Essays on Spatial Effects of Public Schools Infrastructure on Growth and Inequality

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Abstract

This thesis analyses the impact of public investment on growth and spatial inequality in post-apartheid South Africa, focusing on a large public school construction program implemented from 1994 to 2013. Using a unique dataset on school construction, the study assesses the spatial distribution and economic effect of educational investment across local municipalities in KwaZulu-Natal and South Africa more broadly. This thesis is divided into three main chapters. Chapter 2 explores the placement, design, and distribution of public schools and economic activities across 44 local municipalities in KwaZulu-Natal, using Geographic Information System (GIS) techniques to map school locations and night lights as proxies for economic activity from 1992 to 2013. Public schools are classified into fee-paying and non-fee schools, corresponding to different financing model, The analyses shows substantial spatial variations in economic activity and school growth. Ethekwini municipality, for instance, demonstrates higher growth in economic activity and greater school placement variation, especially among fee-paying schools, compared to eDumbe, which shows minimal economic growth and is the least-performing municipality.

Chapter 3 investigates the effects of public school placements on growth and spatial inequality across 120 local municipalities from 1992 to 2013, controlling for a large set of initial conditions and local factors. The results show that investment in fee-paying schools, where schools running costs are partially covered by parents, is associated with positive income growth while investment in non-fee schools appears to have no significant effect on local income and may contribute negatively. Using quantile regression, the analysis reveals that public investment has primarily benefited higher-income municipalities, exacerbating inequality.

Finally, chapter 4 applies hierarchical linear modeling to decompose spatial heterogeneity in educational investment across municipalities over the same period. This chapter finds significant variability in both income and economic growth across municipalities, with metropolitan municipalities receiving a larger share of school construction investment compared to non-metropolitan areas. The findings indicate the presence of random variations or unconditional means in both intercept and slopes for local municipalities where the public schools (fee and non-fee schools) are nested. The analysis suggests that public school investments are spatially uneven, with metropolitan and more affluent areas gaining more resources, which likely contributes to the persistence of inequality in South Africa.

Dedication

"To my late uncle, Bhekisani Lionel Ntuli: a family member and a guiding influence in my educational journey. He once said, 'We have set an example for you, my niblings, that with education anything is possible. It is up to you to decide what's best for your future. The choice is yours, whether it be good or bad. My main wish is that you succeed more than we did in the future.' These words will never fade, and they have given me the courage to carry on. You will always be remembered as a good forebear. It's unfortunate that you left this world before you could celebrate the hard work of your nephews and nieces. Rest well, uncle. I hope you are in a good space alongside my late brother, Xolani 'Skete' Mbambo, and other members of our families."

I extend my heartfelt gratitude to the South African Reserve Bank (SARB), my families (the Ntuli and Mbambo), and my esteemed supervisors, Professors Nicola Viegi and Matthew Clance, for their unwavering support throughout this doctoral project. Your encouragement, guidance, and assistance were invaluable, and I am deeply appreciative. Professor Nicola, I am especially grateful for the opportunity you provided me and for the financial support from SARB, which enabled me to pursue this research endeavor and expand my horizons through international collaborations. I wish you a long life as we need people like you in this world. Lastly, I acknowledge the dedication and perseverance I have demonstrated throughout this journey. Learning new and challenging concepts independently has been a rewarding but sometimes a difficult process.

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Chapter 1

General Introduction

Persistent spatial and economic inequalities, a legacy of South Africa's apartheid history, continue to pose significant challenges, particularly with regard to the provision of public infrastructure and services. These disparities are observable across various regions and municipalities and act as a constraint on inclusive economic development and human progress. This thesis investigates the potential of targeted public investment programs, specifically focused on education infrastructure, to contribute meaningfully to reducing these inequalities. Examining the post-apartheid school construction program, one of the most substantial public infrastructure initiatives implemented by the democratic government, seeks to determine to what extent investments have influenced local economic growth and spatial inequality.

This study is particularly relevant given South Africa's need for economic growth and a significant reduction in its extreme inequality, with a Gini coefficient of 0.63 in 2024, the highest globally. To achieve these objectives, the post-apartheid government has heavily invested in infrastructure to close the gaps created by apartheid injustices. In 1994, the democratic government introduced the Reconstruction and Development Programme (RDP), a major socioeconomic initiative that included substantial investment in education infrastructure, believed to be the first step to equalise access to education and skills across the population. However, despite substantial investments in public infrastructure, high levels of inequality remain a central and persistent policy concern in South Africa. This thesis is a first attempt to evaluate the effect of these policies and to contribute to a global literature on the relationship between public investment, inequality, and economic growth. This study aims to trace the distribution patterns and beneficiaries of these investments, investigating whether their impacts on growth are evenly spread between local municipalities and whether they help alleviate severe inequality.

Although researchers are increasingly interested in the impact of public investment on economic development, studies often neglect the spatial dimensions of inequality, particularly at the small

administrative units such as the local or municipal level in developing countries, due to the lack of quality data. South Africa has long used public infrastructure spending as a primary policy instrument, but its effectiveness in mitigating persistent spatial inequalities remains uncertain. This research addresses this gap by accurately analysing the school construction program and connecting it with local economic trends across municipalities. In doing so, it provides granular new data for the literature on public investment and contributes to ongoing conversations about spatial justice and equitable growth in the post-apartheid period. The results provide valuable information for future infrastructure planning aimed at promoting inclusive development.

To address these questions, this thesis employs geospatial techniques with a large dataset of public school investment that tracks public school construction from 1992 to 2011 in four South African provinces. This data set is connected to local growth and inequality proxy data. Changes in nightlight intensity within municipalities are used to measure economic growth, following the methodologies of Henderson, Storeygard, and Weil (2012) and Chen and Nordhaus (2011), who found a strong link between increased nightlight intensity and economic growth. Inequality is measured by comparing the intensity of nightlight between municipalities at the same time, with lighting disparities indicating regional development and differences in wealth distribution, as shown in studies like Elvidge et al. (2009). Nightlight data, spanning from 1992 to 2011, form a key component of this analysis, supplemented with additional datasets to build a robust local municipal dataset. Public investment in schools is expected to have three key impacts: direct effects, long-term benefits, and complementarity with private investment.

- **Direct Impact**: The construction of public schools creates immediate job opportunities by employing workers during the construction process. Over time, these schools contribute to a more skilled workforce, enhancing employment opportunities (Nelson & Stephens, 2011).
- **Long-Term Impact**: Investments in public school infrastructure increase general access to education, thus increasing the skill levels of the population, improving economic opportunities, and fostering growth (Duflo, 2001).
- **Public-Private Complementarity**: The relationship between public and private investment can be either complementary or substitutive (Falade & Adeosun, 2024; Getachew & Turnovsky, 2015). Public school construction is typically complementary if it generates the skills which private capital leverages for increased productivity (Nguyen & Trinh, 2018). By enhancing workforce skills, public education boosts the returns on private investment, driving economic growth. However, public school investment might be a substitute of private investment if it produces a negative externality by crowding out resources and delivering a skill set which does not match private sector demand.

There is limited research in emerging countries that directly links public school construction with growth and spatial inequalities. The most notable example is a similar large public school construction program in Indonesia, which has been extensively studied (Akresh, Halim, & Kleemans, 2023; Breierova & Duflo, 2004; Duflo, 2001). Martinez-Bravo (2017) highlights how Indonesia's school construction initiatives have improved human capital and local governance, improving the well-being of the poor. The Indonesian program was one of the largest school-building programs worldwide, constructing over 61,000 schools for a population of 275 million. In comparison, the building program that we are analysing in this thesis includes 24,000 schools for a population of around 60 million people, making this program proportionally much larger. However, the South African program has not produced a significant change in growth and spatial distribution, and the thesis attempts to understand this result.

Instead, this research focuses on the role of social infrastructures in addressing growth and inequality. Recognising the significance of social infrastructure projects documented in the RDP of 1994, the study focuses on the role, implementation, and impact of such investments over the past 20 years. Public school construction, the largest social program in South Africa, is an important focus due to its widespread presence throughout the country.

Since the advent of democracy, South Africa's education expenditure has grown from R31.8 billion in 1994 to R317 billion in 2023 (Basic Education Report, 2023), representing 4. 8% of GDP, among the highest levels worldwide. These investments aim to rebuild the educational system and address the inequalities inherited from apartheid, underscoring their critical importance in this analysis.

In South Africa, public school construction is categorised into two types: fee and non-fee schools. The establishment of new schools involves multiple layers of decision-making and institutional coordination, which are critical to understanding resource allocation and educational outcomes. At the national level, the government sets educational policies and financial guidelines. Provincial governments implement these policies, allocate funding, and oversee the construction and maintenance of schools within their regions. Local municipalities identify the need for new schools based on demographic trends, local demand, and community input and then recommend projects to provincial authorities.

Several factors influence school construction decisions:

- Population density: Areas with higher population densities are more likely to require additional schools to accommodate increasing numbers.

- Socioeconomic status: Wealthier areas tend to have more fee-paying schools due to higher demand and the ability to pay, while poorer communities rely on non-fee-paying schools to ensure equitable access to education.
- Existing infrastructure: The availability and condition of current schools often determine the necessity of new construction.

Government funding for schools is generally allocated based on population growth, socioeconomic status, and educational needs. In affluent areas, private investment also plays a significant role in developing fee-paying schools. The key distinction between the two categories is financial: fee-paying schools charge parents additional fees beyond government funding, whereas non-fee-paying schools do not require extra contributions from parents. The Ministry of Education decides a school's classification based on criteria such as community wealth levels.

This dual system creates disparities, as fee-paying schools are predominantly located in wealthier areas, while non-fee-paying schools serve poorer communities. Economic growth in regions with higher-fee schools can exacerbate inequality between these groups.

South Africa has two key regulations for public school attendance: students must attend schools within their residential area or the closest public school. This geographic rule ensures schools are distributed throughout the country, but also ties the impact of public investment in schools to local inequality dynamics.

This thesis focuses on public investment in schools, using a dataset spanning 1992 to 2013. Although the study focuses on school investments, it examines their broader implications for inequality and growth. Despite increasing public investment, South Africa remains one of the most unequal societies worldwide, with persistent disparities in wealth and resource ownership. Minority groups, particularly white citizens, continue to control a significant portion of the means of production compared to other ethnic groups.

The nine provinces of South Africa have diverse economic and social characteristics. However, due to limitations in the geographical dataset, five provinces, Limpopo, Mpumalanga, the North West, the Northern Cape, and the Western Cape, were excluded. The study focuses on four provinces: Gauteng, the country's economic hub and with the largest population; Free State, a province dominated by the mining sector and industrial agriculture; Eastern Cape, a province predominantly rural; KwaZulu-Natal, the second most populous province.

These provinces are representative of key national characteristics, including industrialisation level, mining, rural dynamics, and population density. Together, they represent 61% of the

South African population and include seven of the eight largest metropolitan areas. Although excluded provinces, except the Western Cape, are largely rural, their omission is unlikely to significantly affect the findings, as public investment patterns are determined at the national level and not by local governments.

Literature review: Infrastructure, growth, and inequality

There is a lot of research on infrastructure and growth. However, the causal effects of both infrastructure and growth are unclear. Policy makers in developing countries find it difficult to determine whether expansions in infrastructure promote growth. Several researchers in the literature have shown more interest in an attempt to understand the relationship between public capital and growth. In the context of a neoclassical economy, Arrow and Kruz (2013) discovered that public capital is a productive input to private. The findings of Barro (1990) address the problem in an endogenous growth framework. Within this framework, there is an agreement that spending on infrastructure by the government can bring gains in productivity and thus give rise to growth. In addition, Futagami, Morita, and Shibata (1993) uses an extended version of the model in Barro (1990) to include both public and private capital. The rate of public capital is perceived as an important decision factor for the government.

In addition, empirical studies in macroeconomics suggest that infrastructure plays a positive role in aggregate output. Most of these findings follow the work of Aschauer (1989), who suggested that investment in public infrastructure is an important instrument of the productivity of the aggregate total factor. The economic significance of his results was mostly criticised. The results were not robust to the use of more advanced econometric techniques[1]. More recently, empirical literature has affirmed the importance of the contribution of the production infrastructure. Several of these empirical studies have been conducted in the context of cross-country data panels. Canning (1999), Demetriades and Mamuneas (2000) utilise data from a large panel from different countries to report the consequences of these empirical findings.

The topic on public investment in infrastructure has recently received increasing attention. This paper relates to different strands of literature that study the theoretical and empirical findings of public capital and income distribution. However, the effect of infrastructure has not been researched as much as in the theoretical literature. This is due to its disproportionate impact on individual income. There is analytic literature on public capital and inequality. The authors Galor and Zeira (1993) play an important role in modelling the relationship between public capital and inequality. To model this, they focused more on wealth distribution dynamics that

[1]See e.g Holtz-Eakin and Schwartz (1995), Baltagi and Pinnoi (1995)

involved capital market imperfections. With the use of these models, Aghion and Bolton (1992) found that productivity efficiency can be enhanced by redistributing wealth to the poor class. Improving basic public services such as infrastructure, health, and education can help reduce inequality and improve efficiency. Chatterjee and Turnovsky (2012) explores the dual role that public investment plays as a growth tool and a determinant of inequality. A considerable amount of public capital gives rise to factor income through channels of productivity. Estache and Fay (1995) suggests that in underdeveloped regions, the basic infrastructure plays a crucial role in connecting certain disadvantaged people to core economic activities for better opportunities that contribute to high productivity.

The empirical literature on infrastructure and inequality is extensive compared to the theoretical literature. It is imperative for this research to also highlight empirical literature that is related to the question studied. Most of the literature studies this subject at an aggregate level. The empirical evidence between inequality and infrastructure is not conclusive and is extremely anecdotal. The channels through which public infrastructure capital can play on inequality have been documented in previous literature. The findings of Calderón and Servén (2004) and López (2003) suggest that public capital contributes to growth and helps in the reduction of inequality. Another strand of literature with regards to the African case is by Artadi and Sala-i Martin (2003), who stated that excess public investments contribute to the increase of income inequality. Although Brakman, Garretsen, and Van Marrewijk (2002) suggests that expenditures made by governments on infrastructure within Europe have contributed to the increase of regional disparities. A. Banerjee and Somanathan (2007) documents a positive correlation that state-provided goods and any critical infrastructure have on social status. On the other hand, Office (2006) suggests that the performance of state-provided infrastructure services tends to be worse in the less affluent Indian states.

In the same vein as the empirical studies, López (2003) contributes to the literature by looking at the role that infrastructure plays in both the distribution of income and growth. In his study, telephone density is selected as a measure of infrastructure. In addition, infrastructure plays a pivotal role in raising growth and reducing income inequality. In contrast, Calderón and Chong (2004) obtains different results taking into account both the quality and quantity of various infrastructure sectors such as energy, rails, and roads. The results show a negative relationship with income inequality. Likewise, Jacoby (2000) explains both developments in road services and some communication improvements that play a crucial role in capital gains for poor farmers. The author further explains that extending the infrastructure of roads to all rural areas of Nepal will result in a 10% increase in average income. The author also made it clear that the people who benefit a lot from these infrastructure developments are the owners of land, who happen to be less poor as a result; incomes in the remote rural areas of Nepal are found to be lower. This analysis is based on the research, which looks at the value of the assets

of poor farm regions and the distance to agricultural markets.

In addition to the literature mentioned above, there is a significant number of articles that expand on explaining the ways in which developments in infrastructure services can enhance the human capital of poor individuals. These infrastructure services include health, education, and telecommunication services. The study conducted by Brenneman and Kerf (2002) states that in terms of education, having adequate transport systems in place and safer road networks will contribute quite well to increasing school attendance. Zheng and Kuroda (2013) also points out that the exchange of knowledge in cities is facilitated by infrastructure in telecommunications, together with infrastructure in education. However, it should be noted that although growth can be influenced by programs in transportation infrastructure, the same programs can have a negative effect on inequality. A. Banerjee (2004) in the case of India, finds that there is a positive relationship between accessibility to infrastructure services and income distribution; this is because the gains of infrastructure services less benefited the poor and on the other side benefited the groups that earn high incomes.

Other studies also identify cases in which sanitation and health play a significant role. In the case of India, Jalan and Ravallion (2003) looks at the prevalence of diarrhoea in children under the age of five years. They discovered that in rural areas, diarrhoea cases are more prevalent in households that do not have access to piped water and are very low in those who can access piped water. Likewise, a study by Devoto, Duflo, Dupas, Parienté, and Pons (2012) suggested that improving water access for poor agents in the society may play a crucial role in improving women's health. This is in the sense that improved water access can reduce the amount of time spent collecting water far from their areas of living. This will reduce the stress levels of the people in the community and allow them to have free time to participate in production activities. In a similar fashion, Galiani, Schargrodsky, Hanushek, and Tommasi (2002), in the case of Argentina, reports an 8% reduction of child mortality that is brought about by water access and sanitation. The largest part of mortality reduction occurred in low-income regions where water access is the largest.

There is also literature that looks at trade openness, infrastructure, and inequality. Raychaudhuri and De (2016) uses panel data of 14 Asian countries in trying to comprehend the different relationships between globalisation, infrastructure and income inequality from 1975 to 2006. The authors suggest that both infrastructure and trade openness promote income inequality. They also made it clear that the impact of the developmental infrastructure on trade openness is statistically not significant.

Theoretical framework

Understanding inequality through the lens of investment in public infrastructure is central to this study. Classical theories, such as neoclassical and endogenous growth models, highlight public capital as a key driver of long-term development. These theories also emphasise the state's responsibility in delivering infrastructure as a public good. The World Bank (1994) affirms that strategic public investments can directly reduce inequality, not only by stimulating economic activity but also by enabling more equitable access to essential services. In this context, public infrastructure—particularly educational infrastructure—acts as a channel for redistributing opportunities and wealth between different regions and population groups.

The relationship between infrastructure and inequality can be explained through two interconnected economic concepts: the complementarity–substitutability dynamic between public and private investment, and the redistributive role of public capital. Infrastructure is not neutral; it complements or substitutes for private capital. Where it serves as a substitute (e.g., where public schools reduce the need for private schooling), it may directly reduce inequality. Where it acts as a complement (e.g., enhancing skills that increase the return on private investments), it can expand productivity and economic growth while also improving equity outcomes if access is broad-based.

This study is grounded in the complementarity–substitutability framework as applied to public and private investment. For example, Getachew (2015) and Falade (2024) demonstrate that public investment, when effectively targeted, can foster private sector growth by laying foundational infrastructure. In this thesis, school construction is viewed as a public investment that complements the needs of the private sector by improving human capital: an educated workforce is more productive and attractive to employers and investors.

Nguyen (2018) supports this interpretation by noting that school infrastructure improves the overall returns to private capital through improved workforce quality. In this way, investments in public education help build a symbiotic relationship between the state and the market, aligning with the predictions of endogenous growth theory, which places learning and knowledge at the heart of economic progress.

While some literature cautions that public investment can outweigh private investment, this research takes the position that school construction functions primarily as a complementary force. It increases long-term productivity and encourages inclusive development—key goals for reducing inequality. When well-distributed, these investments help connect disadvantaged communities to economic centres, increase educational attainment, and improve job readiness,

as observed in rural Vietnam (Van de Walle, 2007) and Latin America (Estache, 1995; 2003).

This theoretical framing thus integrates public investment theory, the dynamics of growth and inequality, and the interaction between state and market capital. It informs the central hypothesis of the study: that public school investment is not only an economic stimulus in the short term but also a strategic lever for long-term equity. By analysing georeferenced data on school infrastructure in South African municipalities, this research contributes to a deeper understanding of how infrastructure planning can be used to tackle deep spatial inequalities and promote inclusive growth.

Education policies in South Africa before and after democracy

The democratic government established in 1994 faced an education system that excluded the majority of the black population from effective participation. In the early 1800s, missionary schools were established to provide quality education to black Christian learners, often at little or no cost. However, these schools faced opposition following the Eiselen Report of 1951, which labelled them as inefficient and recommended that they be run by white professionals instead (Fiske & Ladd, 2004b), p. 42. This report paved the way for the Bantu Education Act (Act 47 of 1953), which granted the apartheid government full control over black education (Fiske & Ladd, 2004b). The apartheid regime, which came to power in 1948, systematically dismantled the missionary school system, using education as a tool to exclude black people from the formal economy. By the early 1980s, the government recognised a need to allocate funds to black education due to the demand for better-skilled black labor Fiske and Ladd (2004b). However, funding was insufficient to meet the educational needs of the black population. The National Party, the architects of apartheid, implemented policies that further marginalised black communities. One such policy required families to pay for education, despite knowing that the majority of black people were impoverished and uneducated, relying primarily on livestock and subsistence farming for survival. Table 1.1 illustrates the stark disparities in per capita education funding between racial groups, based on data from (MacKenzie, 1993). From 1970 to 1994, the table highlights a consistent pattern of significantly higher investment in schools serving white students compared to those serving other racial groups. This inequitable allocation of resources left schools predominantly attended by black learners struggling to maintain basic infrastructure, including buildings, playgrounds, and essential facilities. As a result, black students were often forced to attend overcrowded and underresourced schools, with classrooms that were filled beyond capacity Fiske and Ladd (2004b), p. 45. By 1991, there was an estimated shortage of 4,300 schools for black learners, and many of the existing schools lacked access to necessities such as water and electricity Fiske and Ladd (2004b), p. 55.

TABLE 1.1: Per Capita School Expenditure by Race (in nominal Rands)

Year	Black	Coloured	Indian	White
1970	25.31	94.41	124.40	461.00
1980	91.29	234.00	389.66	1169.00
1990	930.00	1983.00	2227.01	3082.00
1991	1169.10	-	-	3969.00
1994	1053.00	3691.00	4687.00	5403.00

Source: Department of Education.

South Africa's public school system can be divided into two distinct periods: the apartheid era (pre-1994) and the democratic era (post-1994). During apartheid, educational investment was heavily skewed in favour of the white minority, followed by Indians, coloureds, and lastly, the black majority. This systemic inequality resulted in significant disparities in educational access and quality. Black children faced overcrowded classrooms due to high participation and repetition rates, compounded by inadequate resources and facilities.

In contrast, white students benefited from smaller class sizes, well-trained teachers, and sufficient high-quality learning materials. These advantages contributed to their superior educational results. The apartheid government's prioritisation of infrastructure and resources for white-dominated municipalities further entrenched inequality. In particular, per capita spending for a white learner was nine times higher than that of a black learner in homelands Kanjee and Sayed (2013).

This stark contrast highlights the deliberate exclusion of black communities from quality education, perpetuating systemic inequality, and privileging other racial groups during the apartheid regime.

The democratic government established in 1994 sought to address the deep disparities in access to education by significantly increasing the resources allocated to the education of the previously marginalised majority. The South African Constitution (Act 108 of 1996) enshrines the right to basic education for all citizens. To fulfill this constitutional mandate, the South African Schools Act (Act 84 of 1996), commonly referred to as SASA, was introduced. SASA aimed to create a standardized system for organising, governing, and funding all schools across the country. In addition, it sought to implement new governance structures through the establishment of School Governing Bodies (SGBs), which were designed to include representatives of parents, teachers, non-teaching staff, and learners Karlsson (2002).

To address school funding challenges, the Department of Education (DoE) considered three policy options: maintaining the existing funding system, standardising per capita expenditure per learner, or relying on school fees as the main funding source Roithmayr (2002). Ultimately,

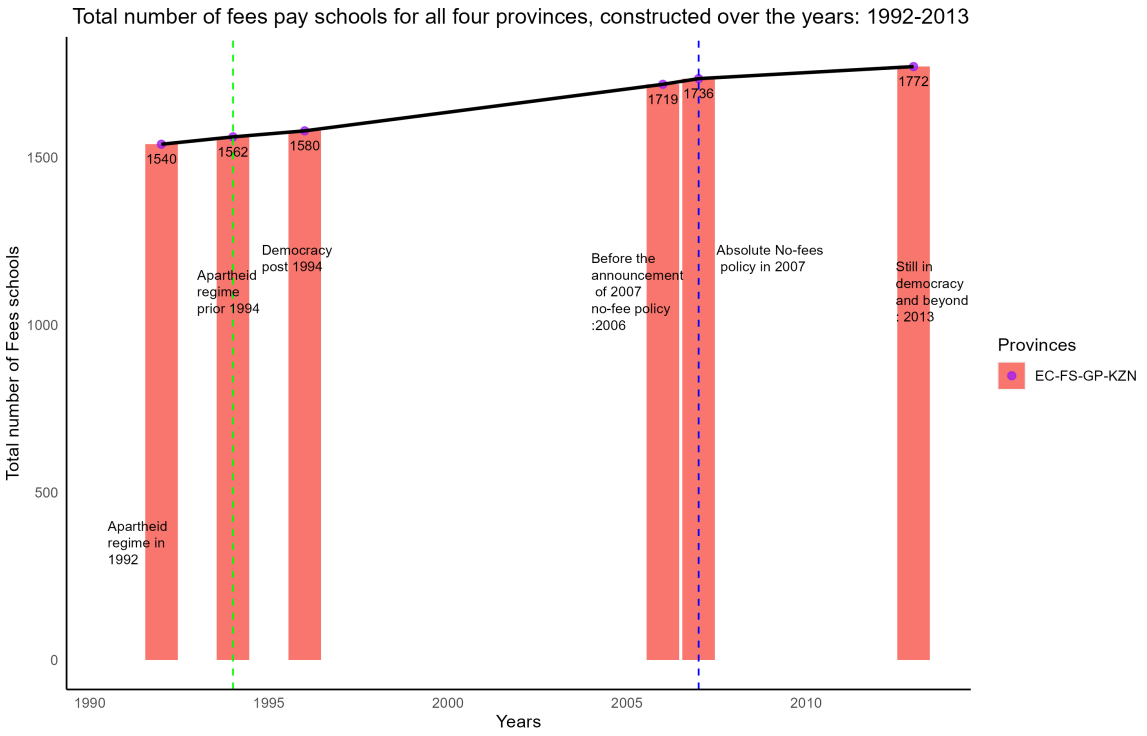
the democratic government opted for a mixed approach. Although standardising per capita funding to some extent, it retained fee-paying school policy, a legacy of the apartheid era, as a supplementary funding mechanism Roithmayr (2002).

One key reason for this decision was the realisation by the African National Congress (ANC) that public funds alone were insufficient to achieve the desired standardisation in education funding levels Fiske and Ladd (2004a). Even the reallocation of resources reserved under apartheid to white learners, which made up only 17% of the population at the time, did not adequately improve the quality of education for the majority Fiske and Ladd (2004a).

The Department of Education (DoE) survey dataset, which we analyse in this thesis, shows the level of infrastructure investment promoted by the Democratic government to address the unequal distribution of resources. The DoE master list dataset consists of information about the schools, such as the names, the locations, the registration dates, whether a school is public or privately owned, and whether the school is exempted from paying school fees or not. In this thesis, the interest is on public schools that pay fees and non-fees. Public schools are differentiated into two groups (fee and non-fee), recorded annually by the Department of Education in each local municipality of South Africa. The National Minister of Education then decides which schools are fee and non-fee. A fee school is funded by the government, but it supplements funding by opening a school governing body that determines how much a parent should pay for a learner attending that school for extra services, whereas in a non-fee school, the government fully subsidizes the school in the absence of school governing bodys' extra fees agreement. The criteria to classify a school as fee or non-fee are based on the economic status of the local municipality such as the levels of poverty, unemployment, and municipal population. However, during apartheid times, these criteria were harsh on black communities as black municipalities were given less of everything.

This thesis uses the public school survey data set from DoE for the period 1992-2013. Only four provinces out of nine are chosen for this study; the reason is that five of those provinces lack important information, for example, a school in Limpopo can be found in the DoE dataset but lacks the registration date or is not identified whether it is a fee or non-fee. The lack of the school's important information reduces this thesis to using public school data for four provinces, namely: Eastern Cape, Free State, Gauteng, and KwaZulu-Natal. Figures (1.1 and 1.2) below show the accumulation of 12145 public schools in total, 1562 for fee and 10583 for non-fee, that were recorded in the database before 1994, constructed by the missionaries and the apartheid government. The number of fee schools increased by 22 from 1540 in 1992 to 1562 in 1994 demonstrated in Figure 1.1, while the non-fee schools in 1992 were 10226 and increased by 357 to 10583 in 1994 under the same apartheid government, see Figure 1.2.

FIGURE 1.1: Public School Construction for fee pay - 1992-2013



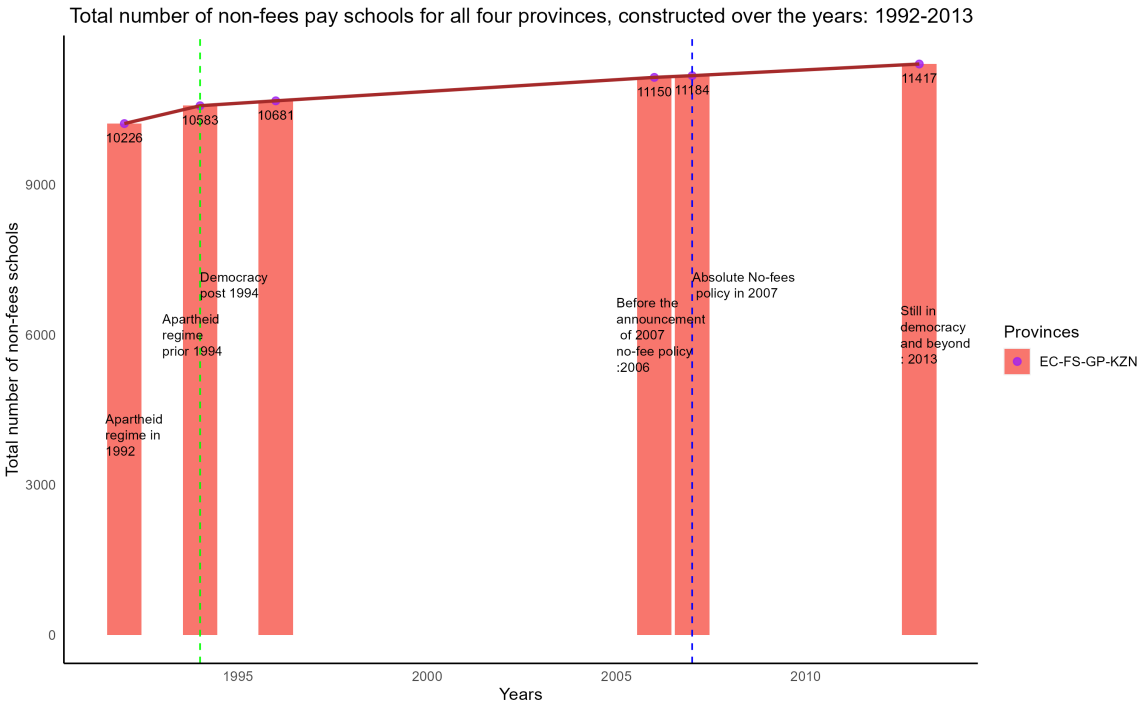
Note: Figure 1.1 shows total number of fee pay schools for all four provinces. We select years when policies were implemented and years before policies were changed during apartheid and democratic eras: 1992, 1994, 1996, 2006, 2007 and 2013. Source: Own Calculation on Department of Education Data

The public schools are used as a proxy for public investment in this study. These public schools are funded by the provincial department of education, which receives funds from the provincial treasury. The national treasury looks at the socio-economic status of a province before it allocates the funds to the provincial department of education. These funds are there to transform a highly inequitable schooling system that benefited whites by expanding the budgets to other races that were excluded from the system.

Figures (1.1 and 1.2) above are also used to show the accumulation of 12145 public schools, both fee and non-fee schools, in total, that were inherited from the apartheid government. When the new democratic government assumed power in 1994, they then built 18 more fee schools, which is why we see a change from 1562 to 1580 in 1996 shown in Figure 1.1, and they also built 98 non-fee as we see a change from 10583 schools in 1994 to 10681 in 1996; see Figure 1.2.

In 2002, Professor Kader Asmal, the former Minister of Education, reviewed all legislation that governed school funding. The review aimed at improving access to free and quality education for all, see Comaroff (2003). The plan recommended that school fees be abolished completely in the poorest quintiles. The plan also suggested that the ANC-led government should set a benchmark for enough school funding.

FIGURE 1.2: Public School Construction for non-fee pay - 1992-2013



Note: Figure 1.2 shows total number of non-fee-pay schools for all four provinces. We select years when policies were implemented and years before policies were changed in apartheid and democracy eras: 1992, 1994, 1996, 2006, 2007, and 2013. Own Calculation on Department of Education Data.

In 2007, a no-fee policy was formed under the new democracy to counteract the apartheid fee school educational policy. The Non-Fees School Policy (NFSP) was announced by the South African National Minister of Education Mrs Naledi Pandor. This was five years after the then-former Minister of Education, Professor Kader Asmal reviewed all legislation that governed school funding in 2002. The main objective of this policy was to provide access to quality education and free poor parents from paying school fees for their children, especially in poor areas of the country. In addition, school fees jeopardise the right to education by promoting the exclusion of pupils from basic education Roithmayr (2003).

Similarly, Figures (1.1 and 1.2) show the spatial distribution of 12920 new public schools (both fee and non-fee) after the newly announced no-fees school policy of 2007. The fee public schools in the four selected provinces were 1736 in 2007, which was before the policy was announced; they increased by 36 from 1736 in 2007 to 1772 in 2013, as displayed in Figure 1.1. Although the non-fee schools in total were 11184 in 2007 and increased to 11417 in 2013, 233 non-fee schools were built after the announcement of the non-fee policy, as demonstrated in Figure 1.2. This shows that there was a huge increase in non-fee schools after the policy than in fee schools. The policy announced 40% of schools as no-fee pay public schools in 2007, as announced by the Minister. In 2011, the number of non-fee public schools increased to 60%, see, for example Sayed and Motala (2012). The Minister of Education uses the Government Gazette to publish a

national list of schools that are non-fee. Since then, the government has been announcing non-fee schools every year in December. Schools in South Africa are grouped into five categories called quintiles. These quintiles range from the poorest (quintile 1) to the least poor (quintile 5). Quintile 1 covers the poorest 20% public schools in the country. Schools that fall in quintiles (1, 2 and 3) are called non-fees-pay public schools, which means parents are not supposed to pay school fees, whereas in a fees school, parents are supposed to pay. In general, a school fee is the amount of money that parents are expected to pay to a school to supplement the government budget to improve the education of pupils. The school holds general meetings with the governing body and the parents to find resolutions on how fees will be paid during the time of the year in a fee school; however, no child in a non-fee school is excluded or denied admission if the school governing body decides on fees that parents cannot afford. Quintile 5 consists of the least poor public schools. Parents or guardians of the children who attend schools in quintiles 4 and 5 are expected to pay school fees agreed upon at the meeting held by parents and the school governing body. Both non-fee and fee schools are government public schools that receive different subsidies from the government. The government allocates a substantial amount of funding to non-fee-paying schools as opposed to fee-paying schools. In fee-paying schools, the school's governing body and parents agree on supplementing government funding with school fees, whereas in non-fee-paying parents are not forced to pay such fees.

The Provincial Education Departments (PEDS) and the Department of Education (DoE) research for the Minister to determine whether a school should be non-fee or fee. Research looks at variables such as the area in which the school is located, the rural population in a province, the size of the school population, the size of school enrolment, the distribution of capital needs, and the level of poverty Sayed and Motala (2012). All these variables help the minister allocate the school to any national quintile within which it falls; for example, schools located in poor rural areas fall under quintile 1, and schools in less poor areas fall in quintile 5.

This thesis begins with the following question. How does public investment in particular school construction affect growth and spatial inequality in South Africa post-apartheid? The question is answered in three chapters. First, we used geospatial technologies to investigate the spatial construction and distribution of public school investment and economic activities in KwaZulu-Natal, South Africa. Second, we assess the empirical effects of public school educational expenditure on growth and spatial inequality for 120 local municipalities in South Africa. Finally, we introduce hierarchical linear models in South African educational expenditure to decompose spatial heterogeneity across 120 local municipalities.

Spatial Distribution of Public Schools and Growth using Spatial Techniques: Evidence from KwaZulu Natal.

This chapter examines the construction of public schools in KwaZulu-Natal in the period 1992-2013 and their effect on local economic development. We map and visualise the placement of public schools, economic activities, and spatial inequalities. The findings indicate that, in most local municipalities of KZN, the proportion of non-fee-paying schools increased significantly after the democratic government came into power in 1994. These shifts were driven by policies that sought to address systemic inequalities perpetuated by the apartheid regime. In contrast, during apartheid, fee-paying schools were prioritised, reflecting policies designed to exclude black South Africans from economic participation.

The study quantifies the growth in fee-paying versus non-fee-paying schools and evaluates economic and educational disparities across municipalities. Ethekwini emerges as the best-performing municipality, exhibiting significant variations in fee-paying schools and a higher growth in night lights, indicating robust economic activity. In contrast, eDumbe is identified as the worst performing municipality, with greater variations in non-fee-paying schools and only slight growth in economic activity over the period. Ethekwini also demonstrates a more equitable distribution of public schools and economic opportunities compared to eDumbe and other municipalities.

This analysis underscores the significant strides made in addressing educational inequality under the democratic government, while highlighting persistent disparities in economic activity and access to education in municipalities in KwaZulu-Natal.

The Effects of Public Infrastructure on Growth and Inequality: Spatial evidence in South African educational expenditure.

This chapter examines the impact of public school placements on economic growth and spatial inequality in four South African regions, namely Gauteng, Free State, Eastern Cape, and KwaZulu-Natal. The chapter uses cross-sectional data from 120 local municipalities between 1992 and 2013, and assesses how initial local conditions and various covariates influence the relationship between school investments and growth outcomes.

The findings reveal that investments in fee-paying schools, where parents contribute partially to school costs, are positively associated with local income growth. Conversely, investments in

non-fee-paying schools are not linked to local income growth and, on average, appear to have negatively impacted growth. To explore the heterogeneity of these effects across income levels, quantile regression is used. The analysis confirms that public investment in South Africa has been more productive for higher-income groups, thereby exacerbating income inequality.

This chapter underscores the dual role of public investment in education as both a driver of growth and a potential amplifier of inequality, particularly when benefits are unevenly distributed. Shedding light on these dynamics provides valuable insights into the intersection of public education policies, economic development, and spatial disparities in South Africa.

Decomposing Heterogeneities across Municipalities using Multilevel Linear Models: Spatial Evidence in South African Educational Expenditure.

This chapter uses a panel of 120 local municipalities between 1992 and 2011 to explore the spatial heterogeneity of the relationship between public investment and growth. The chapter contributes to a growing literature that uses hierarchical linear models (HLMs) to decompose spatial heterogeneity caused by educational infrastructure, educational disparities, and other forms of educational services across regions; see Agasisti and Cordero-Ferrera (2013). The findings indicate that there are random variations or unconditional means in both intercept and slopes for local municipalities where the public schools (fee and non-fee schools) are nested. This heterogeneity indicates that local conditions and local policies have a significant effect on determining the effect of national programs.

General conclusion

This study provides compelling evidence that public investments in school infrastructure have played a role in reshaping educational access and economic activity at the municipal level in South Africa. Using spatial and econometric techniques, the analysis reveals that while post-apartheid policies have led to a sharp rise in non-fee-paying schools, especially in historically underserved municipalities, these efforts have not translated evenly into economic gains. Municipalities like eThekwini for example, benefited more substantially, both in terms of educational service expansion and local economic activity, whereas places like eDumbe saw limited improvements. Furthermore, the analysis finds that investments in fee-paying schools tend to correlate with stronger economic growth, while non-fee school investments show weaker or even negative

associations with local income growth. This divergence points to the unintended consequence that public investments, if not carefully targeted, can reinforce spatial inequality even while trying to reduce it.

While the study offers valuable information, it is not without limitations. First, although the data set spans from 1992 to 2013, several key variables needed for more detailed spatial analysis are missing in five provinces, Limpopo, Western Cape, North West, Northern Cape, and Mpumalanga. Specifically, these provinces lack essential information such as the geographic coordinates of schools, the registration dates, and classification into fee or non-fee-paying categories. Without these data, it becomes difficult to accurately map and assess the distribution and timing of school infrastructure in these areas. If future updates to the EMIS (Education Management Information System) can fill these gaps, particularly for earlier years, it would significantly improve our understanding of how public school investment patterns vary across the country. In addition, the study focuses exclusively on school infrastructure and does not account for other types of public investment, such as transport or health infrastructure, that could also influence economic and educational outcomes. Future research could explore these dimensions by including broader infrastructure data, extending the analysis period, and using more advanced longitudinal approaches. Despite these constraints, this thesis makes a meaningful contribution by providing fine-grained municipal evidence on how educational infrastructure shapes spatial inequality and economic development in post-apartheid South Africa.

Chapter 2

Spatial Distribution of Public Schools and Growth using Spatial Techniques: Evidence from KwaZulu Natal.

2.1 Introduction

Since the end of apartheid, South Africa has faced significant challenges, with slow economic growth and persistent inequality among the most pressing. Addressing these issues has been a top priority, with public school construction being one of the key initiatives. This chapter focuses on the distribution of public schools in KwaZulu-Natal and examines their impact on local economic growth. Using spatial analysis tools, we analyse patterns in municipalities to identify growth trends. Specifically, we explore how the location of schools relates to economic activity, using nightlight intensity as a proxy for economic growth. Nightlight data provides insight into economic conditions and helps us assess whether school locations influence economic inequality. This analysis contributes to a broader discussion on the effectiveness of public infrastructure investments in promoting growth and equity.

Public infrastructures (such as public schools) are important for economic growth, especially in developing countries like South Africa. Studies have associated infrastructure with growth, productivity, human capital, and inequality Canning (1999), Bajar and Rajeev (2015), Calderón and Servén (2004), Chatterjee and Turnovsky (2012), Chatterjee and Turnovsky (2012), A. Banerjee (2004) and Khandker and Koolwal (2007). During the apartheid regime, South Africa faced

educational inequalities such as the unfair distribution of public school investments to all learners equally. Before 1994, the ruling government of that time created policies that benefited minority groups such as whites, indians, and coloureds and excluded black people. It started in 1948 when the National Party (NP) assumed power, and public school investment was then controlled by them, which is why they formulated racial policies that excluded most black people from the South African economy. The unfair distribution of educational investment resulted in a shortage of schools, huge dropout rates, overpopulated classrooms, and many failures within local municipalities that were predominantly dominated by black people Matshipi, Mulaudzi, and Mashau (2017). Missionary schools that were constructed before 1948 were also criticised by the National Party because they were aimed at uplifting black communities, see Hale (2010). Public schools in South Africa are categorised into those that charge fees and non-fee-paying schools. The Minister of Basic Education has a criterion to categorise these public schools as fee or non-fee, which is based on the economic status of the provinces. A fee school concept was born towards the end of apartheid times. It was utilised as a tool to exclude black people from participating in the economy so that they could not access and afford quality education for their children. The fees policy aimed to separate people of the land not only by race but also by affordability Roithmayr (2002).

The 1994 advent of democracy in South Africa came with reforms in the education system. The new democratic government in the ANC was aware that the transition from apartheid would be a huge challenge. The new government amended the constitution to also favour the marginalised groups. An absolute no-fees policy was formed at the dawn of the new democracy to counteract the apartheid fee school educational policy. The non-fees educational policy commenced in 2007, five years after the former Minister of Education reviewed all legislation that governed school funding. The review aimed at improving access to free and quality education for all, see Comaroff (2003). The plan recommended that school fees be abolished completely in the poorest quintiles. It also suggested that the African National Congress (ANC) led government must set a benchmark for enough school funding.

2.1.1 Construction of public schools prior and post-democracy in KwaZulu Natal.

In the apartheid times, public schools were placed according to the policies that favoured white people over other races. To analyse how many schools were before and after 1994, we use the Department of Education (DoE) school dataset, which contains all South African public and private schools.[1] The DoE master list dataset consists of information about the schools, such as the names, the locations, the registration dates, whether a school is public or privately owned and whether the school is exempted from paying school fees or not. This paper uses the same public-school survey dataset from DoE before 1994 and after 1994 for all public schools of

[1] https://www.education.gov.za/Programmes/EMIS.aspx

the local municipalities in KwaZulu-Natal from 1992-2013. Figures (2.1 and 2.2) below show the accumulation of 5202 public schools in total, 960 for fees and 4242 for non-fees, that were recorded in the database in 1992, constructed by the missionaries and the apartheid government. The number of fees schools did not increase in 1994; they remained the same at 960 from 1992, see Figure 2.1, whereas the non-fee accumulated before 1994 were 4242 and remained like that under the same apartheid government in 1994, see Figure 2.2.

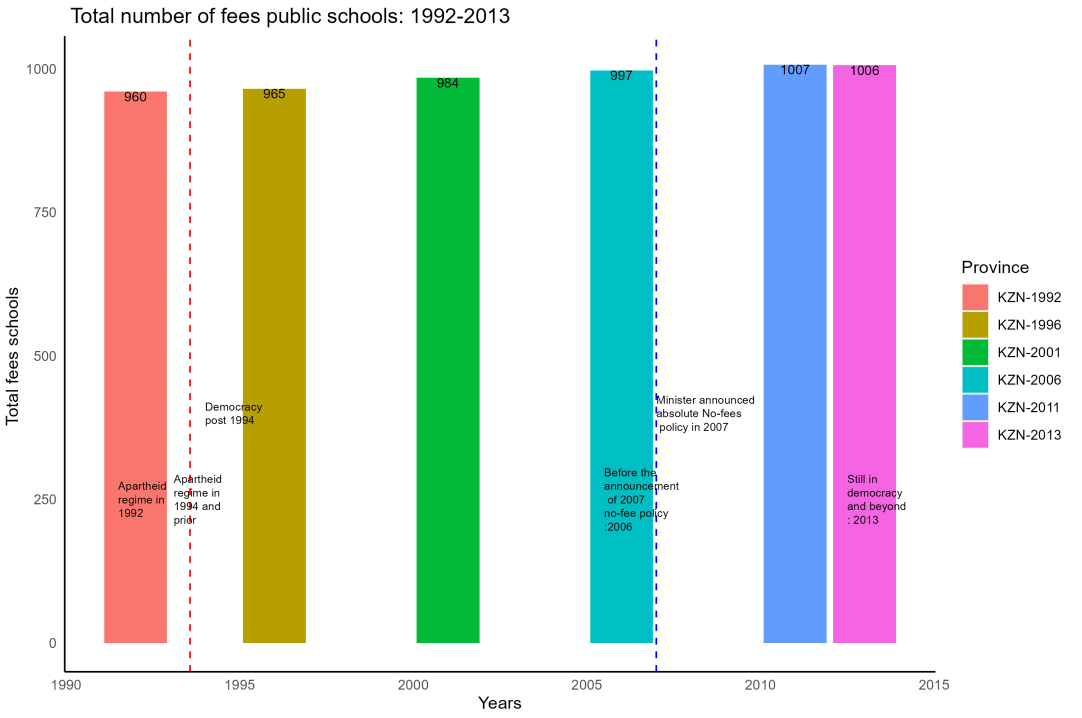
Table 2.1 shows that a proportion of both fee and non-fee schools remain the same over the period studied, less than 30% of fee schools because the government invested more in non-fee-paying schools, as demonstrated by the higher number. Overall, there has been a 4.4% increase in the number of schools from 5202 schools before apartheid to 5431 post apartheid. In total, you had a total of 229 public schools in KwaZulu-Natal. The fee-paying school growth increased by 4.7% from(960 to 1006), whereas non-fee-paying-paying increased by 4.3% from (4242 to 4425) as demonstrated by Table 2.1 and Figures (2.1 and 2.2).

TABLE 2.1: Proportion of fee and non-fee schools over time

Year	**Fee**	**Non-Fee**	**Proportion**
1992	960	4242	0.226
1996	965	4258	0.227
2001	984	4314	0.228
2006	997	4356	0.229
2011	1007	4404	0.229
2013	1006	4425	0.227

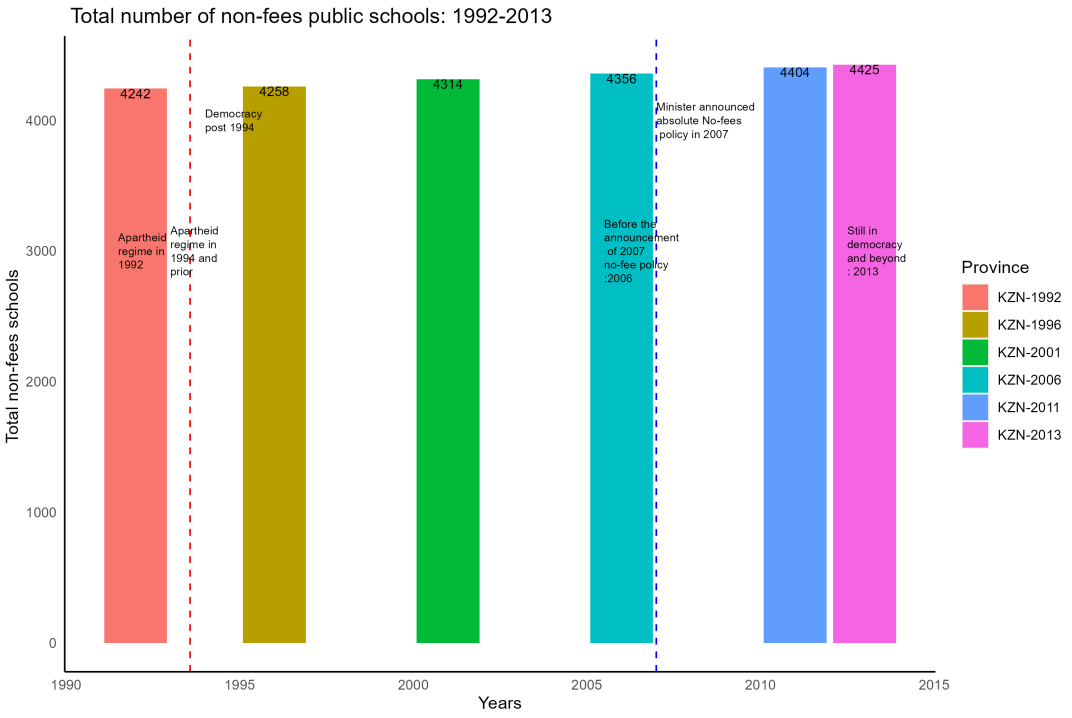
Note: Table 2.1 presents the number of fee-paying and non-fee-paying schools for each year in the dataset, along with the calculated proportion of non-fee schools.

FIGURE 2.1: Total number of fee pay schools: 1992-2013



Note: Figure 2.1 is the total number of fee pay schools for all 44 local municipalities in KwaZulu Natal. We select five year period interval from 1992-2013 to show schools constructed under apartheid and democratic era policies.

FIGURE 2.2: Total number of non-fee pay schools: 1992-2013



Note: Figure 2.2 shows the total number of non-fee-paying schools for all 44 local municipalities in KwaZulu-Natal. We select a five year period interval from 1992-2013 to show schools constructed under apartheid and democratic era policies.

This chapter examines the effectiveness of the implementation of educational policies in the construction of public schools in KwaZulu-Natal from 1992-2013. We consider two eras before and after democracy to observe whether there was a distribution of public investment in the name of fee and non-fee schools. The questions that we trying to answer are: What happened to the construction of public schools when there was a new policy announced, either under apartheid or democratic government? Did those policies influence the construction of public schools? Lastly, we examine if the construction of public schools contributed to the accumulation of human capital for the people of this country, and if not, who was affected by that?

We use the Geographic Information System (GIS) technique to locate public schools and economic activities in KwaZulu-Natal. This will help to understand whether there is a relationship between school construction and economic growth, which is measured using night lights. GIS technologies have played an important role in the spatial analysis of geographic features in recent years Jekel, Lehner, and Vogler (2017); Musakwa (2017); Yuan (2017) and Cil, Fjelde, Hultman, and Nilsson (2019); Salehi and Ahmadian (2017). The technology has become useful over the years for a wide range of mapping and analysis applications internationally, and in the Republic of South Africa in particular. Such technologies are appropriate for a variety of usages including resource management, peacekeeping, labour, land surveying, urban growth monitoring, health services' spatial analysis, traffic planning, service management, and public community facilities Al-Ghamdi, Mirza, Elzahrany, and Dawod (2012); Al-Zahrani (2006); Dawod, Mirza, and

Al-Ghamdi (2011).

This chapter adds to the literature that studies the spatial location of public infrastructure in roads, malls, school facilities, housing, and hospitals, see for example Yang, Tang, Luo, and Law (2015). It also adds to the literature of night lights, which has been introduced in the field of economics by Henderson et al. (2012) and Lowe (2014) as a technique of photographing different places on earth with satellites to learn the movements of people and their economic activities. Public schools are classified as those that charge school fees and those that do not charge school fees. Night lights are used as a proxy for economic activities. This chapter uses geographic information system technology to evaluate the spatial distribution of public schools and night lights over the 1992-2013 period in KZN. Several geospatial functions are performed using ArcMap 10.6 software, for example, to compute mean light growth and the number of schools for the administrative units of local municipalities. The use of Arcmap helps to avoid multiple counting of schools. This study uses a huge survey DoE dataset, some of the schools contain similar information, which makes it difficult to be classified on spreadsheets, but with the aid of Armap it is possible.

This chapter finds an increase in the non-fee-paying schools as a percentage of total public schools (be fee and non-fee) in KZN. This happened after a newly elected democratic government, which is the ANC, assumed power in 1994. The new government brought in new policies documented in the Reconstruction and Development Programme (RDP of 1994) to tackle the atrocities of the former government. The study also shows that during the apartheid regime, there was an increase in fee schools, which were favoured by educational policies designed to exclude black South Africans from participating in the economy. Clearly, it shows that black people were excluded from the economy. The percentage growth among local municipalities for fees versus non-fees is demonstrated.

Furthermore, we show the best and the worst performing municipalities in economic activities and growth in public schools. We find Ethekwini to be the best performing municipality with variations both in fee schools and in non-fee schools, and more growth in average night lights. Likewise, eDumbe is the worst-performing municipality with variations in non-fees rather than fees. The municipality also demonstrates a slight growth in economic activities from 1992-2013. Ethekwini shows more distributions in public schools and economic activities compared to eDumbe and across all municipalities.

2.1.2 Educational infrastructure for development and growth in South Africa.

Public infrastructure in general is good for the development of countries Srinivasu, Rao, et al. (2013). To enhance the human capital of people living in society, the construction of a good-quality school infrastructure can be one of the solutions. Societies and governments around the world strive to improve their education system so that youth are not deprived of the opportunity to acquire knowledge and skills for the better development of their societies. However,

there are mixed arguments about whether expenditures on school infrastructure have a high rate of returns; see, for example,Harbison, Hanushek, et al. (1992), Glewwe and Jacoby (1994) and Hanushek (1995). Education and public school facilities play a major role in the development of new advanced technologies and machinery. However, the World Bank Report Filmer, Langthaler, Stehrer, and Vogel (2018) argues that education does not guarantee the immediate achievement of important learning outcomes.

South Africa (SA) is amongst the countries with high levels of inequality in the world. Educational inequality in SA emerged during the apartheid regime in 1948 when black people were deprived of the opportunity to access well-constructed schools' infrastructure and good education. The development of apartheid policies at that time made it difficult for black people to prosper in that system. The school buildings were overpopulated, leading to many students dropping out. School dropout is a sign of a classroom shortage or the school itself. Researchers have shown that conditions such as overcrowded school facilities can hinder student academic performance Rivera-Batiz and Marti (1995). Unfair distribution of educational resources creates frustration that leads to many cases of school dropout, whereas building and renovating has a positive effect on attendance rates Schady and Paxson (1999). This passage explains the importance of educational infrastructure for human capital and the development of the South African economy. It simply shows that, in addition to other inequalities in the country, the deprivation of access to quality education and infrastructure might have contributed more to the current inequalities in this country. If there had been a fair distribution of public school investment during apartheid times, then the current ruling party would not be dealing with the atrocities of the past.

The advent of democracy in 1994 led to the development of an inclusive system that accommodates people of the land without discrimination by race or affordability. They came up with a policy framework such as the Reconstruction and Development Programme (RDP of 1994). The objective of the policy framework was to distribute SA resources by building infrastructure for the poor, alleviate poverty through job creation, provide social grants and more. Amongst others, school investment was also considered the biggest priority for development and inequality reduction. The question would be: Looking at the educational policies of 1994, has the new government in ANC been able to close the gaps mentioned above, such as the shortage in schools' construction and proper placement?

2.2 Data

The study area of this chapter is KwaZulu-Natal (KZN) province. It is located on the east coast of South Africa. It covers an area of 94361 km^2 and has a population that is approximated to 11 065 240, with Pietermaritzburg being the capital city. Durban is the third most popular city which is found in South Africa and the largest in KZN. The province includes other major towns and cities such as Port Shepstone, Richards Bay, Newcastle, Estcourt, Ladysmith, and

Richmond. Furthermore, the province is divided into one metropolitan municipality called eThekwini Metropolitan and 10 district municipalities, which are subdivided further into 44 local municipalities (LMs). Why KZN? This research is using a big dataset on public schools and the growth of indoor and outdoor artificial lights. To understand the behaviour of school construction in detail, we find it important not only to study the provincial level but also the local municipality level. For that apparent reason, we opted to choose KZN. Amongst the other four provinces examined in chapter 3, we found that KZN is the only province with a huge number of public schools and LMs more than the other three mentioned, which are: Eastern Cape, Free State, and Gauteng. This also justifies the selection of KZN.

2.2.1 Public schools

The dataset on public schools is downloaded from the Education Management Information System (EMIS), which is a function within the Department of Education (DoE).[2] The school dataset contains private and public schools from lower grades, such as grade R, to higher grades such as grade 12. The school dataset has all the schools recorded from the 1800s until 2016. Our study is interested in the (1992 to 2013) period, which correlates with night lights data that is available from 1992-2013. We consider the two regimes (prior and post-democracy) in which these public schools were built. Public schools are categorised into fee schools and non-fee schools. Fee schools are those that supplement government funding with extra parents' fees, whereas non-fees are fully subsidised by the government. The Minister of Education decides which school should be classified as a fee-paying or non-fee-paying school. In addition, DoE master list dataset consists of information about the schools, such as the names, locations, registration dates, geographic coordinates (latitude and longitude), whether a school is public or privately owned, and whether the school is exempt from paying school fees or not.

2.2.2 Night lights

The data on night lights is archived by the National Geophysical Data Centre (NGDC) of the National Oceanic and Atmospheric Administration (NOAA) of the United States.[3] The Defence Meteorological Satellite Program (DMSP) of the United States Air Force Defence department, specifically the DMSP-OLS Nighttime Lights Time Series Version 4 which provides annual composites of stable lights from 1992 to 2013 is the main source for all the night lights data that is used for this study. Satellites from the (DMSP) have been circulating the earth 14 times per day using their Operational Linescan System (OLS) sensors since the early 1970s to read the intensity of earth-based light with a digital archive beginning in 1992. These satellites can extract light between 8:30 pm and 10:00 pm all over the globe. The intensity of the night lights is measured by a digital number which is an integer ranging from 0 (no light luminosity) and 63

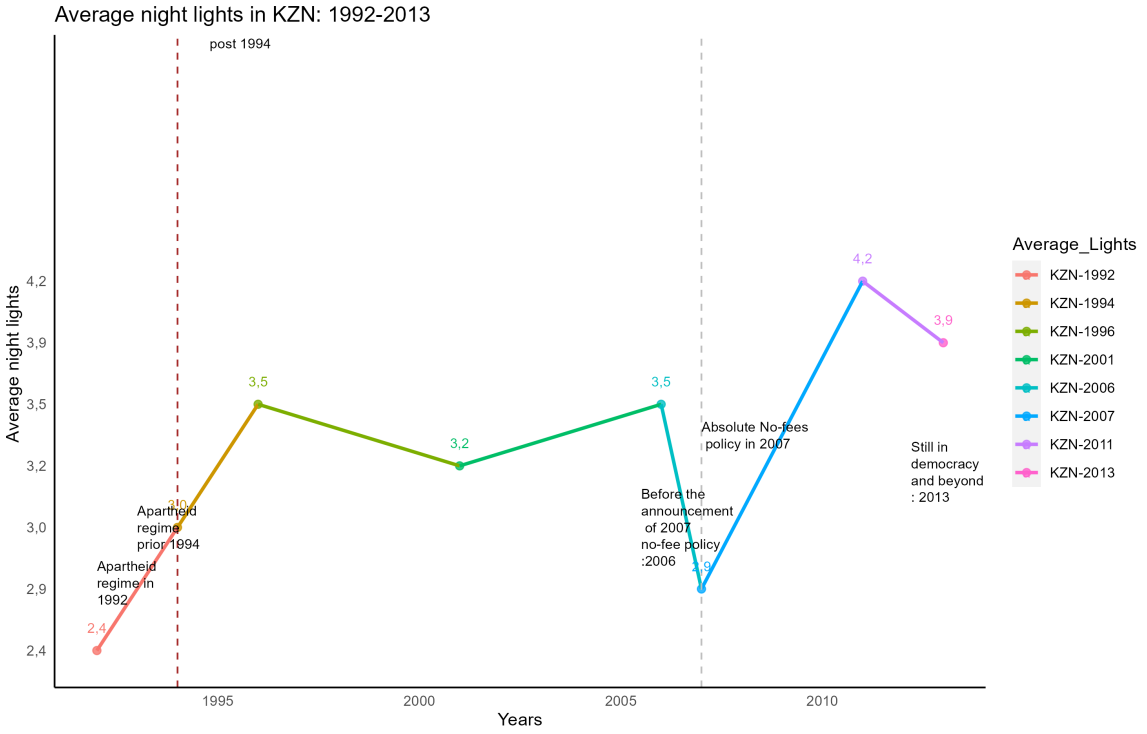
[2] https://www.education.gov.za/Programmes/EMIS.aspx
[3] http://ngdc.noaa.gov/eog/dmsp/downloadV4composites.html

(more light luminosity). Across small geographical areas, the high resolution of this data makes it very useful for spatial analysis of night economic activities. For every 30 arc-second pixels (grid cell) is nearly 0.86 square kilometres on the equator. The data is processed using standard cleaning procedures to remove ephemeral lights like fires and other transient events, as well as to correct for sensor degradation over time. However, there are shortcomings of night-light data as follows: **Low-Coding Schema**: In economically disadvantaged areas, the low-coding schema of nightlight data may result in decreased sensitivity, potentially underestimating light intensity and economic activity. **Top coding or saturation at the high end :** The DMSP-OLS data is prone to saturation in places with high light intensity, making it difficult to differentiate between different levels of economic activity in well-lit locations. The new literature by Bluhm and Krause (2022) is added to address how to deal with the issues of saturation in highly lit areas. Despite its shortcomings, nightlight data is nevertheless an effective instrument for tracking economic activity over time. We recognise that these constraints may have an impact on our estimations, especially in areas with extremely high or low light intensity. However, our extra analysis and robustness tests indicate that the overall patterns in our study are reliable and consistent. Like in Lowe (2014), this study uses geographic administrative units containing stable night lights, cloud-free coverage and average visible lights which constitutes lights from towns, cities, and other places with persistent lighting. In addition, Lowe (2014) also demonstrates the procedure of extracting, cleaning, and computing night lights. This study uses the same procedures to extract and clean night lights to justify its relevance in estimating the economic activities of LMs in KwaZulu Natal. Raster data on night light intensity is available for the entire world. We used ArcMap tools to extract rasters for LMs administrative units from the entire world. The dataset contains images of the world's night light pixels from 1992 to 2013. Figure 2.3 depicts the average night lights for KZN over the period 1992 to 2013. I demonstrate in the Figure the times during the regimes where the policies were made.

2.2.3 Public schools and night lights using Arcmap

Concerning spatial inequalities of services, Dawod, Mirza, Elzahrany, and Al-Ghamdi (2013) use GIS to investigate the spatial distribution of public services such as education, commercial, security, health, religious and sports services over the municipal election areas within Makkah city in Saudi Arabia. Likewise, Al-Enazi, Mesbah, and Anwar (2016) use GIS functions to evaluate the spatial distribution of schools within Jeddah city in Saudi Arabia. Moreover, other studies have utilised GIS to identify spatial inequalities of services using accessibility measures. These accessibility measures include calculating the number of services within the boundaries of the census tract, see reviews by Lin (2004); Zhou, Cheng, Xiao, and Bao (2013). Our study contributes to the literature mentioned in this passage by creating meaningful maps of schools and night lights to examine the effects of school construction on growth and inequality.

FIGURE 2.3: Economic activities in KZN from 1992-2013



Note: Figure 2.3 shows the evolution of economic activities in KZN from 1992-2013

As mentioned above, the schools contain important information about geographic identifiers such as spatial coordinates, municipality names, and administrative IDs. These identifiers facilitate the merging with other data sources, for example, linking the information of the municipal areas with that of public schools and night lights by using matching identification numbers. To determine how many public schools are found in a municipality, we assigned spatial coordinates for each school, and then ArcGis software locates schools in a municipality. In total, 1006 fee schools and 4425 non-fee schools are identified between 1992-2013.

2.2.4 Designing geo-database by linking public schools and night lights using Arcmap.

Table 2.2 exhibits the components used to create layers of maps for KwaZulu-Natal.

TABLE 2.2: Themes of Geodatabase

Thematic layer name	Layer description	Data type	Data source
Local-Municipality	All Local municipalities in KZN	Vector-polygon	GADM
Public-Schools	Fees and Non-Fee public schools	Vector-points	EMIS
Province-KZN	Boundaries of KZN	Vector-polygon	GADM
Country- SA	South African boundaries	Vector-polygon	GADM
Night-Lights	Man-made night lights	Raster	NOAA

Note: Table 2.2 Type of layers used to design and decompose South African administrative units.

The ArcMap application converts school coordinates to point features. The geoprocessing tools incorporate schools' geographic coordinates and municipality data into the attribute file. Arcgis map "intersect overlay" is used to assign the LMs layer to the KZN polygon as well as join school data to these two layers. To identify which municipality the school falls within, I join and relate public schools to LMs using the "Join Data operation". After the join data operation is conducted, each point that represents a school is calculated according to the local municipality shape it falls within. The change in both public schools is calculated by differencing schools between periods 1992-2013 exhibited in Table 2.8 and Table 2.9 of Appendices. Arcgis Spatial Analyst Tool" is used to create rasters of night lights within each municipality. This is done by using "Zonal Statistics as Table operation" within the Arcgis Spatial Analyst tools. The Zonal Statistics as Table operation summarises the values of night lights raster within the LMs polygons and reports the results to a table. The night lights data is incorporated in the same attribute table with the LMs and public schools. In addition, all the features for the country, LMs, public schools and raster are linked together using the relevant identity numbers called FIDs of each attribute table.

Table 2.3 shows a list of LMs in KZN. These municipalities were 51 in total but the country dissolved some of them, which is why they are now 44 LMs.

TABLE 2.3: Local municipalities of KwaZulu-Natal province

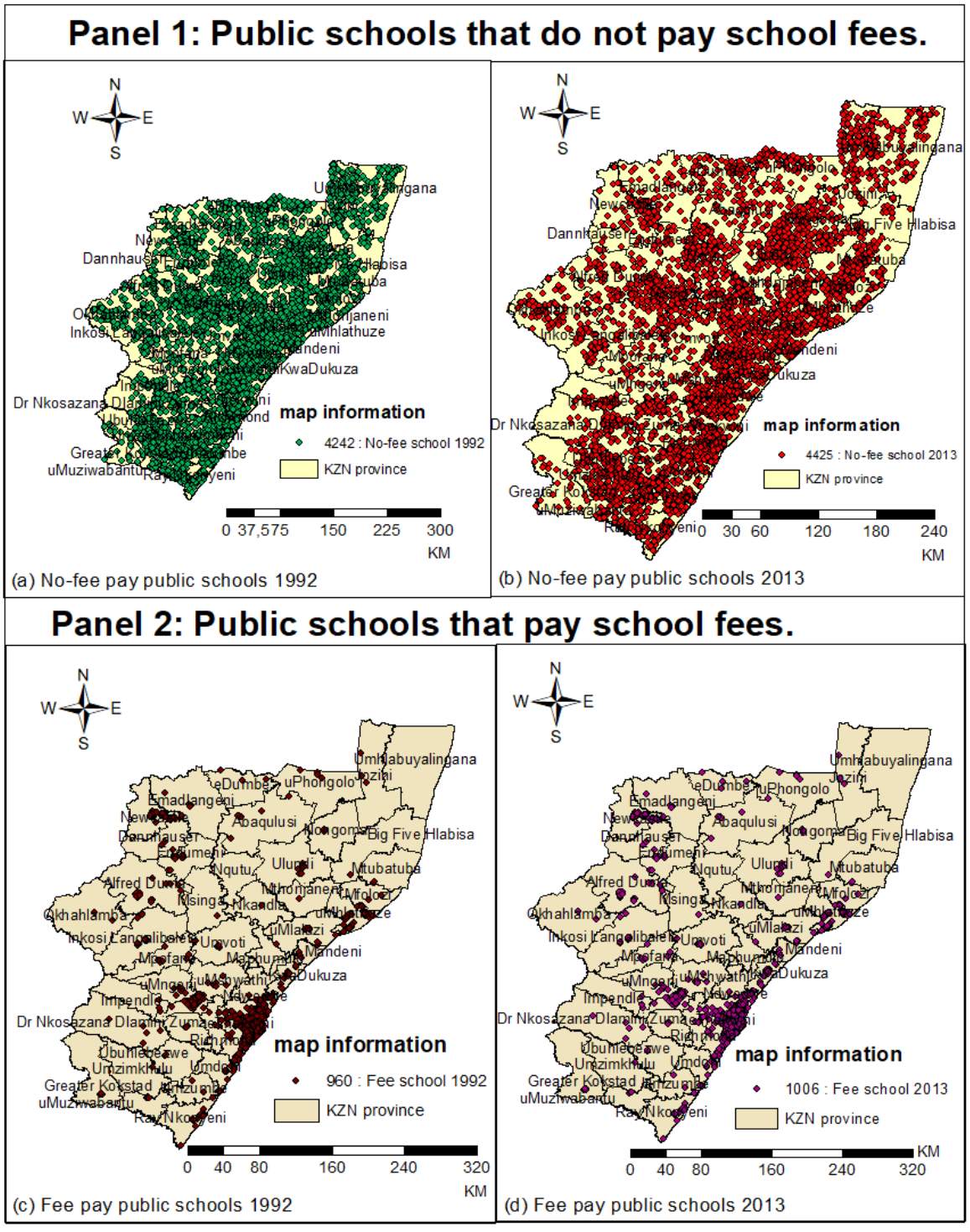
Abbreviation	Full municipality name	District municipality	Province
ULM	Umdoni Local municipality	Ugu	KwaZulu Natal
uMLM	uMuziwabantu Local municipality	Ugu	KwaZulu Natal
RNLM	Ray Nkonyeni Local municipality	Ugu	KwaZulu Natal
ADLM	Alfred Duma Local municipality	Uthukela	KwaZulu Natal
ILLM	Inkosi Langalibalele Local municipality	Uthukela	KwaZulu Natal
OLM	Okhahlamba Local municipality	Uthukela	KwaZulu Natal
ELM	Endumeni Local municipality	Umzinyathi	KwaZulu Natal
NqLM	Nqutu Local municipality	Umzinyathi	KwaZulu Natal
NcLM	Newcastle Local municipality	Amajuba	KwaZulu Natal
EmLM	Emadlangeni Local municipality	Amajuba	KwaZulu Natal
DLM	Dannhauser Local municipality	Amajuba	KwaZulu Natal
eDLM	eDumbe Local municipality	Zululand	KwaZulu Natal
uPLM	uPhongolo Local municipality	Zululand	KwaZulu Natal
ALM	Abaqulusi Local municipality	Zululand	KwaZulu Natal
NoLM	Nongoma Local municipality	Zululand	KwaZulu Natal
ULuM	Ulundi Local municipality	Zululand	KwaZulu Natal
UuLM	Umhlabuyalingana Local municipality	Umkhanyakude	KwaZulu Natal
JLM	Jozini Local municipality	Umkhanyakude	KwaZulu Natal
MtLM	Mtubatuba Local municipality	Umkhanyakude	KwaZulu Natal
uMlLM	uMlalazi Local municipality	Uthungulu	KwaZulu Natal
NkLM	Nkandla Local municipality	Uthungulu	KwaZulu Natal
MaLM	Mandeni Local municipality	iLembe	KwaZulu Natal
KM	KwaDukuza Local municipality	iLembe	KwaZulu Natal
NdLM	Ndwedwe Local municipality	iLembe	KwaZulu Natal
MapLM	Maphumulo Local municipality	iLembe	KwaZulu Natal
DNDZLM	Dr Nkosazana Dlamini Zuma Local municipality	Sisonke	KwaZulu Natal
UbLM	Ubuhlebezwe Local municipality	Sisonke	KwaZulu Natal
UmzuLM	Umzumbe Local municipality	Ugu	KwaZulu Natal
BFHLM	Big Five Hlabisa Local municipality	Umkhanyakude	KwaZulu Natal
RLM	Richmond Local municipality	Umgungundlovu	KwaZulu Natal
GKLM	Greater Kokstad Local municipality	Sisonke	KwaZulu Natal
UmziLM	Umzimkhulu Local municipality	Sisonke	KwaZulu Natal
uMsLM	uMshwathi Local municipality	Umgungundlovu	KwaZulu Natal
MsLM	Msinga Local municipality	Umzinyathi	KwaZulu Natal
eTLM	eThekwini Local municipality	eThekwini	KwaZulu Natal
MkLM	Mkhambathini Local municipality	Umgungundlovu	KwaZulu Natal
TMLM	The Msunduzi Local municipality	Umgungundlovu	KwaZulu Natal
uMngLM	uMngeni Local municipality	Umgungundlovu	KwaZulu Natal
ImpLM	Impendle Local municipality	Umgungundlovu	KwaZulu Natal
MfLM	Mfolozi Local municipality	Uthungulu	KwaZulu Natal
uMhLM	uMhlathuze Local municipality	Uthungulu	KwaZulu Natal
MtLM	Mthonjaneni Local municipality	Uthungulu	KwaZulu Natal
UmvLM	Umvoti Local municipality	Umzinyathi	KwaZulu Natal
MpoLM	Mpofana Local municipality	Umgungundlovu	KwaZulu Natal

Note: Table 2.3 (a) is a list of 44 South African local municipalities' administrative units and districts.

Panel 1 and 2 of Figure 2.4 (a, b, c, and d) show point features distribution of public schools within the LMs over the 1992-2013 period. The Figure also illustrates a great variation across LMs in terms of the number of fees and non-fee public schools from 1992-2013. Figure 2.4(a) shows the total number of 4242 non-fee schools in 1992 and they accumulated over the years to 4425 in 2013 as demonstrated in Figure 2.4 (b). Similarly, the total number of fee schools in 1992 was 960 and it increased over the years to 1006 in the year 2013, as demonstrated in Figure 2.4 (c and d).

Figure 2.5 displays economic activities happening only at night for local municipalities of KZN. The graphs show that there has been a positive increase in artificial lights on average from

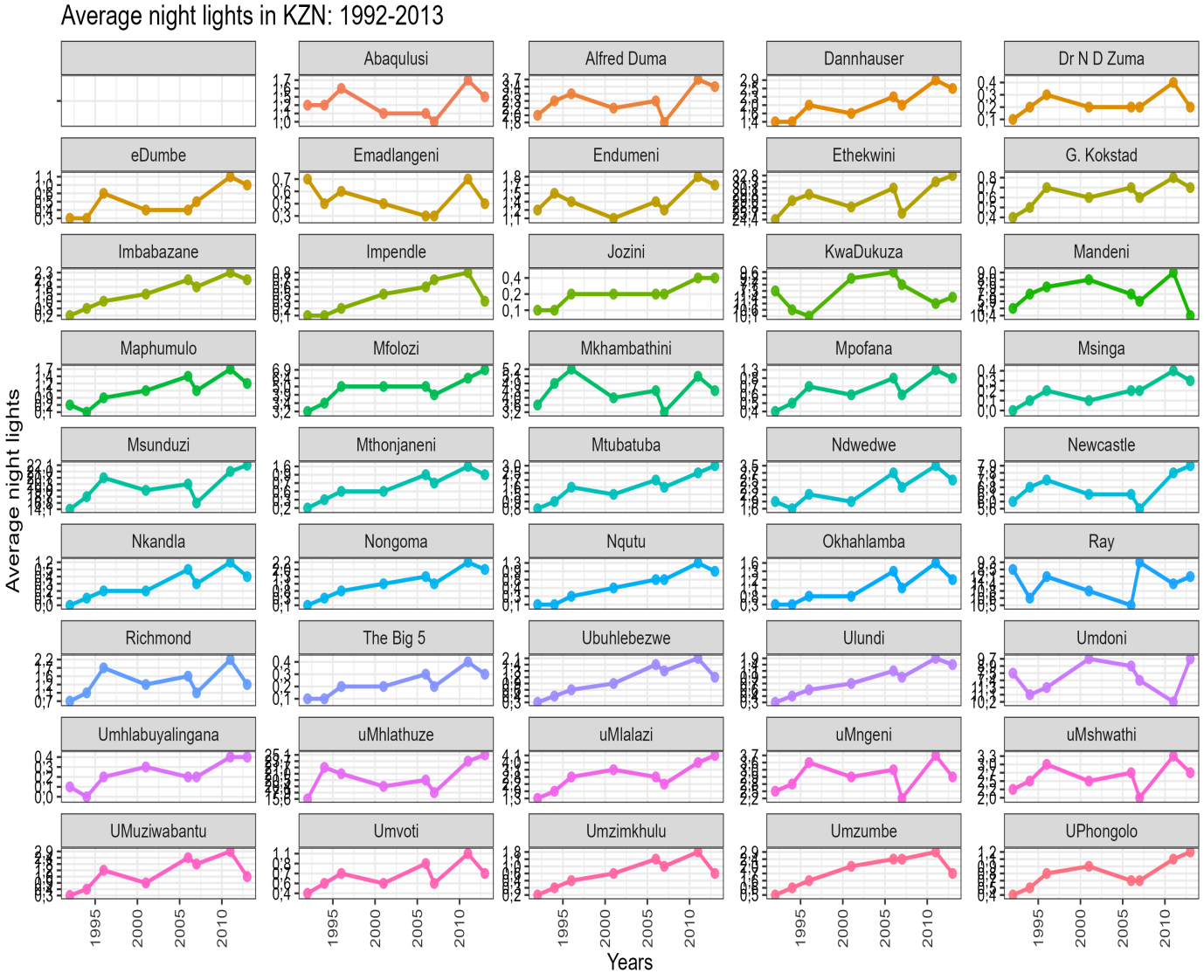
FIGURE 2.4: KZN non-fee, and fee public schools: 1992-2013



Note: Figure 2.4 Panel(1-2) (a, b, c, and d) show the placements of non-fee and fee schools in KwaZulu Natal administrative units using ArcMap software. The schools are in point form.

1992-2013, however, the municipalities also demonstrate a small decline in 2007 and 2013. For local municipalities in KZN, Figure 2.5 displays economic activity that only occurs at night. The graphs show an upward trend in artificial lights (economic growth) from 1992 to 2013, but the municipalities also show a slight decline in 2007 and 2013.

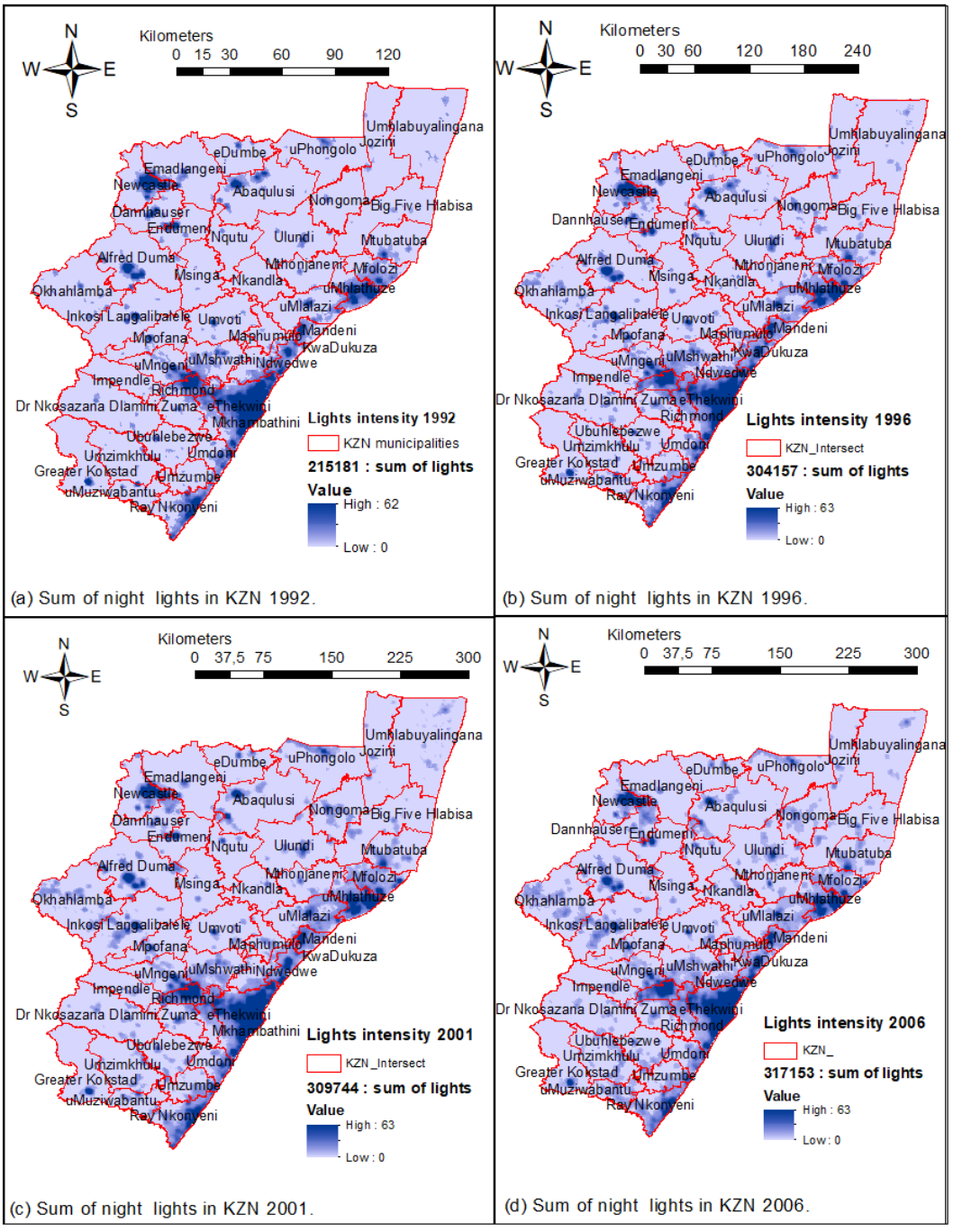
FIGURE 2.5: Average artificial lights intensity by municipality in KZN



Note: Figure 2.5 displays average artificial lights for each local municipality in KZN.

Figure 2.6 (a-d) and Figure 2.6 (e and f) show the intensity of night lights images in the year 1992-2013 for all KZN LMs. The figures show that there has been an increase in the sum of economic activities as it indicated by Figure 2.6(a) which shows a sum of 215181-night lights in 1992. The sum of these lights increase between 1992-2011 in Figures 2.6 (b, c, d) and Figure 2.6 (e) and drop to 360082 in 2013 shown by Figure 2.6(f). The intensity is represented by light blue (low intensity) and dark blue (high intensity).

FIGURE 2.6: KZN night lights intensity 1992-2013

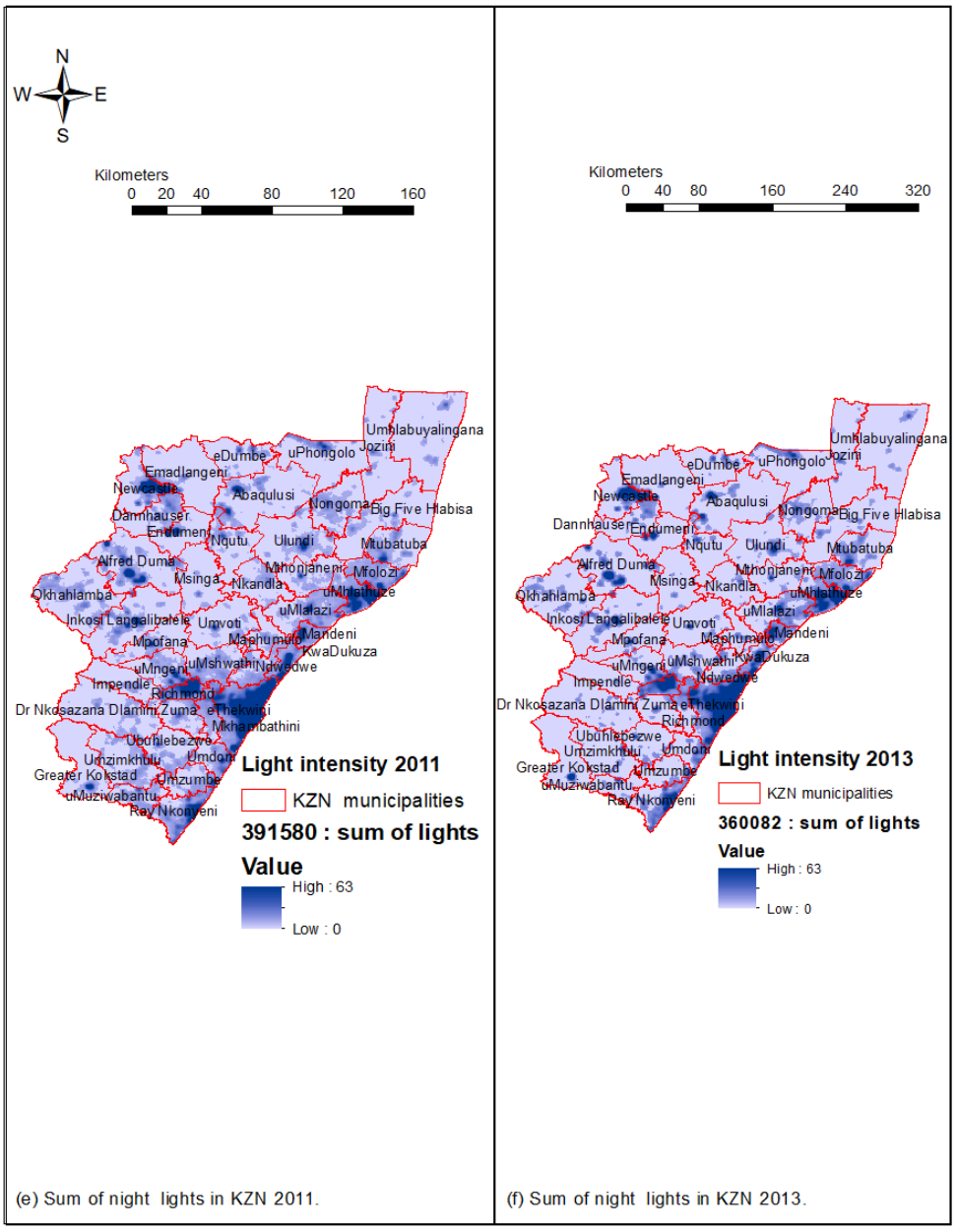


Note: Figures 2.6 (a, b, c, and d) show the distributions in the sum of light intensity in KwaZulu Natal administrative units using ArcMap software. The lights are in pixel form or rasters.

2.3 Fee versus non-fee: The impact of educational policies prior and post-democracy.

Figures (2.8 and 2.9) depict the percentage of fee versus non-fee as a percentage of total public schools (fee and non-fee). During apartheid times, the government that was in power formulated

FIGURE 2.6: KZN Night lights intensity 1992-2013

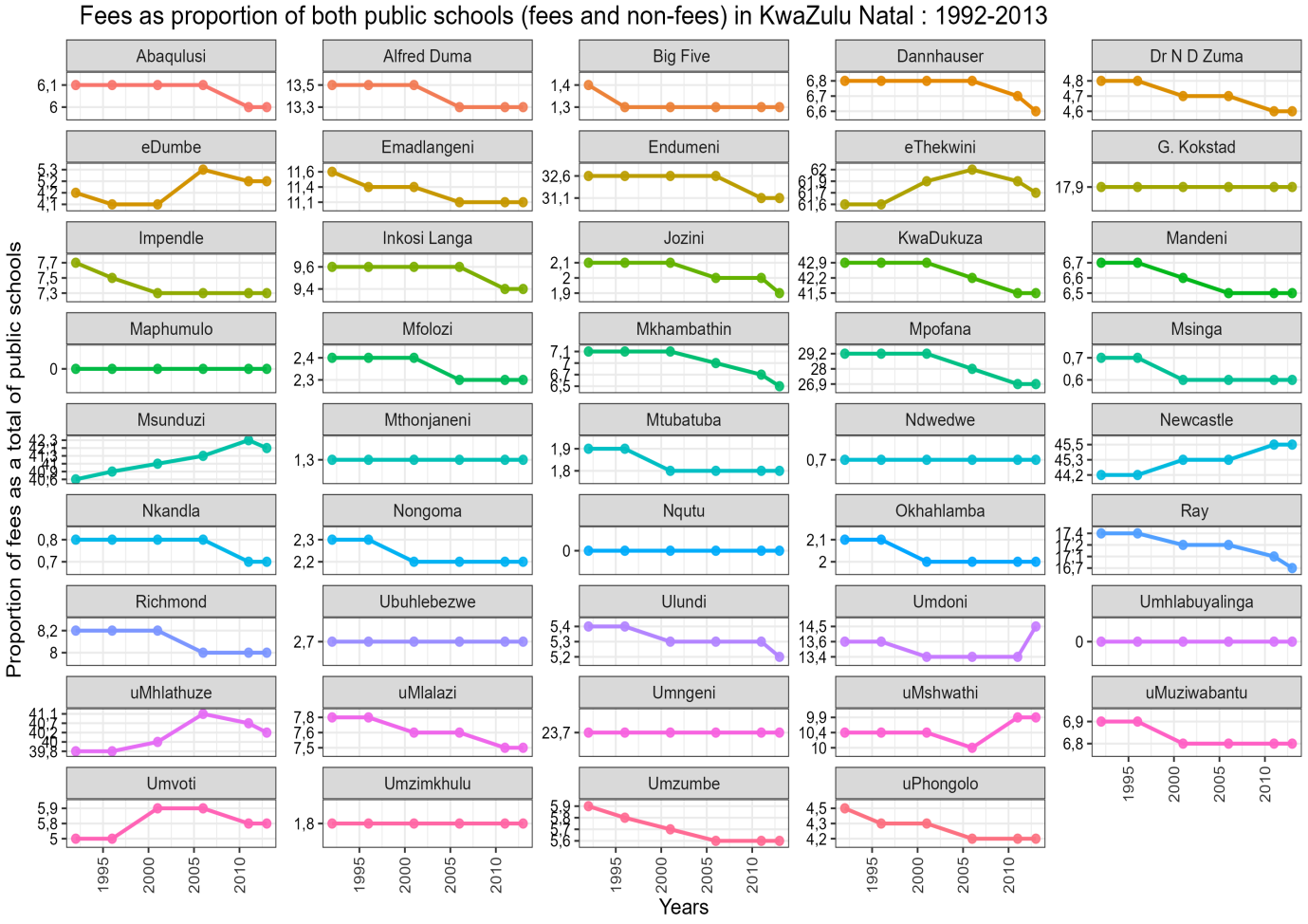


Note: Figures 2.6 (e and f) show the distributions in the sum of light intensity in KwaZulu Natal administrative units using ArcMap software. The lights are in pixel form or rasters.

public school policies that supported the construction of fee schools. Figure 2.8 demonstrates that before 1994 we see that there was an investment in fee. When the democratic government assumed power in 1994 they introduced the RDP programme to tackle the inequalities of the country. The public schools were amongst the policies that were documented in the RDP to fight crimes of the former government. Figure 2.8 shows either no growth of fees or a decline post-apartheid. This is simply because after ANC-led government did not immediately destroy all the fee policies from the former government, instead they adjusted some of them. Figure 2.8 shows a decline of fee in many municipalities during democracy but the decline is way after

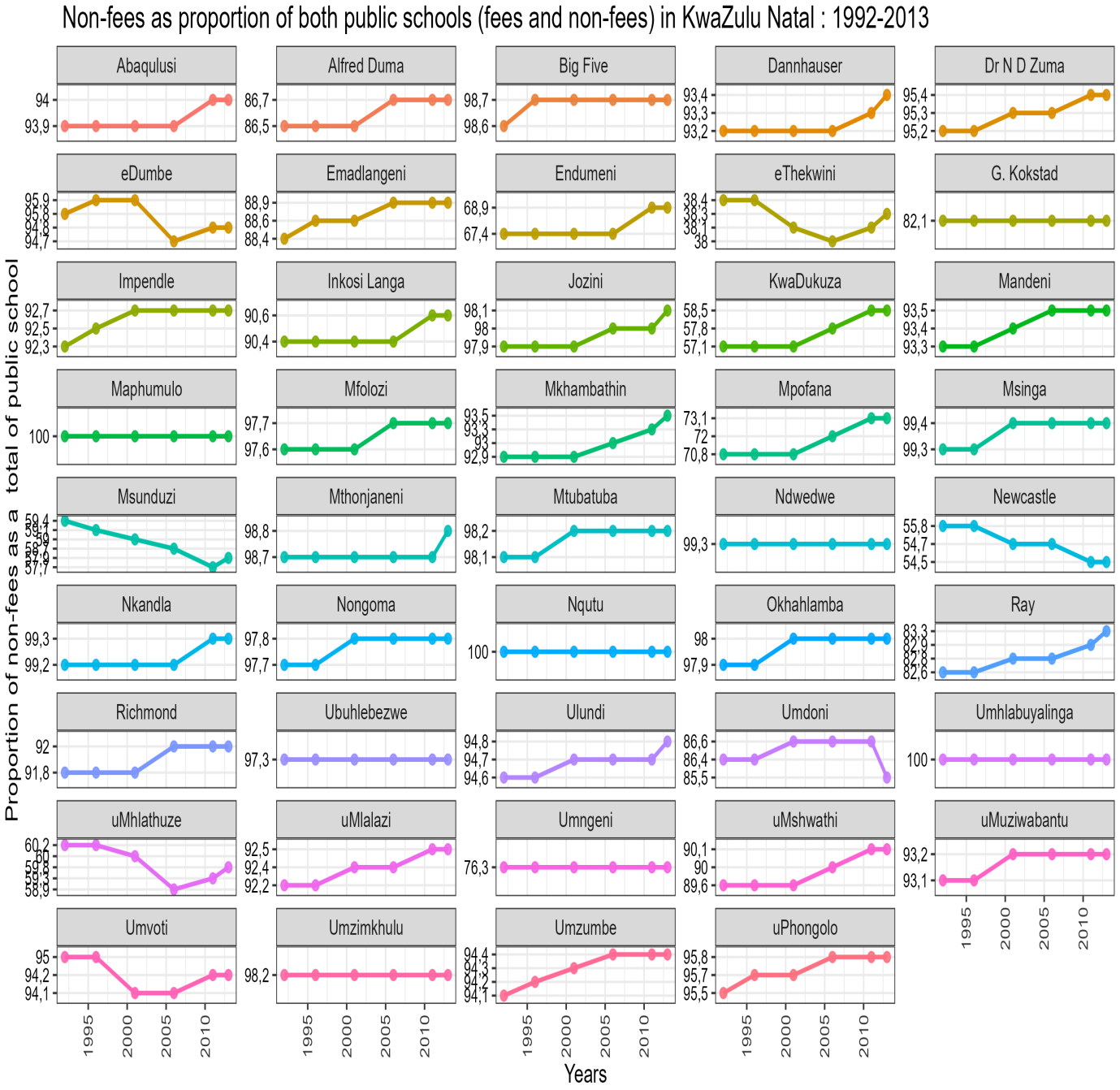
1994, whereas when you look at Figure 2.9 there is an increase in the construction of non-fee. In addition, the abolishment of fee pay school policy also contributed to the increase in non-fees as demonstrated in the Figures. Only in municipalities in big cities like EThekwini where you find that even during democracy you still experience an increase in fee public schools, but overall there is an increase in non-fees during democracy in KZN local municipalities.

FIGURE 2.8: Percentage of fee public schools



Note: Figure 2.8 show percentage of all public fee schools in KwaZulu Natal.

FIGURE 2.9: Percentage of non-fee public schools



Note: Figure 2.9 shows the percentage of all public non-fee schools in KwaZulu Natal.

2.4 Local municipalities that show an increase in both public schools and lights.

2.4.1 Ethekwini and eDumbe municipalities.

We provide a more detailed illustration of the data for the best and worse municipalities. The criterion that we use to choose the best and the worse municipality is that: we look at 44 LMs

of KZN, then we select municipalities that show an increase in both non-fees and fees schools as well as mean lights between 1992-2013. We discover that 7 LMs such as Ethekwini, Newcastle, The uMsunduzi, Umhlathuze, Umvoti, Umdoni and eDumbe show an increase in both non-fees and fees public schools as well as night lights, see Table 2.4, Table 2.5 and Table 2.6 below. Ethekwini is the leading municipality with more investment in schools in 1992, which increases over the years until 2013, whereas eDumbe is the lowest. The total number of both non-fee and fee schools in Ethekwini is 949, and eDumbe with the lowest total of 77. All the other 37 municipalities show change only in either fees or non-fees schools as indicated in the appendix Tables (2.8, 2.9, and 2.10).

TABLE 2.4: Seven municipalities where non-fee schools increased (1992–2013)

Local municipality	**Non-fees schools in 1992**	**No-fee schools in 1996**	**No-fee schools in 2001**	**No-fee schools in 2006**	**No-fee schools in 2011**	**No-fee schools in 2013**	**Total No-fee and Fee 1992- 2013**	**Total Change No-fee schools 1992-2013**
ULM	70	70	71	71	71	71	83	1
NcLM	58	58	58	58	60	60	110	2
eDLM	68	70	71	72	73	73	77	5
eTLM	346	348	353	357	361	363	949	17
TMLM	104	104	105	105	105	106	183	2
uMhLM	65	65	66	66	67	67	112	2
UmvLM	95	95	96	96	98	98	104	3

Note: Table 2.4 Distribution of non-fee schools over the years in 7 local municipalities.

TABLE 2.5: Seven municipalities where fee schools increased (1992–2013)

Local municipality	**Fee schools in 1992**	**Fee schools in 1996**	**Fee schools in 2001**	**Fee schools in 2006**	**Fee schools in 2011**	**Fee schools in 2013**	**Total Nofee and Fee 1992-2013**	**Total Change Fee 1992-2013**
ULM	11	11	11	11	11	12	83	1
NcLM	46	46	48	48	50	50	110	4
eDLM	3	3	3	4	4	4	77	1
eTLM	555	559	573	582	587	586	949	31
TMLM	71	72	73	74	77	77	183	6
uMhLM	43	43	44	46	46	45	112	2
UmvLM	5	5	6	6	6	6	104	1

Note: Table 2.5 Distribution of fee schools over the years in 7 local municipalities.

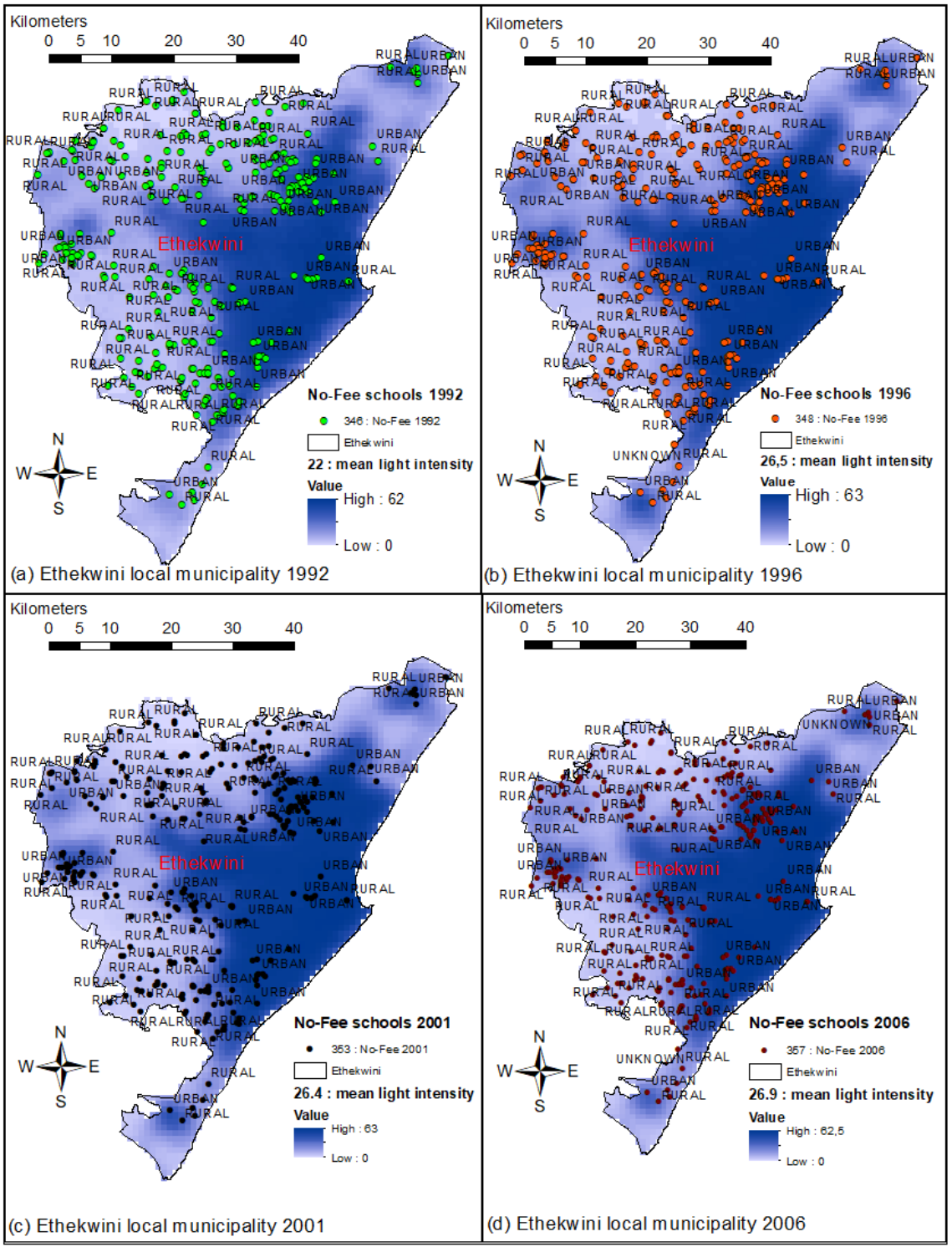
TABLE 2.6: Average night lights in seven local municipalities: 1992-2013

Local municipalities	**Average brightness 1992**	**Average brightness 1996**	**Average brightness 2001**	**Average brightness 2006**	**Average brightness 2011**	**Average brightness 2013**
ULM	2,7	3,8	3,7	3,6	4,2	3,3
NcLM	6,1	7,1	6,5	6,1	7,7	8,0
eDLM	0,3	0,6	0,4	0,5	1,1	1,0
eTLM	22,0	26,5	26,4	26,9	27,8	29,3
TMLM	12,4	18,0	17,9	18,0	18,4	19,3
uMhLM	10,6	14,4	15,5	14,2	16,4	17,3
UmvLM	0,4	0,6	0,6	0,7	1,1	0,6

Note: Table 2.6 Distribution of average night lights over the years in seven local municipalities.

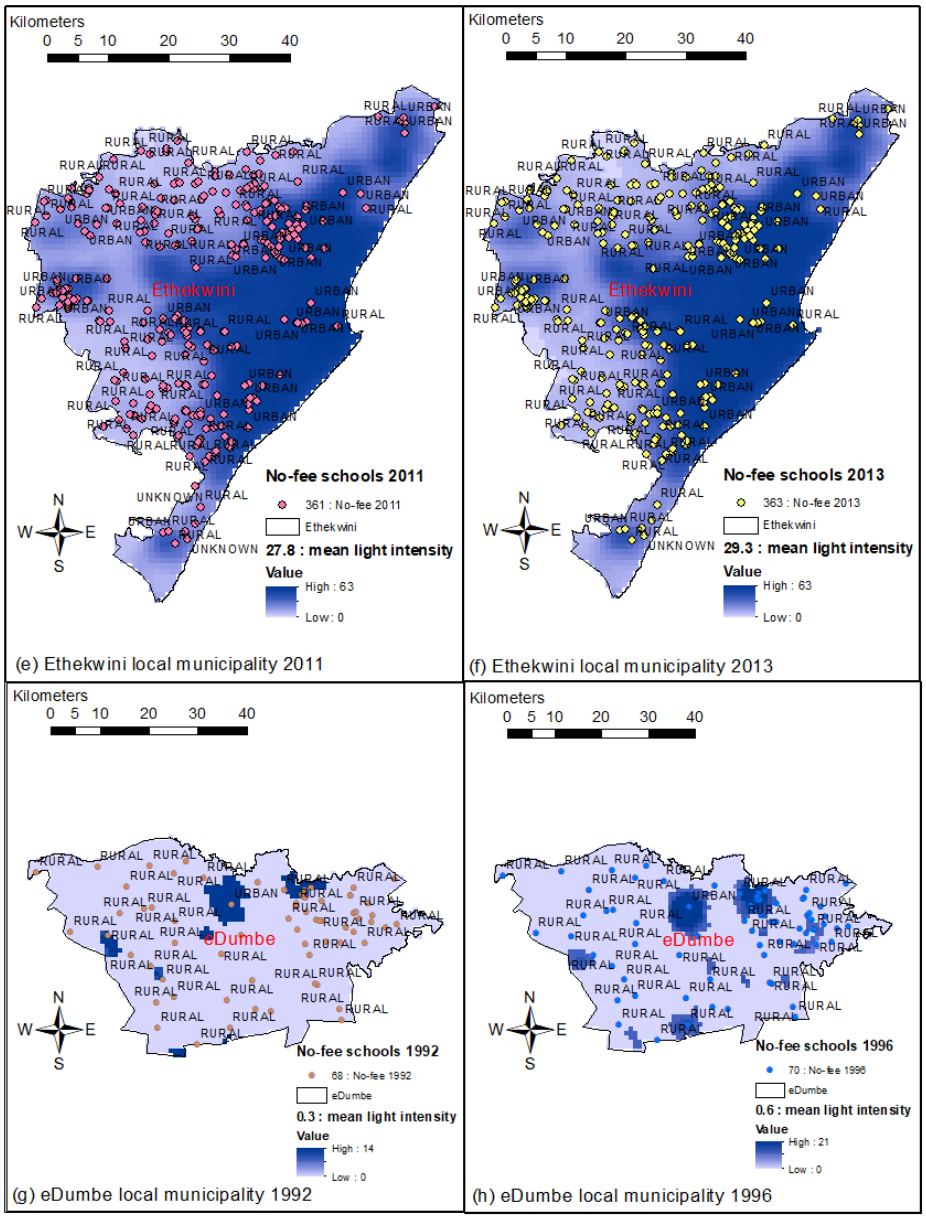
Figure 2.10 below shows the maps of Ethekwini and eDumbe, the best and worst local municipalities in terms of the accumulation of non-fee schools and night lights over the period 1992-2013. Figure 2.10 (a-d) and Figure 2.11 (e and f) show the increase in public school investment in Ethekwini with 346 non-fee schools and mean light intensity of 22 in 1992 which increase by 2 schools and mean light of 4.5 in 1996, In 2001 the schools also increase by 5 to 353 with a small decline of 0.1 in night lights, the mean night lights in 2006 increase by 0.5 to 26.9 and schools by 4. The municipality also experiences an increase of 4 schools to 361 and 0.9 mean lights to 27.8 in 2011, and lastly, there is a total of 363 schools in 2013 and night lights of 29.3. The Ethekwini municipality shows more public non-fees school investment made in the rural areas than in the urban areas, however, there are more economic activities taking place in the urban areas like Durban central and surrounding townships such as Umlazi as indicated in Figure 2.10 (a-d) and Figure 2.11 (e and f) by strong light intensity.

FIGURE 2.10: Ethekwini non-fee and lights intensity



Note: Figures 2.10 (a,b,c and d) show Ethekwini and eDumbe, the best and worse performing municipalities in terms of non-fee schools and night lights over the period 1992-2013.

FIGURE 2.11: Non-fee schools and light intensity from eThekwini to eDumbe

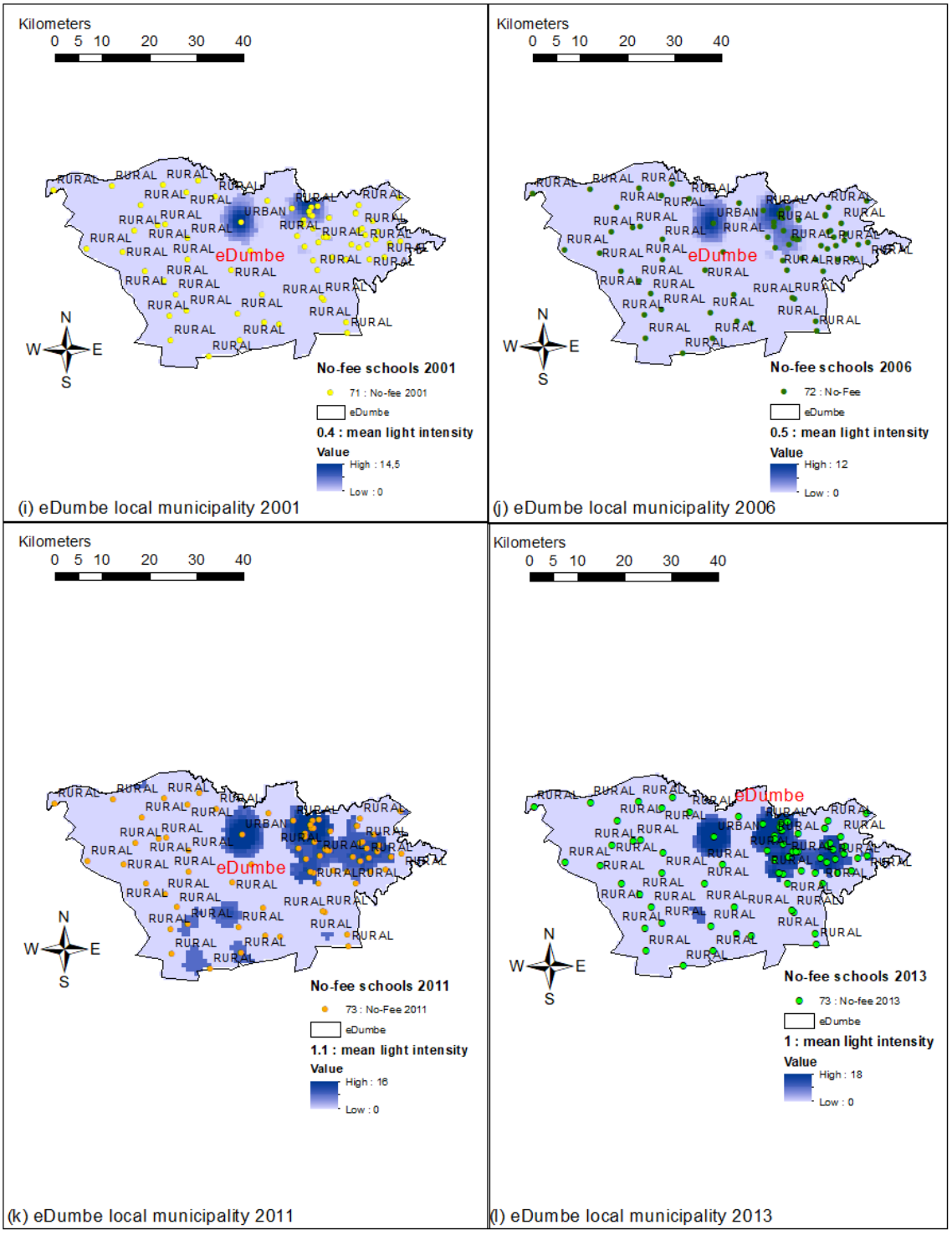


Note: Figures 2.11 (e, f, g, and h) show Ethekwini and eDumbe, the best and worst performing municipalities in terms of non-fee schools and night lights over the period 1992-2013.

In contrast Figure 2.11 (g and h) above and Figure 2.12 (i- l) show a concomitant increase in public school investment in eDumbe with 68 non-fee schools and mean light intensity of 0.3 in 1992 which increase by 2 schools and 0.3 mean light in 1996, schools also increase by 1 in 2001-2011 but the night lights drop to 0.4 and start increasing again by 0.1 in 2006, there are 73 non-fee schools and mean light of 1.1 in 2011, whereas in 2013 there is a slight decrease of light by 0.1 and public schools remain the same as in 2011. It is interesting to point out that eDumbe shows an increase in lights and public schools that are built in the rural areas of

the municipality, whereas Ethekwini shows fewer non-fee schools located in urban areas with a strong economic activity in the same areas of the municipality.

FIGURE 2.12: eDumbe non-fee and light intensity



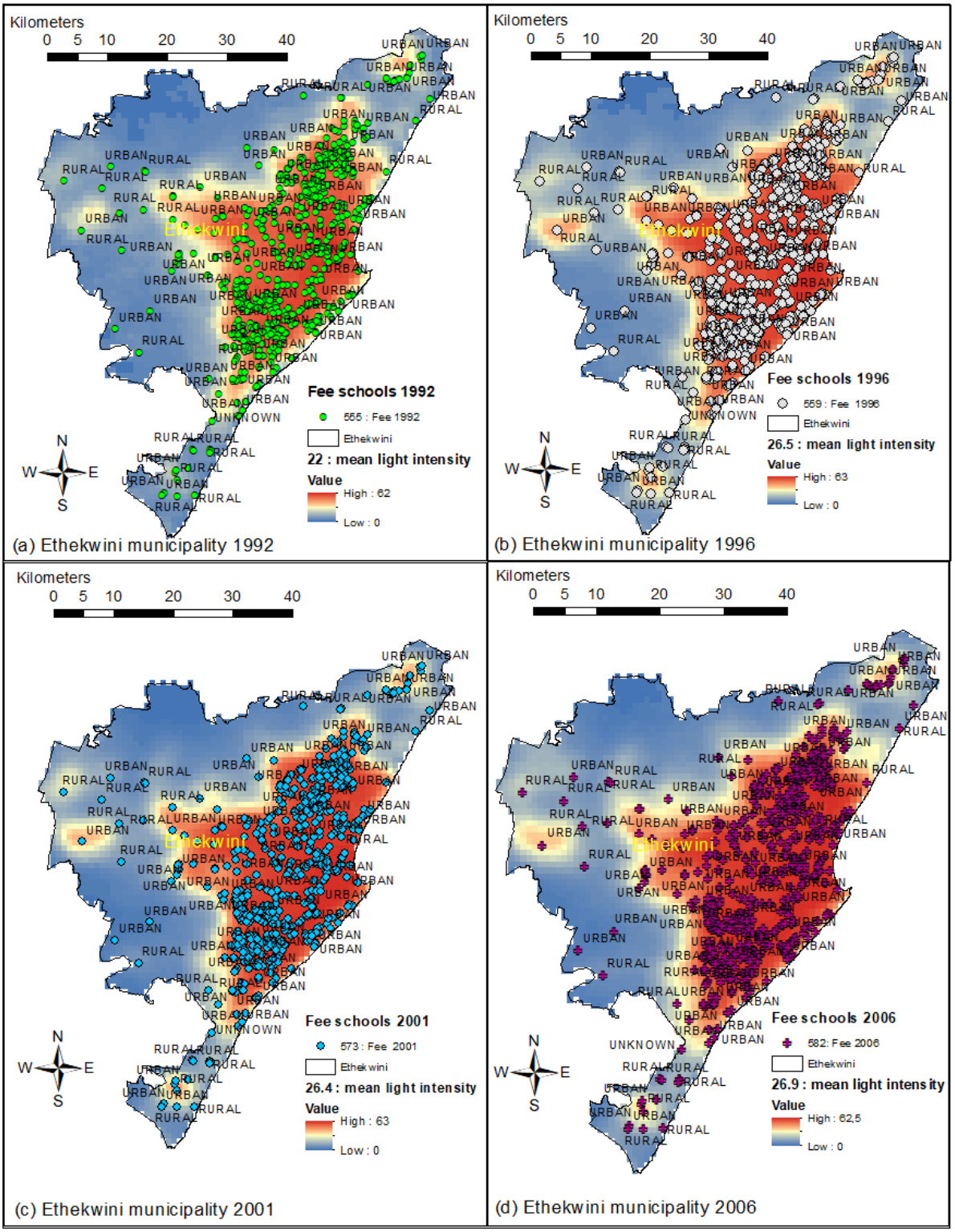
Note: Figures 2.12 (i, j, k, and l), show Ethekwini and eDumbe, the best and worse performing municipalities in terms of non-Fees schools and night lights over the period 1992-2013.

Likewise, Figure 2.13 also shows the maps of Ethekwini and eDumbe, the best and worst

performing municipalities in terms of fee schools and night lights in the period 1992-2013. Figure 2.13 (a-d) and Figure 2.14 (e and f) show the increase in public school investment in Ethekwini with 555 fee schools and a mean light intensity of 22 in 1992 which increase by 4 schools and a mean light intensity of 4.5 in 1996. In 2001, the schools also increased by 14 to 573, with a small decline of 0.1 in night lights; the mean night light in 2006 increased by 0.5 to 26.9 and schools by 9. The municipality also experiences an increase of 5 schools to 587 and 0.9 mean lights to 27.8, and lastly, there is a drop of 1 school in 2013 that resulted in a total of 586 schools in 2013 and a night lights increase of 1.5 to 29.3. The Ethekwini shows more increase in fee schools than in non-fee public schools in the urban areas of Durban city centre as well as nearby suburbs and townships. The fee schools are well concentrated in the urban areas, whereas the non-fee schools dominate the rural areas of the metropolitan municipality. Overall, the Ethekwini municipality grows better in terms of lights where fee schools are located than non-fee. Figure 2.14 (g-h) and Figure 2.15 Figure (i-l)show public school investment in eDumbe with 3 fee schools and mean light intensity of 0.3 in 1992, there is no school increase between 1992-2001 and only slight increase in mean light, schools also increase by 1 in 2006-2011 but the night lights increase to 0.5 in 2006, increases by 0.6 in 2011 and decreases slightly by 0.1 in 2013. The public schools remained at 4 between 2006-2011. The figures also demonstrate that eDumbe has more investment in non-fee schools that are identified in rural areas, and over time, the light intensity becomes stronger in rural areas.

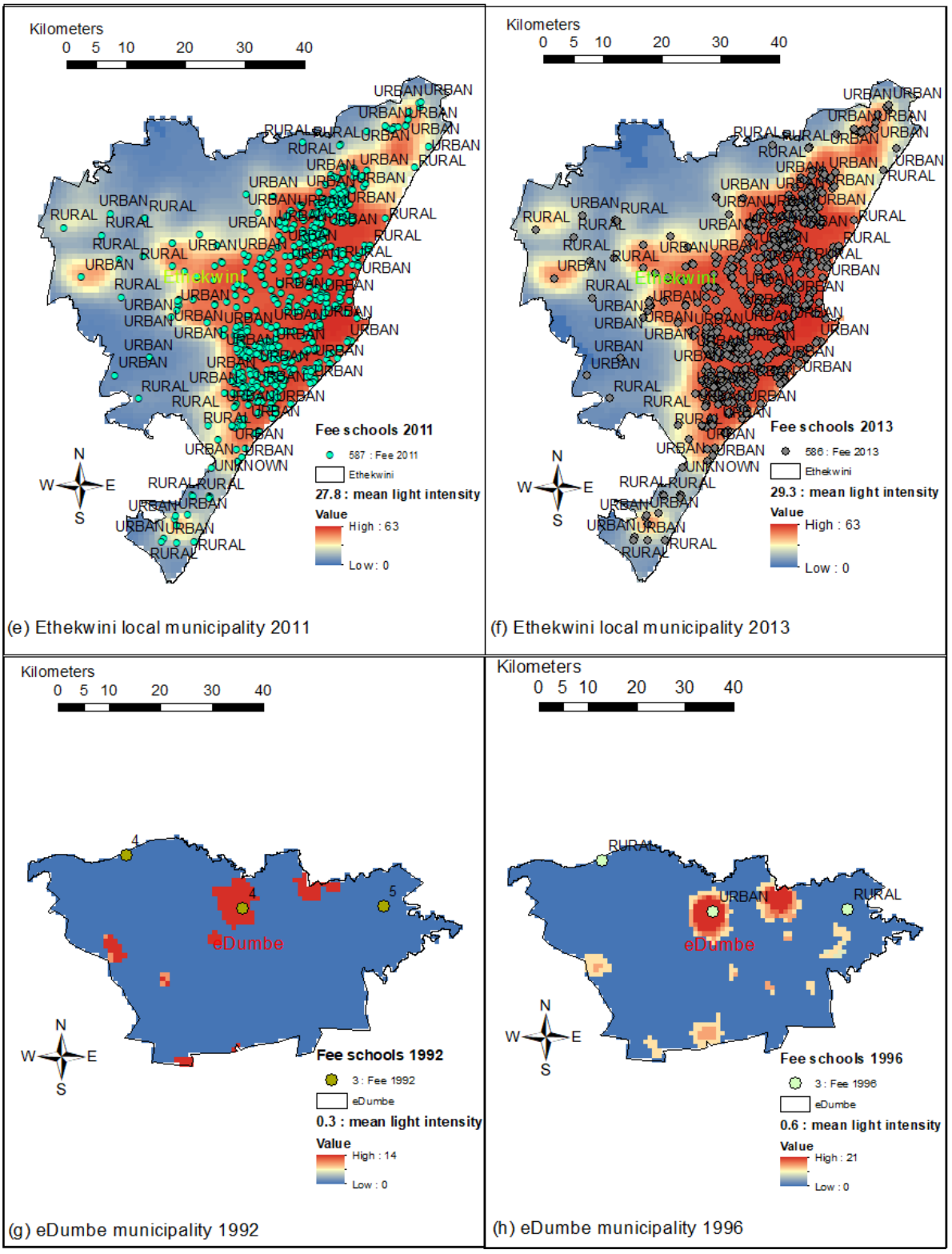
When comparing Ethekwini to eDumbe, it is clear that overall Ethekwini municipality has more investment in both public schools and more growth in night lights than eDumbe and the rest of the LMs.

FIGURE 2.13: Ethekwini fee and light intensity



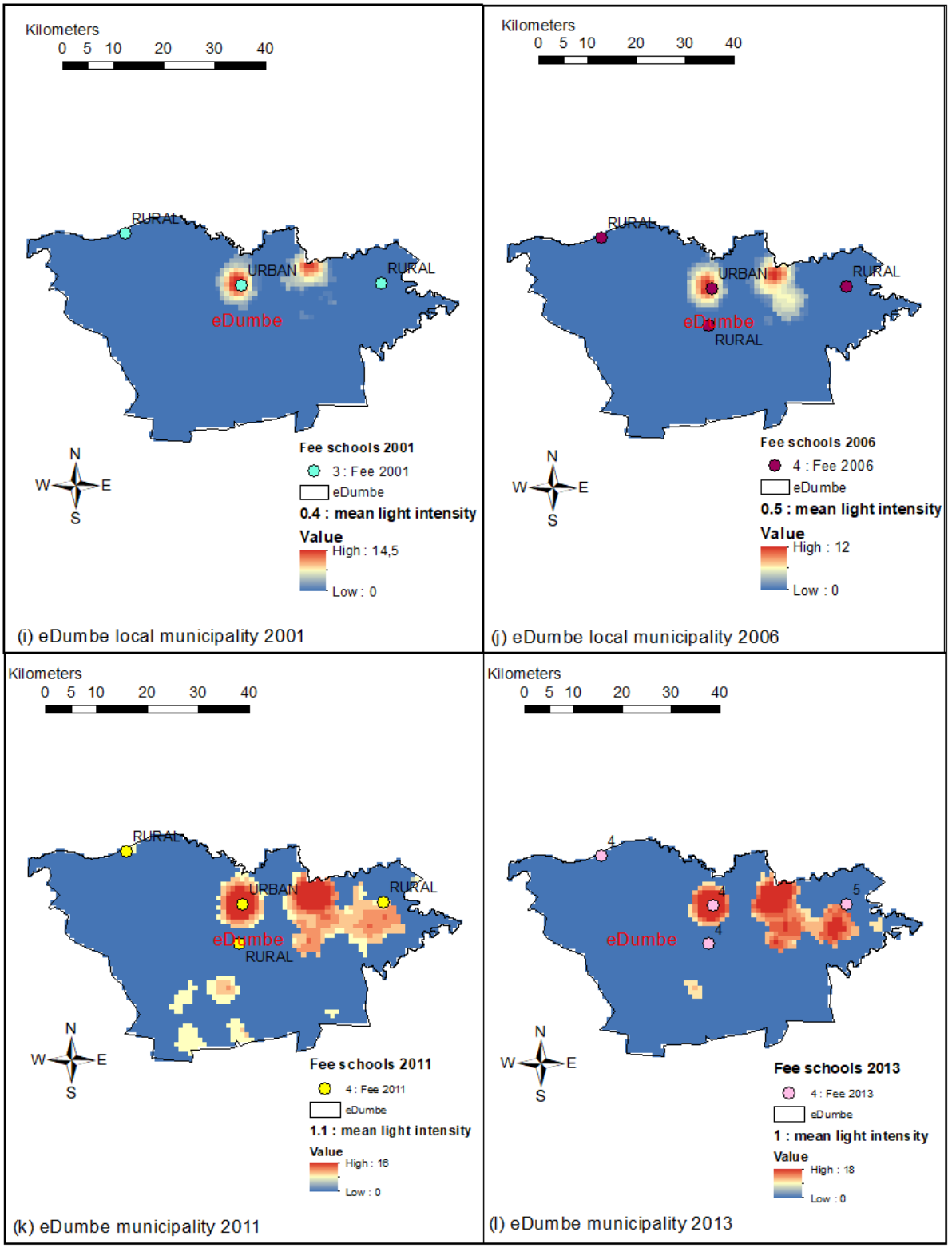
Note: Figures 2.13 (a, b, c, and d), show the maps of Ethekwini and eDumbe, the best and worse performing municipalities in terms of fee schools and night lights in the period 1992-2013.

FIGURE 2.14: Fee Schools and light intensity from eThekwini to eDumbe



Note: Figures 2.14 (e, f, g, and h), show the maps of Ethekwini and eDumbe, the best and worse performing municipalities in terms of fee schools and night lights in the period 1992-2013.

FIGURE 2.15: eDumbe fee schools and light intensity

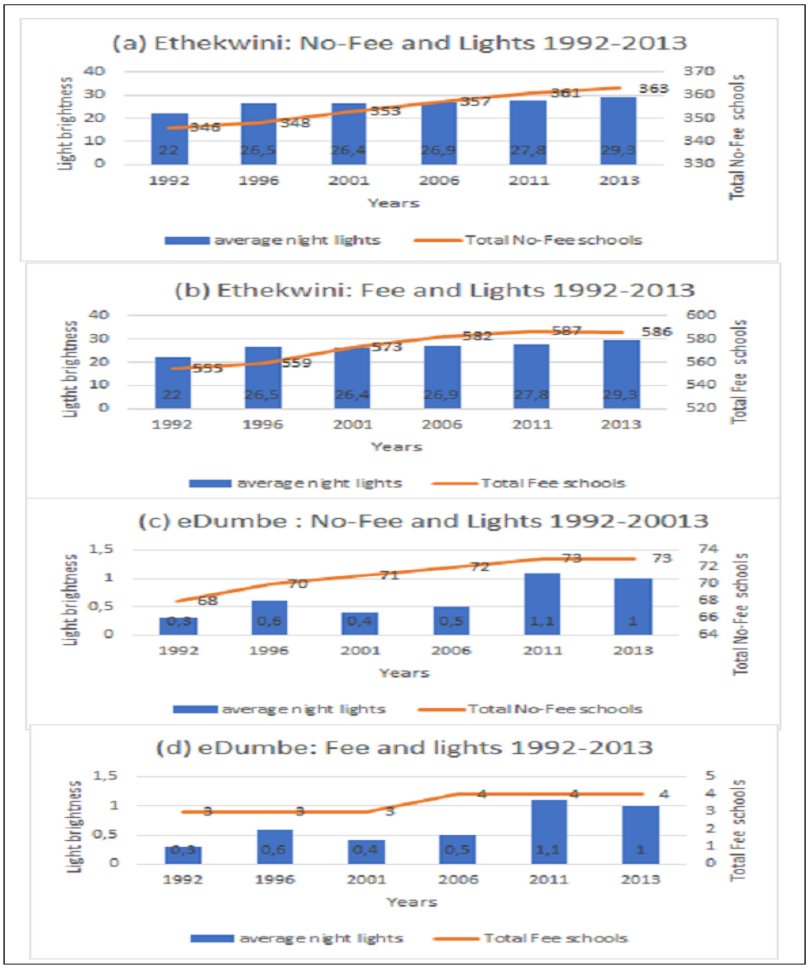


Note: Figures 2.15 (i, j, k and l), show the maps of Ethekwini and eDumbe, the best and worse performing municipalities in terms of fee schools and night lights in the period 1992-2013.

2.4.2 Quintiles: Ethekwini and eDumbe municipalities

Figure 2.16 (a-d) exhibits the graphs of the best and worst LMs. The graphs of Ethekwini in Figure 2.16 (a and b) show that the total number of both non-fee and fee schools increases on an annual basis from 1992-2013, and the economic activities also increase in the same period. There is a huge increase in fee schools than in non-fee schools, even in percentage terms. Likewise, graphs c and d of Figure 2.16 show eDumbe municipality with an increase in both (non-fee and fee) and night lights. However, there is a slight decrease in the local economic activities of eDumbe, particularly in 2001 and 2013. There is more increase in non-fee than fee in eDumbe, but in percentage terms, fee schools show a 33.3 % growth rate, which is more than 7.3 % for non-fee schools. The growth in percentage terms of both Ethekwini and eDumbe is demonstrated in Table 2.7.

FIGURE 2.16: Graphical representation non-fee and fee 1992-2013



Note: Figures 2.16 (a and b) show that as the total number of both non-fee and fee schools increases on an annual frequency for 21 years over the 1992-2013 period, the economic activities also increase in the same period.

TABLE 2.7: Growth in fee and non-fee schools in eThekwini and eDumbe (1992–2013)

Local municipalities	Non-fee schools 1992	Non-fee schools 2013	% Growth: No-Fee 1992-2013	Fee schools 1992	Fee schools 2013	% Growth: Fee 1992-2013
eTLM	346	363	4.9	555	586	5.6
eDLM	68	73	7.3	3	4	33.3

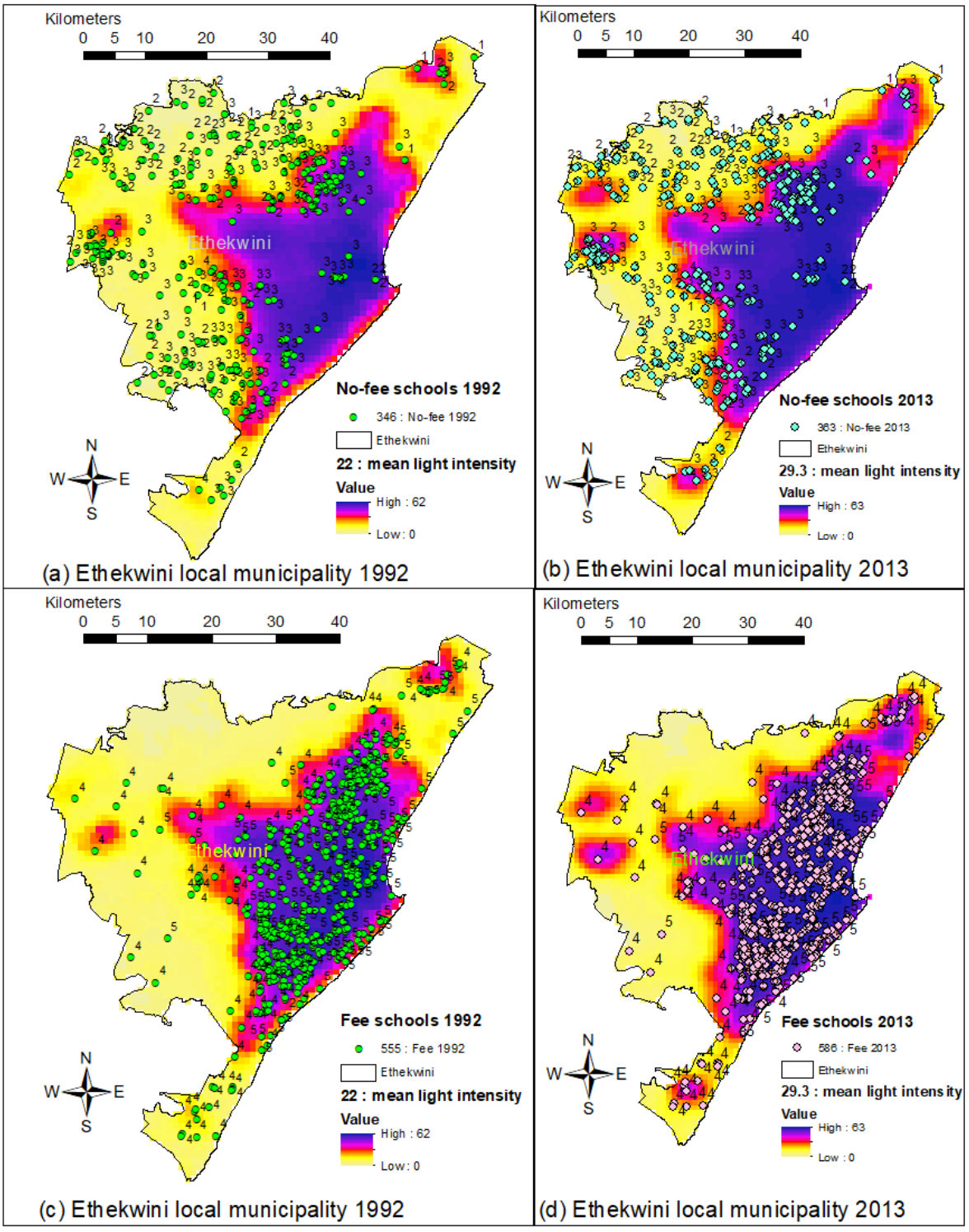
Note: Table 2.7 is the growth of public schools in the best and worst performing municipalities.

Figure 2.17 (a-d) shows the quintiles in eThekwini which indicate whether a school is a poor or rich school and whether the area surrounding the schools is dominated by poor or rich people. Figure 2.17 (a) shows more public schools investment in 1992 made by the government in rural areas with average economic activities of 22, all the schools that are represented by a number between 1-3 don't pay fees, because parents of the pupils that go to those schools are poor. Figure 2.17 (b) shows that even though the investment in schools increased in 2013 to 363, more of this investment still happens in the poor rural areas of Ethekwini municipality and parents don't pay fees. In contrast, Figure 2.17 (c-d) shows that public investment in 1992 and 2013 happens in the areas that are dominated by rich people, and parents in these schools pay fees; any school that falls in these quintiles 4 and 5 must pay fees. Overall fee schools in Ethekwini demonstrate more growth than No-Fee even in percentage terms as indicated by Table 2.7 above. This is also the criterion that is used by the minister to allocate schools.

Similarly, Figure 2.18 (a-d) shows the quintiles in eDumbe, which also indicate whether the school is poor or rich. Figure 2.18 (a) shows more public school investment in 1992 made by the government in rural areas with average economic activities of 22, all the schools that are represented by a number between 1-3 don't pay fees, because parents of the pupils that go to these schools are poor. Figure 2.18 (b) show that even though the investment in non-fee schools increased in 2013 to 73, more of this investment still happens in the poor rural areas of eDumbe municipality, and parents don't pay fees. In contrast, Figure 2.18 (c-d) shows that public investment in 1992 and 2013 happened in the areas that were dominated by poorer than rich people, but because there were still few rich people around then few investments were made and parents in these schools pay fees, any school that falls in these quintiles 4 and 5 must pay fees. Overall, fee schools in eDumbe demonstrate are less than non-fee, but in percentage terms fee schools grow more, as indicated by Table 2.7 above. This is also the criterion that is used by the minister to allocate schools.

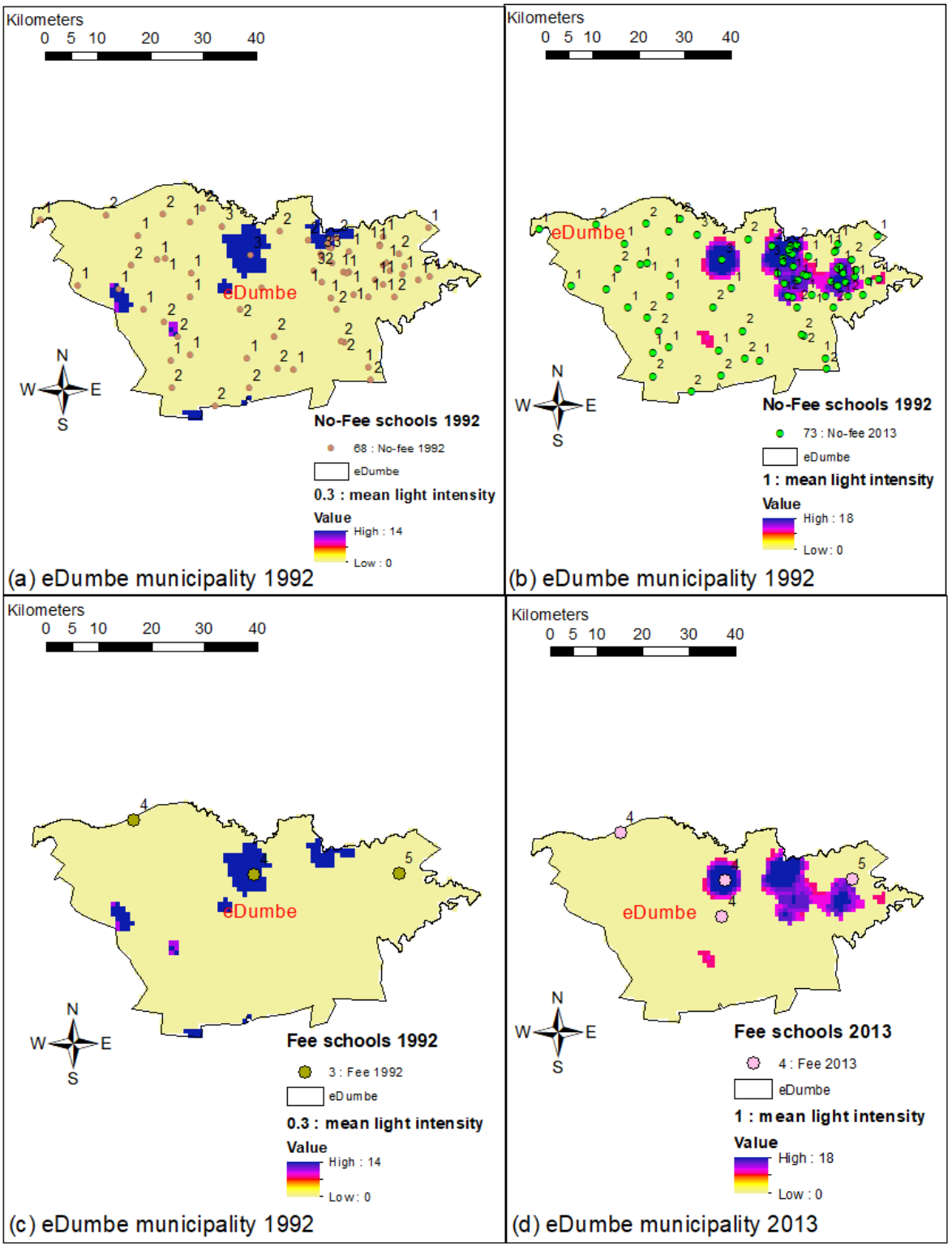
Suffice it to say, Ethekwini is bigger compared to other LMs of KZN. It is a metropolitan municipality that is associated with better growth in the province. Hence, it is fair to state that these are some of the contributing factors that make the municipality the best in terms of economic activities and public school investment.

FIGURE 2.17: Ethekwini non-fee and fee quintiles 1992-2013



Note: Figures 2.17 (a-d) show the quintiles for non-fee and fee for Ethekwini municipality which indicate whether the school is poor or rich and whether the area surrounding the schools is dominated by poor or rich people.

FIGURE 2.18: eDumbe non-fees and fees quintiles 1992-2013



Note: Figures 2.18 (a-d) show the quantiles for non-fee and fee for eDumbe municipality which indicate whether the school is poor or rich and whether the area surrounding the schools is dominated by poor or rich people.

2.5 Conclusion

The RDP program, a key component of the South African government's development plans, has focused on increasing the availability and accessibility of public school investments to local municipalities. This will provide relief for unemployed parents who are unable to afford to pay their children's expensive school fees. When compared to the other 9 provinces of South Africa, KZN is unique in that it is the province with the greatest number of local municipalities and districts. It is also the province that is home to a well-known city like Durban.

To combat inequality and promote growth, the chapter addressed the question of whether before or post-apartheid educational policies had an impact on the creation of public schools in KwaZulu-Natal. We reported the evidence of the rise in the percentage ratio of fee-based versus non-fee schools using data from 44 local municipalities between 1992 and 2013. When the democratic government came into power, we noticed a decrease in the percentage of schools that charge fees and an increase in non-fee schools. Geographic Information System (GIS) technology, specifically ArcMap, was used to process light rasters and school locations into layers of maps for better visualisation to locate public schools and growth.

This chapter discussed further the best and worst municipalities in terms of schools and light accumulation. Public schools are classified as those that pay fees and those that do not pay fees (non-fee). Night lights are all artificial lights that are only observed at night during economic activities. We demonstrate using GIS applications, various steps to gather information datasets with similar features called thematic data layers. The GIS application integrates the geodatabase by using intersect overlay, zonal statistics and sampling tools. Public schools are converted from latitude and longitude coordinates to visible points on a map, whereas night light is used as a proxy for economic activities. Results suggested that Ethekwini has more accumulation in terms of public school investment and light distribution from 1992-2013. There is a greater increase in the number of fee-paying schools than non-fee-paying schools in the municipality. Economic activities have also shown an increase over the period. On the other hand, eDumbe municipality showed less accumulation in terms of public schools and light. The result confirms that, unlike Ethekwini, eDumbe municipality has a greater increase in non-fees than fees schools and the economic activities show growth, although in some other years there are slight declines. Other than 7 municipalities that showed an increase in both schools, 37 of them showed accumulation in non-fee schools only. This chapter demonstrated a methodological technique for analysing the spatial distribution of public school investment and night lights in municipal areas.

In addition, the chapter demonstrated quintiles, which tell whether the school is located in poor rural areas or rich urban areas. The best municipality shows that more fee schools are identified in the urban areas, such as the city centre of Durban, majority of non-fee schools are identified in the outskirts of Durban city centre. On the other hand, the eDumbe municipality

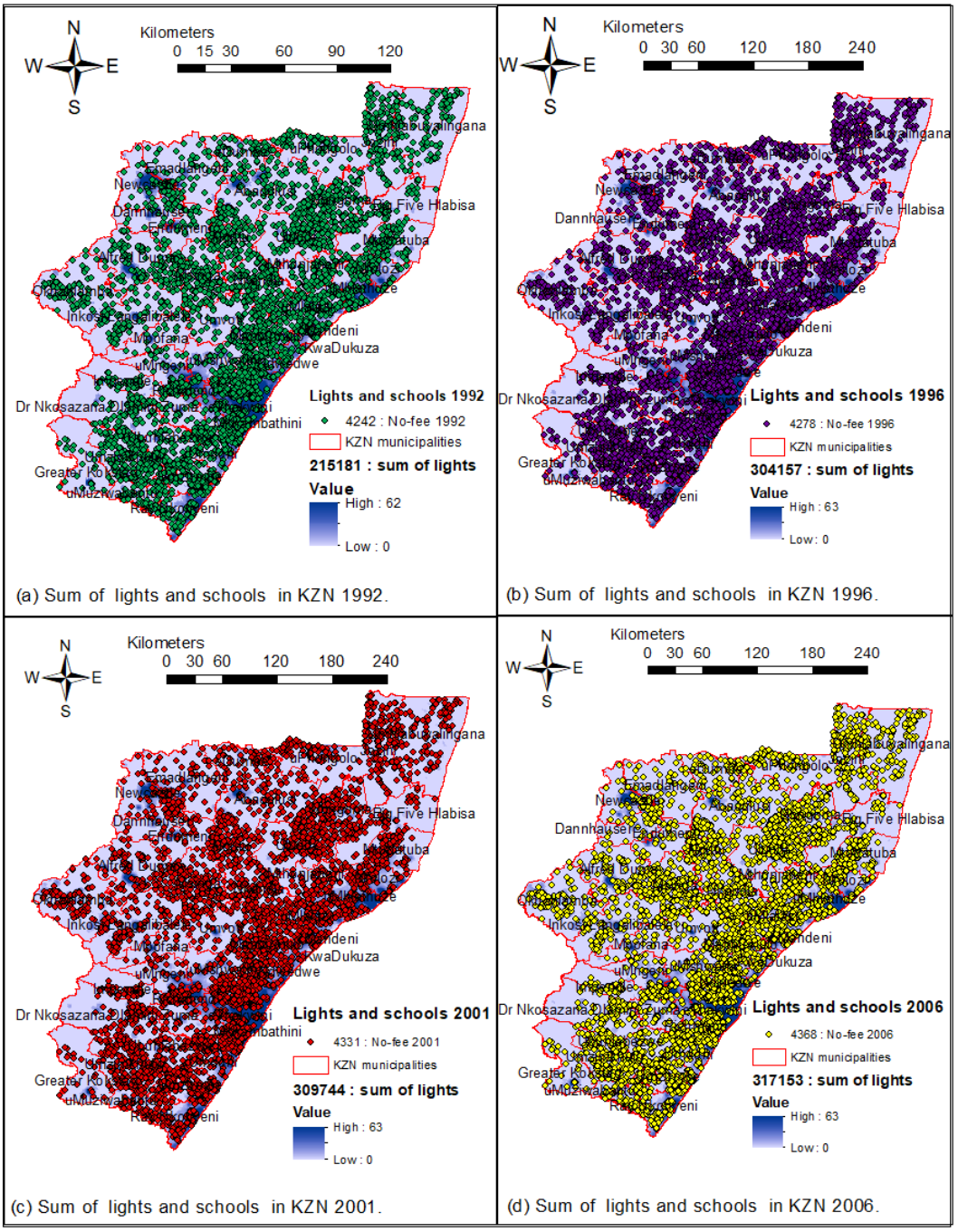
demonstrated more non-fee schools in the outskirts of Paulpietersburg central and a few fee schools.

2.6 Appendix

2.6.1 Public school and night lights layers

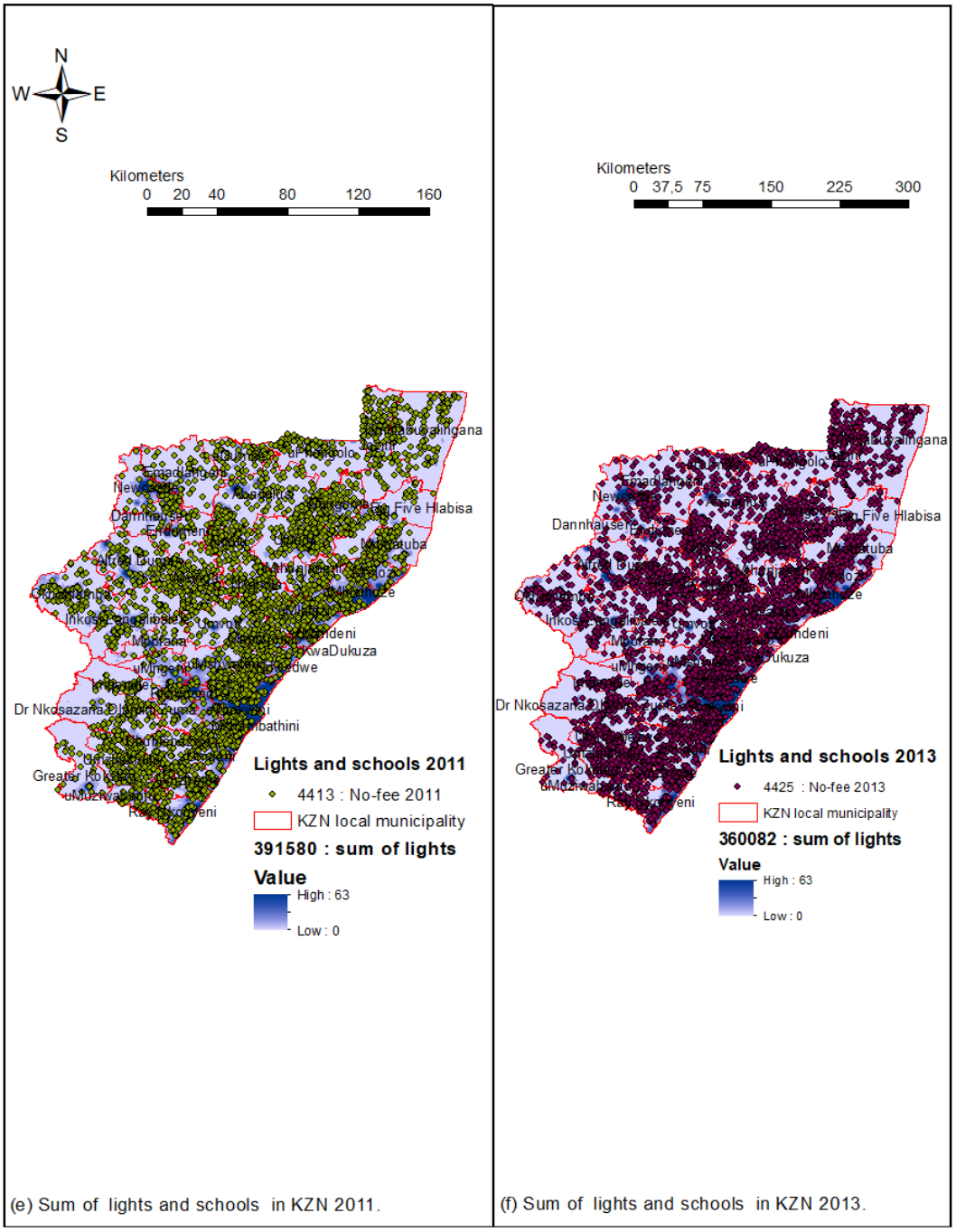
Figure 2.19 (a-d) and Figure 2.20 (e-f) show the non-fee schools represented by points in the same map with night lights represented by blue light intensity. I decided to split a period 1992-2013 into 5 years apart to see distributional patterns of schools and lights on maps e.g 1992, 1996, 2001, 2006, 2011 and 2013. The maps show that the schools and lights have been increasing, starting with 4242 in 1992 and the sum of lights of 215181 which increase over the year until 4425 in 2013 and light sum of 360082. A similar story is repeated for fee schools in Figure 2.21 (a-d) and Figure 2.21 (e-f). The maps show that the fee schools and lights have been increasing, starting with 960 in 1992 and the sum of lights of 215181 which increased over the years until 1006 in 2013 and light sum of 36008.

FIGURE 2.19: Non-fee schools



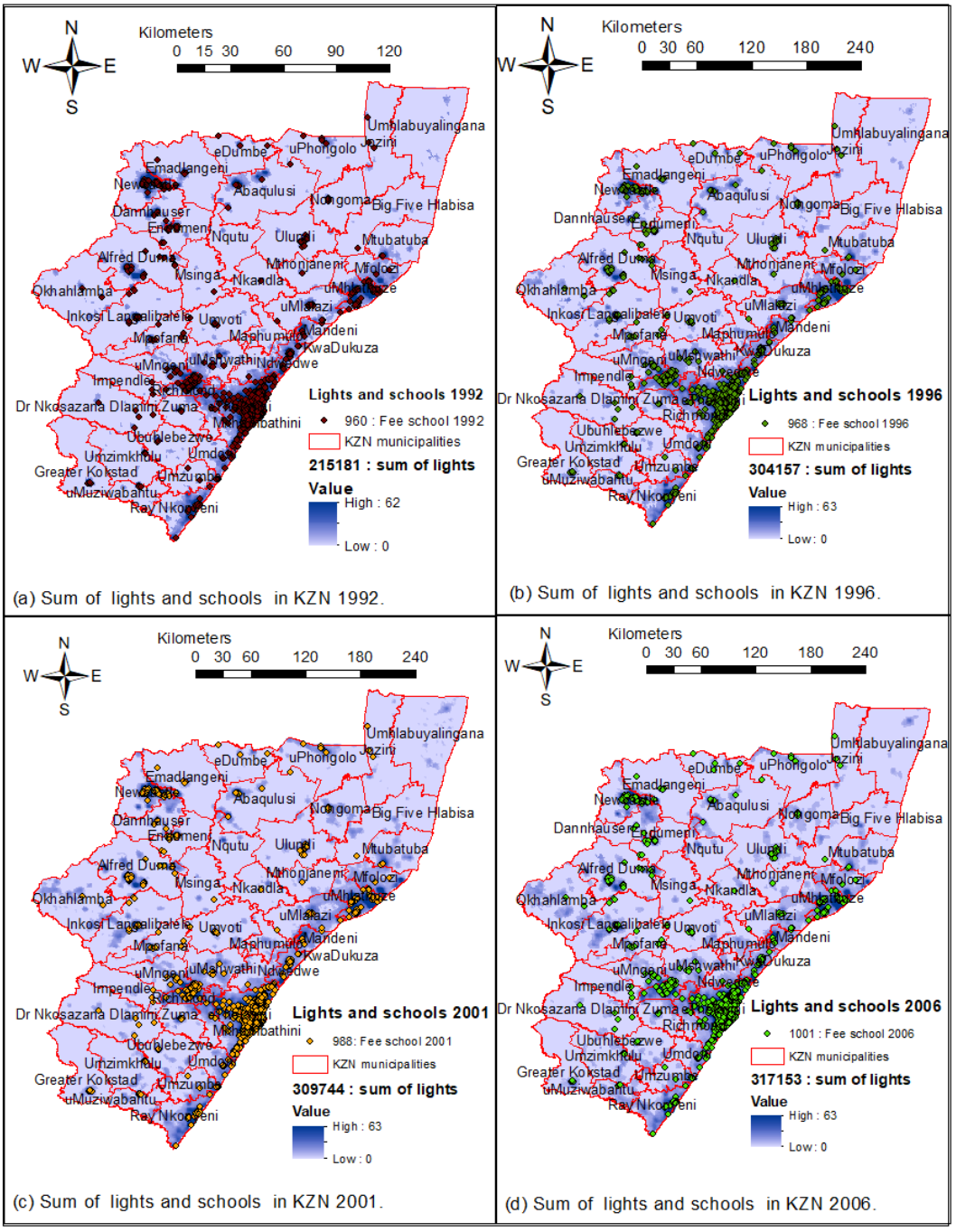
Note: Figures 2.19 (a-d) show the non-fee schools represented by points in the same map with night lights represented by blue light intensity. I decided to split a period 1992-2013 into 5 years apart to see distributional patterns of schools and lights on maps e.g 1992, 1996, 2001, 2006, 2011 and 2013.

FIGURE 2.20: Non-fee schools (continuation)



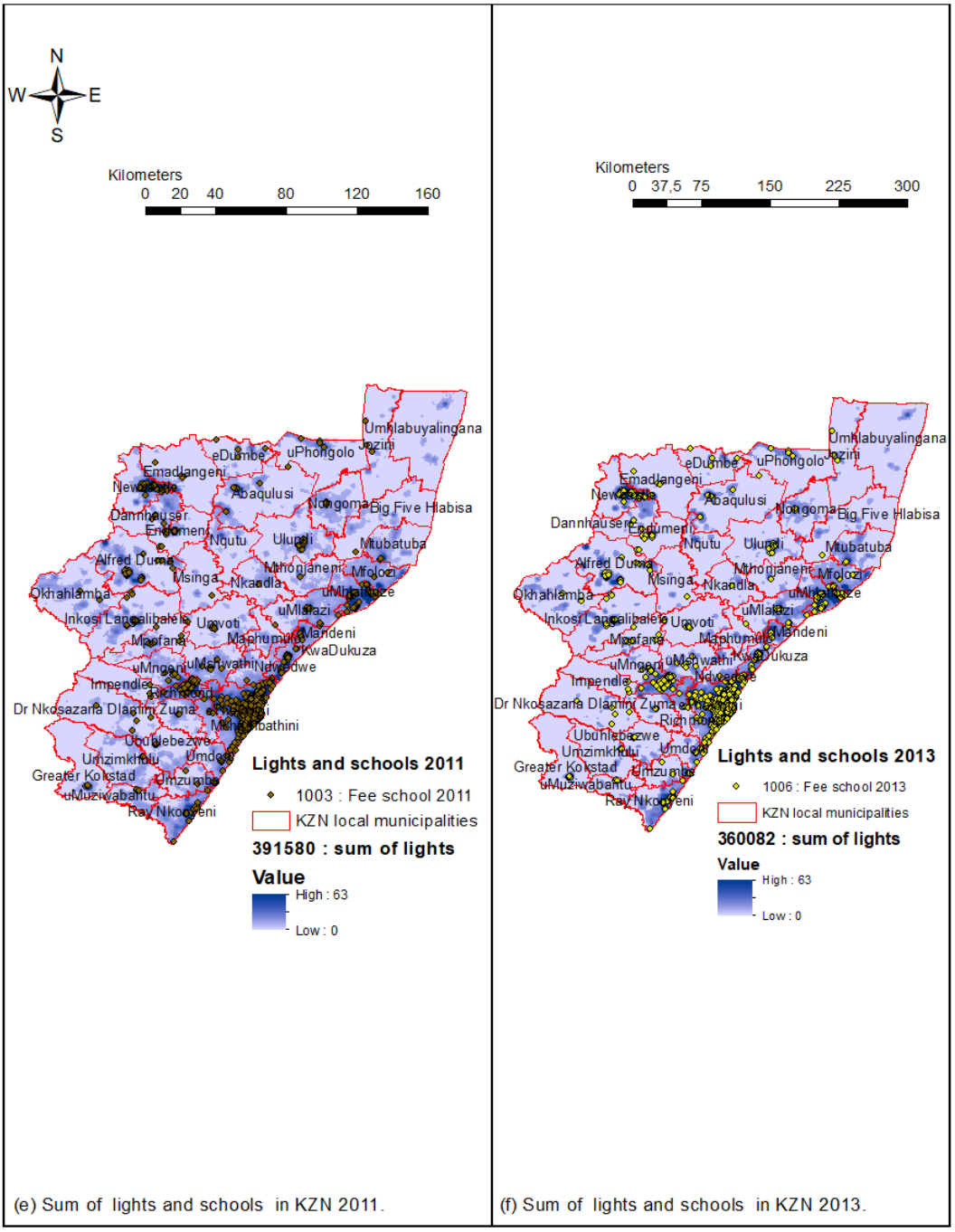
Note: Figures 2.20 (e-f) show the non-fee schools represented by points in the same map with night lights represented by blue light intensity. I decided to split a period 1992-2013 into 5 years apart to see distributional patterns of schools and lights on maps e.g 1992, 1996, 2001, 2006, 2011 and 2013.

FIGURE 2.21: Fees schools



Note: Figures 2.21 (a-d) show the fee schools represented by points in the same map with night lights represented by blue light intensity. I decided to split a period 1992-2013 into 5 years apart to see distributional patterns of schools and lights on maps e.g 1992, 1996, 2001, 2006, 2011 and 2013.

FIGURE 2.22: Fee schools (continuation)



Note: Figures 2.22 (e-f) show the fee schools represented by points in the same map with night lights represented by blue light intensity. I decided to split a period 1992-2013 into 5 years apart to see distributional patterns of schools and lights on maps e.g 1992, 1996, 2001, 2006, 2011 and 2013.

2.6.2 Growth in public schools and night lights within the LMs.

Table 2.8 displays all the 44 LMs of KZN over a period 1992-2013, 37 of them have only increase in non-fees. I decided not to remove the 7 LMs that have both variations in terms of public schools. The main aim of this table is to show the municipalities that have increase or no

increase in non-fees. Even though these municipalities have increase only in No-Fee schools but they show increase in average night lights and its annual growth rate over 1992-2013 period, See Table 2.9. Table 2.10 shows percentage growth in public school and night lights over 1992-2013. LMs that have only increase in non-fees show more annual growth of lights rate than those with increase in both this is indicated in last column of Table 2.10. This happens because in the beginning of 1992 more municipalities had less or no lights and later on in 2013 it increase, whereas other municipalities like those in big cities such as Ethekwini, The Msunduzi, Newcastle and uMhlathuze municipalities already had economic activities in the initial period 1992 so that is why their light growth is not that much in 2013.

TABLE 2.8: Non-fee and fee pay public schools and how they change in 1992-2013

FID	**Local municipalities of KZN**	**No-Fee schools 1992**	**No-Fee schools 2013**	**Change No-Fee pay schools 1992-2013**	**Fee schools 1992**	**Fee schools 2013**	**Change in Fee pay schools 1992-2013**
0	Umdoni	70	71	1	11	12	1
1	uMuziwabantu	54	55	1	4	4	0
2	Ray Nkonyeni	95	100	5	20	20	0
3	Alfred Duma	166	170	4	26	26	0
4	Inkosi Langa	94	96	2	10	10	0
5	Okhahlamba	94	99	5	2	2	0
6	Endumeni	29	31	2	14	14	0
7	Nqutu	129	136	7	0	0	0
8	Newcastle	58	60	2	46	50	4
9	Emadlangeni	38	40	2	5	5	0
10	Dannhauser	55	57	2	4	4	0
11	eDumbe	68	73	5	3	4	1
12	uPhongolo	107	115	8	5	5	0
13	Abaqulusi	123	126	3	8	8	0
14	Nongoma	129	136	7	3	3	0
15	Ulundi	192	200	8	11	11	0
16	Umhlaba	126	128	2	0	0	0
17	Jozini	141	151	10	3	3	0
18	Mtubatuba	105	112	7	2	2	0
19	uMlalazi	165	173	8	14	14	0
20	Nkandla	128	133	5	1	1	0
21	Mandeni	56	58	2	4	4	0
22	KwaDukuza	36	38	2	27	27	0
23	Ndwedwe	149	152	3	1	1	0
24	Maphumulo	107	112	5	0	0	0
25	Dr Zuma	100	103	3	5	5	0
26	Ubuhlebezwe	107	108	1	3	3	0
27	Umzumbe	112	117	5	7	7	0
28	Big Five	73	78	5	1	1	0
29	Richmond	45	46	1	4	4	0
30	Gr. Kokstad	23	23	0	5	5	0
31	Umzimkhulu	161	161	0	3	3	0
32	uMshwathi	69	73	4	8	8	0
33	Msinga	149	166	17	1	1	0
34	eThekwini	346	363	17	555	586	31
35	Mkhambathini	39	43	4	3	3	0
36	The Msunduzi	104	106	2	71	77	6
37	uMngeni	29	29	0	9	9	0
38	Impendle	36	38	2	3	3	0
39	Mfolozi	82	86	4	2	2	0
40	uMhlathuze	65	67	2	43	45	2
41	Mthonjaneni	76	79	3	1	1	0
42	Umvoti	95	98	3	5	6	1
43	Mpofana	17	19	2	7	7	0

Note: Table 2.8 displays all the 44 LMs of KZN over a period 1992-2013, 37 of them have only increase in non-fee. I decided not to remove the 7 LMs that have both variations in terms of public schools.

TABLE 2.9: Change in the growth of average night lights within LMs 1992-2013

FID	**Local municipalities in KZN**	**Average night lights 1992**	**Average night lights 2013**	**Change in night lights 1992-2013**	**Growth of night lights (%)**	**Average annual lights growth rate 1992-2013**
0	Umdoni	2,714	3,256	0,541	3583,484	0,950
1	uMuziwabantu	0,394	1,053	0,658	25268,782	7,959
2	Ray Nkonyen	5,385	7,528	2,142	1756,959	1,894
3	Alfred Duma	1,612	3,073	1,461	6100,916	4,314
4	Inkosi Langa	0,600	1,893	1,293	16560,530	10,264
5	Okhahlamba	0,264	1,186	0,922	37755,093	16,627
6	Endumeni	1,255	1,705	0,450	7866,991	1,707
7	Nqutu	0,061	0,907	0,845	162962,5	65,684
8	Newcastle	6,097	7,969	1,871	1539,935	1,461
9	Emadlangeni	0,606	0,457	-0,148	16400,177	-1,166
10	Dannhauser	1,246	2,350	1,103	7920,647	4,215
11	eDumbe	0,309	1,006	0,697	32232,065	10,732
12	uPhongolo	0,394	1,335	0,940	25224,675	11,342
13	Abaqulusi	1,191	1,406	0,214	8295,808	0,859
14	Nongoma	0,131	2,013	1,882	76212,997	68,397
15	Ulundi	0,270	1,460	1,189	36867,353	20,941
16	Umhlaba	0,099	0,341	0,242	100484,615	11,617
17	Jozini	0,112	0,387	0,274	88777,952	11,633
18	Mtubatuba	0,719	2,937	2,218	13799,840	14,684
19	uMlalazi	1,306	3,938	2,631	7551,790	9,588
20	Nkandla	0	0,435	0,435	n/a	n/a
21	Mandeni	4,895	10,823	5,928	1942,889	5,766
22	KwaDukuza	7,085	10,882	3,797	1311,394	2,552
23	Ndwedwe	1,639	2,347	0,708	6000,628	2,058
24	Maphumulo	0,134	1,093	0,958	74400	34,017
25	Dr Zuma	0,161	0,422	0,260	61685,714	7,670
26	Ubuhlebezwe	0,346	1,166	0,819	28734,827	11,255
27	Umzumbe	0,459	1,55	1,095	21681,002	11,364
28	Big Five	0,059	0,585	0,525	169198,893	42,400
29	Richmond	0,803	1,389	0,586	12352,972	3,475
30	Gr. Kokstad	0,434	0,705	0,270	22900,635	2,961
31	Umzimkhulu	0,160	0,607	0,447	62333,460	13,298
32	uMshwathi	2,142	2,471	0,328	4566,791	0,730
33	Msinga	0,0425	0,297	0,255	234900	28,535
34	eThekwini	21,983	29,305	7,322	354,887	1,586
35	Mkhambathini	3,624	4,004	0,380	2659,272	0,499
36	Msunduzi	12,358	19,324	6,965	709,136	2,683
37	uMngeni	2,274	2,746	0,471	4295,842	0,986
38	Impendle	0,055	0,259	0,203	179650	17,445
39	Mfolozi	2,983	6,582	3,599	3252,096	5,745
40	uMhlathuze	10,586	17,305	6,718	844,604	3,022
41	Mthonjaneni	0,140	0,875	0,734	71080,327	24,902
42	Umvoti	0,366	0,638	0,272	27216,704	3,548
43	Mpofana	0,449	0,768	0,319	22163,257	3,386

Note: Table 2.9 displays change in the growth of average lights in the 44 LMs of KZN over a period 1992-2013.

TABLE 2.10: Growth in public schools and lights for the fastest and slowest growing LMs

Local Municipality of KZN	% Growth: No-Fee 1992-2013	% Growth: Fee 1992-2013)	Average lights 1992	Average lights 2013	Change lights 1992-2013	Growth of lights %	Annual growth of lights rate
Top 20							
Nkandla	3,9	0,0	0,0	0,4	0,4	n/a	n/a
Nongoma	5,4	0,0	0,1	2,0	1,9	1436,3	68,4
Nqutu	5,4	0,0	0,1	0,9	0,8	1379,4	65,7
Big Five	6,8	0,0	0,1	0,6	0,5	890,4	42,4
Maphumulo	4,7	0,0	0,1	1,1	1,0	714,4	34,0
Msinga	11,4	0,0	0,0	0,3	0,3	599,3	28,5
Mthonjaneni	3,9	0,0	0,1	0,9	0,7	523,0	24,9
Ulundi	4,2	0,0	0,3	1,5	1,2	439,8	20,9
Impendle	5,6	0,0	0,1	0,3	0,2	366,4	17,4
Okhahlamba	5,3	0,0	0,3	1,2	0,9	349,2	16,6
Mtubatuba	6,7	0,0	0,7	2,9	2,2	308,4	14,7
Umzimkhulu	0,0	0,0	0,2	0,6	0,4	279,3	13,3
Jozini	7,1	0,0	0,1	0,4	0,3	244,3	11,6
Umhlabuyali	1,6	0,0	0,1	0,3	0,2	244,0	11,6
Umzumbe	4,5	0,0	0,5	1,6	1,1	238,7	11,4
uPhongolo	7,5	0,0	0,4	1,3	0,9	238,2	11,3
Ubuhlebezwe	0,9	0,0	0,3	1,2	0,8	236,4	11,3
eDumbe	7,4	33,3	0,3	1,0	0,7	225,4	10,7
Inkosi Langa	2,1	0,0	0,6	1,9	1,3	215,5	10,3
uMlalazi	4,8	0,0	1,3	3,9	2,6	201,3	9,6
uMuzi	1,9	0,0	0,4	1,1	0,7	167,2	8,0
Dr Zuma	3,0	0,0	0,2	0,4	0,3	161,1	7,7
Mandeni	3,6	0,0	4,9	10,8	5,9	121,1	5,8
Mfolozi	4,9	0,0	3,0	6,6	3,6	120,7	5,7
Bottom 20							
Alfred Duma	2,4	0,0	1,6	3,1	1,5	90,6	4,3
Dannhauser	3,6	0,0	1,2	2,4	1,1	88,5	4,2
Umvoti	3,2	20,0	0,4	0,6	0,3	74,5	3,5
Richmond	2,2	0,0	0,8	1,4	0,6	73,0	3,5
Mpofana	11,8	0,0	0,4	0,8	0,3	71,1	3,4
uMhlathuze	3,1	4,7	10,6	17,3	6,7	63,5	3,0
Gr. Kokstad	0,0	0,0	0,4	0,7	0,3	62,2	3,0
Msunduzi	1,9	8,5	12,4	19,3	7,0	56,4	2,7
KwaDukuza	5,6	0,0	7,1	10,9	3,8	53,6	2,6
Ndwedwe	2,0	0,0	1,6	2,3	0,7	43,2	2,1
Ray Nkonyen	5,3	0,0	5,4	7,5	2,1	39,8	1,9
Endumeni	6,9	0,0	1,3	1,7	0,5	35,9	1,7
eThekwini	4,9	5,6	22,0	29,3	7,3	33,3	1,6
Newcastle	3,4	8,7	6,1	8,0	1,9	30,7	1,5
uMngeni	0,0	0,0	2,3	2,7	0,5	20,7	1,0
Umdoni	1,4	9,1	2,7	3,3	0,5	20,0	1,0
Abaqulusi	2,4	0,0	1,2	1,4	0,2	18,0	0,9
uMshwathi	5,8	0,0	2,1	2,5	0,3	15,4	0,7
Mkhambathi	10,3	0,0	3,6	4,0	0,4	10,5	0,5
Emadlangeni	5,3	0,0	0,6	0,5	-0,1	-24,5	-1,2

Note: Table 2.10 shows percentage growth in public schools and night lights for the fastest and slowest growing municipalities over 1992-2013.

Chapter 3

The Effects of Public Infrastructure on Growth and Inequality: Spatial evidence in South African educational expenditure.

Abstract

Economic inequality in South Africa is reflected in major spatial disparities. From the advent of democracy, investment in public infrastructure was meant to bridge the unequal access to resources and services and provide an opportunity for economic growth. In this chapter, we study the relationship between public investment, spatial inequality and growth using local municipality data on public school investment from 1992 to 2013. Controlling for a large set of local initial conditions and covariates, the results show that investment in fee-paying schools, where school costs are partially covered by parents' contributions, is associated with positive local income growth. Investment in non-fee schools instead is not associated with local income growth and, on average, seems to have harmed local growth. We use quantile regression to analyse the differential effect of public investment at different income levels, and the analysis confirms that public investment in South Africa has been more productive at the higher end of the income distribution, thus contributing to increasing the level of inequality in the country.

3.1 Introduction

It is a well-known fact that South Africa is a very unequal society. Moreover, apartheid segregation policies configured a country that is equally unequal in space, with access to public infrastructures and public services largely following the patterns of racial segregation. At the advent of democracy, public infrastructure investment was earmarked as the principal instrument to recompose the Apartheid divisions. Large programs for investment in housing, sanitation, roads, and school infrastructure (among others) have always been at the forefront of public policies in democratic times.

This chapter analyses the effect of public investment on spatial inequality and growth from 1992 to 2013 in South Africa, focusing on investment in public schools, one of the largest and continuous programs of public investment in the country. We use a large dataset of geo-located new school buildings from the Department of Education, and we correlate this public investment with changes in socio-economic conditions at the local municipality level.

The chapter contributes to a growing literature looking at the relationship between public investment, growth and inequality Getachew and Turnovsky (2015). The theoretical literature on the issue is large, but there is little empirical evidence outside cross-country studies. The main argument is around the level of complementary between public investment and private investment and how much public investment, by helping human capital accumulation, access to markets and information, helps in reducing the inequality along the process of development, (Barro, 1990), (Calderón & Servén, 2004) and (Artadi & Sala-i Martin, 2003).

Most papers that study empirically the effects of public investment on growth assume homogeneity of the effect across sub-national regions, as most of the studies focus on a cross-section of countries Fosu, Getachew, and Ziesemer (2012). In this paper, instead, we focus on the heterogeneity of the effect of public investment at the local level, looking at the way public investment interacts with local conditions to generate patterns of growth and inequality.

We start by estimating a simple regression which predicts only homogeneous slope coefficients of public schools on income growth. We then introduce a quantile approach which allows for the heterogeneity and the distribution coefficient slopes between. We use data from 120 local municipalities (LMs) based on the availability of data. The income growth of the LMs is proxied by night light data, which is the artificial light that is extracted at night when economic activities are happening. On the other hand, public schools are used as a measure of infrastructure investment. The findings indicate that on average, public investment in fee-paying schools is associated with positive income growth, whereas non-fee schools have a negative influence on

income growth. However, the OLS can be misleading when considering the non-linear model, which shows the distribution of slope in quantiles. Results by the non-linearity model indicate that in the lower and upper quantiles, fee-pay schools have a negative effect on growth, except in the middle quantiles, where fee schools are associated with growth in incomes. On the other hand, the non-fee schools in local municipalities with low change in lights i.e lower quantiles, are associated with positive growth but along other quantiles distribution, the fee schools are negatively associated with income growth.

The chapter is structured as follows: section 3.2 is the background of public infrastructure in public schools, section 3.3 is the related studies, section 3.4 is the regional disparities amongst municipalities, section 3.5 is methods and data, section 3.6 is empirical results and discussion, and finally, section 3.7 is the conclusion.

3.2 Background

3.2.1 Public school evolution before and after democracy in South Africa

South Africa experienced educational injustices under the apartheid era, such as the unjust distribution of public school funding to all students equally. Before 1994, the dominant government at the time implemented laws that excluded Black people while benefiting minority groups, including whites, indians, and coloureds. Beginning in 1948, when the National Party (NP) came to power, they controlled public school funding and created racial laws that kept the majority of black South Africans out of the country's economy. In the local towns that were predominantly occupied by black people, the unjust distribution of educational investment led to a shortage of schools, significant dropout rates, overcrowded classrooms, and many failure rates Matshipi et al. (2017). Additionally, missionary schools built prior to 1948 were designed to improve black communities, and missionary schools built before 1948 were also criticised by the National Party, see for example Kgoale (1986).

In South Africa, public schools are divided into those that charge fees and those that do not. Based on the provinces' economic standing, the Minister of Basic Education has a criterion to classify these public schools as fee or non-fee-paying. In the years following the end of apartheid, the idea of fee schools was born. To prevent black people from accessing and affording high-quality education for their children, the idea was used as a tactic to keep them out of the economy. The fees policy sought to divide the population of the country not just along racial lines but also based on affordability Roithmayr (2002).

The introduction of democracy in South Africa in 1994 was accompanied by changes to the educational system. The ANC's newly elected democratic government was aware of how difficult the end of apartheid would be. The constitution was changed by the new administration to also benefit disadvantaged communities. They created a framework for policy, such as the Reconstruction and Development Programme (RDP of 1994). The goal of the policy framework was to disperse SA's wealth by creating infrastructure for the underprivileged, reducing poverty by creating jobs, offering social subsidies, and other things. Investment in schools was likewise regarded as having the highest importance for growth and the reduction of inequality, among other things. At the beginning of the new democracy, a strict fees policy inherited from the apartheid government was never abolished because the government did not have enough funds to cater for the marginalised South Africans. Professor Kader Asmal, a former minister of education, examined all of the laws governing school finance in 2002. Five years after the legislation governing school finance was examined by the previous minister of education, the non-fees educational policy was implemented in 2007. The review sought to increase everyone's access to affordable, high-quality education Comaroff (2003). The proposal suggested that all fee schools in the quintiles with the lowest incomes be eliminated. Furthermore, it implied that the African National Congress (ANC)-led administration adopt a standard for adequate education spending.

3.2.2 Public schools built before and after 1994, in terms of number.

This chapter utilises the Department of Education's (DoE) dataset, which includes both public and private schools.[1] The DoE master list collection contains details about the schools, including their names, addresses, registration dates, ownership status (public or private), and whether or not they are exempt from paying school fees. As we already stated, we are interested in public schools (both fee-paying and non-fee-paying schools) that were built in accordance with apartheid and democratic-era construction policies.

The DoE information displays a total of 12145 public schools that were documented in the database, schools that were created by the apartheid government and missionaries before 1994, with 1562 charging fees and 10583 not. Under the same apartheid administration, the number of fee-paying schools climbed by 22 from 1540 in 1992 to 1562 in 1994, whilst the number of non-fee-paying schools increased by 357 from 10226 in 1992 to 10583 in 1994. It is crucial to note that these are the schools that can be located in the four provinces that were chosen for this chapter: KwaZulu Natal, Gauteng, the Free State, and Eastern Cape. The reason the other five provinces were left out was that they lacked crucial educational data.

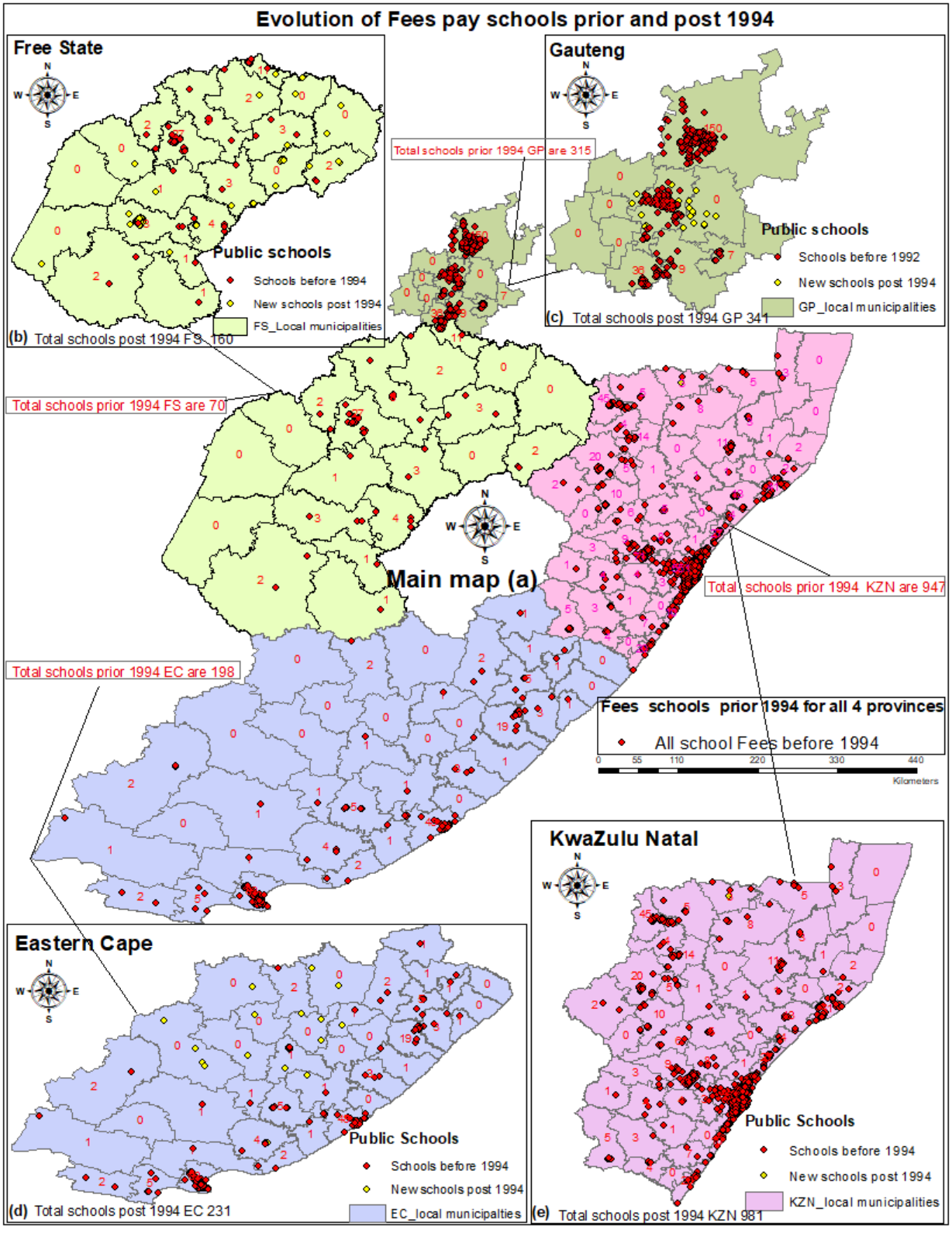
[1] https://www.education.gov.za/Programmes/EMIS.aspx

A total of 12145 public schools, including fee and non-fee-paying schools, were left over from the apartheid regime in 1994, the year of democracy. When the new democratic administration came into office in 1994, they built 18 additional fee-paying schools, increasing the number from 1562 to 1580 in 1996. They also built 98 non-fee-paying schools, increasing the number from 10583 to 10681.

Lastly, a new absolute no-fee policy was announced in 2007. We see an accumulation of 12920 public schools, both fee and non-fee, after the newly announced no-fee school policy of 2007. The fee schools in the four selected provinces were 1736 in 2007, which was before the policy was announced, and they increased by 36 from 1736 in 2007 to 1772 in 2013. Whereas the non-fee schools in total were 11184 in 2007 and increased to 11417 in 2013, so 233 non-fees were built after the announcement of the no-fee policy.

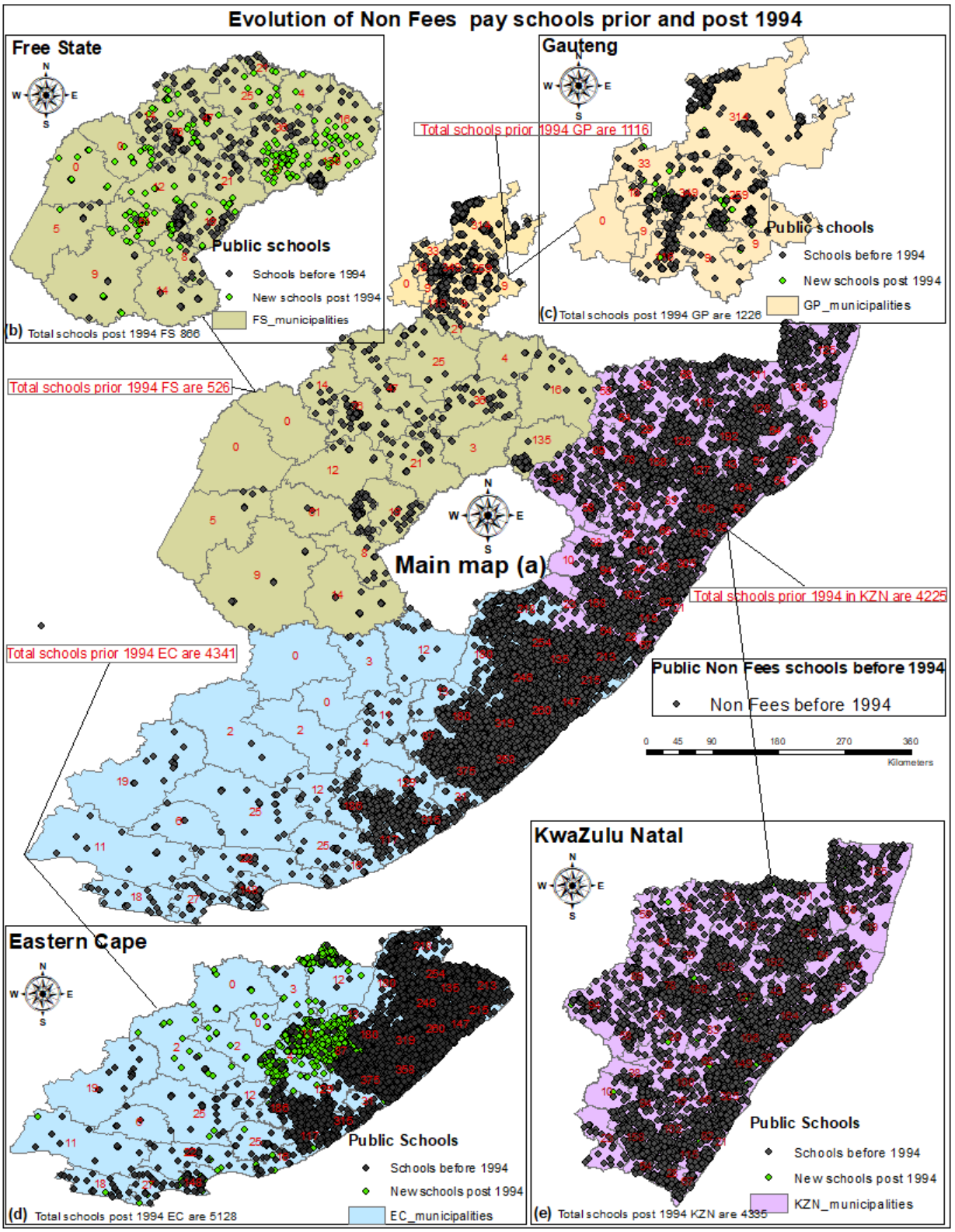
This study uses geographical maps and points to demonstrate what public school investment was like before 1994 (apartheid regime era) and when a newly elected democratic government assumed power in 1994, going forward. Figure 3.1 - main map(a) shows all public schools that were built during the apartheid era as indicated by red points within the local municipalities (LM's) of the four chosen provinces which are Eastern Cape (EC), Free State (FS), Gauteng (GP) and KwaZulu Natal (KZN), the same main map(a) shows with red numbers, the total numbers within the administrative units of the LMs prior 1994. The other maps at the outskirts of the main map in Figure 3.1, such as b-e, show the number of new schools that were built when the newly elected government took over in 1994; they are represented by yellow points. In these maps, we put all the fee schools before and after 1994, represented by red and yellow points, to show that there was a change in public schools in LMs. Likewise, the main map (a) of Figure 3.2 demonstrates the evolution of non-fee public schools between the two eras. The non-fee schools before 1994 are represented by grey points, and when you check the administrative units of the maps at the outskirts of the main map(a), which are b-e, you can see that post-1994, there has been an increase in the number of non-fee schools as demonstrated with quetzal green points. In terms of numbers, there has been a huge increase in the introduction of non-fee public schools investment, which is aimed at transforming a highly inequitable and racially differentiated schooling system compared to the fee. This ensures that there are at least adequate schools that cater for the population of disadvantaged communities, and no one should be denied the right to education.

FIGURE 3.1: Fee public schools prior and post 1994



Note: Figure 3.1 (a)- is the main map that shows fee schools that were built during the apartheid era, as indicated by red points. Four provinces are used: Eastern Cape, Free State, Gauteng and KwaZulu-Natal, main map(a) also shows with red numbers, the total number of schools before 1994. Figure 3.1 (b-e) shows the number of new schools that were built when the newly elected government took over in 1994 they are represented by yellow points.

FIGURE 3.2: Non-fee public schools prior and post 1994

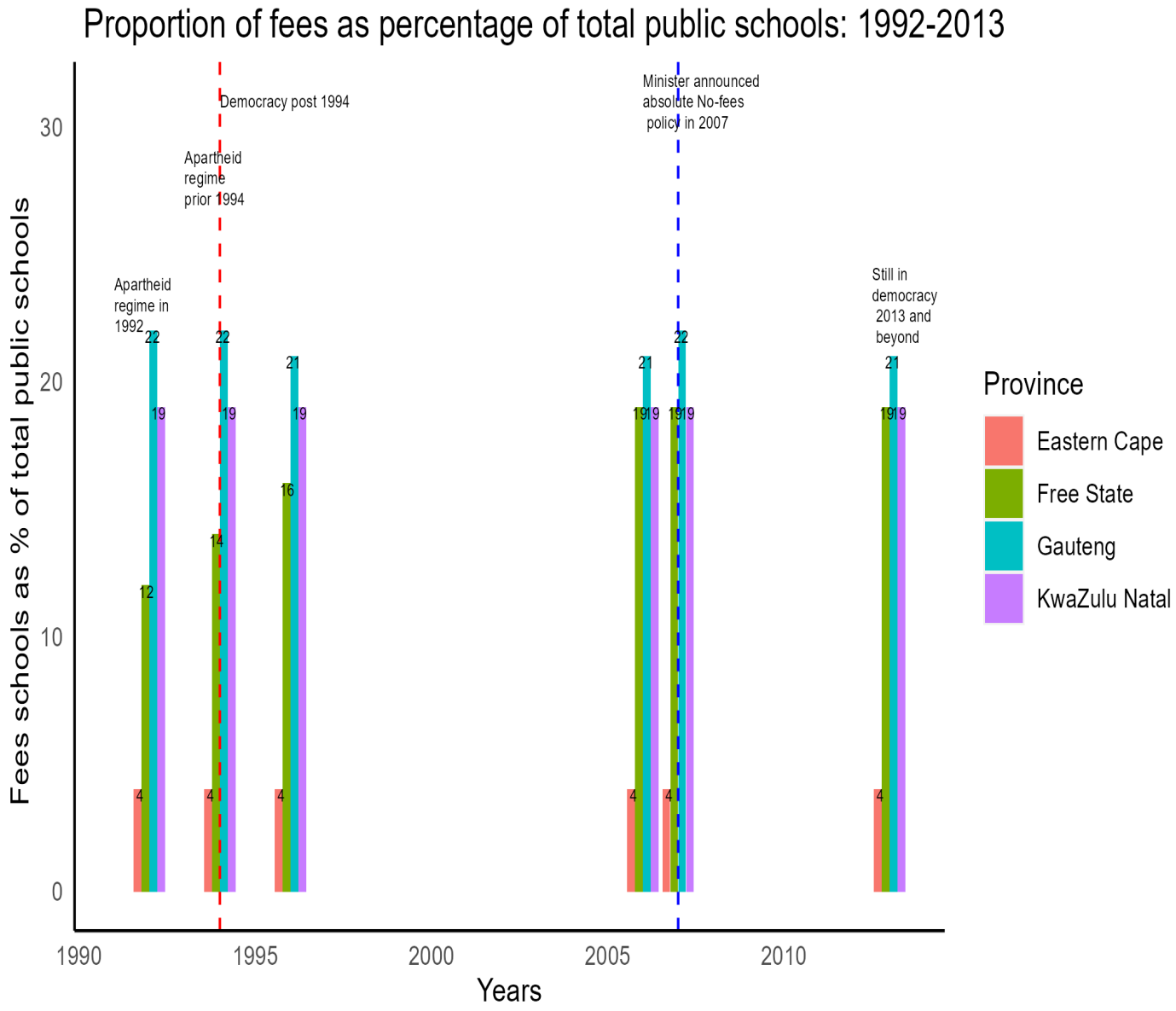


Note: Figure 3.2 (a) the main map shows all public non-fee schools that were built during the apartheid era, as indicated by grey points. Four provinces were chosen in Eastern Cape: Free State, Gauteng and KwaZulu-Natal. The main map(a) also shows, with red numbers, the total number of schools prior to 1994. Figure 3.2 (b-e) show the number of new schools that were built when the newly elected government took over in 1994, which are represented by green points.

3.2.3 The percentage of fee versus non-fee from 1992-2013

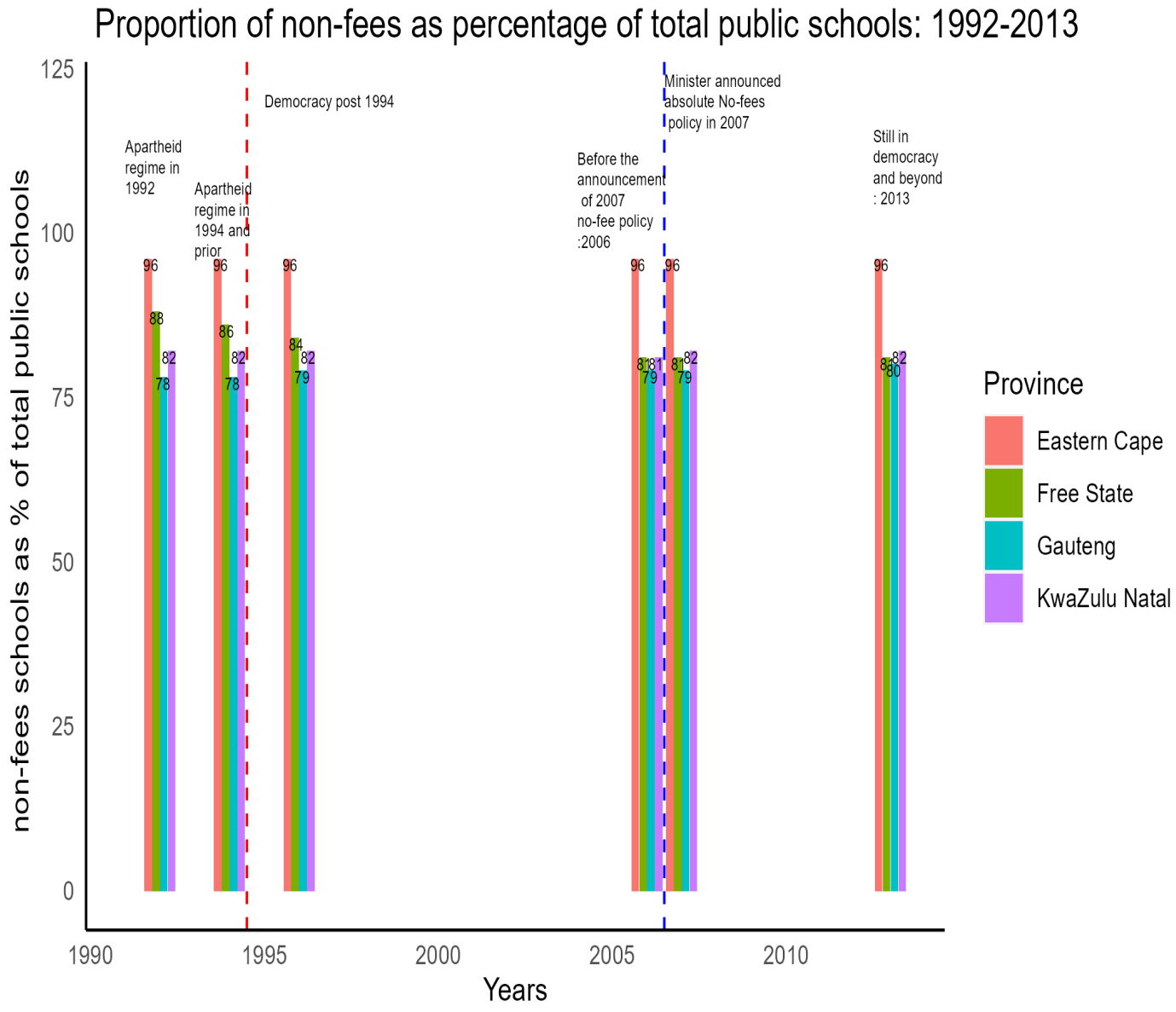
Figures (3.3 and 3.4) display the proportion of fee and non-fee schools in each province between 1992 and 2013. The proportion of non-fee schools is higher than the proportion of fee schools. The ratio of these schools does not change significantly over a year; in Gauteng and the Free State, the ratio of fee schools changes, whereas there are fewer changes in Eastern and KwaZulu-Natal. The figures also show what policies and regimes these ratios occurred under.

FIGURE 3.3: Fee schools as a percentage of total public schools



Note: Figure 3.3 shows fee schools as a percentage of total public schools. We select years when school policies were implemented and years before policies were changed in apartheid and democracy eras: 1992, 1994, 1996, 2006, 2007, and 2013.

FIGURE 3.4: Non-fee schools as a percentage of total public schools



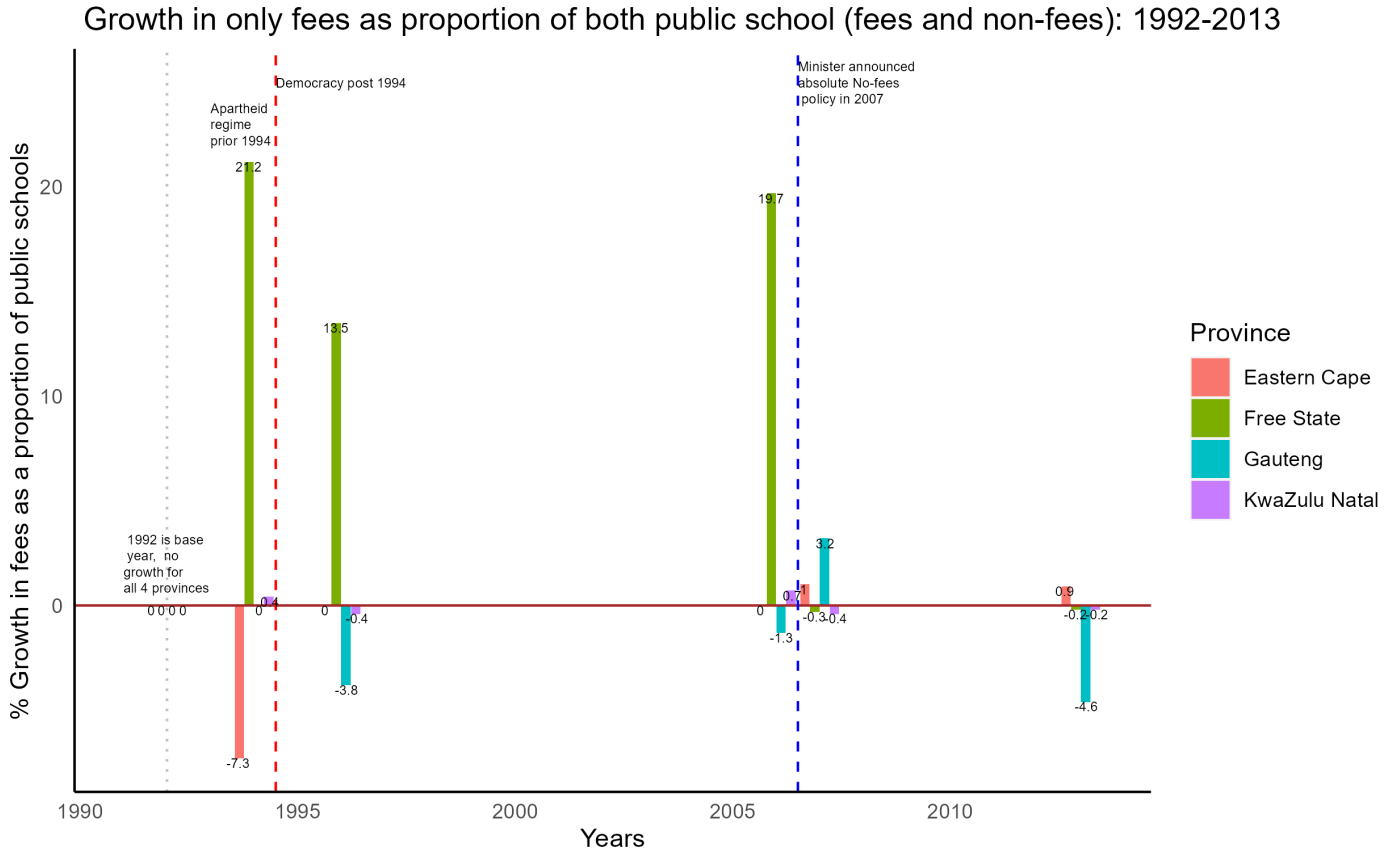
Note: Figure 3.4 demonstrates non-fee schools as a percentage of total public schools. We select years when policies were implemented and years before policies were changed in the apartheid and democracy eras: 1992, 1994, 1996, 2006, 2007, and 2013.

3.2.4 The growth rate of fee versus non-fee from 1992-2013

Figures (3.5 and 3.6) depict the trends in provincial fee and non-fee growth between 1992 and 2013. Since we want to track growth and our study runs from 1992 to 2013, we choose to use 1992 as the baseline year. Figure 3.5 in the Free State demonstrates a huge growth in fee schools and a decline in non-fee schools before and after democracy, as demonstrated in Figure

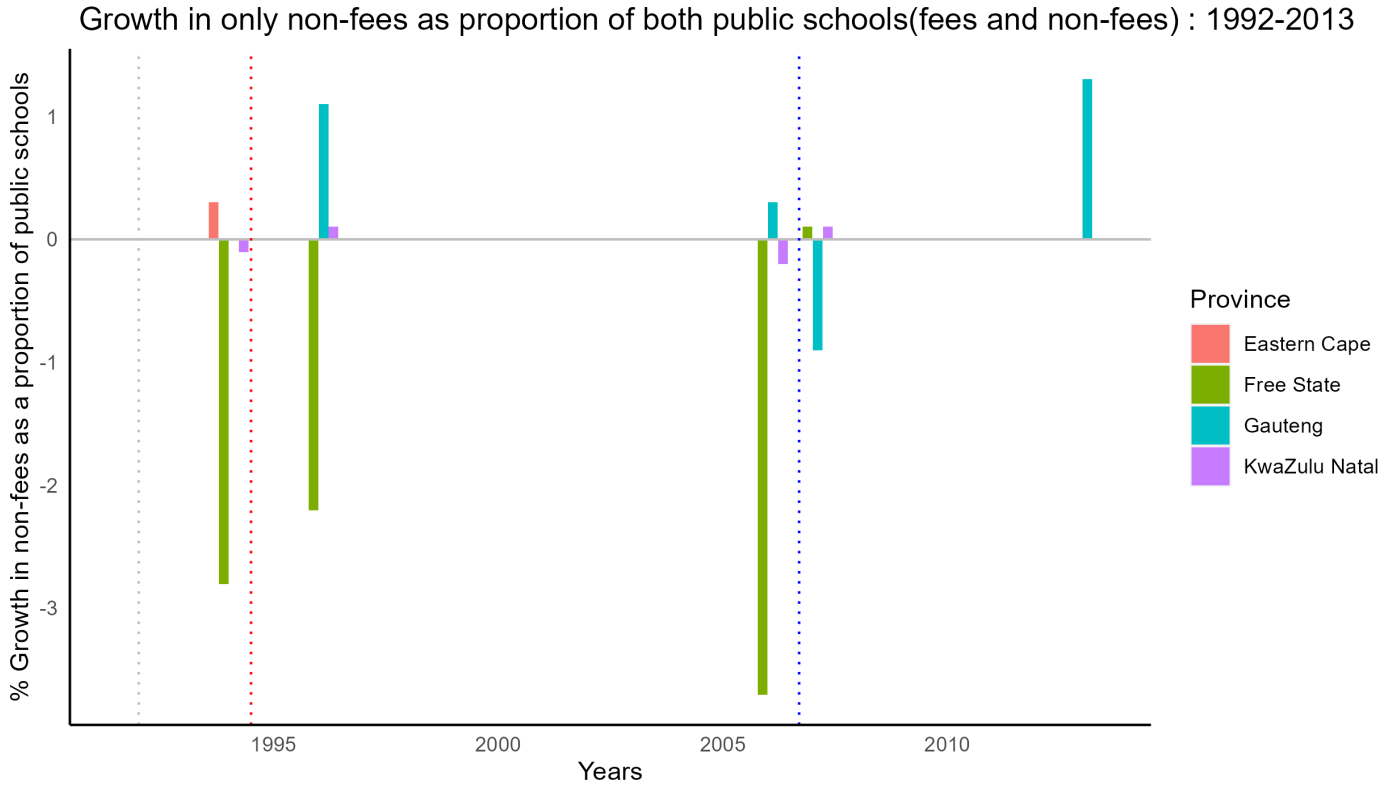
3.6, but when the fees policy was announced in 2007, the growth in fee schools declines as opposed to non-fee schools. Before 1994, KwaZulu-Natal saw an increase in fee schools and a decline in non-fee schools; after democracy was established, we observed a decline in fee schools and an increase in non-fee, even after the implementation of the non-fees policy in 2007 as shown in Figures (3.5 and 3.6). Gauteng displays a decline in fee schools and an increase in non-fee schools during the democratic regime; however, after the policy was implemented, fee schools once again outweighed non-fee schools in 2013, see Figures (3.5 and 3.6). Lastly, in Eastern Cape, fee schools decreased and non-fee schools increased before democracy, but during democracy, fee schools increased compared to non-fee, even after the announcement of the 2007 absolute no-fees policy, see Figures (3.5 and 3.6).

FIGURE 3.5: Growth rate in fee schools as a proportion of public schools



Note: Figure 3.5 is the growth rate in fee schools as a proportion of public schools. We select years when policies were implemented and years before policies were changed in the apartheid and democracy eras: 1992, 1994, 1996, 2006, 2007, and 2013.

FIGURE 3.6: Growth in non-fee schools as a percentage of public schools



Note: Figure 3.6 shows the percentage growth in non-fee schools as a percentage of public schools. We select years where policies were implemented and years before policies were changed in the apartheid and democracy eras: 1992, 1994, 1996, 2006, 2007 and 2013.

3.3 Related studies

Globally, prior research has indicated that the benefits of public infrastructure capital might either result in more or less economic development, which could either exacerbate or aggravate inequality. More of this earlier research, for example, discovered beneficial long-term impacts of public infrastructure on economic growth Straub (2008). To begin with, López (2003) adds to the literature by examining the impact that infrastructure has on both economic growth and income distribution. In his research, Lopez uses telephone density as a measure of infrastructure, and it is discovered that infrastructure has a significant impact on both increasing growth and lowering income disparity. Additionally, improving infrastructure opens up chances for investing in human capital. For example, more members of society may be able to send their children to hospitals and schools that are located far from where they live. van de Walle and Mu (2007) in Vietnam suggests that infrastructure such as roads in rural areas has a great impact on the rates of school completion, especially at the primary level. Basic infrastructure

in underdeveloped regions plays an important role in connecting disadvantaged individuals to core economic activities such as getting exposure to better job opportunities that are located in the cities, and this also contributes to high productivity Estache and Fay (1995). The literature by Gannon, Liu, et al. (1997) also suggests that infrastructure improvements reduce the cost of transactions and production in disadvantaged poor regions. Jacoby (2000) likewise explains both developments in road services and some communication improvements play a crucial role in capital gains for poor farmers. The author explains further that extending the infrastructure of roads to the whole rural areas of Nepal will give a ten per cent rise to the average income. The author also made it clear that people who gain largely from these infrastructural developments are the owners of land who happened to be less poor, as a result, incomes in the remote rural areas of Nepal are found to be lower.

It is appropriate to use passages from works of literature that have already examined locally the impact of public infrastructure on growth and inequality, because this chapter is about public schools in local municipalities in South Africa. Despite the limited amount of local literature on this study. Fedderke and Garlick (2008) provides a comprehensive assessment of the connection between infrastructure and growth in the context of South Africa. The study constructs a theoretical framework to analyse these relationships, and afterwards compares the theoretical framework to the empirical framework. In the end, the authors discover a strong positive correlation between infrastructure and economic growth.

Our research is limited to public infrastructure, particularly public schools, and how they affect inequality and growth. Inequalities in education in South Africa first surfaced in 1948 under the apartheid government, when black people were denied access to quality education and well-built school facilities. Black people found it challenging to succeed in that system due to the emergence of apartheid practices at the time. The overcrowding in schools caused many students to drop out. The lack of classrooms or the institution itself may be the cause of school dropouts. According to research, factors like overpopulated classrooms can make it difficult for students to do well academically Rivera-Batiz and Marti (1995). Building school infrastructure has a favourable impact on attendance rates, however, unfair allocation of educational resources leads to dissatisfaction and numerous occurrences of school dropout Schady and Paxson (1999). In addition to other disparities in the nation, the lack of access to decent infrastructure and education may have had a greater impact on the inequalities that exist now. The current ruling party would not be coping with the crimes of the past if funding for public schools had been distributed fairly during the apartheid era.

3.4 Regional disparities in South Africa

The regional inequalities in this paper refer to the income inequalities proxied by night-time lights and the differences in terms of the investments in public school infrastructure amongst local municipalities in South Africa. Night-time lights are man-made lights that reflect the influence of economic activities, which only happen at night as a result of activities by residents living within local municipalities. Using night-time lights as the index of income inequality is useful because it clearly shows how much economic activity has taken place in each region. Given other factors such as the size and the developmental state of the LMs then one can also expect inequalities in terms of economic activities and infrastructure. We will do an empirical analysis of the economic activities of lights. From the perspective of night-time lights, we choose local municipality night lights corrected for gas flaring. More specifically, we difference the lights in each local municipality for the period 1992-2013 to get the change in income lights between the two periods(1992 and 2013). It is important to mention that SA has 9 provinces but 4 out of the 9 provinces are studied and the remaining 5 are excluded due to the lack of spatial information such as public school infrastructure geographic coordinates, the year in which the school was established, same registration for the establishment of the schools in all the years and the identification whether a school pays fees or not. This is indicated in Table 3.10 of the Appendix, where five schools per province are selected to demonstrate some missing information about public schools in the province.

3.5 Data and Model Description

Table 3.1 a description of the variables used in the analysis, and Table 3.2 are the summary statistics. The analysis uses average night light data in municipalities for the period 1992 to 2013. Each local municipality is within 4 provinces: (1) Eastern Cape, (2) Free State, (3) Gauteng and (4) KwaZulu-Natal. This period corresponds with public investment in schools in 1992 and the impact the investments had until 2013.

The Department of Education in each local municipality of South Africa provides annual data on public schools, which are then defined as fee and no-fee schools by the National Minister of Education. The data includes public schools that were registered on the national school database before 1992, as well as those periods after. There are 120 LMs observed during the period 1992 to 2013, and the remaining municipalities were excluded due to public school locations missing from the data. The dataset on public schools is downloaded from the Education Management Information System (EMIS), which is a function within the Department of Basic

Education (DoE). The school dataset comprises the public schools from lower grades, such as grade R, to higher grades, such as grade 12. In addition, the school dataset also contains important information about geographic identifiers such as spatial coordinates, municipality names, administrative IDs, registration date, whether a school is in a rural or urban and quintiles.

The data on night lights is archived by the National Geophysical Data Centre (NGDC) of the National Oceanic and Atmospheric Administration (NOAA) of the United States.[2] The Defence Meteorological Satellite Program (DMSP) of the United States Air Force Defence Department, specifically the DMSP-OLS Nighttime Lights Time Series Version 4 which provides annual composites of stable lights from 1992 to 2013 is the main source for all the night lights data that is used for this study. Satellites from the DMSP have been circulating the Earth 14 times per day using their Operational Linescan System (OLS) sensors since the early 1970s to read the intensity of Earth-based light with a digital archive beginning in 1992. These satellites can extract light between 8:30 pm and 10:00 pm all over the globe. The intensity of the night lights is measured by a digital number which is an integer ranging from 0 (no light luminosity) and 63 (more light luminosity). Across small geographical areas, the high resolution of this data makes it very useful for spatial analysis of night economic activities. For every 30 arc-second pixel (grid cell) is nearly 0.86 square kilometres on the equator. The data is processed using standard cleaning procedures to remove ephemeral lights like fires and other transient events, as well as to correct for sensor degradation over time. However, there are shortcomings of night-light data as follows: **Low-Coding Schema**: In economically disadvantaged areas, the low-coding schema of nightlight data may result in decreased sensitivity, potentially underestimating light intensity and economic activity. **Top coding or saturation at the high end :** The DMSP-OLS data is prone to saturation in places with high light intensity, making it difficult to differentiate between different levels of economic activity in well-lit locations. The new literature by Bluhm and Krause (2022) is added to address how to deal with the issues of saturation in highly lit areas. Despite its shortcomings, nightlight data is nevertheless an effective instrument for tracking economic activity over time. We recognise that these constraints may have an impact on our estimations, especially in areas with extremely high or low light intensity. However, our extra analysis and robustness tests indicate that the overall patterns in our study are reliable and consistent. Like in Lowe (2014), this study uses geographic administrative units containing stable night lights, cloud-free coverage and average visible lights, which constitute lights from towns, cities, and other places with persistent lighting. In addition, Lowe (2014) also demonstrates the procedure of extracting, cleaning, and computing night lights. This study uses the same procedures to extract and clean night lights to justify its relevance in estimating the economic activities of LMs in South Africa. Raster data on night light intensity is available for the entire world. We used ArcMap tools to extract rasters for LMs administrative units from the entire world. The dataset contains images of the world's night light pixels from 1992

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

to 2013. The night lights are artificial outdoor lights captured at night by satellite, and they are used in this study as a proxy for economic activities in the administrative units of South Africa.

TABLE 3.1: Description of variables

Abbreviation	Variable type	Description	Measurement
ΔY	Dependent	Average lights	Change in average night lights
INI	Control	Initial lights	Initial night lights in 1992
$AL2013$	Control	average lights	Average night lights in 2013
$Fees1992$	Interest	Fee schools	Number schools that pay school fees 1992
$Fees2013$	Interest	Fee schools	Number schools that pay school fees 2013
ΔF	Interest	Fee schools	Change in schools that pay school fees
$Non\_Fees1992$	Interest	No Fee schools	Number schools that don't pay school fees 1992
$Non\_Fees2013$	Interest	No Fee schools	Number schools that don't pay school fees 2013
ΔNF	Interest	No-Fee schools	Change in schools that do not pay school fees
$\Delta Ratio\_educ$	Interest	Ratio of education	Change in ratio of education
$\Delta Ratio\_mat$	Interest	Ratio of matric	Change in ratio of matric
ΔPOP	Control	Population density	Change in population density in 1996-2011
ILL	Control	Illiterate	Fraction of illiterate in 1996
ΔFD	Control	Formal dwellings	Change fraction of formal dwellings in 1996-2011
ΔUN	Control	Unemployed	Change in fraction of unemployment in 1996-2011
RUG	Control	Ruggedness index	Measures geographical features of land
ΔAHH	Control	Average households	Change in average household 1996-2011

Note: Table 3.1 is a description of the variables used in the analysis.

TABLE 3.2: Descriptive statistics

Variables	Obs.	Mean	Std.Dev.	Median	Min	Max.
ΔY	120.00	1.23	2.00	0.58	-2.52	9.49
INI	120.00	3.25	7.52	0.35	0.00	50.71
$AL2013$	120.00	4.87	9.21	1.31	0.05	57.51
$Fees1992$	120.00	12.86	54.04	2.00	0.00	555.00
$Fees2013$	120.00	14.73	57.07	3.00	0.00	584.00
ΔF	120.00	1.88	6.65	0.00	0.00	62.00
$Non\_Fees1992$	120.00	85.22	90.53	54.00	0.00	375.00
$Non\_Fees2013$	120.00	98.38	93.71	58.50	6.00	444.00
ΔNF	120.00	13.16	27.01	4.00	0.00	151.00
$\Delta Ratio\_educ$	106.00	0.27	0.07	0.26	0.16	0.47
$\Delta Ratio\_mat$	106.00	0.11	0.04	0.11	0.03	0.25
ILL	120.00	0.18	0.06	0.19	0.00	0.31
ΔPOP	120.00	22.81	112.81	3.17	-202.99	993.83
ΔFD	120.00	18.95	14.10	16.58	-27.43	73.70
ΔUN	120.00	35.34	9.34	34.89	14.67	56.44
RUG	120.00	2.70	1.35	2.88	0.28	5.36
ΔAHH	120.00	-0.79	0.41	-0.71	-1.96	0.35

Note: Table 3.2 is a descriptive statistics.

The analysis will use several control variables such as change in: population density, fraction of illiterate people, fraction of formal dwellings, average households, ratio of education, ratio of matric, fraction of unemployed and ruggedness that measure initial conditions in 1996, which are gathered from the census and measured in administrative units. Similar to Obikili et al.

(2015), the analysis uses the nationwide population density for the local municipalities extracted from the South African census of 1996, which also included census for the black population for the first time. Population density should help control for changes over time and reduce the chance that results are driven by these demographic changes. We do note that a more populated local municipality could experience a different growth pattern than a less populated municipality. Initial conditions for the determinants help control for the initial conditions in local municipalities, which could influence the current conditions since apartheid created physical and institutional barriers to divide the population according to race.

The growth literature has demonstrated that many variables could account for increased growth. This study controls environmental and geographical conditions such as ruggedness, agricultural limitations and the portion of land that can be utilised for agricultural purposes in the local municipalities.

The change in night lights ΔY in descriptive statistics Table 3.2 above is derived from differencing the initial night lights in 1992 (INI) from the average night lights in 2013 (AL2013). Descriptive statistics indicate differences across the variables in the sample. The average level of artificial lights (INI) in 1992 is relatively low at approximately 3.3 % with high variation across municipalities; however, in 2013, the average economic activities ($AL2013$) slightly increased to approximately 4.9 % with high variation. Similarly, the change in public school infrastructure is derived from differencing the number of public schools in 1992 ($Fees1992$ or $Non\_Fees1992$) from the number of schools in 2013 ($Fees2013$ or $Non\_Fees2013$). The change in ΔY is inline with the period of (ΔF and ΔNF), the change in public schools investment 1992-2013. The descriptive statistics in Table 3.2 also indicate that the average level of non-fee schools is relatively higher than that of Fee schools across local municipalities over the studied period 1992-2013.

The public school location and night lights data are processed using Arcgis, and the regression is analysed by STATA and R computer programs. The linear regression is

$$\begin{aligned}\Delta Y = \beta_0 + \beta_1 \text{INI} + \beta_2 \Delta F + \beta_3 \Delta NF + \beta_4 \Delta POP + \beta_5 \text{ILL} + \beta_6 \Delta \text{Ratio\_educ} \\ + \beta_7 \Delta \text{Ratio\_matric} + \beta_8 \text{RUG} + \beta_9 \Delta \text{AHH} + \beta_{10} \Delta \text{UN} + \beta_{11} \Delta \text{FD} + \epsilon\end{aligned} \tag{3.1}$$

where ΔY represents night lights, a well-documented proxy for economic activity. For example, Henderson et al. (2012) used satellite photos of night lights to predict economic growth, claiming that changes in night lights are substantially associated with changes in GDP. The baseline value INI is the average night lights in 1992, it is included on the right side to control for the initial level of night lights. This helps to ensure that the analysis focuses on the change

relative to the starting point, accounting for any initial differences between municipalities. Secondly, for Isolation effects: Controlling for these differences allows us to isolate the effect of the intervention or policy. For example, if a new policy is implemented to improve public school infrastructure, we want to see its effect on night lights regardless of how bright or dim the area was initially. Lastly, for accurate analysis, without controlling for initial differences, the analysis could be skewed. For instance, a wealthier municipality might show a bigger increase in night lights simply because it started in a better position, not necessarily because of the new policy or change. In addition, Barro (1991) emphasises the relevance of initial conditions in his work on economic convergence, finding that regions with lower initial development levels tend to rise quicker after controlling for other factors. The other determinants of the ΔY are the change in number of schools for both fee (ΔF) and non-fee (ΔNF) schools, change in population density between 1996 and 2011 (ΔPOP), fraction of illiterate in 1996 (ILL), change in the ratio of education between 1996 to 2011 ($\Delta Ratio\_educ$), change in the ratio of matric between 1996 to 2011 ($\Delta Ratio\_matric$), change fraction of people living in formal dwellings between 1996 and 2011 (ΔFD), change of fraction of unemployed between 1996 to 2011 (ΔUN), ruggedness of landscape in 1996 (RUG) and change in average number of households between 1996 to 2011 (ΔAHH). The variable ΔF reflects changes in the education industry, particularly in schools that charge fees. This variable could reflect changes in economic situations, parental ability to pay, or educational regulations that could impact local growth. See, for example, Becker (2009) emphasises the value of education as a type of human capital that contributes to economic progress. The change in non-fee school variable ΔNF could include policy reforms towards more inclusive education or economic challenges that cause a rise in non-fee schools. The impact on night lights could be through enhanced access to education, resulting in long-term economic prosperity. See authors like Psacharopoulos and Patrinos* (2004) who evaluate global studies on the returns to education and find that increased access to education, particularly free schooling, greatly improves economic outcomes. Population density changes ΔPOP are important because they affect demand for services, infrastructure, and total economic activity. This variable helps control for population changes that may drive changes in night lights. Simon and McConnell (1998) argue that higher population density can lead to greater economic dynamism due to increased demand for services and goods. The fraction of illiterate population (ILL) captures the initial educational attainment level. Areas with higher illiteracy might struggle to grow economically, impacting changes in night lights. This variable controls for the baseline educational quality. Hanushek and Woessmann (2008) examine the importance of education quality, particularly literacy, in promoting economic growth. Changes in the education ratio $\Delta Ratio\_educ$ reflect changes in the population's educational levels. Increased education is often associated with improved economic outcomes, which may be reflected in night lights, see for example Schultz (1961) emphasises how higher education levels lead to productivity and economic growth. The change in the matric ratio variable $\Delta Ratio\_matric$ is primarily concerned with the change in matriculation rates, which indicate a higher degree of educational attainment.

This could indicate better future employment prospects and economic growth, see for example Mankiw, Romer, and Weil (1992) incorporate education into their expanded Solow model to demonstrate its effect on economic growth. The control variable (RUG) takes into account geographical variables that may have an impact on economic development. More rugged places may be less accessible, limiting infrastructure development and consequently night illumination. Literature such as Nunn and Puga (2012) investigate the impact of rough terrain on historical and current economic results. The change in the average household size variable ΔAHH may reflect economic or social developments. Larger households may suggest economic pressures, whilst smaller households could imply better economic conditions and urbanisation. Household size can reflect economic conditions and social systems. A. V. Banerjee and Duflo (2011) investigate how household dynamics influence poverty and economic decisions. Changes in the unemployment fraction variable ΔUN correspond to developments in the labour market. Higher unemployment may diminish economic activity, resulting in fewer night lights. Unemployment is a crucial economic indicator. Blanchard and Wolfers (2000) investigate how macroeconomic shocks and labour market institutions interact to effect unemployment and, consequently, economic activity. The change in formal dwellings variable ΔFD measures changes in housing quality and infrastructure. A rise of formal residences usually indicates economic development, which could lead to higher night illumination. The construction of formal housing is frequently related with economic development and better living conditions. Glaeser and Gottlieb (2009) address how urban development, particularly housing quality, influences and drives economic growth.

3.6 Results

We present the basic OLS regression results in Table 3.3, the interaction terms and other control variables in Table 3.4, the quantiles in Table 3.5 and lastly Tables (3.6, 3.7,3.8 and 3.9) in the appendices show the robustness of the quantile results since the results don't change that much.

3.6.1 Linear Regression

Table 3.3 column 1 presents the initial night light data in 1992 effects on the change from 1992 to 2013 and it indicates that there has been no convergence, i.e. places with more lights (proxy for higher income) had greater growth in the period 1992-2013. This result is contrary to common economic theory that expects higher growth in economic activities in areas with lower initial night-time lights or local municipalities with lower levels of initial night-time lights to have higher growth in economic activities than local municipalities with more.

Column 2 in Table 3.3 introduces the main theme of the analysis, i.e. the effect of public investment in fee schools and non-fee schools on the growth of areas, i.e local municipalities. The results indicate that public investment in fee schools has a positive effect on an area's growth and a negative effect on non-fee schools, but not significant. As additional controls are included in columns 3-5, the effect for fee schools is still positive but no longer significant. These results imply that the independent effect of school becomes absorbed by the initial condition or that the investment in school simply followed the path of light. Investment in a fee-paying school went in the richer areas, but investment in school infrastructure does not have an independent effect on economic growth (on average).

TABLE 3.3: Basic OLS regressions

	Dependent variable:				
	Change in Night lights 1992-2013				
	Model	Model	Model	Model	Model
	(1)	(2)	(3)	(4)	(5)
Average lights 1992	0.185***			0.179***	0.135***
	(0.018)			(0.030)	(0.034)
Change in fee schools		0.093***	0.064**	0.032	0.012
		(0.030)	(0.026)	(0.023)	(0.021)
Change in non-fee schools		−0.003	−0.011*	−0.008	−0.002
		(0.007)	(0.006)	(0.006)	(0.005)
Change in population density			0.009***	0.0002	0.001
			(0.001)	(0.002)	(0.002)
Fraction illiterate					−10.112***
					(3.607)
Change in ratio of education					3.471
					(2.901)
Change in ratio of matric					12.530***
					(4.190)
Ruggedness					0.206*
					(0.114)
Change in average household					0.163
					(0.350)
Change in fraction unemployed					0.002
					(0.018)
Change in formal dwellings					0.031***
					(0.011)
Observations	120	120	120	120	120
R^2	0.517	0.096	0.325	0.542	0.618

Note: Table 3.3 is a basic OLS regression.
Robust standard errors at local municipality in parentheses *p<0.1 **p<0.05, ***p< 0.01

3.6.2 Interaction terms: initial lights and schools

Interaction terms are introduced to see if there is an extra dimension of the building of public schools that has helped or hindered the convergence process.[3] The new linear regression is

$$\begin{aligned}\Delta Y = \beta_0 + \beta_1 \text{INI} + \beta_2 \text{Ifs} + \beta_3 \text{Infs} + \beta_4 \Delta F + \beta_5 \Delta NF + \beta_6 \Delta POP + \beta_7 \text{ILL} \\ + \beta_8 \Delta \text{Ratio\_educ} + \beta_9 \Delta \text{Ratio\_matric} + \beta_{10} \text{RUG} + \beta_{11} \Delta \text{AHH} + \beta_{12} \Delta \text{UN} + \beta_{13} \Delta \text{FD} + \epsilon\end{aligned} \tag{3.2}$$

where variables such as INI, ΔY, ΔF, ΔNF, ΔPOP, ILL, ΔRatio_educ, ΔRatio_matric,RUG, AHH, UN and FD are defined above in linear regression equation 3.1, Ifs and Infs are the introduced interaction terms for fee and non-fee. The interaction terms are expressed as levels rather than changes. The interaction terms are constructed using the initial night lights in 1992 and the number of fee-paying and non-fee-paying public schools from 1992 to 2013. The following is a breakdown of the interaction terms in our model: **fee interaction term** : Ifs = average initial lights $\times$ ΔFee. **Non-fee interaction term**: Infs = average initial lights $\times$ Δnon_Fee.

Table 3.4 column 1 presents initial night lights in 1992, the interaction terms for both fee and non-fee schools' effects on the change from 1992 to 2013. Column 1 of Table 3.4 further indicates that "initial night lights in 1992" is positively associated with growth (although we still cannot make a causality statement) - it could be that people have moved from poorer to richer places. The initial night light coefficient tells us that areas that initially had economic activities grow more than those with little or no lights, which in turn increases spatial inequality. Likewise, the "fee schools interaction term" is positively associated with growth in the same period, i.e. building a fee school has helped the growth of the areas that were already richer. Overall, the interaction term slope coefficient for the fee schools contributes more to increasing the spatial inequality than the non-fee schools. Becker (1964) claims that investing in education, particularly in higher-quality institutions, can result in significant human capital and economic productivity gains. This effect may be increased in more developed areas where the infrastructure and economic environment can better support and employ educated people. The "non-fee interaction term" has significantly worsened the economic trajectories of those areas. According to Psacharopoulos and Patrinos* (2004), expanding access to education is important, but so is the quality and type of education. Non-fee schools, which frequently serve low-income

[3] Interaction terms for fee (Ifs) and non-fee ($Infs$) are a product of initial night lights in year 1992 multiplied by the change in either fees or non-fees schools

populations, may not contribute as much to economic growth in previously developed areas as fee-paying schools.

TABLE 3.4: Interaction terms and other control variables

	Dependent variable:		
	Change in night lights 1992-2013		
	Model 1	Model 2	Model 3
Average lights 1992	0.211^{***}	0.133^{***}	0.123^{***}
	(0.031)	(0.033)	(0.036)
Interaction term for fee	0.004^{**}	0.004^{*}	0.005^{*}
	(0.002)	(0.003)	(0.003)
Interaction term for non-fee	-0.001^{***}	-0.003^{***}	-0.002^{***}
	(0.0004)	(0.001)	(0.001)
Change in fee schools		−0.017	−0.021
		(0.027)	(0.027)
Change in non-fee schools		0.006	0.003
		(0.005)	(0.005)
Change in ratio of matric		13.692^{***}	12.858^{***}
		(3.358)	(3.968)
Change in population density		0.009^{**}	0.006^{*}
		(0.003)	(0.003)
Change in formal dwellings		0.022^{**}	0.026^{**}
		(0.010)	(0.011)
Fraction illiterate			-9.452^{***}
			(3.471)
Change in ratio of education			3.762
			(2.744)
Ruggedness			0.126
			(0.110)
Change in average households			0.092
			(0.334)
Change in fraction unemployed			0.002
			(0.017)
Observations	120	120	120
R^2	0.531	0.675	0.715
Note:			*p<0.1; **p<0.05; ***p<0.01

Note: Table 3.4 is a basic OLS regression and the introduction of the interaction terms together with other control variables. Robust standard errors at local municipality in parentheses *p<0.1 **p<0.05, ***p< 0.01

As additional controls are included in Columns 2-3 in Table 3.4 above, the initial night lights and the interaction term for a fee are still associated with growth and significant, whereas the interaction term for non-fee is also significant but not associated with growth. The positive and very significant coefficient for Change in ratio of matric implies that an increase in the proportion of the population achieving matriculation is closely related to an increase in night lights. This emphasises the relevance of higher education in promoting economic development. Authors such as Mankiw et al. (1992) also emphasise that greater levels of educational achievement, such as matriculation, help to create human capital, which is a crucial driver of economic development. This result highlights the importance of education in promoting economic progress. Aside from the debate over whether public schools were established in areas that already had night lights or vice versa, controlling for both population density and formal dwellings also influences the growth of economic activities. The changes in population density and formal dwellings contribute to identifying the factors at play. Their significance suggests that schools were not only built in areas where lights already existed, but that these factors also played a role in driving growth. The positive and significant coefficient for "Change in population density" indicates that as population density increases, so do the economic activities. This may be attributed to increased economic activity and infrastructural development in densely populated areas. See, for example, Simon and McConnell (1998) addresses how higher population density can boost economic activity by increasing demand for goods and services. This finding supports the assumption that population density is an essential element in promoting economic development. The significant and positive coefficient for "Change in formal dwellings" suggests that as the fraction of formal dwellings increases, so does the number of night lights. This shows that improved housing quality is linked to economic development, see for example Glaeser and Gottlieb (2009) on the wealth of cities. Fraction illiterate has a huge, significant negative effect on growth, this is because individuals with lower literacy levels are at a disadvantage to poor employment opportunities, which then could result in lower or no income, see literature, e.g Davidson (1990). On the other hand, "Change in fraction of unemployment" and "Ruggedness of landscape", "Change in average households " do not show an independent effect on growth on average. Further, Table 3.4 above clearly shows that the results on the interaction terms are robust to whatever variable we introduce. The last thing to do is to look at the coefficient distributions in different quantiles, such as the first and the last 10 percentiles, as well as the median.

3.6.3 Quantiles

The linear regression estimates the mean of the slopes, so with quantiles, we can identify the evolution of the distributions that the simple linear regression is unable to show. When we talk of inequality, we could have a non-linear effect along the distribution, therefore, we use the

quantile regression to see what the effect is on the bottom quantile as well as the top quantile of the coefficients. The quantiles that we are using are the quantiles of the dependent variable, the change in night lights in the period 1992-2013, represented by the distribution of taus (0.1, 0.2, 0.5, 0.8, and 0.9). The regression model used to evaluate these quantiles is derived from equation 3.2 above; everything is the same in that equation, we only replaced the dependent variable ΔY by its quantiles.

The first starting point is to look at the evolution in the distributions of initial night lights on the change in night lights. As it is demonstrated in Table 3.5 column 1 below, the OLS average of the coefficient of initial lights indicated that there is no convergence- local municipalities with more lights had greater growth in the period 1992-2013. In contrast, the narrative is different at a lower quantile presented by (tau = 0.1) in column 2, we see a significant negative sign on initial lights which implies convergence- meaning local municipalities with fewer lights such as those at the outskirts of town have greater growth than those that already had more lights in period 1992-2013. Columns 3-6 of Table 3.5 present initial lights associated with income growth. The evolution of these distributions is demonstrated in Figure 3.7 with quantiles on the horizontal axis "taus" and "estimates" on the vertical axis, the initial night lights are presented as "lit92".

Now let us look at the distributions of the main theme of the analysis, the effect of interaction terms for fee and non-fee public schools on the change of night lights. Table 3.5 column 1 presents the mean OLS regression which is associated with positive growth of economic activities, however at lower quantiles i.e (tau = 0.1) column 2 Table 3.5 below, the coefficient result for fee schools interaction term indicates a significant negative effect on growth, this means that building a fee pay school in LMs with lower income or less economic activities results to negative growth. This coefficient distribution becomes significantly positive in the middle quantiles, i.e (tau = 0.2-0.5) columns (3-4). The results become surprising at upper quantiles, where we discover that adding an extra school investment in LMs that are rich results in negative growth of income in columns (5-6). The mixed indications of the coefficients indicate that the influence of fee-paying schools varies with development level. They make a beneficial contribution in moderately developed areas, but in highly developed places, the influence may diminish or even turn negative. Figure 3.7 below shows the evolution of these fee schools interaction coefficient estimates, which are presented as variable "I-fss".

On the other hand, the OLS regression for the non-fee schools' interaction term predicts a negative growth on average, see in Table 3.5 column 1, whereas at the lower 10 percentile column 2 the slope of the coefficient estimate is negative and significant which means adding non-fee schools in the areas that are disadvantaged lead to less or not much of economic activities, this can be true because introducing a school in a rural area where there is so much poverty could result to people not even attending to that school and some people will move to other better

areas school, hence you may expect to see less to non-economic activities taking place.

TABLE 3.5: Quantiles

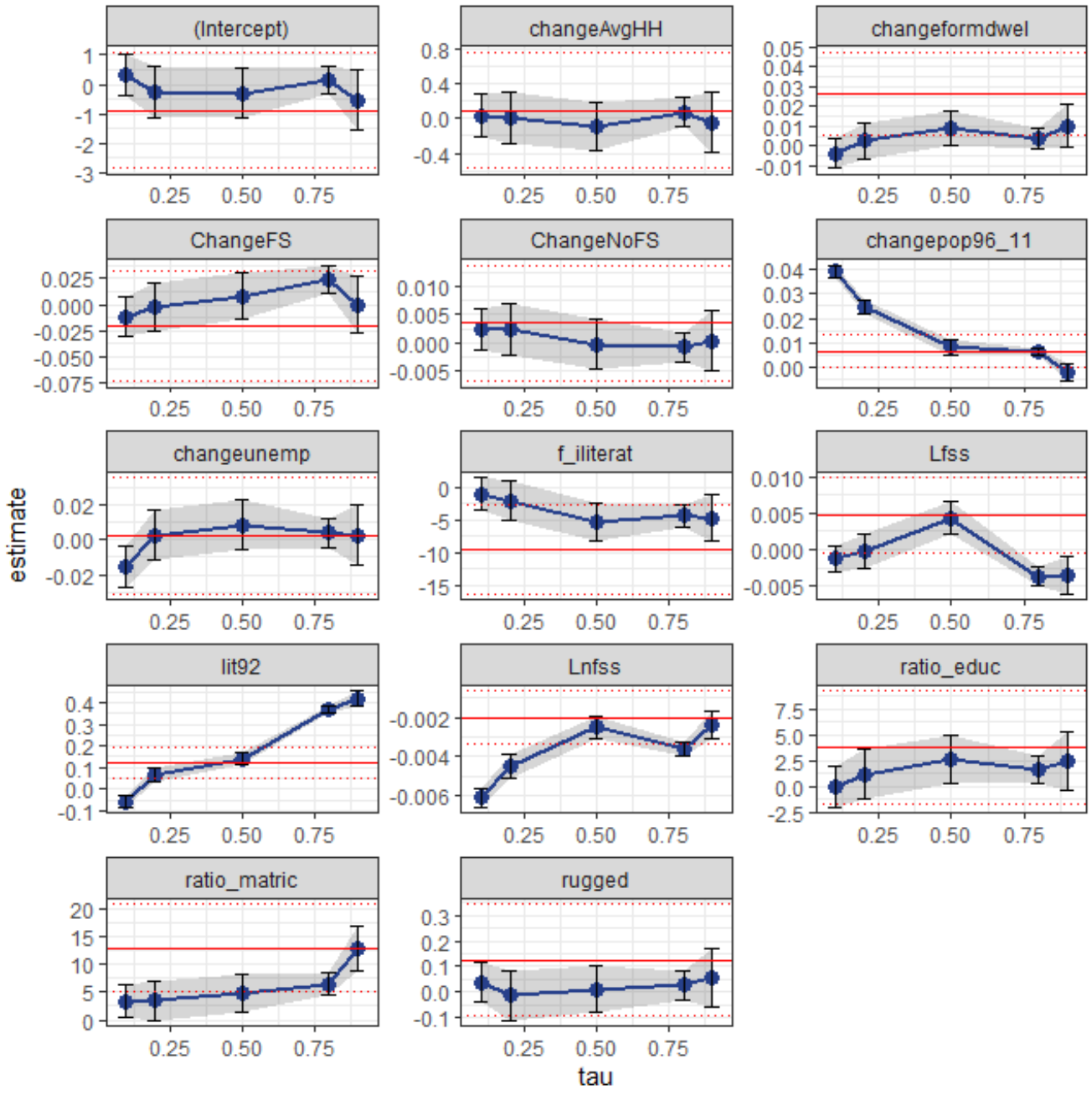
	Dependent variable:					
	Change in Night lights 1992-2013					
	OLS	tau = 0.1	tau = 0.2	tau = 0.5	tau = 0.8	tau = 0.9
	(1)	(2)	(3)	(4)	(5)	(6)
Initial night lights 1992	0.123***	−0.058***	0.067***	0.141***	0.366***	0.417***
	(0.036)	(0.013)	(0.016)	(0.015)	(0.009)	(0.018)
Interaction term for fee	0.005*	−0.001	−0.0002	0.004***	−0.004***	−0.004***
	(0.003)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Interaction term for non-fee	−0.002***	−0.006***	−0.004***	−0.002***	−0.004***	−0.002***
	(0.001)	(0.0002)	(0.0003)	(0.0003)	(0.0002)	(0.0004)
Change in fee schools	−0.021	−0.012	−0.002	0.008	0.025***	−0.0004
	(0.027)	(0.010)	(0.012)	(0.011)	(0.007)	(0.014)
Change in non-fee schools	0.003	0.002	0.002	−0.0002	−0.001	0.0004
	(0.005)	(0.002)	(0.002)	(0.002)	(0.001)	(0.003)
Change in ratio of matric	12.858***	3.384**	3.444*	4.855***	6.379***	12.764***
	(3.968)	(1.438)	(1.743)	(1.679)	(0.996)	(2.032)
Change in population density	0.006*	0.039***	0.024***	0.008***	0.006***	−0.003
	(0.003)	(0.001)	(0.002)	(0.001)	(0.001)	(0.002)
Change in formal dwellings	0.026**	−0.004	0.003	0.009*	0.004	0.010*
	(0.011)	(0.004)	(0.005)	(0.004)	(0.003)	(0.005)
Fraction illiterate	−9.452***	−1.084	−2.108	−5.233***	−4.318***	−4.643**
	(3.471)	(1.258)	(1.525)	(1.469)	(0.871)	(1.777)
Change in ratio of education	3.762	−0.043	1.157	2.569**	1.594**	2.433*
	(2.744)	(0.994)	(1.205)	(1.161)	(0.689)	(1.405)
Ruggedness	0.126	0.039	−0.013	0.012	0.026	0.057
	(0.110)	(0.040)	(0.048)	(0.046)	(0.028)	(0.056)
Change in average households	0.092	0.033	0.002	−0.088	0.072	−0.047
	(0.334)	(0.121)	(0.147)	(0.141)	(0.084)	(0.171)
Change in fraction unemployed	0.002	−0.015**	0.003	0.008	0.004	0.002
	(0.017)	(0.006)	(0.007)	(0.007)	(0.004)	(0.009)
Observations	120	120	120	120	120	120

Note: Table 3.5 is the distribution of the quantiles for the outcome.
Robust standard errors at local municipality in parentheses *p<0.1 **p<0.05, ***p< 0.01

These coefficients are also negative along the 20th percentile throughout the 90th percentile column (3-6), which indicates that placing extra non-fee schools in the rich areas does not result in any positive growth. The consistent negative impact shows that non-fee schools may not contribute favourably to economic growth, potentially due to lower quality or limited resources.

This effect is more pronounced in less developed places. Figure 3.7 below shows the evolution of these Non-fee interaction coefficient estimates represented as variable "I-nfss".

FIGURE 3.7: Quantiles



Note: Figure 3.7 The evolution of the distributions of night light quantiles on the horizontal axis (tau). and estimates on the vertical axis (estimate)

We also control for the change in both public school investments like it is done in growth models. The results of Change in Fee schools in Table 3.5 above show that at lower and lower middle quantiles column (2-3), a change in fee schools is associated with negative and not statistically significant growth, whereas at upper middle and upper quantiles in columns (5). The effect of

increasing fee schools is particularly noticeable in highly developed locations, where they can greatly contribute to economic activities. Figure 3.7 above shows the distribution of the slope of the coefficient of this variable presented as "ChangeFS".

On the other hand, the Change in non-fee schools is not growth enhancing in all quantiles and is not statistically significant in the lower, lower middle and upper middle quantiles, see above Table 3.5 columns (2-5) apart from the upper quantile in column 6. This implies that non-fee schools may not have a significant role in promoting economic development, regardless of the area's initial level of development. The distribution of this variable is also demonstrated in Figure 3.7 above as "ChangeNoFS".

The " change in ratio of matric " shows meaningful results. At lower quantiles, the coefficient is positive (3.384) and significant, indicating that increasing matriculation rates has a favourable effect on night lights even in less developed places. At the middle quantiles, the coefficient rises (4.855), with a greater favourable impact in moderately developed locations. At the top quantiles, the coefficient is much higher (12.764), indicating a very large beneficial effect in highly developed areas. The increasing positive coefficients across quantiles indicate that improving educational attainment (measured by matriculation rates) has a bigger impact on economic growth as initial development improves. These slope coefficients and their quantiles are also depicted in Figure 3.7 above, the variable is "ratio_matric".

The results for controlling the "Change in population density" variable show that, on average, slope coefficients are growth-enhancing and statistically significant. At lower quantiles, the coefficient is positive and significant (0.039), indicating that population density is an important factor in increasing night lights in less developed locations. At the middle quantiles, the coefficient decreases but remains positive (0.008), indicating a weaker but still beneficial effect. At the top quantiles, the coefficient becomes positive and significant (0.006), implying that increased population density in highly urbanised places contributes to night lights growth; however, in column 6, the slope coefficient is negative and not statistically significant. The findings indicate that population density is most helpful in less developed and developed places. These slope coefficients and their quantiles are also depicted in Figure 3.7 above, the variable is "changepop96_11".

Formal dwellings ("Change in formal dwellings") show that on average the slopes are positive and significant and are associated with growth in incomes at 5 % levels of significance. At lower quantiles, the coefficient is slightly negative and negligible (-0.004), indicating little impact in less developed areas. At the middle quantile, the coefficient becomes positive and significant (0.009), indicating a beneficial impact on moderately developed areas. At the upper quantiles, the coefficient stays positive and significant (0.010), indicating that the impact on highly developed

areas will continue to be positive. The creation of formal houses appears to boost economic growth, especially in moderately and highly developed areas. Increased education ratios have a favourable effect on economic growth, particularly in moderately and highly developed countries. The distributions are also found in Figure 3.7 above as " changeformdwel".

The slope coefficients of the "Average fraction of illiterate" as demonstrated by the OLS in Table 3.5 column 1 above show that there is a negative and significant relationship between the variable and the growth in economic activities. At lower quantiles, the coefficient is negative but insignificant (-1.084), indicating a modest impact in less developed areas. At the middle quantile, the coefficient becomes more negative and significant (-5.233), indicating that higher illiteracy rates have a considerable negative impact on economic growth in moderately developed areas. At the top quantiles, the coefficient stays negative and significant (-4.643), indicating a continued negative effect in highly developed locations. High illiteracy rates impede economic growth, especially in developed areas. The distributions are also found in Figure 3.7 above as " f_iliterat".

The "Change in ratio of education" on average slope coefficient does not show any statistical significance. At lower quantiles, the coefficient is nearly zero and insignificant (-0.043), indicating that it has little impact in less developed areas. At the middle quantiles, the coefficient is positive and significant (2.569), indicating a beneficial effect in moderately developed locations. At the upper quantiles, the coefficient is still positive and significant (2.433), indicating a consistent beneficial impact in highly developed locations. Increased education ratios have a favourable effect on economic growth, particularly in moderately and highly developed countries. The distributions are also found in Figure 3.7 above as " ratio_educ".

The coefficients for "Ruggedness" are generally small and insignificant, implying that an area's geographical roughness has no meaningful impact on the variation in night lights across the distribution. Ruggedness does not appear to play a significant role in determining economic growth as assessed by night lights. The distributions are also found in Figure 3.7 above as " rugged".

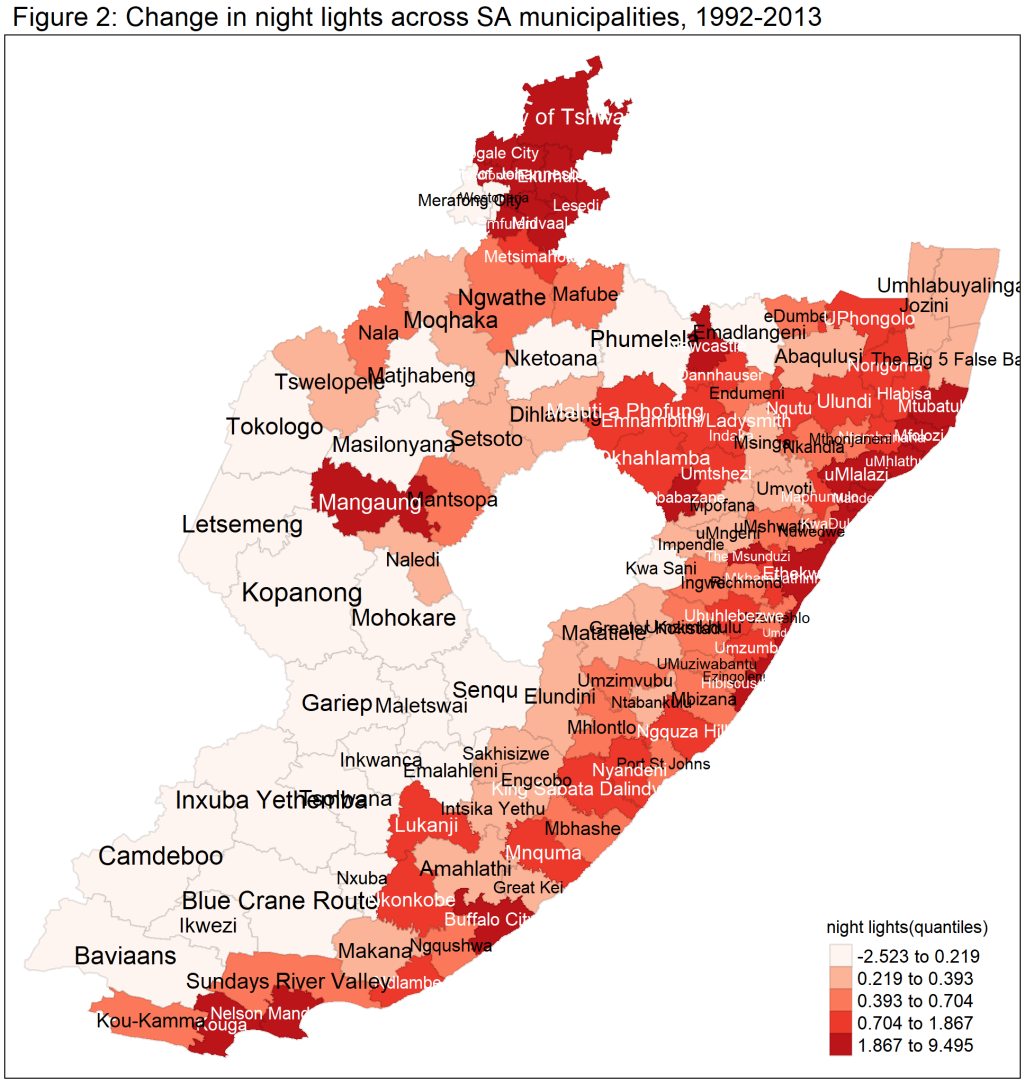
The slope coefficients for " Changes in average households" are generally small, implying that changes in the average size of households don't have little impact on economic activities across the distribution. This implies that variations in household size are not a significant driver of economic progress. The distributions are also found in Figure 3.7 above as " changeAvgHH"

The variable " Change in fraction unemployed at lower quantiles show a negative and significant relationship (-0.015), indicating that higher unemployment rates impede economic growth.

on the middle quantiles, the coefficient turns positive (0.008) but is small, indicating no evident impact on moderately developed areas. Upper quantiles show a positive but insignificant coefficient (0.002), indicating minimal impact in highly developed locations. Unemployment is a substantial impediment to growth in less developed countries, but its impact decreases as development progresses.The distributions are also demonstrated in Figure 3.7 above as " changeunemp".

Figure 3.8 demonstrates the quantile distributions of change night lights for local municipalities with less and more economic growth incomes. The LMs are found to be at the upper quantiles in terms of growth are : City of Johannesburg, City of Tshwane, Ekurhuleni,Mandeni, Mfolozi, Midvaal, Mogale city, Umhlathuze, and Umlalazi.

FIGURE 3.8: Change in night lights quantiles



Note: Figure 3.8 demonstrates the quantile distributions of change night lights for local municipalities.

3.7 Conclusion

In this chapter, we investigated the role of the effects of public school infrastructure on economic growth and inequality for local municipalities in South Africa. We controlled for other important variables such as population, fraction illiterate, formal dwellings, fraction unemployed, ruggedness and average households using both linear and non-linearity models i.e the simple linear regression and quantiles for the period 1992-2013. Unlike other papers that only focus on schools enrollment, school attainment and school services in general that are associated with achievement in particular subjects, this paper looked specifically at public schools infrastructure investment which is divided into fees and non-fees paying schools on economic incomes which is proxied by artificial night lights and thus contribute to literature as there have not been studies that focus on the effects of the number of schools on economic growth and inequality in South Africa. In the context of South Africa, we found that public infrastructure in fee schools is associated with significant positive growth incomes whereas in non-fee it is not enhancing growth but is negatively significant, that's when we used linear models which only calculated the coefficients averages. We then decided to examine the effects of these infrastructures using quantiles which showed the distribution of the slope coefficients over the growth incomes proxied by a change in artificial night lights. Using the quantiles, we created an interaction term for initial lights and each public school category (fee or non-fee). The results in the distribution demonstrated that the interaction term for fee schools is not associated with growth in lower and upper quantiles, but only in the lower middle and middle quantiles where it's positive and significant. On the other hand, the slope coefficients of the interaction of non-fee showed that at lower quantiles building a school in a poor local municipality results in growth, but as you move along the distribution of the other quantiles we experienced strong negative slopes which were also significant, this simply means adding an extra school from lower-middle to upper-middle did not enhance growth incomes. These findings might have significant policy implications. First, it should be noted that building extra (fee or non-fee) may not translate into positive economic growth and a reduction in income inequality. Putting a school infrastructure that is not proper in a municipality that is poor, if there is already an existing school which is not doing well, definitely, an additional school will have little or no impact on the growing incomes of that municipality. Introducing a good school will lead to a quality labour force, but if the school is not proper, then definitely a poor labour force is created, which in the long run will result in poor or no economic growth in incomes. On the other hand, building proper schools in rich local municipalities will result in more economic inequalities. It is important that when policymakers make decisions about placing school infrastructure, they should look at a lot of factors, such as the state of the municipality, the size, distances, etc., not only those factors which are influenced by their political interests, but rather the interest of the public at large.

3.8 Appendix

TABLE 3.6: Robustness check: Economic activities 1992-1994

	Dependent variable:					
	Change in Night lights 1992-2013					
	OLS	tau = 0.1	tau = 0.2	tau = 0.5	tau = 0.8	tau = 0.9
	(1)	(2)	(3)	(4)	(5)	(6)
Initial lights 1992	0.056*	−0.155***	−0.160***	0.123***	0.279***	0.164***
	(0.034)	(0.010)	(0.017)	(0.011)	(0.012)	(0.009)
Change in lights 1992-1994	0.728***	0.883***	0.926***	0.628***	0.574***	0.629***
	(0.136)	(0.039)	(0.068)	(0.045)	(0.049)	(0.036)
Interaction term for fee	0.001	0.0004	0.005***	0.0002	−0.003***	−0.002***
	(0.002)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Interaction term for non-fee	−0.002**	−0.004***	−0.003***	−0.002***	−0.002***	0.002***
	(0.001)	(0.0002)	(0.0003)	(0.0002)	(0.0002)	(0.0002)
Change in fee schools	−0.006	−0.006	−0.003	0.021**	0.015*	−0.017**
	(0.024)	(0.007)	(0.012)	(0.008)	(0.009)	(0.006)
Change in non-fee schools	0.002	0.002	0.002	−0.002	−0.002	−0.002
	(0.005)	(0.001)	(0.002)	(0.002)	(0.002)	(0.001)
Change in ratio of matric	9.315***	4.589***	3.393*	2.905**	5.722***	10.393***
	(3.539)	(1.020)	(1.786)	(1.182)	(1.285)	(0.951)
Changein population density	0.009***	0.029***	0.025***	0.010***	0.001	0.006***
	(0.003)	(0.001)	(0.002)	(0.001)	(0.001)	(0.001)
Change in formal dwellings	0.013	−0.002	0.003	0.005	−0.001	−0.001
	(0.010)	(0.003)	(0.005)	(0.003)	(0.003)	(0.003)
Fraction illiterate	−7.797**	−2.399***	−3.099**	−4.693***	−4.014***	−6.388***
	(3.057)	(0.881)	(1.543)	(1.021)	(1.110)	(0.822)
Change in ratio of education	2.321	−0.257	0.650	2.950***	2.117**	3.346***
	(2.420)	(0.697)	(1.221)	(0.808)	(0.879)	(0.650)
Ruggedness	0.055	0.013	−0.020	−0.058*	0.045	−0.018
	(0.097)	(0.028)	(0.049)	(0.032)	(0.035)	(0.026)
Change in average households	−0.056	0.005	−0.051	−0.253**	−0.097	−0.303***
	(0.294)	(0.085)	(0.148)	(0.098)	(0.107)	(0.079)
Change in fraction unemployed	0.009	0.006	0.002	0.010*	0.007	0.005
	(0.015)	(0.004)	(0.007)	(0.005)	(0.005)	(0.004)
Observations	120	120	120	120	120	120

Note: Table 3.6 is a portion of the change in economic activities during the apartheid era (1992-1994). It is for robustness check.
Robust standard errors at local municipality in parentheses *p<0.1 **p<0.05, ***p< 0.01

TABLE 3.7: Robustness check: : Economic activities 1992-1995

	Dependent variable:					
	Change in Night lights 1992-2013					
	OLS	tau = 0.1	tau = 0.2	tau = 0.5	tau = 0.8	tau = 0.9
	(1)	(2)	(3)	(4)	(5)	(6)
Initial lights 1992	0.066*	−0.177***	−0.146***	0.131***	0.262***	0.229***
	(0.034)	(0.013)	(0.016)	(0.014)	(0.012)	(0.008)
Change in lights 1992-1995	0.860***	1.179***	0.829***	0.682***	1.229***	1.353***
	(0.173)	(0.065)	(0.083)	(0.074)	(0.062)	(0.040)
Interaction term for fee	0.0005	−0.002**	0.005***	0.00001	−0.006***	−0.007***
	(0.002)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Interaction term for non-fee	−0.002***	−0.002***	−0.004***	−0.003***	−0.002***	−0.0002
	(0.001)	(0.0002)	(0.0003)	(0.0003)	(0.0002)	(0.0001)
Change in fee schools	−0.004	0.051***	0.008	0.025**	0.025***	0.017***
	(0.024)	(0.009)	(0.012)	(0.010)	(0.009)	(0.006)
Change in non-fee schools	0.003	0.0003	0.002	−0.001	−0.0003	−0.0001
	(0.005)	(0.002)	(0.002)	(0.002)	(0.002)	(0.001)
Change in ratio of matric	10.463***	−0.472	3.379*	2.402	5.178***	5.060***
	(3.573)	(1.346)	(1.705)	(1.523)	(1.269)	(0.833)
Change in population density	0.011***	0.026***	0.029***	0.011***	0.003***	0.006***
	(0.003)	(0.001)	(0.002)	(0.001)	(0.001)	(0.001)
Change in formal dwellings	0.009	0.007*	0.003	0.004	0.001	0.005**
	(0.010)	(0.004)	(0.005)	(0.004)	(0.004)	(0.002)
Fraction illiterate	−7.717**	−3.489***	−2.566*	−4.168***	−3.721***	−3.906***
	(3.117)	(1.174)	(1.488)	(1.329)	(1.107)	(0.727)
Change in ratio of education	3.044	2.516***	0.567	2.203**	2.228**	2.157***
	(2.452)	(0.924)	(1.171)	(1.045)	(0.871)	(0.572)
Ruggedness	0.010	−0.058	−0.044	−0.045	−0.015	0.008
	(0.101)	(0.038)	(0.048)	(0.043)	(0.036)	(0.023)
Change in average households	0.093	−0.172	0.042	0.023	0.180*	0.171**
	(0.298)	(0.112)	(0.142)	(0.127)	(0.106)	(0.069)
Change in fraction unemployed	0.010	0.0005	0.006	0.009	0.008	−0.001
	(0.015)	(0.006)	(0.007)	(0.006)	(0.005)	(0.003)
Observations	120	120	120	120	120	120
Note:						*p<0.1; **p<0.05; ***p<0.01

Note: Table 3.7 shows a portion of the change in economic activities during the apartheid era (1992-1995). It is for robustness check.
Robust standard errors at local municipality in parentheses *p<0.1 **p<0.05, ***p< 0.01

TABLE 3.8: Robustness check: : Economic activities 1992-1996

	Dependent variable:					
	Change in Night lights 1992-2013					
	OLS	tau = 0.1	tau = 0.2	tau = 0.5	tau = 0.8	tau = 0.9
	(1)	(2)	(3)	(4)	(5)	(6)
Initial lights 1992	0.039	−0.254***	−0.223***	0.123***	0.185***	0.113***
	(0.034)	(0.011)	(0.010)	(0.008)	(0.014)	(0.008)
Change in lights 1992-1996	0.745***	1.315***	1.004***	0.542***	1.046***	1.145***
	(0.133)	(0.042)	(0.039)	(0.031)	(0.052)	(0.030)
Interaction term for fee	0.001	−0.010***	0.007***	0.001	−0.005***	−0.006***
	(0.002)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Interaction term for non-fee	−0.001**	0.0004**	−0.001***	−0.002***	−0.001***	0.002***
	(0.001)	(0.0002)	(0.0002)	(0.0001)	(0.0002)	(0.0001)
Change in fee schools	−0.007	0.060***	0.011	0.021***	0.019**	0.006
	(0.023)	(0.007)	(0.007)	(0.006)	(0.009)	(0.005)
Change in non-fee schools	0.003	−0.002	−0.0002	−0.0002	−0.001	−0.0004
	(0.004)	(0.001)	(0.001)	(0.001)	(0.002)	(0.001)
Change in ratio of matric	10.299***	2.148*	2.632**	2.313***	3.714***	4.671***
	(3.469)	(1.093)	(1.024)	(0.823)	(1.370)	(0.776)
Change in population density	0.009***	0.021***	0.018***	0.009***	0.002*	0.011***
	(0.003)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Change in formal dwellings	0.005	−0.009***	−0.0001	0.003	0.002	0.002
	(0.010)	(0.003)	(0.003)	(0.002)	(0.004)	(0.002)
Fraction illiterate	−6.599**	−1.376	−1.948**	−2.672***	−3.348***	−4.658***
	(3.051)	(0.961)	(0.901)	(0.723)	(1.205)	(0.683)
Change in ratio of education	2.429	0.721	0.443	1.365**	1.843*	2.778***
	(2.390)	(0.753)	(0.706)	(0.567)	(0.944)	(0.535)
Ruggedness	0.014	−0.133***	−0.068**	−0.028	−0.013	−0.050**
	(0.097)	(0.031)	(0.029)	(0.023)	(0.038)	(0.022)
Change in average households	0.100	−0.063	−0.015	−0.016	0.115	−0.087
	(0.289)	(0.091)	(0.085)	(0.069)	(0.114)	(0.065)
Change in fraction unemployed	0.012	0.020***	0.011**	0.013***	0.005	−0.001
	(0.015)	(0.005)	(0.004)	(0.003)	(0.006)	(0.003)
Observations	120	120	120	120	120	120

Note: Table 3.8 is a portion of the change in economic activities during the apartheid era (1992-1996). It is for robustness check.
Robust standard errors at local municipality in parentheses *p<0.1 **p<0.05, ***p< 0.01

TABLE 3.9: Quantiles without interaction terms

	Dependent variable:					
	Change in Night lights 1992-2013					
	OLS	tau = 0.1	tau = 0.2	tau = 0.5	tau = 0.8	tau = 0.9
	(1)	(2)	(3)	(4)	(5)	(6)
Initial lights 1992	0.043	−0.209***	−0.102***	0.151***	0.188***	0.214***
	(0.033)	(0.011)	(0.019)	(0.014)	(0.015)	(0.013)
Change in lights 1992-1994	0.800***	1.292***	1.159***	0.909***	0.751***	0.567***
	(0.131)	(0.042)	(0.077)	(0.054)	(0.059)	(0.052)
Change in fee schools	−0.0005	−0.004	0.014	0.010	−0.006	−0.015**
	(0.018)	(0.006)	(0.010)	(0.007)	(0.008)	(0.007)
Change in non-fee schools	−0.001	0.002	0.0002	−0.002	−0.002	−0.0002
	(0.004)	(0.001)	(0.003)	(0.002)	(0.002)	(0.002)
Change in ratio of matric	9.034**	2.753**	1.588	−0.041	4.964***	9.895***
	(3.609)	(1.167)	(2.101)	(1.480)	(1.609)	(1.435)
Change in population density	0.004**	0.015***	0.010***	−0.001	−0.003***	−0.001*
	(0.002)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Change in formal dwellings	0.016*	0.009***	0.012**	0.014***	0.010**	0.009**
	(0.009)	(0.003)	(0.006)	(0.004)	(0.004)	(0.004)
Fraction illiterate	−8.614***	−3.817***	−4.182**	−3.936***	−6.918***	−4.954***
	(3.077)	(0.995)	(1.792)	(1.262)	(1.372)	(1.224)
Change in ratio of education	2.134	1.892**	1.979	1.447	3.184***	2.674***
	(2.476)	(0.800)	(1.442)	(1.016)	(1.104)	(0.985)
Ruggedness	0.090	−0.017	−0.0005	0.009	−0.006	0.007
	(0.099)	(0.032)	(0.057)	(0.040)	(0.044)	(0.039)
Change in average households	0.004	−0.042	0.019	−0.152	−0.110	−0.012
	(0.299)	(0.097)	(0.174)	(0.123)	(0.133)	(0.119)
Change in fraction unemployed	0.009	0.001	0.006	0.011*	0.003	0.005
	(0.015)	(0.005)	(0.009)	(0.006)	(0.007)	(0.006)
Observations	120	120	120	120	120	120

Note: Table 3.9 shows a portion that shows the addition of an explanatory variable, the change in economic activities during the apartheid era (1992-1994). Both fee and non-fee school variables are eliminated. Standard errors at local municipality in parentheses *p<0.1 **p<0.05, ***p< 0.01.

TABLE 3.10: Excluded Provinces

DataYear	Province	Institution	GIS-long	GIS-lat	Regist.date	NoFee-School
2016	Mpumalanga	A PETIT PAS	99	99	23-Jun-10	n/a
2016	Mpumalanga	AA KHUMALO	31,0965	-25,34195	12-Mar-02	unknown
2016	Mpumalanga	ACEK ACADEMY	31,0113	-25,3259	01-Jan-02	n/a
2016	Mpumalanga	ACORN - OAKS	99	99	UNKNOWN	unknown
2016	Mpumalanga	ACORNHOEK	31,0724	-24,6017	12/31/1899	n/a
DataYear	Province	Institution	GIS-long	GIS-lat	Regist.date	NoFee-School
2016	North West	CENTRAL PRIMARY	99	99	unknown	unknown
2016	North West	DIPHETOGO SECONDARY	99	99	30-May-16	unknown
2016	North West	MADIBA A TOLOANE	99	99	unknown	unknown
2016	North West	MADINYANE P.	99	99	27-May-16	unknown
2016	North West	MERIDIAN	99	99	30-May-16	unknown
DataYear	Province	Institution	GIS-long	GIS-lat	Regist.date	NoFee-School
2016	Western Cape	GAIA	18.4897	na	99	NO
2016	Western Cape	DARUN-NA	18.47081	na	99	NO
2016	Western Cape	ATLANTIC	18.4390	na	99	NO
2016	Western Cape	KNYSNA CHRISTIAN	23.071752	na	99	NO
2016	Western Cape	EAGLE'S NEST	18.743455	na	99	NO
DataYear	Province	Institution	GIS-long	GIS-lat	Regist.date	NoFee-School
2016	Northern Cape	XUNKHWESA	24,65462	-28,70804	1/1/1996	YES
2016	Northern Cape	BANKSDRIF SECONDARY	24,80923	-27,71937	1/1/1996	YES
2016	Northern Cape	BARKLY WES HiGH	24,50931	-28,52358	1/1/1996	YES
2016	Northern Cape	BARKLY WEST	24,50956	-28,52621	1/1/1996	YES
2016	Northern Cape	BARKLY PRIMARY	24,50072	-28,53502	1/1/1996	YES
DataYear	Province	Institution	GIS-long	GIS-lat	Regist.date	NoFee-School
2016	Limpopo	ABRAM SIBASA	29,15390	-23,78332	12/31/1899	YES
2016	Limpopo	AGISHANANG	29,15364	-23,61181	12/31/1899	YES
2016	Limpopo	AGRICULTURAL HIGH	29,37314	-24,01054	12/31/1899	NO
2016	Limpopo	AKADEMIE REFORMIA	29,46036	-23,8847	12/31/1899	n/a
2016	Limpopo	ALAPHA SECONDARY	28,79192	-23,40169	12/31/1899	YES

Note: Table 3.10 is showing why some of the provinces were not included in the study. It is simple because they lack spatial information about schools such as geographic coordinates(longitude and latitude), missing registration dates and non-availability of school status whether it qualifies a fee or non-fee school.

Chapter 4

Decomposing Heterogeneities across Municipalities using Multilevel Linear Models: Spatial Evidence in South African Educational Expenditure.

4.1 Introduction

In the previous chapter, we analysed the effects of public infrastructure investment on economic growth and inequality under the assumption that the relationship across local municipalities remains constant over time and space. Specifically, we used a single regression model with one slope and one intercept, implicitly assuming homogeneity across all municipalities — whether rural, township, or urban. For example, we treated the impact of infrastructure investment as identical regardless of a municipality's location (e.g., rural vs. city) or characteristics (e.g., population density). While we partially addressed heterogeneity through quantile regression (by segmenting the analysis for poorer, middle-class, and richer groups using night lights as a proxy for economic activity), this approach focused only on variation in the dependent variable (night lights) rather than accounting for differences in municipal traits.

In this chapter, we explicitly account for heterogeneity across municipalities by distinguishing between rural and urban areas and incorporating local characteristics such as population density,

geographic ruggedness, and changes over time. This allows us to:

- **Capture differential effects**: Public infrastructure investment may have distinct impacts in rural versus urban settings. For instance, urban areas with higher population density might have more fee-paying schools, while rural areas rely more on non-fee schools.
- **Model varying intercepts and slopes**: Unlike the prior assumption of fixed relationships, we now allow intercepts (baseline outcomes) and slopes (effect magnitudes) to vary. For example, Population density or ruggedness could shift baseline economic growth (intercepts), or the effectiveness of infrastructure investment (slope) might differ due to administrative quality (e.g., urban investments may be better managed than rural ones).
- Address non-homogeneous outcomes: The quality of infrastructure (e.g., buildings, services) and its economic returns may systematically differ across regions. Urban areas might benefit more from efficient investments, whereas rural areas could suffer from poor implementation.

While the quantile regression in the previous chapter explored non-linear relationships in the dependent variable (e.g., how night lights—a proxy for economic activity—varied across income quantiles), this chapter focuses on heterogeneity in the independent variables (e.g., municipal traits). The two approaches are complementary: quantile regression reveals distributional effects, while multilevel modelling uncovers geographic and contextual variation.

By relaxing the homogeneity assumption, we better reflect real-world complexity. Acknowledging heterogeneity ensures policies account for divergent local realities, such as urban efficiency versus rural administrative challenges, rather than treating all municipalities as identical.

This chapter focuses on the spatial distribution of public school construction investment and its effects by using hierarchical models to decompose the variations across local municipalities of South Africa. The relationship between economic activities and investment in public school construction is complex but this chapter seeks to investigate whether these educational investments result in fair and favourable outcomes or whether particular local municipalities benefit more than others. In essence, the chapter provides insight into how public school construction can either worsen or reduce spatial or economic inequality.

Educational expenditure is an important component in determining the quality of education delivered in various regions. According to Hanushek and Woessmann (2011), investing in education could lead to better economic growth, educational outcomes and social development. However, Baker and Corcoran (2012) suggest that gaps in educational funding frequently result

in unequal opportunities, reinforcing socioeconomic inequities. Understanding these differences is critical for policymakers seeking to build inclusive educational systems. School construction investment is not spread out evenly across geographic areas. Political influence, local wealth, and the structure of the community all play a big role in this Brasington (2002). Reardon, Kalogrides, and Shores (2019) discover that metropolitan areas often get more financing for each learner compared to rural places. This makes the variations in public education expenditure even bigger. Researchers can use spatial analysis tools to produce maps and to visualise these variations. They can compute and find out which areas need help the most. One of the questions that was asked in the previous chapters is as follows: Who is the main contributor to South Africa's inequalities, particularly educational expenditures? In South Africa, the biggest contributor to all types of inequalities is the apartheid government. How public investment in general was allocated was simply based on racial lines. For that reason, it is fair to say that the disparities that are witnessed in local municipalities currently are a result of segregation and selective allocation of resources by the apartheid government.

The previous chapters also raised questions about whether public investment by the democratic government closes the gap or not. Although there has been a lot of investment in public investment, particularly education expenditure, which is estimated to be around 317 billion in 2023 compared to 31.8 billion in 1994, which is the first year of democratic government (Basic Education Report 2023). The previous chapter discovered that municipalities that already had night lights in 1992 are still growing faster than the poorer ones over the years. This chapter seeks to understand that even if that might be the case, that richer municipalities grew more than poorer, can we see slope variations for local municipalities to be above or below the mean? and how is the local municipality classified? In this case, we have a dummy variable for metro and non-metropolitan municipalities.

Why opt for multilevel models? The combination of multilevel models and spatial analysis provides a powerful approach to analysing the difficulties of public school expenditure across local municipalities. By integrating these methodologies, we can account for both the multilevel structure of educational data and potential spatial relationships between neighbouring locations Ferraro, Agasisti, Porcelli, and Soncin (2021). This method provides more knowledge of the factors that encourage educational spending, which is critical for effective policy development.

For a very long time, the ordinary least squares (OLS) regressions have been widely used as a method for estimating conditional means for the coefficients of linear regression of the dependent and explanatory variables, see Berggren (2020). However, there are some significant drawbacks to this OLS linear regression model, one of which is that it can only identify average relationships in the data. It does not account for or address differences in how variables relate to one another across regions (in this case, local municipalities) or social groups. Our standard errors are biased

as a result of ignoring these variations, which makes claims about statistical significance based on them false. A different approach is to use a multilevel linear model (MLM), an extension of linear regression modelling that allows us to break down different sources of variation. At least with this approach, the OLS's limitations are addressed, see for example Corrado and Fingleton (2011), the number of advantages in taking a multilevel approach.

Other papers have used MLM before, intending to compare factors affecting students' achievements across regions. They used MLM nested data structures for instance (student-level, school-level, regional level and country level), each of these levels is nested within each other Agasisti and Cordero-Ferrera (2013), Goddard, Sweetland, and Hoy (2000), Bowers and Urick (2011). Most of these studies find heterogeneity within regions but never really explain the causes. This chapter seeks to decompose heterogeneities within 120 Local municipalities (LMs) of South Africa using a hierarchical linear model (HLM) between the periods of 1992-2013. Public schools are classified as (non-fee and fee), those that are funded fully by the government and those that supplement government funds by paying extra fees. These two types of public schools are nested within local municipalities, and municipalities are nested within provinces. The chapter starts by estimating a simple regression which predicts only the conditional means of public school infrastructure investment on explanatory variables, i.e. dummy variables. Furthermore, it introduces an MLM approach which allows for the unconditional means of intercepts and slope coefficients for local municipalities. This chapter also demonstrates a decomposition of this slope heterogeneity with examples. This chapter also uses the Poisson of the hierarchical model to look at the factors that influence the rate of school development, as well as the characteristics of municipalities that build fee-paying versus non-fee-paying schools.

The findings indicate that all 120 LMs are affected by strong internal regional heterogeneity, where some areas have public school investment well above the municipal mean, and others are placed amongst the worst performers in the area. These slope heterogeneities exist because of various policies at the local municipality level, provincial level and national level. In South Africa, during the apartheid era, fee schools were allocated a bigger budget but the whites were less in population than other races. When the democratic government assumed power in 1994, more public school investment had to be injected into a huge population, which might be the other reason we see these heterogeneities. Furthermore, it depends on where and who is managing public school investment at that time and where that person thinks a particular investment could be more effective if located in a particular area. In some instances, political intervention plays a role in the placement of these investments. The results from the Poisson regression show that most of the public school construction investment was made in the metropolitan municipalities, as opposed to the non-metropolitan local municipalities.

The chapter is structured as follows: section 4.2 Related studies, section 4.3 Data description, section 4.4 Empirical results and discussion of multilevel models and section 4.5 Conclusion.

4.2 Related studies

South Africa has a complicated social and economic situation. This is mostly because of the history of apartheid that resulted in income inequality problems, higher rates of poverty and huge differences in economic opportunities across local municipalities. These differences directly influence how local municipalities can finance education infrastructure. This leads to unfairness and unequal access to educational resources such as school buildings. Income inequality is a huge reason behind differences in how expenditure on education is conducted. South Africa struggles with high income inequality. Since 1993, the Gini coefficient has been one of the highest globally, see Leibbrandt, Woolard, Finn, and Argent (2010). This is not just a national problem; we see these disparities when we look at various regions and local municipalities as well.

In local municipalities where average incomes are higher, there's usually more funding available for education. These municipalities can generate more revenue through local taxes, which can be spent on school infrastructure. This means better facilities, more qualified teachers, and extra learning materials. For instance, municipalities in richer provinces like Gauteng and Western Cape often spend more per learner than those in poorer provinces like Eastern Cape and Limpopo Van der Berg (2008). Because of this difference in funding, students from wealthier backgrounds have better chances for academic success.

On the other side, local municipalities where average incomes are lower face tough challenges when it comes to funding education. They often can't raise enough money through local taxes since their residents earn less. So, schools here might struggle with not enough funds, leading to crowded classrooms and old buildings that need repairs. Also, they might lack essential educational materials Fiske and Ladd (2004a). This lack of funding makes educational inequalities even worse because kids there miss out on what they need to do well in school.

The urban-rural divide, a reflection of the underlying socio-economic gap in South Africa, which is also responsible for educational spending, is yet another construct. Compared to rural areas, urban areas in large cities such as Johannesburg, Cape Town, and Durban generally have higher incomes, better infrastructure and greater economic opportunities. Urban cities advantage; however, thereby enabling these local municipalities to spend more on education through better-resourced schools and consequent educational outcomes. Rural South Africa, especially

the former homelands, remains underdeveloped and economically marginalised. In the areas where these people live, typically, schools are underfunded and do not have everything necessary for them to achieve at higher levels. This disparity in funding for education between metropolitan and exurban areas also plays a major role in the perpetuation of educational inequality throughout.

4.3 Data description

The Education Management Information System (EMIS), a division of the Department of Education (DoE), allows users to obtain a dataset on public schools.[1] Private and public schools, ranging in grade level from grade R to grade 12, are included in the school dataset. All schools from the 1800s to 2016 are included in the school dataset. The (1992 to 2013) is the time period that corresponds with the night lights data that is available from 1992 to 2013. This period is the focus of our investigation. We look at the two regimes in which these public schools were established (before and after democracy). Public schools are divided into fee-based and non-fee-based options. Fee schools are those that charge parents additional payments in addition to the government's subsidy, whereas schools without fees get complete government funding. Which school should be categorised as a fee or non-fee school is left up to the Minister of Education. Additionally, the DoE master list collection includes data on the schools' names, locations, registration dates, geographic coordinates (latitude and longitude), ownership status (public or private), and whether or not they are exempt from paying school fees. Public schools are used as a proxy for infrastructural investment.

Table 4.1 describes the lists of variables.

TABLE 4.1: Description of variables

Abbreviation	Variable type	Description
F	Dependent	Fee schools
NF	Dependent	Non Fee schools
D1996	Control	dummy variable for the year 1996
D2001	Control	dummy variable for the year 2001
D2006	Control	dummy variable for the year 2006
D2011	Control	dummy variable for the year 2011
Pop-density	Control	Change in population density 1996 to 2011
Rugg	Control	Ruggedness

Note: Table 4.1 describes variables

[1] https://www.education.gov.za/Programmes/EMIS.aspx

4.4 Empirical Results and Discussion of multilevel models

4.4.1 Multilevel Linear Modelling

In the previous chapter, we looked at the effects of public schools on growth, proxied by artificial night lights in 120 local municipalities (LMs) with complete data about schools were used to evaluate whether public schools contribute towards growth as proxied by artificial night lights. These LMs were extracted from four provinces (Gauteng, Free State, Eastern Cape and KwaZulu-Natal) as explained in the previous cross-sectional paper as to why other provinces were excluded. This chapter introduces the Multilevel Linear Model (MLM), an extension of linear regression modelling in which we can decompose different sources of variation Dedrick et al. (2009). The MLM examines how public school investments (fee or non-fee schools) vary over the municipalities. Bear in mind that fee schools are government public schools that supplement their school fees by paying extra fees than non-fee schools, which are fully taken care of by the government. The information about these schools is acquired from the Department of Basic Education (DoE). The variation in the coefficients will help us to understand what happens to each group or municipality's parameters, other than the conditional average mean for all the LMs, which the ordinary least squares (OLS) estimates. Now that we have a basic understanding of multilevel modelling, to build the multilevel model, we are going to start by estimating OLS in the next sections. Before we start, let us imagine we are interested in how school investment changes over time (e.g over years) and what the main sources of that change are. More precisely, we want to separate between variation, how school investment changes in the municipalities compared to others and within variation, how school investment varies relative to their average/trend.

4.4.1.1 Random Intercept

As we get introduced to MLM, let us visit the following equation of the simple linear regression, which predicts the conditional mean of the OLS

$$Y = \beta_0 + \beta_i X + \epsilon \tag{4.1}$$

where y is the dependent variable of public schools (fee and non-fee), and X represents dummy variables for the 5 year averaged from 1992 to 2011, I also added other control variables such as change in population density and ruggedness, β_0 and β_i are the intercept and the slope coefficient, we define β_0 as the conditional mean of Y if the value of x is 0. In the context of a

simple single-level linear regression such as this, one intercept is common to all individuals in the population of interest. However, when individuals are grouped or clustered together, like in this study (e.g public schools within local municipalities), there will potentially be a separate intercept for each cluster, which means that different means may exist for dependent variables for x = 0 across different clusters. Table 4.2 shows the regression results for our dependent variable public schools on the dummies, (D1996, D2001, D2006 and D2011) are dummy variables for the five-year averages for years 1996, 2001, 2006 and 2011, where we have excluded a dummy variable D1992 for the base year 1992 to avoid perfect collinearity, Pop-density controls for population density and Rugg controls for ruggedness or terrain. The reason for these regression results is to show that the OLS only demonstrates the conditional mean averages for all local municipalities. Tables and figures in the next sections will demonstrate how we used the MLM to get variations in intercepts and slope coefficients. The aim is to show differences in the intercepts and slopes.

TABLE 4.2: Basic linear regression

	Dependent variable: Public schools			
variables	estimate	std-error	t-value	p-value
Intercept	4.34	6.67	0.65	0.51
D1996	2.62	6.84	0.38	0.70
D2001	2.16	6.85	0.31	0.75
D2006	1.45	6.85	0.21	0.83
D2011	0.94	6.85	0.13	0.89
Pop-density	0.15***	0.01	18.51	0.000
Rugg	10.92***	1.63	6.71	0.000

Note: Table 4.2 shows a simple linear regression results for our dependent variable Public schools on the dummies, (D1996, D2001, D2006 and D2011, Population density, Ruggedness).
Robust standard errors at local municipality in parentheses *p<0.1 **p<0.05, ***p< 0.01

Let us consider the same model (4.1) by allowing group or cluster intercepts and slopes, which leads to the following level 1 model in multilevel modelling.

$$Y_{ij} = \beta_{0j} + \beta_{1j}X + \epsilon_{ij} \tag{4.2}$$

where

$$\beta_{0j} = \gamma_{00} + \mu_{oj} \tag{4.3}$$

substituting 4.3 into 4.2 gives a full model 4.4

$$Y_{ij} = \gamma_{00} + \mu_{oj} + \beta_{1j}X + \epsilon_{ij} \tag{4.4}$$

where ij subscripts refer to the individual schools within each municipality i and j represents the municipalities(also know as a cluster of municipalities).

Y_{ij} is still the variable of interest (fee pay or non-fee) schools. β_{0j} - is the combination of grand intercept and deviation of the jth (cluster of municipalities), γ_{00} - is the regression's intercept that holds across clusters. It can be interpreted as the grand mean (fixed intercept) or the average of the outcome over all the individuals (municipal school investment). μ_{oj} is the between variation, which tells how different clusters or municipalities are from each other in their fee and non-fee school investments on the intercept; it is the random effect because it varies from cluster to cluster. You can also say it is a deviation of the jth group municipality investment from the grand mean (or fixed intercept). If everyone has the same investment in fee or non-fee, this would be 0. The larger the differences, the bigger the coefficient will be. ϵ_{ij} represents the residual or the within variation, which tells us how much each individual varies around their average. Table 4.3 shows the estimated random variations and fixed effects coefficient for the fee schools' public investment in local municipalities. The variances of random effects are represented by τ_j^2 as variance among the clusters and σ^2 as between variance among individuals in a cluster. In addition, the values of τ_0^2 =3075.330, τ_1^2 = 6.141, τ_2^2 =5.645 and τ_3^2 =6.483 reflect the variation in coefficients across municipalities and σ^2 = 7.718 which is the (residual) within individuals in the cluster. All the results of variation show that the largest source of random variation in fee schools is a variation from differences in mean intercept, with lesser variation from the coefficient for dummies across local municipalities and the coefficient of the within variation. LRT in Table 4.3 is the likelihood ratio test (chi-square), and the p-values show that we have significant variations in the unconditional means. The fixed effects are significant at the 5% level only at the dummy variable in 2011. To demonstrate how the random intercepts work, let's take one local municipality, e.g Johannesburg, to demonstrate how the estimated intercept in Table 4.8 of the appendices is calculated. As we mentioned above in MLM that β_{0j} is the combination of γ_{00} which is the grand intercept or fixed effect + μ_{oj} which is the deviation of the cluster municipality or you can call it random effect. So using Table 4.3 below and Table 4.7 of the appendices for the case of Johannesburg, β_{0j} = 12.8583 + 106,72 adds up to 119,57 which is the estimated intercept for Johannesburg in Table 4.8. Equation 4.4 is the full model in which the multiple levels are combined into a unified equation. In this section, we only explain the variables for a simple random intercept, as it is often done in MLM. That is why we did not say much about $\beta_{1j}X$ because it forms part of the random slopes; we will clarify this variable in the next section.

TABLE 4.3: Fixed and Random effects: Fees schools in 120 local municipalities

Dependent variable: Fees school							
(Random effect):							
	Groups	name	variance	stdDev	LRT	pvalue	
	mnname	Intercept	3075.330	55.456			
		D1996	6.141	2.478	48.75	0.00	
		D2001	5.645	2.376	43.26	0.00	
		D2006	6.483	2.546	50.32	0.00	0.37
		D2011	6.235	2.532	49.32	0.00	0.36
	Residual	σ^2	7.718	2.778			
(Fixed effects) :							
	estimate	Std-error	tvalue	pvalue			
Intercept	12.8583	5.0687	2.537	0,17			
D1996	0.4000	0.4240	0.943	1.27			
D2001	1.3167	0.4191	3.141	0,09			
D2006	1.5167	0.4274	3.549	0.09			
D2011	1.033	0.389	2.657	0.00			
Number of obs:	600	groups:	mnname	120			

Note: Table 4.3 are the fixed and random effects:

4.4.1.2 Random Slopes

The model of the random slope is the actual model 4.2 above, which accommodates the independent predictor variable $\beta_{1j}x$. So model 4.2 can be expressed in two separate levels.

$$Level1 : Y_{ij} = \beta_{0j} + \beta_{1j}x + \epsilon_{ij} \tag{4.5}$$

$$Level2 : \beta_{0j} = \gamma_{00} + \mu_{oj} \tag{4.6}$$

$$\beta_{1j} = \gamma_{10} \tag{4.7}$$

The model now includes an independent predictor and the slope γ_{10} relating to the dependent variable. The interpretation of γ_{10} is the same as that of simple linear regression β_1. So what this means is that rather than having a single slope γ_{10} common to all municipalities or clusters, there is a unique effect for the group of $\gamma_{10} + \mu_{1j}$, where γ_{10} is the average slope coefficient between x variables represented as dummies in this paper and y which is public school (be fee

or non-fee) across clusters, and μ_{ij} is the cluster-specific variation of the relation between two variables. The random slopes model is represented as follows:

$$Y_{ij} = \gamma_{00} + \mu_{oj} + \gamma_{10} x_{ij} + \mu_{ij} + \epsilon_{ij} \tag{4.8}$$

which takes us back to the full model in (4.4) above. This is the model that is estimated in this paper to find heterogeneities in both the slope and intercept of public schools over 120 local municipalities. Variables are defined the same as the one above in random intercept with the inclusion of mean slope and its deviations. Table 4.8 shows the estimates for the randomly selected 23 LMs out of 120 to show if there is heterogeneity in the intercepts and slopes for fee schools. Figure 4.1 also shows all 120 LMs and their slope heterogeneities in the map as they are depicted in Table 4.8. Likewise, let us demonstrate the calculation of random slopes depicted in Table 4.8. Let's take Johannesburg again. As mentioned in the above section in MLM β_{1j} is the combination of γ_{10} which is the grand slope or fixed effect + μ_{1j} which is the deviation of the cluster municipality or you can call it random effect, so in this case, we demonstrate using D1996 as an explanatory variable. So using Table (4.3 and 4.7) in the case of Johannesburg, β_{1j} = 0,4000 + (-1,84) adds up to -1.44 which is the estimated slope for Johannesburg in Table 4.8. The estimated full model is the one in equation (4.8). In the case of Johannesburg, you would expect the following calibrated model.

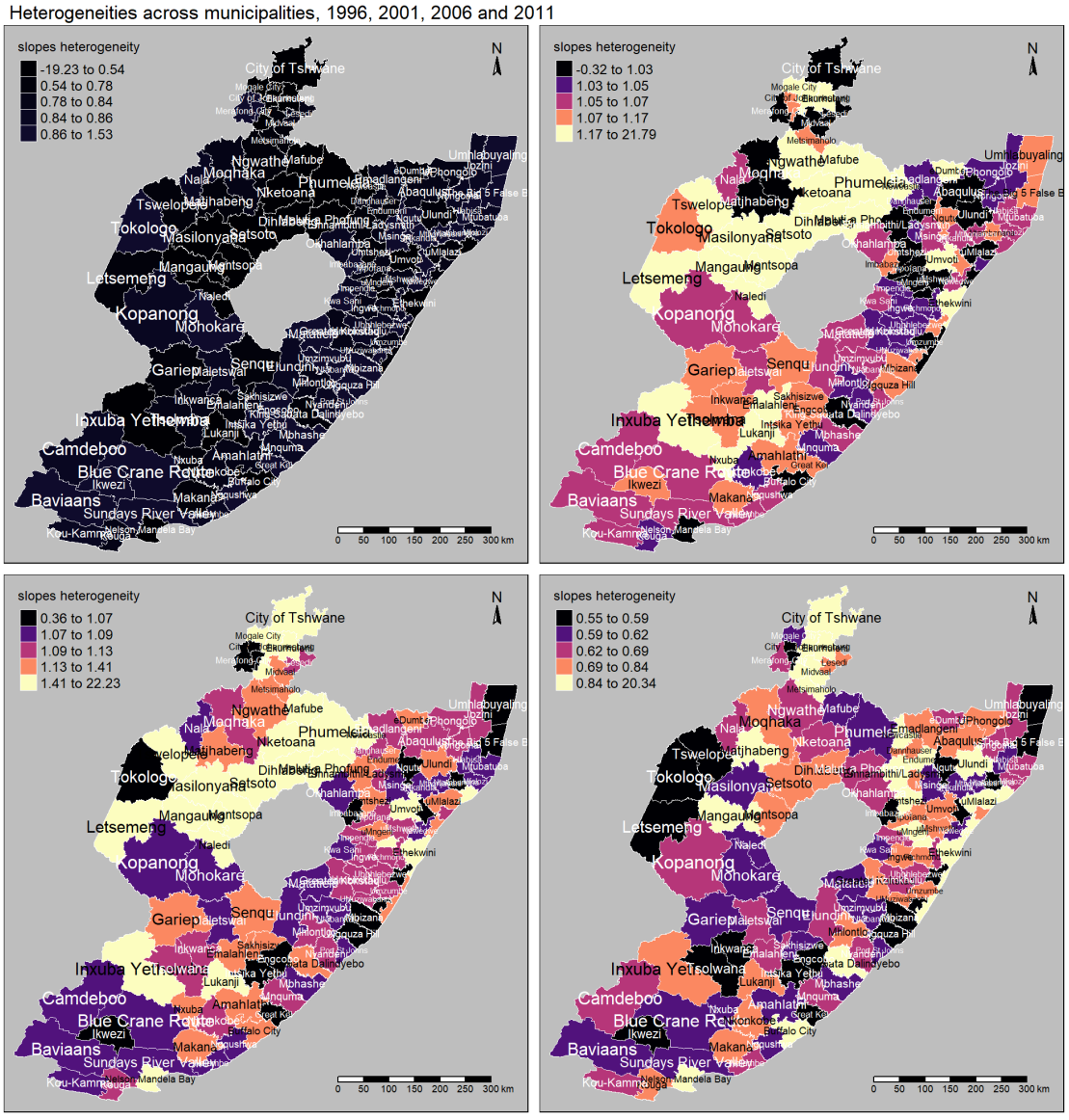
$$Y_{ij} = 119,57 - 1.44 x_{ij} + \epsilon_{ij} \tag{4.9}$$

where Y_{ij} is still the dependent variable (i.e fee schools) in Johannesburg municipality (i) and cluster j, x_{ij} are explanatory variables i.e dummies, ϵ_{ij} is the error term. Likewise, Table 4.8 shows the estimated regression for random (intercepts and slopes) with non-fee as a dependent variable and other variables remaining as they are as indicated above. Furthermore, the table shows all LMs, for the variations in intercepts and slopes in both fee and non-fee for the remaining LMs see Tables (4.6 and 4.9) of the appendices.

Similar to what we did with the fees school above in Table 4.3. Table 4.4 shows the estimated random variations and fixed effects coefficients for the non-fee schools' public investment in local municipalities. The variances of random effects are represented by τ_j^2 as variance among the clusters and σ^2 as between variance among individuals in a cluster. In addition, the values of $\tau_0^2 = 8179.20$, $\tau_1^2 = 25.97$, $\tau_2^2 = 32.85$ and $\tau_3^2 = 143.81$ reflect the variation in coefficients across municipalities and $\sigma^2 = 7.718$ which is the (residual) within individuals in the cluster. The fixed effects of our dummy variable are positive and significant.

Figure 4.2 shows the slope heterogeneities for 120 selected municipalities for non-fee schools.

FIGURE 4.1: Slope heterogeneities: public investment in fee schools



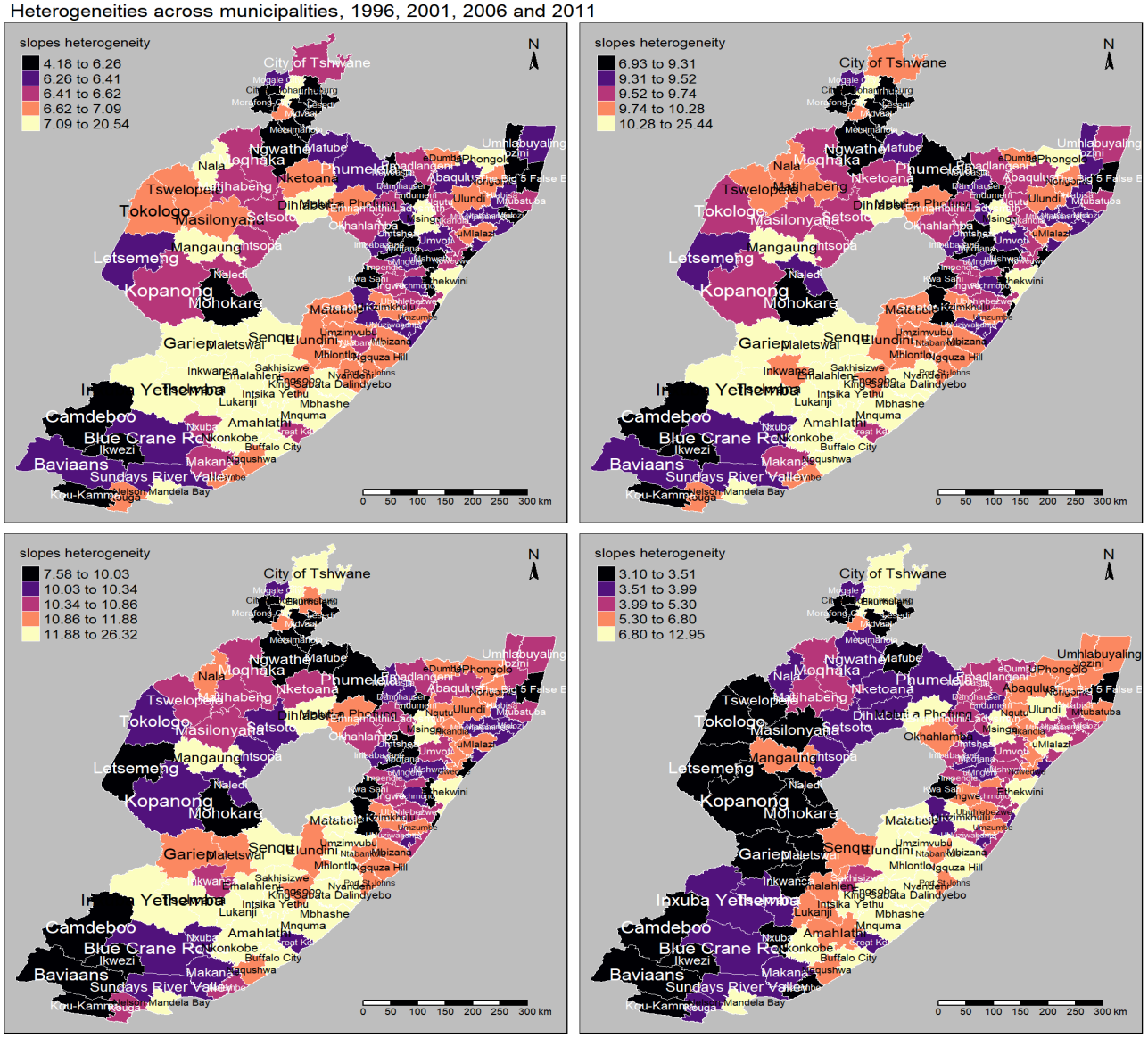
Note: Figure 4.1 sows the slope variations across local municipality. Some municipalities have slopes above the estimated mean, and others way below the mean.

TABLE 4.4: Fixed and Random effects: non-fees schools in 120 local municipalities.

Dependent variable: Non-Fees school									
(Random effects):									
	Groups	Name	Variance	Std-Dev.	LRT	pvalue	Corr		
	mnname	Intercept	8179.20	90.439					
		D1996	25.97	5.096	2.37	0.67	0.04		
		D2001	32.85	5.731	2.43	0.66	0.05	1.00	
		D2006	31.91	5.649	2.48	0.59	0.15	0.99	1.00
	Residual		143.81	11.992					
(Fixed effects):									
	estimate	Std.error	tvalue	pvalue					
Intercept	85.225	8.328	10.233	0.00					
D1996	7.117	1.617	4.402	0.01					
D2001	10.325	1.634	6.318	0.00					
D2006	11.392	1.632	6.981	0.00					
D2011	12.567	1.548	8.117	0.00					
Number of obs:	600	groups	mnname	120					

Note: Table 4.4 demonstrates the fixed and random effects:

FIGURE 4.2: Slope heterogeneities: public investment in non-fee schools



Note: Figure 4.2 is the slope heterogeneities in each local municipality. Some municipalities have slopes above the estimated mean and others way below.

4.4.1.3 Results for using multilevel model

Table 4.3 above examined the fixed effects, averaging over local municipalities and random effects. The fixed effects results show that, on average, the investment in public fee schools had a positive effect in local municipalities, but it was not significant, only in 2011 when the fee schools showed a positive effect in local municipalities and significant at 5% level. The standard deviation (stdDev.) of random effects for dummy variables shows how much local municipalities deviate from the averages of fixed effects. This suggests that there is heterogeneity between the municipalities. Some local municipalities have slopes above the average mean, whereas others are below the average municipality mean. The variations in standard deviations are significant as demonstrated by the likelihood ratio test and p-values in 4.3. The tables and figures above and in the appendices, specifically Tables (4.7 and 4.8) and Figure 4.1 above, clearly show that there are variations in both intercepts and slopes for the local municipalities where fee schools were invested. All the figures above show the sizes of the slopes in quintiles; black represents the smallest slope and white represents the biggest slope.

Likewise, we also examined the investment in non-fee schools using fixed effects, averaging over local municipalities and random effects. The fixed effects results also show that, on average, the investment in public non-fee schools had a positive effect in local municipalities as demonstrated by dummies (D1996, D2001, D2006, D2011). These fixed effects slopes are positive and significantly different from zero. The standard deviation (stdDev.) of random effects for dummy variables shows how much local municipalities deviate from the averages of fixed effects.

Numerous policies at the local, provincial, and national levels have resulted in these heterogeneities. Additionally, it depends on who is in charge of managing public school investments at the time and where they believe a particular investment would be more successful if placed. The Department of Education (DoE) distributes the funds to the provincial level, so these funds are requested by the provincial authorities from the South African central government and then distributed to the local municipalities that carry out the work. The effectiveness of provincial or municipal authorities may impact the figures for a specific investment and the assumptions upon which they are based. The cities of Tshwane, the city of Johannesburg, and Ethekwini, which are located in cities, seem to have larger slope variations in school fees over time, as shown in the appendices Table 4.8 and Figure 4.1 above. This further supports the idea that when funds are requested, it depends on who manages them at the time; in this case, the priority may be the cities, where there may be a need to increase school investment taking other factors such as the population into consideration. On the other hand, Table 4.9 of the appendices and Figure 4.2 above show that, in addition to major cities like Johannesburg, Tshwane, and Ethekwini, we also have LMs in Buffalo, Dihlabeng, Mandela Bay, Ekurhuleni, and Emalahleni that have

increased their school investments over time in non-fee schools. As shown by the tables and maps, as well as the appendices, some of these LMs are primarily dominated by rural areas, which simply indicates that these heterogeneities are present everywhere, see appendices Tables (4.6 and 4.9)..

4.4.2 Multilevel Poisson regression

The multilevel Poisson regression is one of the hierarchical models. In this case, it will help us to find out which type of location are fee schools being constructed as opposed to non-fee schools. If your dependent variable is a count variable (for example, the number of fee or non-fee paying schools built), you could employ a multilevel Poisson regression model. This is acceptable when the outcome variable represents the count of events. The multilevel Poisson regression model can be defined as:

$$\log(\lambda_{ij}) = \beta_{0j} + \beta_{1j}X + \beta_2\text{Metro} + \beta_3\text{Pop-density} + \beta_4\text{Rugg} \tag{4.10}$$

- Where:

  λ_{ij} represents the predicted number of public schools (fee or non-fee) i in municipality j. β_{0j}, varies by municipality (random effect). $\beta_{1j}X$ refers to the fixed effects for the year dummies. β_2 Metro is the fixed effect for metro status, and it is binary, for metropolitan = 1 and non-metropolitan municipality = 0. β_3 Pop-density is the fixed effect for population density. β_4 Rugg is the fixed effect for ruggedness.

Note that Y_{1j} in the previous hierarchical model represented the count of school, either fee or non-fee, in the municipalities. In the multilevel Poisson regression, instead of using Y_{1j} as the count. The expected count λ_{ij} is calculated based on the log-linear relationship $\log(\lambda_{ij})$ between the dependent variable and the independent variables.

This model will be split into two, one for fee schools and the other one for non-fee schools as demonstrated below:

Model for Fee-Paying Schools:

$$\log(\lambda_{ij}^{(\text{fee})}) = \beta_{0j}^{(\text{fee})} + \beta_{1j}^{(\text{fee})}X + \beta_2^{(\text{fee})}\text{Metro} + \beta_3^{(\text{fee})}\text{Pop-density} + \beta_4^{(\text{fee})}\text{Rugg} \tag{4.11}$$

Model for Non-Fee-Paying Schools:

$$\log(\lambda_{ij}^{(\text{non-fee})}) = \beta_{0j}^{(\text{non-fee})} + \beta_{1j}^{(\text{non-fee})} X + \beta_2^{(\text{non-fee})} \text{Metro} + \beta_3^{(\text{non-fee})} \text{Pop-density} + \beta_4^{(\text{non-fee})} \text{Rugg} \tag{4.12}$$

4.4.2.1 Results using multilevel Poisson regression

Table 4.5 demonstrates that metropolitan municipalities have a considerable favourable effect on the number of fee-paying and non-fee-paying schools, as demonstrated by positive and significant coefficients of a metro variable. The year dummy indicators (1996, 2001, 2006, 2011) demonstrate a significant increase in the number of schools (both fee and non-fee) over time. Population density has no substantial effect on the number of any type of school. Ruggedness reduces the number of fee-paying schools while increasing the number of non-fee-paying schools, with the latter being particularly significant.

Likewise Table 4.5 shows that non-metropolitan municipalities have fewer fee-paying and non-fee-paying schools than metropolitan areas. Non-metropolitan areas are less likely to have both types of schools, demonstrating that school construction differs between metropolitan and non-metropolitan regions. The absence of a significant influence from population density shows that other factors may be at work in driving school development in these areas.

TABLE 4.5: Multilevel Poisson regression

	Dependent variable:	
	fee	non_fee
	(1)	(2)
D_1996	0.037	0.080***
	(0.036)	(0.014)
D_2001	0.118***	0.113***
	(0.039)	(0.014)
D_2006	0.139***	0.124***
	(0.041)	(0.014)
D_2011	0.168***	0.135***
	(0.044)	(0.014)
Metro	3.090***	1.873***
	(0.586)	(0.337)
Pop-density	−0.0001	0.00002
	(0.0001)	(0.00004)
Ruggedness	−0.072	0.361***
	(0.112)	(0.063)
Constant	0.847**	2.826***
	(0.346)	(0.193)
Observations	600	600
Log Likelihood	−1,271.498	−2,712.638
Akaike Inf. Crit.	2,560.996	5,443.275
Bayesian Inf. Crit.	2,600.569	5,482.848
Note:	*p<0.1; **p<0.05; ***p<0.01	

4.5 Conclusion

The multilevel linear model (MLM), an extension of linear regression modelling that breaks down various sources of municipality heterogeneities between the years 1992 and 2011, was the subject of this chapter. It is significant to note that while other papers have looked for heterogeneity, they have never really explained its causes. According to the results, there are random variations in both intercepts and slopes for local municipalities. Numerous policies at the local, provincial, and national levels have resulted in these heterogeneities. Additionally, it depends on who is in charge of managing public school investments at the time and where they believe a particular investment would be more successful if placed. Additionally, a researcher will need to travel to the municipalities in order to identify additional causes of these heterogeneities.

4.6 Appendix

TABLE 4.6: Estimated regression for Random (intercepts and slopes)

	Dependent variable: Fees school				
	slope heterogeneity: column 3-6				
municipalities	Intercept	D1996	D2001	D2006	D2011
Johannesburg	106,72	-1,84	0,03	1,58	3,71
Mandela Bay	71,25	-0,66	-0,59	0,45	2,47
Msunduzi	59,60	-0,67	-0,37	0,50	2,07
Abaqulusi	-5,81	0,38	-0,30	-0,39	-0,20
Amahlathi	-12,03	0,40	-0,21	-0,38	-0,42
Baviaans	-12,82	0,46	-0,26	-0,44	-0,45
Blue	-12,82	0,46	-0,26	-0,44	-0,45
Buffalo	34,46	0,00	-0,62	-0,12	1,19
Camdeboo	-11,82	0,45	-0,26	-0,43	-0,41
City of Tshwane	138,86	-0,83	-1,64	0,39	4,81
Dannhauser	-9,82	0,43	-0,28	-0,42	-0,34
Dihlabeng	-9,58	-2,12	2,43	2,28	-0,31
eDumbe	-10,44	0,30	-0,13	-0,28	-0,36
Ekurhuleni	-5,63	-1,54	1,74	1,65	-0,18
Elundini	-11,82	0,45	-0,26	-0,43	-0,41
Emadlangeni	-8,81	0,42	-0,28	-0,41	-0,31
Emalahleni	-11,45	0,30	-0,11	-0,27	-0,40
Emfuleni	22,60	-0,05	-0,35	-0,02	0,78
Emnambithi	7,21	0,24	-0,39	-0,28	0,25
Endumeni	0,20	0,32	-0,34	-0,34	0,00
Engcobo	-13,82	0,47	-0,25	-0,45	-0,48
Ethekwini	555,66	-10,68	1,28	9,35	19,30
Ezingoleni	-0,96	0,87	1,07	1,07	0,55
Gariep	0,62	0,75	1,16	1,18	0,61
Great Kei	-0,96	0,87	1,07	1,07	0,55
Greater	4,04	0,82	1,03	1,11	0,73
Hibiscus	19,06	0,66	0,93	1,22	1,25
Hlabisa	0,04	0,86	1,06	1,07	0,59
Ikwezi	-0,96	0,87	1,07	1,07	0,55
Imbabazane	-0,96	0,87	1,07	1,07	0,55
Impendle	2,04	0,84	1,05	1,09	0,66
Indaka	4,04	0,82	1,03	1,11	0,73
Ingwe	3,04	0,83	1,04	1,10	0,69
Inkwanca	-0,17	0,81	1,11	1,13	0,58
Intsika	-0,96	0,87	1,07	1,07	0,55
Inxuba	4,56	0,47	1,40	1,48	0,75
Jozini	2,04	0,84	1,05	1,09	0,66
King	18,06	0,67	0,94	1,22	1,21
Kopanong	1,04	0,85	1,05	1,08	0,62
Kou Kamma	1,04	0,85	1,05	1,08	0,62
Kouga	4,04	0,82	1,03	1,11	0,73
KwaSani	0,04	0,86	1,06	1,07	0,59
KwaDukuza	26,07	0,58	0,89	1,28	1,49
Lesedi	6,05	0,80	1,02	1,12	0,79
Letsemeng	-0,43	0,55	1,40	1,41	0,57
Lukanji	7,14	0,34	1,49	1,60	0,84
Mafube	0,10	0,22	1,74	1,75	0,59
Makana	3,83	0,77	1,09	1,16	0,72
Maletswai	1,04	0,85	1,05	1,08	0,62
Maluti	2,32	0,25	1,67	1,71	0,67
Mandeni	3,04	0,83	1,04	1,10	0,69
Mangaung	34,94	-19,23	21,79	22,23	1,95
Mantsopa	4,63	-0,14	2,04	2,12	0,75
Maphumulo	-0,96	0,87	1,07	1,07	0,55
Masilonyana	0,57	0,54	1,39	1,42	0,61
Matatiele	0,04	0,86	1,06	1,07	0,59
Matjhabeng	26,29	0,63	0,83	1,23	1,50
Mbhashe	0,04	0,86	1,06	1,07	0,59
Mbizana	-0,96	0,87	1,07	1,07	0,55
Merafong	2,00	1,53	0,31	0,36	0,65
Metsimaholo	10,42	0,61	1,13	1,30	0,95
Mfolozi	1,04	0,85	1,05	1,08	0,62
Mhlontlo	4,04	0,82	1,03	1,11	0,73
Midvaal	8,05	0,77	1,01	1,14	0,86

.....continuation of Table 4.6

	Dependent variable: Fees school				
	slope heterogeneity: column 3-6				
municipalities	Intercept	D1996	D2001	D2006	D2011
Mkhambathini	2,04	0,84	1,05	1,09	0,66
Mnquma	2,04	0,84	1,05	1,09	0,66
Mogale	0,10	0,22	1,74	1,75	0,59
Mohokare	0,04	0,86	1,06	1,07	0,59
Moqhaka	7,05	0,78	1,01	1,13	0,83
Mpofana	6,05	0,80	1,02	1,12	0,79
Msinga	0,04	0,86	1,06	1,07	0,59
Mthonjaneni	0,04	0,86	1,06	1,07	0,59
Mtubatuba	1,04	0,85	1,05	1,08	0,62
Nala	1,04	0,85	1,05	1,08	0,62
Naledi	0,57	0,54	1,39	1,42	0,61
Ndlambe	1,04	0,85	1,05	1,08	0,62
Ndwedwe	0,04	0,86	1,06	1,07	0,59
Newcastle	46,58	-0,18	1,32	2,01	2,20
Ngqushwa	0,04	0,86	1,06	1,07	0,59
Ngquza	-0,96	0,87	1,07	1,07	0,55
Ngwathe	1,41	0,71	1,19	1,23	0,63
Nkandla	0,04	0,86	1,06	1,07	0,59
Nketoana	2,57	0,51	1,38	1,43	0,68
Nkonkobe	4,04	0,82	1,03	1,11	0,73
Nongoma	2,04	0,84	1,05	1,09	0,66
Nqutu	-0,96	0,87	1,07	1,07	0,55
Ntabankulu	0,04	0,86	1,06	1,07	0,59
Ntambanana	-0,96	0,87	1,07	1,07	0,55
Nxuba	0,41	0,72	1,20	1,22	0,60
Nyandeni	2,04	0,84	1,05	1,09	0,66
Okhahlamba	1,04	0,85	1,05	1,08	0,62
Phumelela	-0,06	0,41	1,54	1,55	0,59
Port	0,04	0,86	1,06	1,07	0,59
Randfontein	-0,96	0,87	1,07	1,07	0,55
Richmond	3,04	0,83	1,04	1,10	0,69
Sakhisizwe	0,83	0,80	1,11	1,13	0,61
Senqu	0,62	0,75	1,16	1,18	0,61
Setsoto	3,63	-0,13	2,05	2,11	0,72
Sundays	0,04	0,86	1,06	1,07	0,59
TheBigfv	-0,96	0,87	1,07	1,07	0,55
Tokologo	-0,96	0,87	1,07	1,07	0,55
Tsolwana	-0,17	0,81	1,11	1,13	0,58
Tswelopele	-0,43	0,55	1,40	1,41	0,57
Ubuhlebezwe	2,04	0,84	1,05	1,09	0,66
Ulundi	10,05	0,75	0,99	1,15	0,93
Umdoni	10,05	0,75	0,99	1,15	0,93
Umhlabuyalingana	-0,96	0,87	1,07	1,07	0,55
uMhlathuze	42,84	0,13	1,06	1,69	2,07
uMlalazi	13,06	0,72	0,97	1,18	1,04
uMngeni	8,05	0,77	1,01	1,14	0,86
uMshwathi	7,05	0,78	1,01	1,13	0,83
Umtshezi	9,05	0,76	1,00	1,15	0,90
UMuziwabantu	3,04	0,83	1,04	1,10	0,69
Umvoti	4,57	0,49	1,37	1,45	0,75
Umzimkhulu	2,04	0,84	1,05	1,09	0,66
Umzimvubu	0,04	0,86	1,06	1,07	0,59
Umzumbe	6,05	0,80	1,02	1,12	0,79
UPhongolo	4,04	0,82	1,03	1,11	0,73
Vulamehlo	-0,96	0,87	1,07	1,07	0,55
Westonaria	-0,96	0,87	1,07	1,07	0,55

TABLE 4.7: Estimated group-level (local municipalities) errors: random effects

	Dependent variable: Fees school				
	slope heterogeneity: column 3-6				
municipalities	Intercept	D1996	D2001	D2006	D2011
Johannesburg	106,72	-1,84	0,03	1,58	3,71
Mandela Bay	71,25	-0,66	-0,59	0,45	2,47
Msunduzi	59,60	-0,67	-0,37	0,50	2,07
Abaqulusi	-5,81	0,38	-0,30	-0,39	-0,20
Amahlathi	-12,03	0,40	-0,21	-0,38	-0,42
Baviaans	-12,82	0,46	-0,26	-0,44	-0,45
Blue	-12,82	0,46	-0,26	-0,44	-0,45
Buffalo	34,46	0,00	-0,62	-0,12	1,19
Camdeboo	-11,82	0,45	-0,26	-0,43	-0,41
City of Tshwane	138,86	-0,83	-1,64	0,39	4,81
Dannhauser	-9,82	0,43	-0,28	-0,42	-0,34
Dihlabeng	-9,58	-2,12	2,43	2,28	-0,31
eDumbe	-10,44	0,30	-0,13	-0,28	-0,36
Ekurhuleni	-5,63	-1,54	1,74	1,65	-0,18
Elundini	-11,82	0,45	-0,26	-0,43	-0,41
Emadlangeni	-8,81	0,42	-0,28	-0,41	-0,31
Emalahleni	-11,45	0,30	-0,11	-0,27	-0,40
Emfuleni	22,60	-0,05	-0,35	-0,02	0,78
Emnambithi	7,21	0,24	-0,39	-0,28	0,25
Endumeni	0,20	0,32	-0,34	-0,34	0,00
Engcobo	-13,82	0,47	-0,25	-0,45	-0,48
Ethekwini	555,66	-10,68	1,28	9,35	19,30

Note: Table 4.7 demonstrates the outcomes or variations for each local municipality with fees schools as a dependent variable. This table shows that some municipalities have public investment well above the municipal mean and others are placed among the worst performers. This indicates how much intercepts or slopes shifted up and down in a particular group.

TABLE 4.8: Estimated regression for Random (intercepts and slopes)

	Dependent variable: Fees school				
	slope heterogeneity: column 3-6				
municipalities	Intercept	D1996	D2001	D2006	D2011
Johannesburg	119,57	-1,44	1,34	3,09	4,74
Mandela Bay	84,11	-0,26	0,73	1,97	3,50
Msunduzi	72,46	-0,27	0,95	2,02	3,10
Abaqulusi	7,05	0,78	1,01	1,13	0,83
Amahlathi	0,83	0,80	1,11	1,13	0,61
Baviaans	0,04	0,86	1,06	1,07	0,59
Blue	0,04	0,86	1,06	1,07	0,59
Buffalo	47,31	0,40	0,69	1,39	2,22
Camdeboo	1,04	0,85	1,05	1,08	0,62
City of Tshwane	151,72	-0,43	-0,32	1,90	5,84
Dannhauser	3,04	0,83	1,04	1,10	0,69
Dihlabeng	3,28	-1,72	3,74	3,79	0,72
eDumbe	2,41	0,70	1,19	1,23	0,67
Ekurhuleni	7,22	-1,14	3,05	3,17	0,85
Elundini	1,04	0,85	1,05	1,08	0,62
Emadlangeni	4,04	0,82	1,03	1,11	0,73
Emalahleni	1,41	0,70	1,21	1,24	0,63
Emfuleni	35,46	0,35	0,97	1,50	1,82
Emnambithi	20,07	0,64	0,93	1,23	1,28
Endumeni	13,06	0,72	0,97	1,18	1,04
Engcobo	-0,96	0,87	1,07	1,07	0,55
Ethekwini	568,51	-10,28	2,60	10,87	20,34

Note: Table 4.8 demonstrates the regression outcomes for each individual local municipality with Fees school a dependent variable. This table is a summation of groups averages in Table 4.3 with individual or random effect for each municipality in Table 4.4, eg slope for Ethekwini in 2011 (1.033 + 1930) = 20.34.

TABLE 4.9: Estimated regression for Random (intercepts and slopes)

	Dependent variable: Non Fees school				
		slope heterogeneity: column 3-6			
municipalities	Intercept	D1996	D2001	D2006	D2011
Johannesburg	382,72	7,90	11,51	14,26	12,95
MandelaBay	172,75	9,81	13,45	14,94	7,63
Msunduzi	93,65	6,53	9,67	10,80	5,56
Abaqulusi	112,04	6,40	9,54	10,78	6,03
Amahlathi	128,91	7,41	10,70	12,01	6,48
Baviaans	4,43	6,32	9,35	9,98	3,29
Blue	19,74	6,36	9,41	10,12	3,68
Buffalo	311,59	7,71	11,22	13,57	11,13
Camdeboo	11,64	6,25	9,28	9,95	3,47
City of Tshwane	313,34	6,53	9,89	12,28	11,16
Dannhauser	46,66	6,26	9,32	10,19	4,36
Dihlabeng	27,24	9,28	12,70	13,38	3,92
eDumbe	63,65	6,78	9,92	10,87	4,80
Ekurhuleni	266,39	5,89	9,13	11,27	9,95
Elundini	171,54	6,71	9,96	11,53	7,55
Emadlangeni	31,98	6,51	9,59	10,37	3,99
Emalahleni	114,79	20,54	25,44	26,32	6,33
Emfuleni	115,05	6,98	10,21	11,45	6,12
Emnambithi	81,16	6,45	9,57	10,63	5,24
Endumeni	22,09	6,10	9,12	9,85	3,73
Engcobo	171,54	6,71	9,96	11,53	7,55
Ethekwini	303,33	7,24	10,69	13,00	10,91
Ezingoleni	20,58	6,28	9,32	10,04	3,70
Gariep	3,81	7,62	10,81	11,40	3,29
Great Kei	25,60	6,52	9,59	10,33	3,83
Greater	15,62	6,26	9,30	9,99	3,57
Hibiscus	60,14	6,34	9,43	10,37	4,71
Hlabisa	48,38	6,37	9,45	10,33	4,41
Ikwezi	-1,27	6,21	9,22	9,82	3,14
Imbabazane	50,63	6,27	9,34	10,23	4,46
Impendle	32,13	6,58	9,67	10,44	4,00
Indaka	71,64	6,41	9,52	10,52	5,00
Ingwe	86,96	6,42	9,54	10,64	5,39
Inkwanca	0,13	7,15	10,27	10,85	3,19
Intsika	174,08	18,67	23,40	24,67	7,81
Inxuba	16,10	8,95	12,32	12,94	3,63
Jozini	135,65	6,20	9,34	10,72	6,63
King	309,58	7,11	10,54	12,89	11,07
Kopanong	6,27	6,57	9,63	10,26	3,34
Kou Kamma	12,88	6,19	9,22	9,89	3,50
Kouga	23,10	6,70	9,79	10,51	3,77
KwaSani	3,12	6,20	9,21	9,83	3,25
KwaDukuza	29,20	6,18	9,22	9,99	3,92
Lesedi	3,12	6,20	9,21	9,83	3,25
Letsemeng	-0,55	6,34	9,37	9,96	3,16
Lukanji	86,50	17,77	22,30	23,09	5,57
Mafube	-1,54	6,34	9,36	9,95	3,14
Makana	20,05	6,49	9,56	10,27	3,69
Maletswai	3,85	7,25	10,39	10,99	3,29
Maluti	142,53	6,99	10,24	11,64	6,82
Mandeni	49,38	6,37	9,45	10,34	4,43
Mangaung	113,74	10,69	14,37	15,51	6,15
Mantsopa	15,07	6,51	9,57	10,25	3,56
Maphumulo	101,58	6,58	9,74	10,91	5,77
Masilonyana	10,39	6,66	9,74	10,39	3,45
Matatiele	209,28	6,82	10,12	11,90	8,51
Matjhabeng	76,49	6,62	9,75	10,78	5,13
Mbhashe	348,31	7,22	10,71	13,28	12,06
Mbizana	204,31	6,81	10,10	11,85	8,38
Merafong	-1,56	4,78	6,93	7,58	3,10
Metsimaholo	15,71	6,13	9,14	9,84	3,57
Mfolozi	68,76	6,24	9,33	10,32	4,92
Mhlontlo	237,08	6,90	10,23	12,18	9,22
Midvaal	2,13	6,20	9,21	9,82	3,23
Mkhambathini	39,39	6,12	9,16	9,99	4,17

.....continuation of Table 4.9

	Dependent variable: Fees school				
	slope heterogeneity: column 3-6				
municipalities	Intercept	D1996	D2001	D2006	D2011
Mtubatuba	100,42	6,53	9,68	10,85	5,74
Nala	18,08	7,10	10,23	10,92	3,65
Naledi	3,57	6,43	9,48	10,09	3,27
Ndlambe	12,18	6,67	9,74	10,40	3,49
Ndwedwe	141,99	6,55	9,74	11,15	6,79
Newcastle	50,89	6,18	9,24	10,13	4,47
Ngqushwa	113,79	7,09	10,33	11,56	6,08
Ngquza	206,30	6,81	10,10	11,87	8,44
Ngwathe	24,77	5,66	8,63	9,38	3,80
Nkandla	121,97	6,44	9,60	10,89	6,28
Nketoana	31,71	6,62	9,71	10,49	3,99
Nkonkobe	187,17	7,48	10,83	12,47	7,96
Nongoma	124,00	6,68	9,88	11,18	6,34
Nqutu	123,12	6,51	9,68	10,98	6,31
Ntabankulu	126,85	6,58	9,77	11,09	6,41
Ntambanana	43,84	6,32	9,38	10,24	4,29
Nxuba	6,16	6,42	9,46	10,10	3,33
Nyandeni	251,72	7,04	10,40	12,42	9,60
Okhahlamba	88,84	6,59	9,74	10,84	5,44
Phumelela	18,22	6,27	9,30	10,01	3,64
Port	140,24	6,81	10,03	11,42	6,75
Randfontein	11,32	6,13	9,14	9,81	3,46
Richmond	37,88	6,30	9,36	10,18	4,14
Sakhisizwe	49,83	11,92	15,69	16,42	4,54
Senqu	84,15	16,47	20,83	21,64	5,48
Setsoto	17,62	6,56	9,63	10,32	3,63
Sundays	16,59	6,30	9,34	10,03	3,60
TheBigfv	11,90	6,16	9,18	9,85	3,48
Tokologo	-0,95	6,67	9,74	10,32	3,16
Tsolwana	21,25	9,61	13,07	13,70	3,77
Tswelopele	1,90	6,88	9,98	10,58	3,23
Ubuhlebezwe	94,49	6,46	9,60	10,74	5,58
Ulundi	186,41	6,80	10,07	11,72	7,93
Umdoni	13,63	6,26	9,29	9,97	3,52
Umhlabuyalingana	118,42	6,37	9,52	10,80	6,19
uMhlathuze	47,23	6,30	9,37	10,24	4,38
uMlalazi	160,90	6,86	10,11	11,62	7,28
uMngeni	20,58	6,28	9,32	10,04	3,70
uMshwathi	61,81	6,22	9,29	10,25	4,75
Umtshezi	28,78	6,21	9,25	10,02	3,91
UMuziwabantu	46,97	6,39	9,48	10,34	4,37
Umvoti	76,29	6,29	9,39	10,43	5,12
Umzimkhulu	152,67	6,66	9,88	11,34	7,07
Umzimvubu	245,03	6,92	10,27	12,25	9,42
Umzumbe	111,00	6,79	9,99	11,21	6,01
UPhongolo	108,45	7,36	10,62	11,81	5,95
Vulamehlo	76,18	6,46	9,58	10,62	5,12
Westonaria	2,70	6,24	9,26	9,87	3,24

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