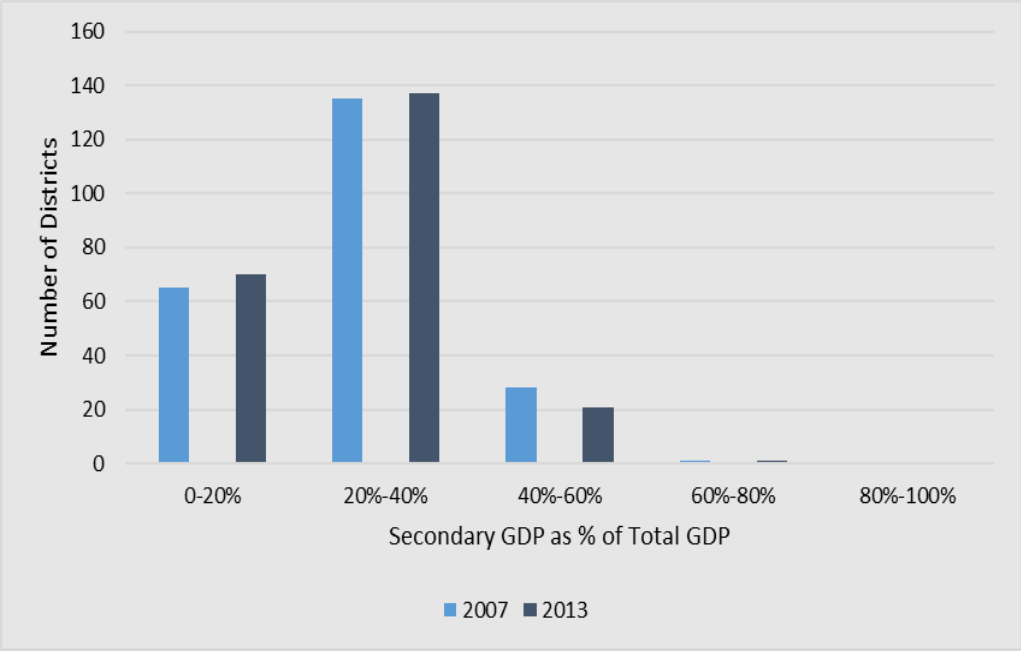
Source: World Bank, Author Calculations

Figure A2: Histogram of Primary Share of GDP as a % of Total GDP



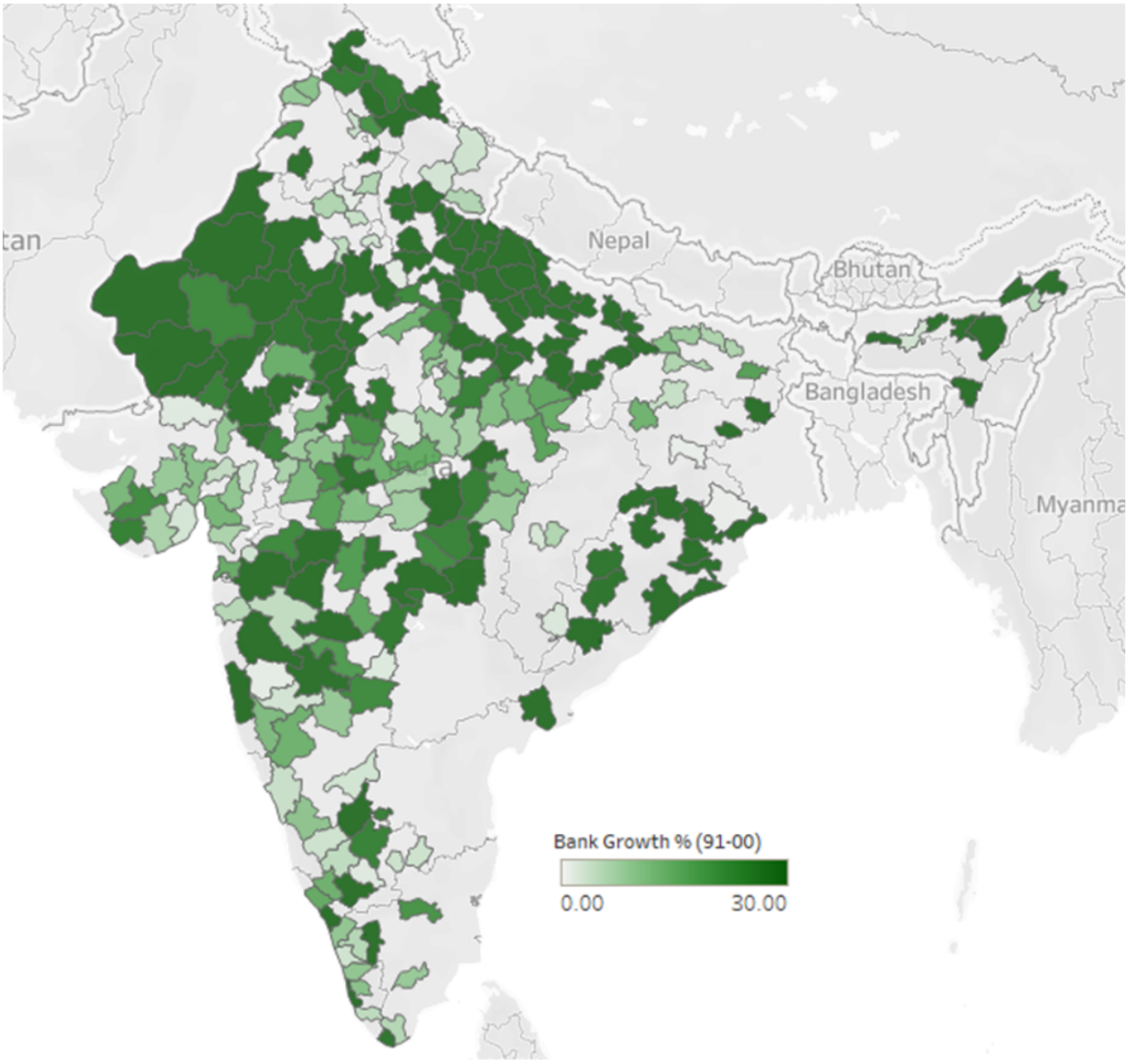
Source: International Crops Research Institute for the Semi-Arid Tropics, Author Calculations

Figure A3: Histogram of Secondary Share of GDP as a % of Total GDP



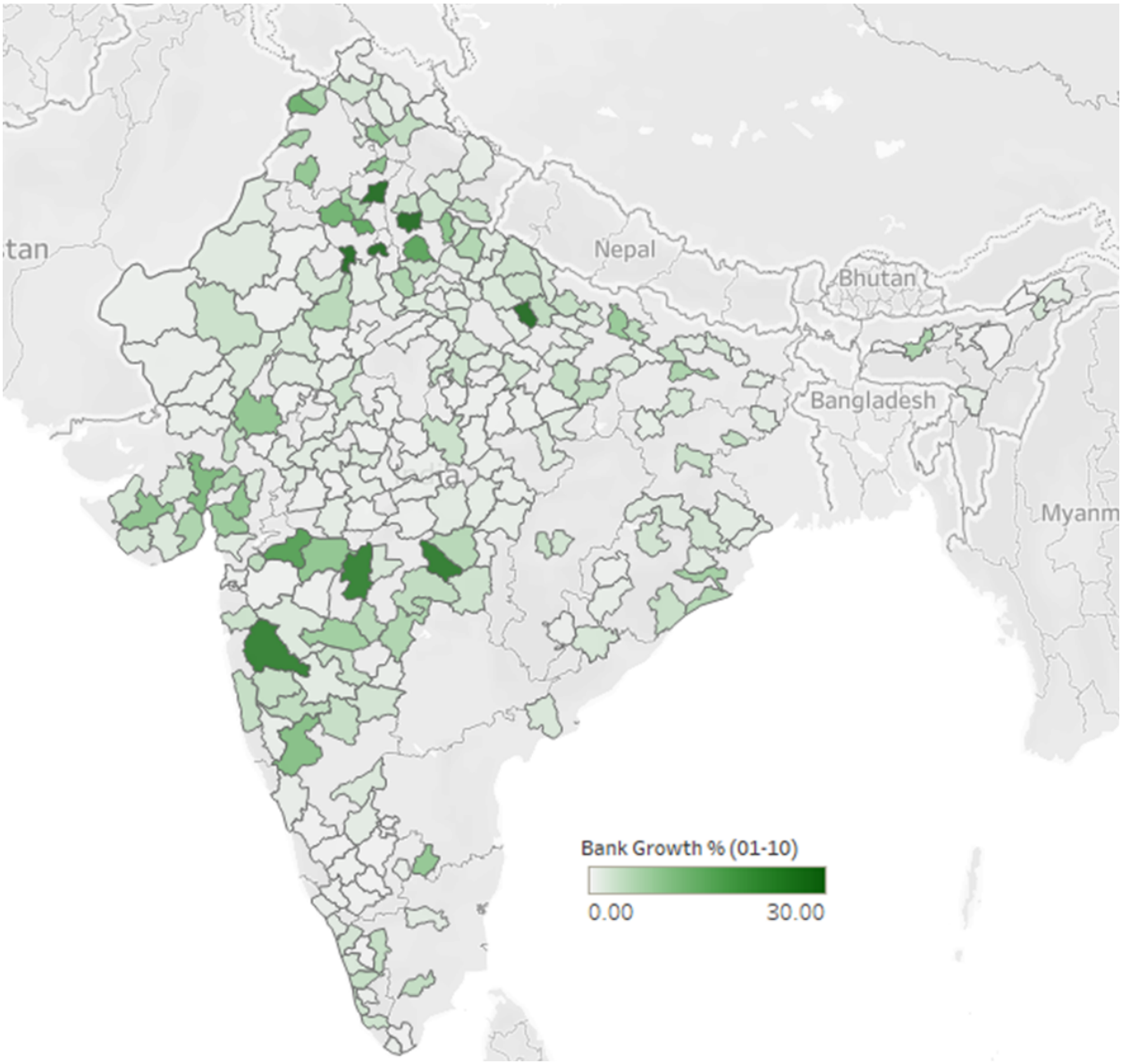
Source: International Crops Research Institute for the Semi-Arid Tropics, Author Calculations

Figure A4: Bank Growth Rate between 1991 and 2000



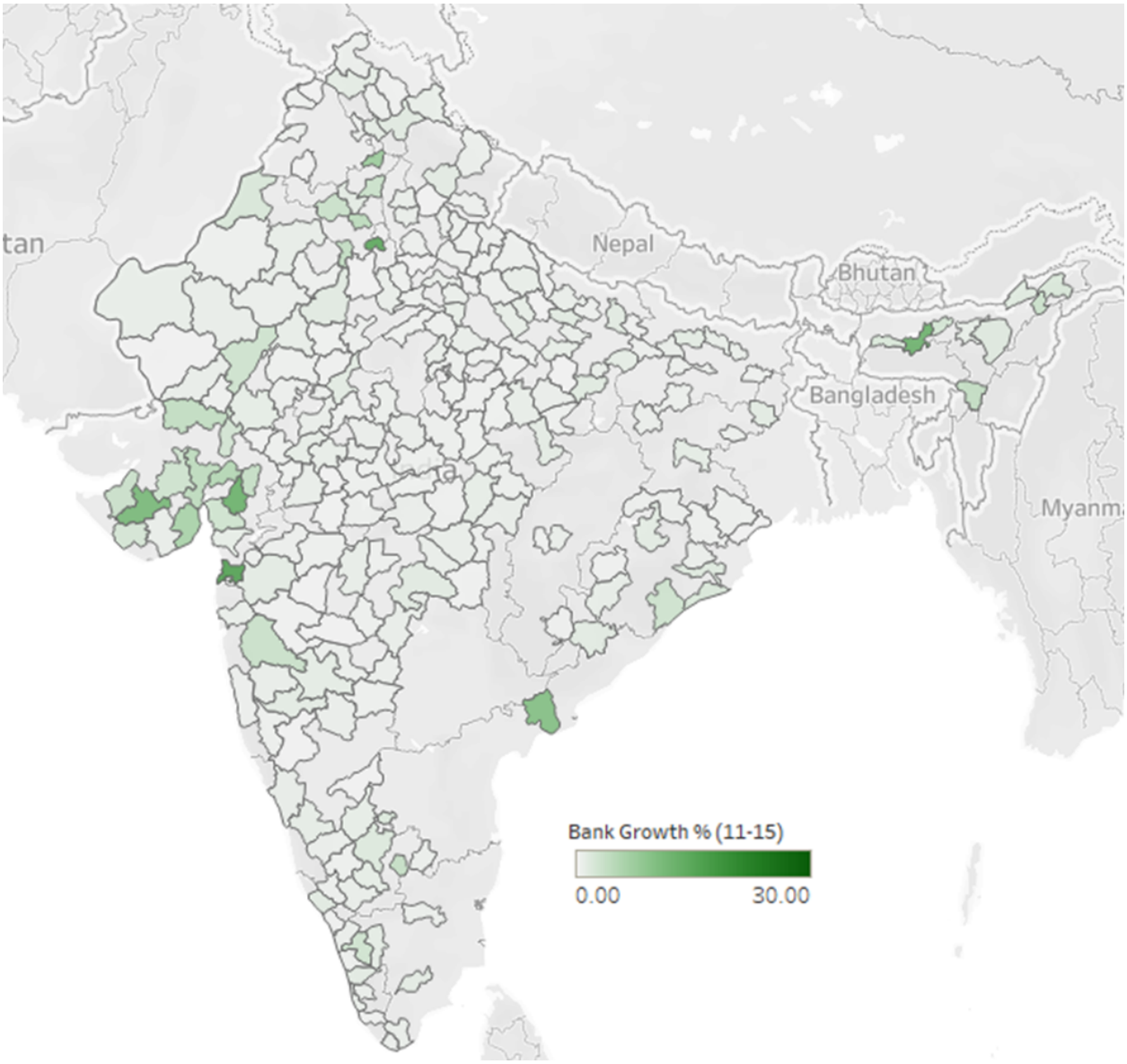
Source: International Crops Research Institute for the Semi-Arid Tropics, Visual Made by Author

Figure A5: Bank Growth Rate between 2001 and 2010



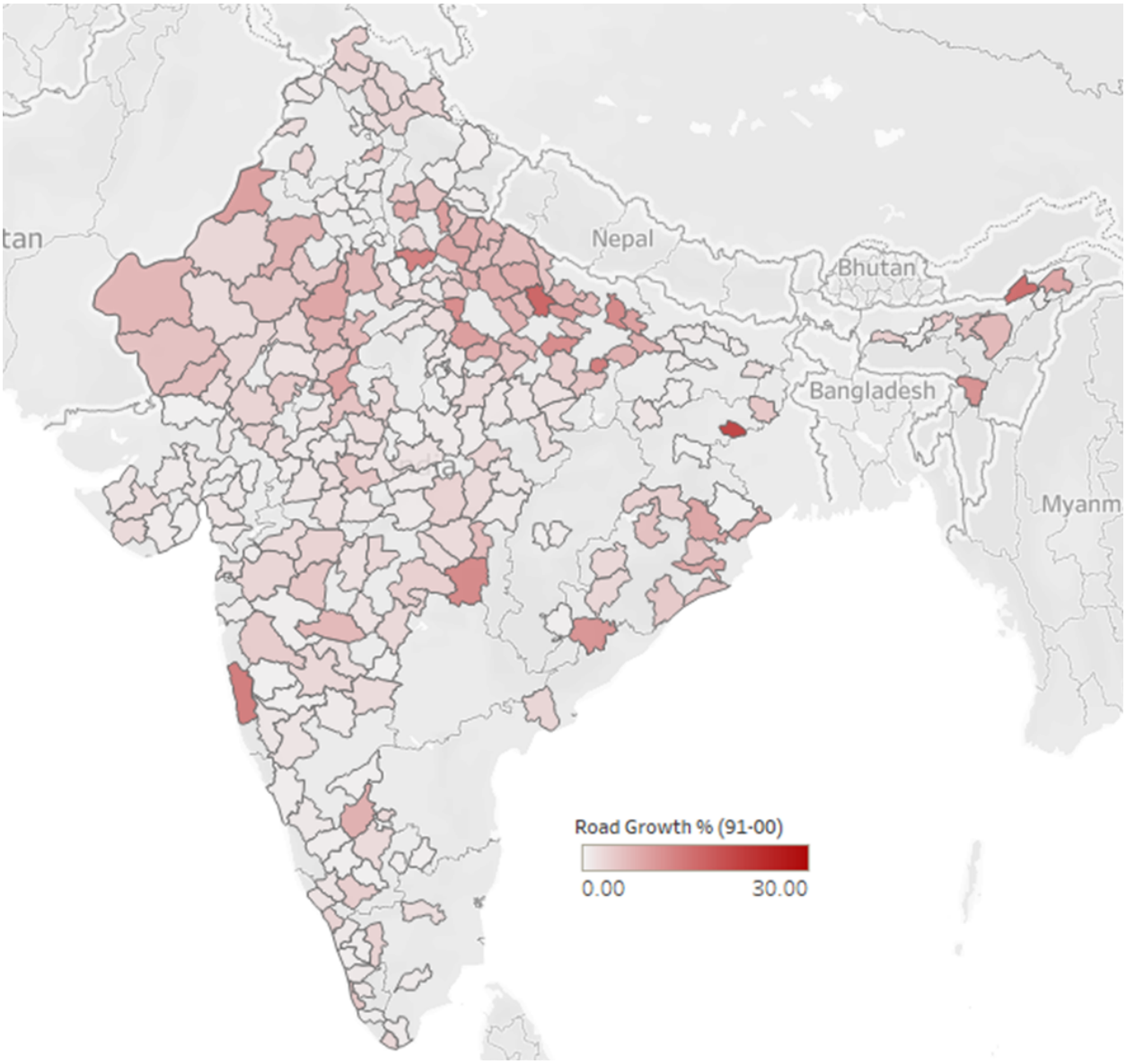
Source: International Crops Research Institute for the Semi-Arid Tropics, Visual Made by Author

Figure A6: Bank Growth Rate between 2011 and 2015



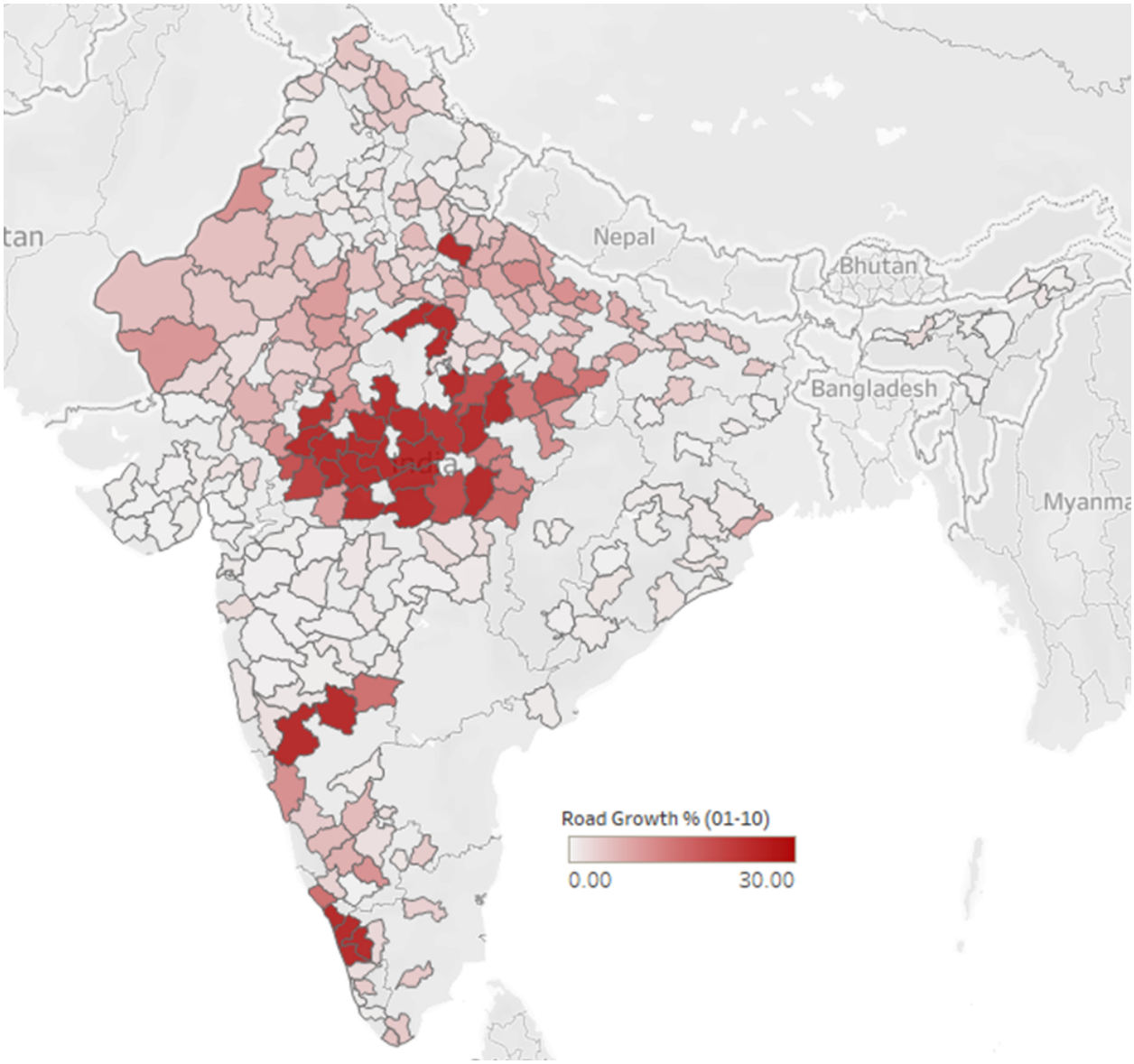
Source: International Crops Research Institute for the Semi-Arid Tropics, Visual Made by Author

Figure A7: Road Growth Rate between 1991 and 2000



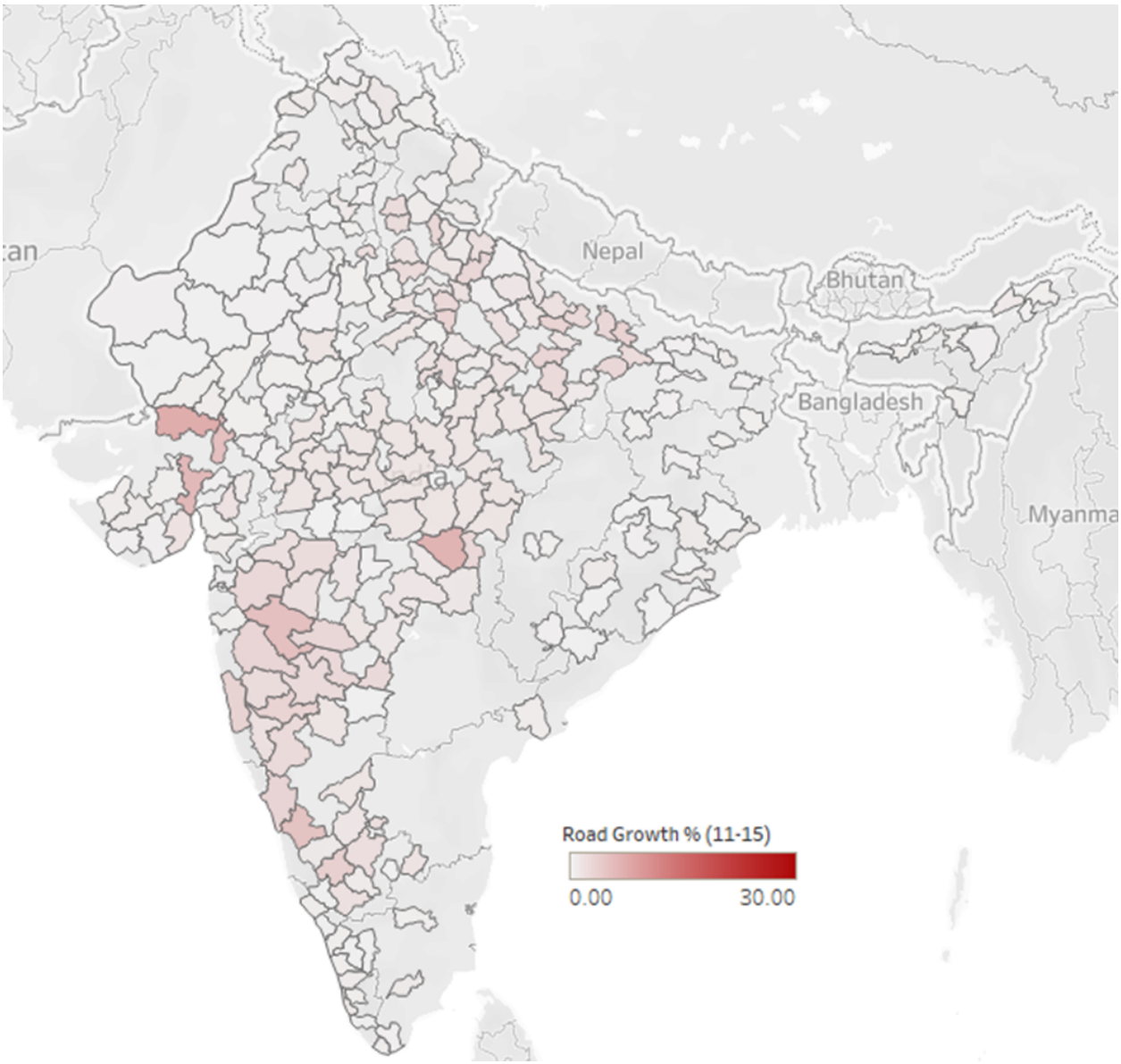
Source: International Crops Research Institute for the Semi-Arid Tropics, Visual Made by Author

Figure A8: Road Growth Rate between 2001 and 2010



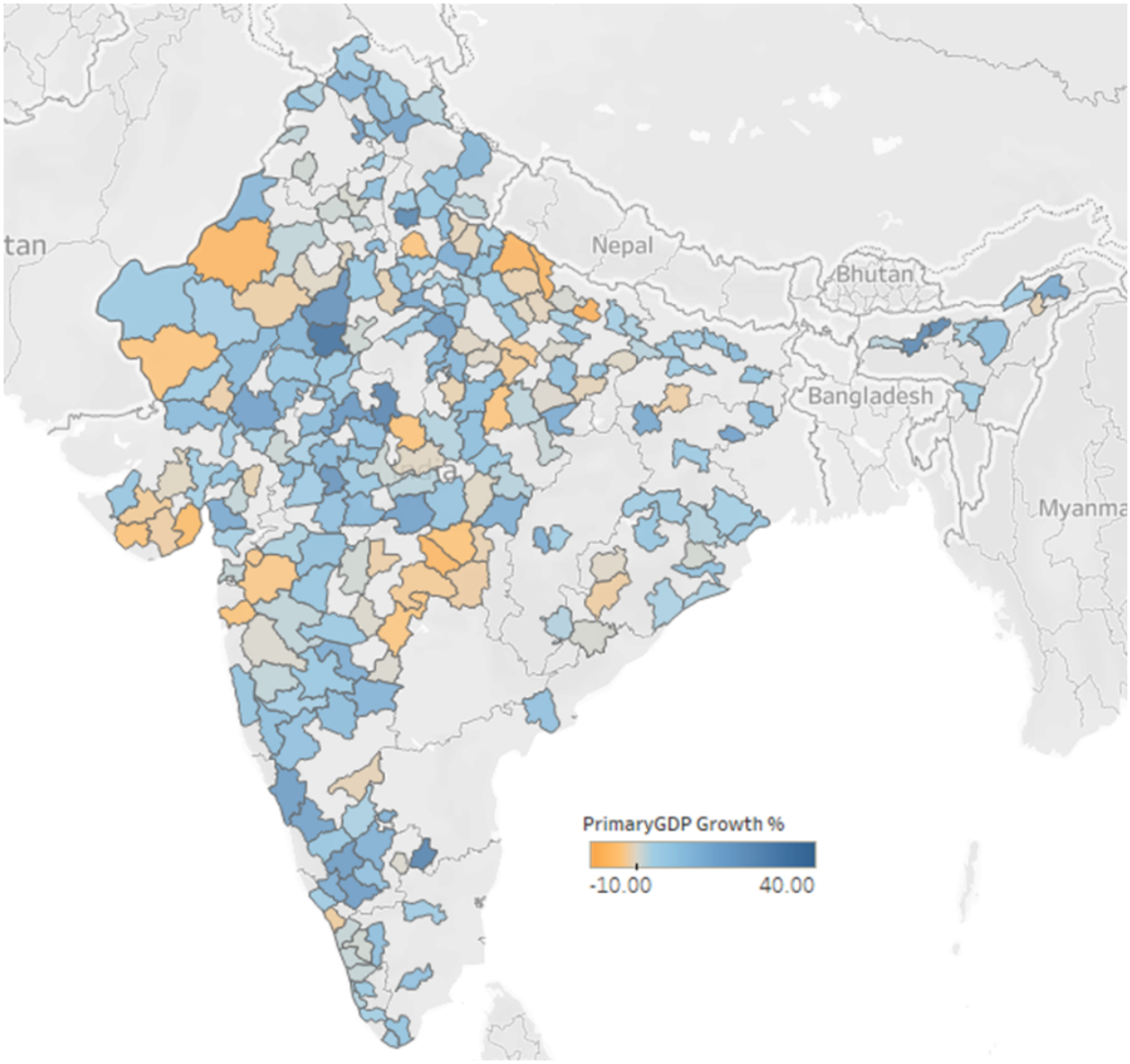
Source: International Crops Research Institute for the Semi-Arid Tropics, Visual Made by Author

Figure A9: Road Growth Rate between 2011 and 2015



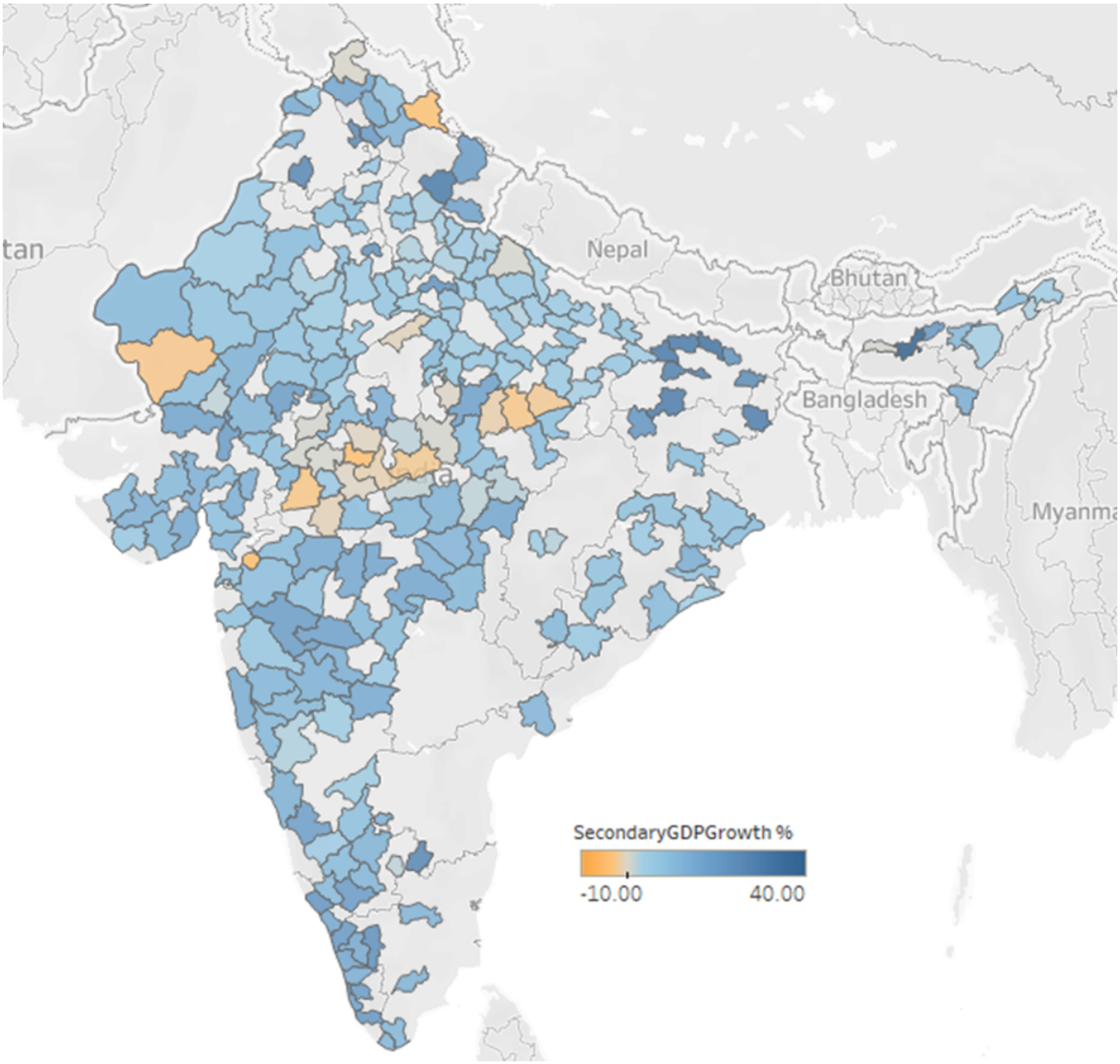
Source: International Crops Research Institute for the Semi-Arid Tropics, Visual Made by Author

Figure A10: Primary GDP Growth Rate between 2007 and 2013



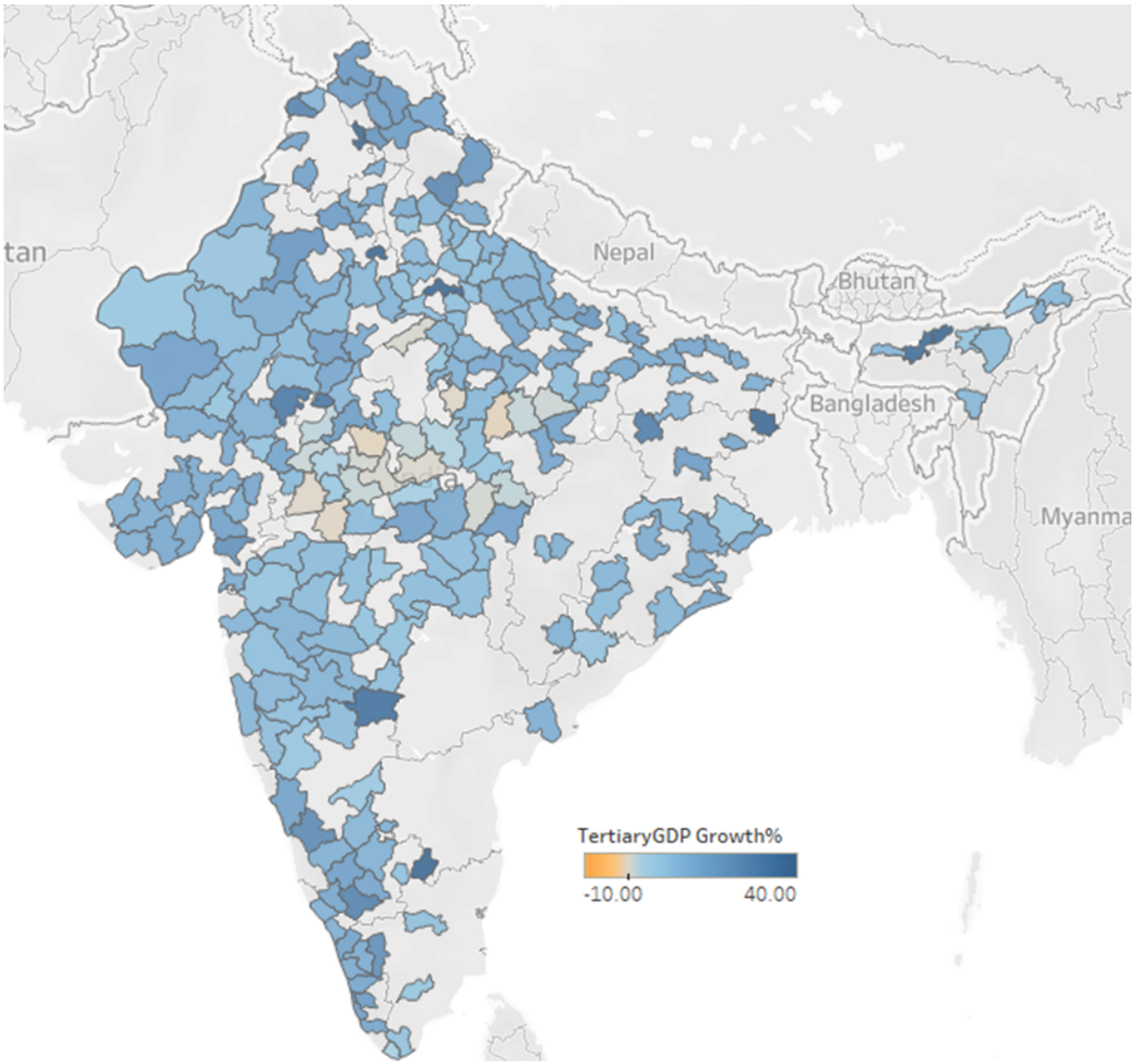
Source: International Crops Research Institute for the Semi-Arid Tropics, Visual Made by Author

Figure A11: Secondary GDP Growth Rate between 2007 and 2013



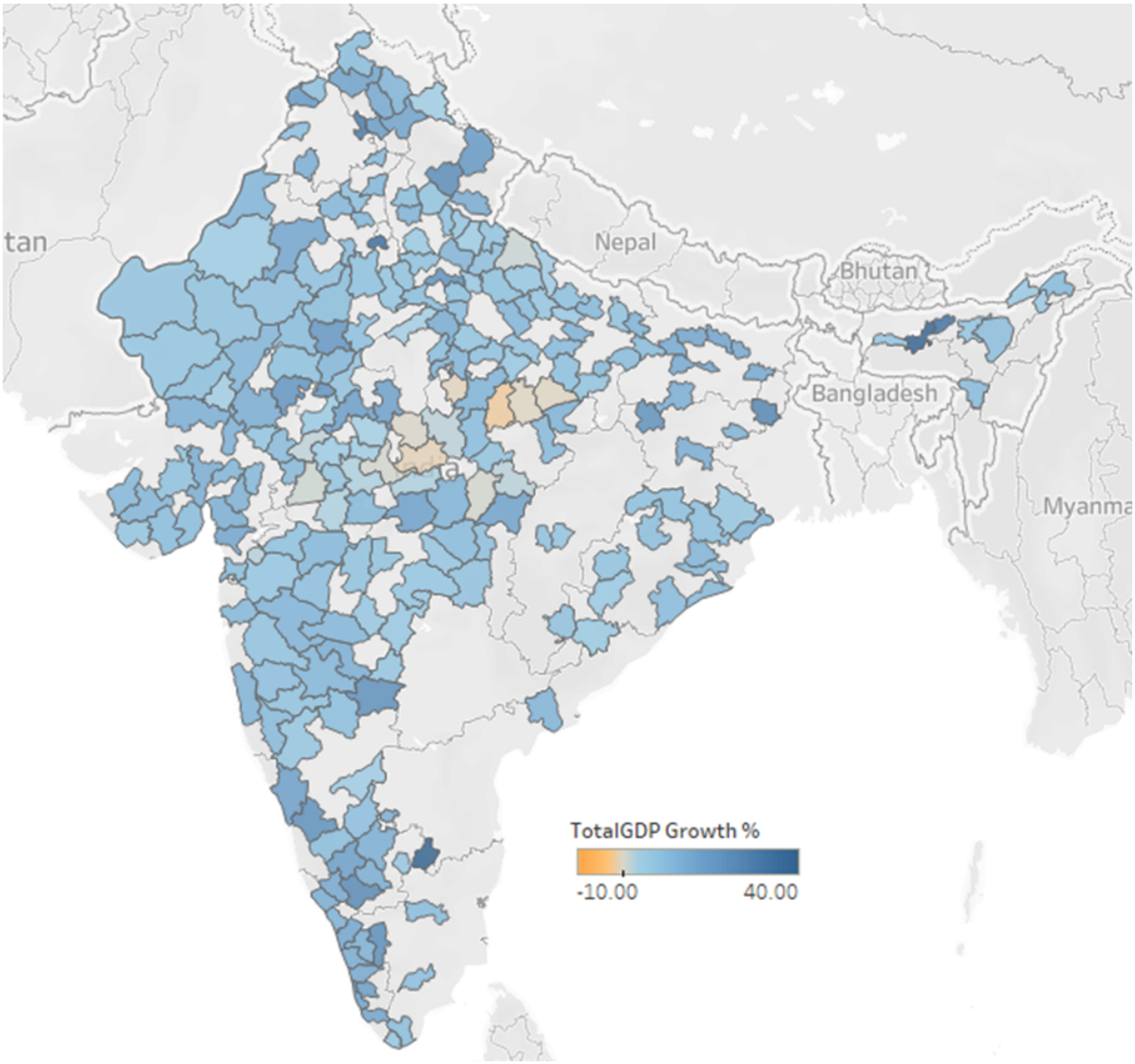
Source: International Crops Research Institute for the Semi-Arid Tropics, Visual Made by Author

Figure A12: Tertiary GDP Growth Rate between 2007 and 2013



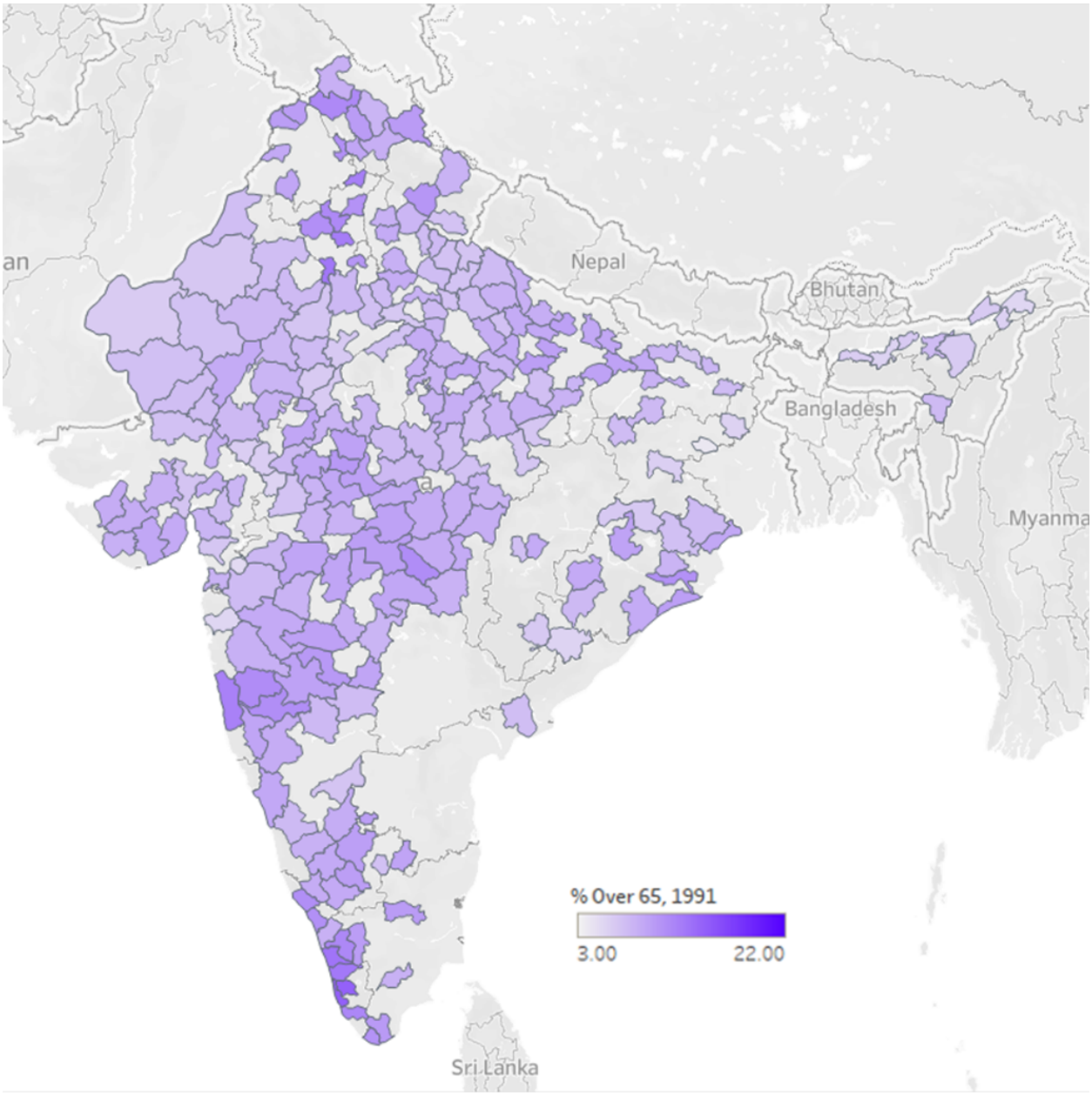
Source: International Crops Research Institute for the Semi-Arid Tropics, Visual Made by Author

Figure A13: Total GDP Growth Rate between 2007 and 2013



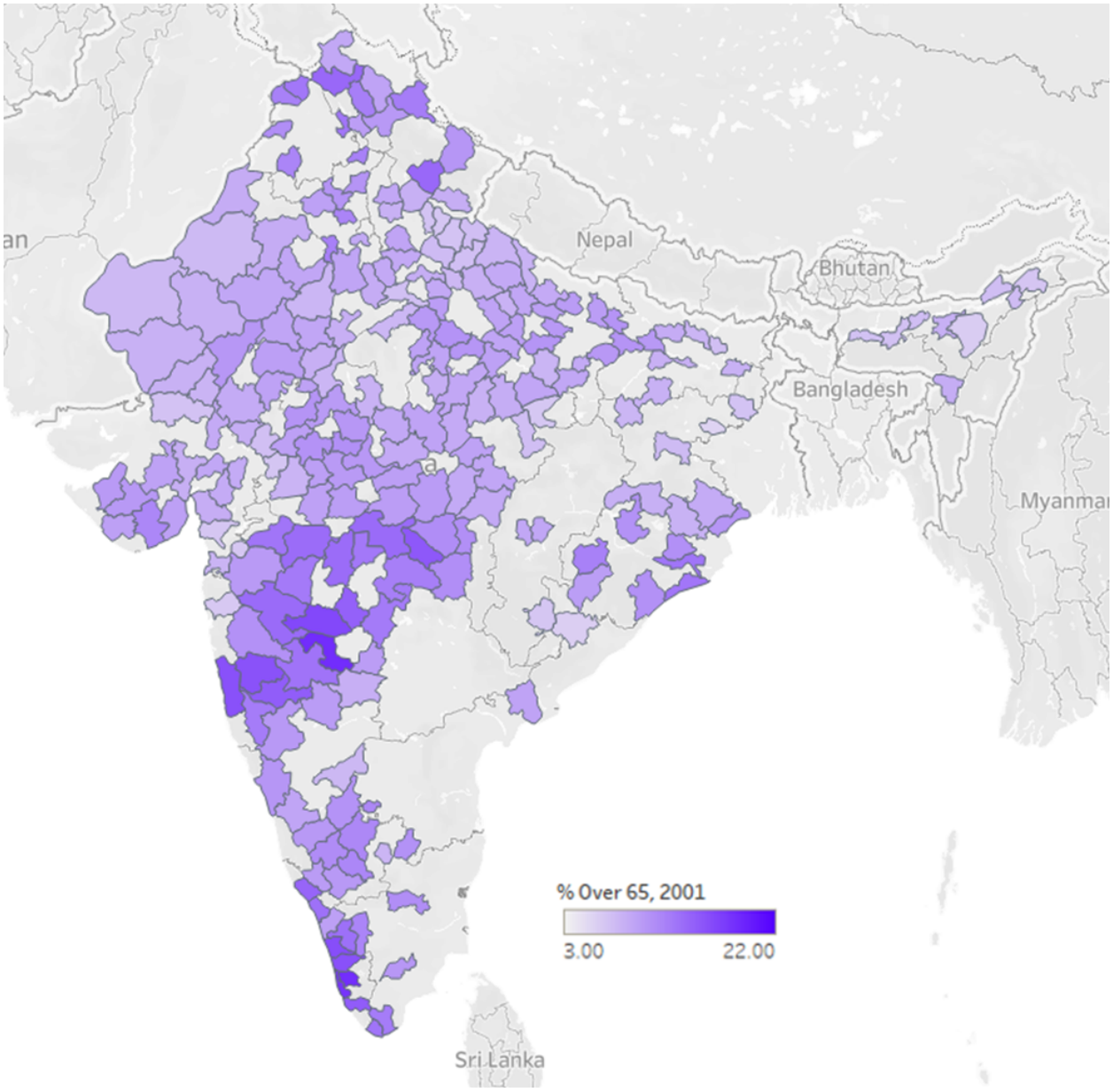
Source: International Crops Research Institute for the Semi-Arid Tropics, Visual Made by Author

Figure A14: Percent of Population Over 65, 1991



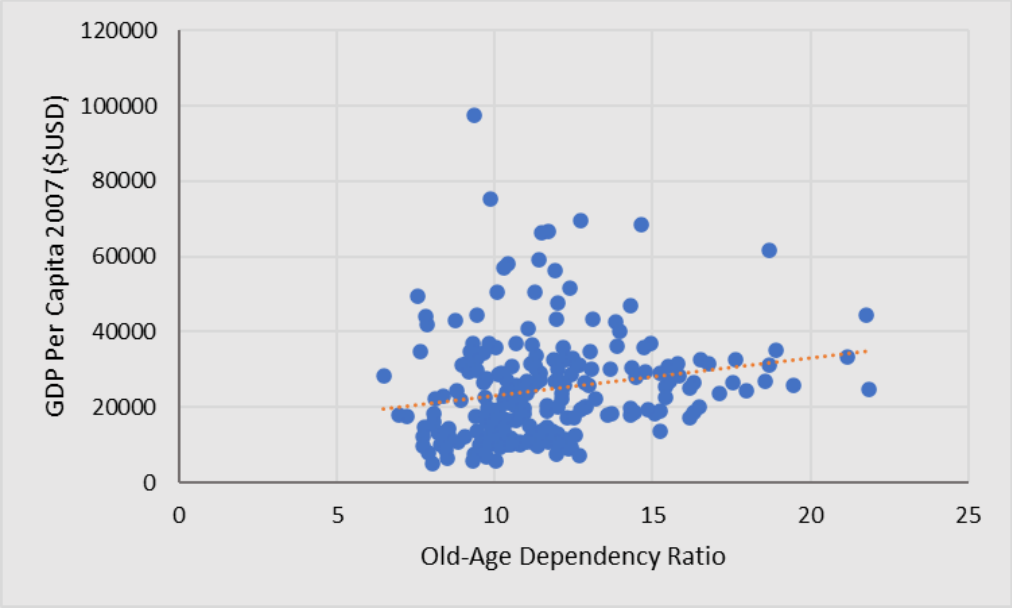
Source: Indian Census Data, Visual Made by Author

Figure A15: Percent of Population Over 65, 2001



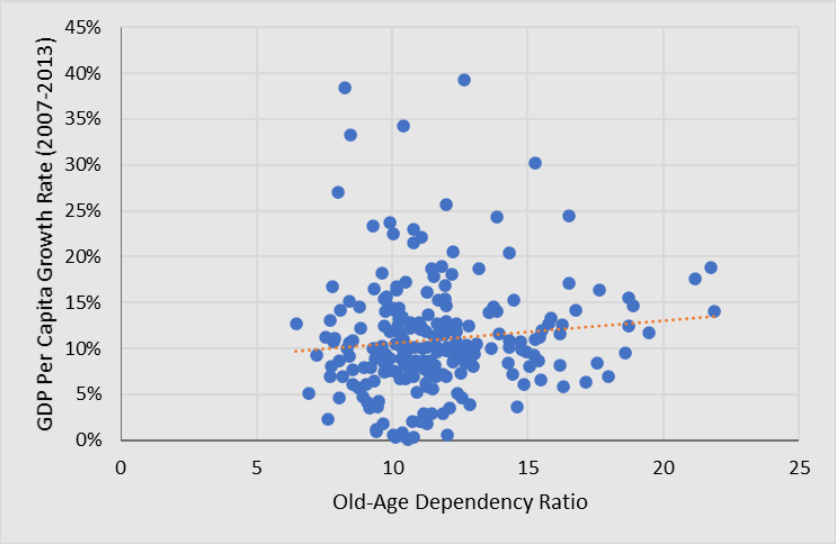
Source: Indian Census Data, Visual Made by Author

Figure A16: Percent of Population Over 65, 2001



Source: International Crops Research Institute for the Semi-Arid Tropics, Author Calculations

Figure A17: Plot of Old-Age Dependency Ratio Against GDP per Capita Growth Rate



Source: International Crops Research Institute for the Semi-Arid Tropics, Author Calculations

Table A1: Summary Statistics for Key Variables

Variable	Observations	Mean	Std Dev	Min	Max
Over65_1991 (%)	229	8.345	1.633	3.909	14.687
Over65_2001 (%)	229	9.886	2.356	5.494	18.581
Over65_2011 (%)	229	11.379	2.832	6.518	21.692
GDPPerCapGrowthRate (%)	229	10.959	6.301	-1.827	39.239
PrimaryGDPPerCapGrowthRate (%)	229	6.116	7.699	-8.619	36.456
SecondaryGDPPerCapGrowthRate (%)	229	9.809	7.598	-4.384	44.024
TertiaryGDPPerCapGrowthRate (%)	229	14.309	7.929	-0.742	47.386
PrimaryShare2007	229	0.257	0.107	0.003	0.483
PrimaryShare2013	229	0.217	0.116	0.002	0.565
SecondaryShare2007	229	0.271	0.104	0.118	0.624
SecondaryShare2013	229	0.255	0.098	0.085	0.609
TertiaryShare2007	229	0.472	0.089	0.262	0.708
TertiaryShare2013	229	0.526	0.099	0.293	0.805
BankGrowthRate_9100 (%)	229	37.836	38.912	0.568	147.179
BankGrowthRate_0110 (%)	228	4.147	8.523	-5.517	73.751
BankGrowthRate_1115 (%)	228	1.258	2.462	-1.567	17.501
RoadGrowthRate_9100 (%)	229	3.783	3.892	0.057	24.717
RoadGrowthRate_0110 (%)	229	9.666	15.372	0.014	119.636
RoadGrowthRate_1115 (%)	229	1.252	1.304	0.014	8.535

Source: Author Calculations

Table A2: GDP Per Capita Growth Rate (2007-2013) Regression Results

VARIABLES	(1) GDPPerCapGrowthRate
Over65 2001	0.329*
	(0.180)
GDPPerCap2007	-2.55e-05
	(2.99e-05)
Constant	8.335***
	(1.836)
Observations	229
R-squared	0.016

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Source: Author Calculations

Table A3: Primary GDP Per Capita Growth Rate (2007-2013) Regression Results

VARIABLES	(1) PrimaryGDPPerCapGrowthRate
Over65 2001	-0.272
	(0.218)
PrimaryGDPPerCap2007	9.355
	(153.9)
Constant	8.754***
	(2.282)
Observations	229
R-squared	0.007

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Source: Author Calculations

Table A4: Secondary GDP Per Capita Growth Rate (2007-2013) Regression Results

VARIABLES	(1) SecondaryGDPPerCapGrowthRate
Over65 2001	0.798***
	(0.208)
SecondaryGDPPerCap2007	-88.29
	(71.91)
Constant	2.580
	(2.156)
Observations	229
R-squared	0.066

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Source: Author Calculations

Table A5: Tertiary GDP Per Capita Growth Rate (2007-2013) Regression Results

VARIABLES	(1) TertiaryGDPPerCapGrowthRate
Over65 2001	0.129
	(0.233)
TertiaryGDPPerCap2007	-63.73
	(73.37)
Constant	13.78***
	(2.281)
Observations	229
R-squared	0.004

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Source: Author Calculations

Table A6: Road Growth Rate (1991-2000) Regression Results

VARIABLES	(1) RoadGrowthRate_9100
Over65_1991	-0.395**
	(0.156)
Constant	7.077***
	(1.326)
Observations	229
R-squared	0.027

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Source: Author Calculations

Table A7: Road Growth Rate (2001-2010) Regression Results

VARIABLES	(1) RoadGrowthRate_0110
Over65_2001	-0.442
	(0.432)
Constant	14.04***
	(4.391)
Observations	229
R-squared	0.005

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Source: Author Calculations

Table A8: Road Growth Rate (2011-2015) Regression Results

VARIABLES	(1) RoadGrowthRate_1115
Over65_2011	0.0616**
	(0.0303)
Constant	0.551
	(0.355)
Observations	229
R-squared	0.018

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Source: Author Calculations

Table A9: Bank Growth Rate (1991-2000) Regression Results

VARIABLES	(1) BankGrowthRate_9100
Over65_1991	-3.947**
	(1.560)
Constant	70.77***
	(13.26)
Observations	229
R-squared	0.027

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Source: Author Calculations

Table A10: Bank Growth Rate (2001-2010) Regression Results

VARIABLES	(1) BankGrowthRate_0110
Over65_2001	0.359
	(0.239)
Constant	0.594
	(2.429)
Observations	228
R-squared	0.010

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Source: Author Calculations

Table A11: Bank Growth Rate (2011-2015) Regression Results

VARIABLES	(1) BankGrowthRate_1115
Over65_2011	-0.0654
	(0.0575)
Constant	2.003***
	(0.675)
Observations	228
R-squared	0.006

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Source: Author Calculations