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Does basic infrastructure shape the urbanization–growth relationship? Evidence from a cross-country panel

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Abstract---Urbanization has the potential to create agglomeration advantages; however, the extent to which these advantages are realized may vary with the infrastructure available to support increasingly concentrated populations. This study examines whether the relationship between urbanization and economic growth varies with the level of basic-services infrastructure using an unbalanced panel of 158 economies over 2000–2024. Data are drawn from the World Bank’s World Development Indicators. A Basic Services Infrastructure Index is constructed using principal component analysis of access to electricity, urban drinking water, and urban sanitation, while Internet penetration is treated separately as a measure of digital connectivity. Using two-way fixed-effects estimation, the study examines direct and moderating relationships while accounting for country and year effects. The results indicate no statistically significant direct association between urbanization and GDP-per-capita growth. However, the positive and statistically significant interaction between urbanization and basic-services infrastructure indicates that the urbanization–growth association becomes more favourable as access to basic services increases. In contrast, Internet penetration does not exhibit a statistically significant moderating relationship. The basic-services interaction remains stable across multiple robustness specifications, although it weakens in the restricted sample for which human-capital data are available. Finally, marginal-effects analysis does not identify a statistically significant positive infrastructure threshold within the observed range. Overall, the findings highlight the importance of

considering basic-service capacity when examining the relationship between urbanization and economic growth.

Keywords---Urbanization, Economic growth, Basic infrastructure, Digital connectivity, Panel data, Fixed-effects model.

1 Introduction

Urbanization is perhaps the most transformative structural process associated with economic development. By concentrating people and economic activity into urban centers, urbanization has the ability to produce agglomeration economies by placing firms, workers, and markets in close enough proximity to enable specialization, labor market matching, knowledge sharing, and productivity growth. However, the economic benefits associated with urbanization are not automatic. When urban expansion occurs rapidly, it can lead to increased congestion, crowding, and pressures on critical public goods, such as transportation systems, schools, and healthcare facilities; if the infrastructure supporting these needs cannot meet the increased demand of expanding urban populations.

Thus, although urbanization and economic development are often associated, the evidence suggests that there is no consistent relationship between urbanization and economic growth. For example, Turok & McGranahan (2013) argue that the impact of urbanization on the economy varies significantly among countries based upon the broader context of urban development. Cross-country evidence shows significant variation in economic performance due to both the rate of urbanization and the level of urbanization achieved. For instance, Lewis (2014) found in Indonesia that the level of urbanization was positively correlated with economic growth; however, rapid urban population growth was negatively correlated with output growth. Additionally, Ng et al. (2019) demonstrated using a panel of 60 countries an inverted U-shape relationship between urbanization and economic growth. These findings highlight that the key economic questions are not merely about whether or how much urbanization is linked to economic growth but also what factors affect that relationship.

One possible factor affecting the relationship between urbanization and economic performance could be basic infrastructure. As populations and economic activities continue to concentrate within cities, so too will the demand for power generation, water supply, waste management and other essential services. In order for cities to effectively absorb the increasing concentrations of populations and businesses, adequate provision of these services is required. Where basic infrastructure does not grow at a sufficient rate relative to the expansion of cities, limitations may exist regarding the translation of agglomeration advantages into enhanced economic performance. Thus, infrastructure may have an effect not only through its role as an input into the production function but also through its role in influencing the relationship between urbanization and economic performance.

Although there exists a large body of research examining the relationship between urbanization and infrastructure and ultimately economic performance, relatively

little comparative evidence exists demonstrating that the relationship between urbanization and economic performance consistently varies depending on the availability of basic infrastructure across countries. Typically studies analyze either the effects of urbanization and/or infrastructure independently or include each as separate determinants of economic performance. An exception to this includes Lewis (2014), who demonstrates that expenditures on local infrastructure can moderate negative effects of rapid urban population expansion on growth in Indonesia. Expenditures on local infrastructure do not always reflect the degree to which residents of an area have actual access to essential services. Furthermore, findings obtained from a single-country context do not provide insight into how access to basic infrastructure influences the relationship between urbanization and economic performance in countries undergoing varying degrees of urbanization and investment in infrastructure.

This paper addresses this issue by investigating a panel dataset of 158 countries from 2000-2024 using data from the World Bank's World Development Indicators. Access to basic services is measured through a weighted composite indicator representing access to electricity, urban drinking water and urban sanitation. The measure for digital connectivity is represented by Internet usage alone. The empirical analysis uses two-way fixed effects models that control for both country-specific and time-varying effects, as well as interaction terms between urbanization and each dimension of infrastructure. Using this approach allows researchers to assess whether the relationship between urbanization and GDP per capita growth varies depending on the availability of basic services and whether there is a comparable moderating relationship for digital connectivity.

In several ways this paper adds to existing literature concerning the effects of infrastructure on economic performance. First, this paper examines infrastructure as a moderator in the relationship between urbanization and economic growth in addition to being an independent determinant of economic performance. Second, this paper measures basic services through realized access to electricity, drinking water and sanitation rather than through some form of expenditure or singular physical asset. Finally, by separating the two dimensions of basic service infrastructure (electricity, water/sanitation) from digital connectivity, we allow for the possibility that these two forms of infrastructure may influence the relationship between urbanization and economic growth differently. Additionally, our cross-country design permits us to examine these relationships across economies with very different levels of urbanization and infrastructure development.

The remainder of the paper is structured as follows. Section 2 reviews the literature on urbanization, economic growth and infrastructure and develops the study hypotheses. Section 3 describes the data, construction of the Basic Services Infrastructure Index and empirical estimation strategy. Section 4 presents the empirical results, including the interaction models, marginal-effects analysis and robustness and sensitivity tests. Section 5 discusses the findings, their relationship with previous literature, and their economic and policy implications. Section 6 concludes the paper.

2. Literature Review

2.1 Urbanisation and Economic Development

Urbanization has long been linked to the development of an economy since the location-based aggregation of people and the related business activities produces several advantages. In addition, from an agglomeration economics viewpoint, the spatial concentration of firms, workers and customers can reduce transactional costs, improve labour market matching, promote specialization, facilitate information exchanges, and encourage knowledge spillovers. As a result of these factors, productivity can rise; investment will become attractive again; and finally, production and employment will grow.

At the same time, however, the growing concentration of people in cities may lead to diseconomies due to increased congestion, crowding, prices for land and housing, environmental degradation, and uneven access to basic public services. Therefore, it cannot be taken for granted that all benefits resulting from urbanization arise automatically. Turok et al. (2023) state this dualism clearly in their argumentation that positive effects of agglomeration can be significantly reduced if the negative externalities generated during the course of urbanization do not receive adequate treatment.

In earlier years too, the question was raised as to whether there exists a simple or unconditionally positive connection between urbanization and economic development. Turok and McGranahan (2013) in their review of the existing research results from Africa and Asia concluded that the developmental impacts of urbanization and thus the size of agglomeration-related effects can differ greatly. Furthermore, they stated that there does not exist a straightforward linear relation between urbanization and economic growth, and that the economic growth potential of urbanization is dependent upon the broader conditions under which urban development occurs. In particular, they differentiate between urbanization, understood here as an increase in the proportion of the population residing in urban areas, and urban population growth, which may also include an increase in the population within cities due to natural population growth. This differentiation is important for cross-country empirical analyses where urbanization is usually quantified via the share of the total population living in urban areas.

Additional evidence supporting this conclusion comes from empirical studies showing that the association between urbanization and economic growth varies depending on setting and model specification. For example, Lewis (2014), studying Indonesia, found that the level of urbanization was positively associated with economic growth over 1960–2009, whereas the rate of urban population growth was negatively associated with output growth. An additional analysis based on a subnational dynamic-panel methodology provided further evidence of these opposing effects regarding levels and rates. Likewise, Ng et al. (2019), using fixed-effect panel analysis for 60 countries between 1980–2010, reported that there existed an inverse U-shaped relationship between urbanization and economic growth. According to this finding, initially growth rises with an increase in urbanization until, after reaching a specific level, it falls again. These findings

indicate that the effects of urbanization on economic development may depend on both the type and phase of the urbanization process.

Evidence collected most recently supports this heterogeneity. Liu et al. (2024), using panel data for 27 Chinese provinces from 2006 to 2020 along with spatial econometrics, showed that the relationship varies across regions and with the form of economic agglomeration. Additionally, they found that spatial spillover effects occurred. Moreover, according to their study, the relationship varied between different regions and how economic agglomeration developed influenced the extent to which the urbanization process contributed to regional economic growth. Their model specification is important conceptually since they included an interaction term between urbanization and economic agglomeration. This recognizes that the relationship between urbanization and economic performance may depend on other favorable economic conditions.

Therefore, the available empirical evidence implies that urbanization should not be viewed as a self-contained or consistently growth-promoting process. There are possible pathways of agglomeration through which the density of urban populations can contribute to improved productivity and economic growth. However, empirical outcomes have differed concerning countries, regions and stages of urban development. Thus, rather than simply investigating whether urbanization contributes to economic growth; we need to ask about the conditions under which the relationship between urbanization and economic growth becomes either more or less favorable. These findings provide the basis for considering infrastructure as a potential factor shaping the urbanization–growth relationship, which is examined in the following section.

2.3 Infrastructure as a Moderating Factor in the Relationship Between Urbanization and Economic Growth

The process of urbanization and the process of developing infrastructure are interdependent. As population and economic activities move to urban areas, there will be an increase in the demand for electricity, water, sanitation, transportation, telecommunications and other fundamental infrastructures. Therefore, the potential for increased productivity through agglomeration may depend partly on the ability of infrastructure systems to support increasing urban density. When the supply of infrastructure matches or exceeds the level of urbanization, agglomeration may lead to specialized relationships and communication among urban dwellers. However, when the infrastructure supplying services becomes congested due to insufficient provision, then some of the advantages of agglomeration may be diminished.

The idea presented here parallels concepts explored throughout the literature on urban development. Turok et al. (2023) describe how urban agglomeration can enhance productivity by facilitating proximity, specialization, knowledge transfer and labor market matching; however, they also provide examples of larger cities experiencing congestion, crowding and other detrimental externalities. Unless sufficient resources are devoted to the construction of essential infrastructure and effective urban planning strategies are implemented, many of these externalities may reduce the net benefits associated with concentrating economic activity in urban centers. Thus, the concept of infrastructure should be viewed as

contributing to the enabling environment within which the economic impacts of urbanization are realized rather than just being another input into the determination of economic performance.

There is also evidence that urbanization is associated with increased demand for infrastructure. El-Bouayady et al. (2024) utilize panel data representing forty-two African countries during 2005–2021 along with two-step system GMM to examine the relationship between urbanization and various aspects of infrastructure development. Their findings illustrate that the nature of the relationship between urbanization and infrastructure varies depending upon the type of infrastructure; specifically, urbanization is positively associated with the total infrastructure index, electrical distribution, Internet penetration and fixed broadband subscriptions, but negatively associated with water-related infrastructure and mobile telephone subscriptions. Therefore, the study indicates that urbanization and infrastructure development are closely related, although the relationship varies across different types of infrastructure. This observation is particularly relevant for countries undergoing rapid urbanization, where capacity for service delivery may not grow proportionally with increasing urban concentration. Furthermore, recent global evidence suggests that urbanization may be accompanied by unevenly-distributed improvements in infrastructure.

Utilizing remote-sensing methods to construct an index measuring the difference in per capita infrastructure investments across regions spanning 2000–19, Pandey et al. (2025) identify strong positive associations between regional-level differences in per-capita public-private sector investments and both urbanization and gross domestic product growth; additionally, they document large increases in regional-level disparities in per-capita public-private sector investments in nearly all countries analyzed. The authors predict even greater increases in disparities in per-capita public-private sector investments in many developing nations -- especially in countries with high levels of urban primacy. While their research does not include analyses assessing whether such disparities affect economic-growth moderation, their findings contribute to a broader understanding that public-private sector investments in physical infrastructure do not expand uniformly as urbanization accelerates.

Additional indirect evidence suggesting that complementary conditions can influence the strength of the association between urbanization and economic growth is found in research utilizing interaction terms. For example, Liu et al. (2024) include an interaction term representing the product of an indicator of urbanization and an indicator of economic agglomeration in a spatial model analysing 27 Chinese provinces. Their estimates indicate that the association between urbanization and economic growth varies with the level of economic agglomeration, illustrating how complementary structural characteristics may shape the economic relationship associated with urbanization. Similarly, since the extent to which essential services and networks can support expanding urban densities may also determine their association with economic performance, infrastructure represents a potential moderating variable influencing the association between urbanization and economic growth.

Relevant empirical evidence supporting this argument was developed by Lewis (2014) for Indonesia. Rather than treating infrastructure and urbanization as separate independent variables explaining variation in economic growth rates, Lewis specifically investigates whether expenditures on local area-specific infrastructure moderate the economic implications of rapid expansions in local-area specific populations. To achieve this objective, Lewis utilizes a sub-national dynamic panel data estimation approach to analyze whether the interaction between time-varying indicators of local area-specific population growth and prior-period expenditures on local-area specific infrastructure have a positive association with subsequent-period local-area specific GDP growth. The author reports a positive interaction, indicating that higher expenditures on local infrastructure are associated with a weaker negative relationship between rapid local population growth and subsequent economic growth. The findings reported in Lewis (2014) serve as important precedent for estimating whether infrastructure moderates the association between urbanization and economic growth internationally.

The present study differs from Lewis (2014) in several important respects. Lewis examines local-government infrastructure expenditure and population growth within Indonesia, whereas the present study focuses on realized access to basic services and the share of the national population living in urban areas. In addition, the present analysis uses a cross-country panel covering economies with widely differing levels of urbanization and infrastructure provision. These differences provide a basis for examining whether basic-services infrastructure moderates the urbanization-growth relationship across countries.

Collectively, the evidence from previous studies provides a basis for considering urbanization and infrastructure jointly rather than solely as separate correlates of economic performance. On one hand, urbanization may create opportunities for productivity gains associated with agglomeration while generating increased demands for basic infrastructure services on which agglomeration-based productivity gains ultimately rely. On the other hand, realizing those opportunities may depend upon available infrastructure capacity, thereby providing a conceptual justification for assessing whether basic-service provision moderates the association between urbanization and economic growth.

2.4 Research Gap and Hypothesis Development

The prior literature supports three major points. First, while urbanization can produce productivity gains through agglomeration, the relationship between urbanization and economic growth will vary depending on the broader context of urbanization. Second, infrastructure supplies critical services and productive capabilities necessary to sustain economic activity; however, when infrastructure is provided inadequately, it limits the potential benefits resulting from increased urban concentrations. Third, there is considerable evidence that both urbanization and infrastructure are interrelated, and that complementary conditions may shape the relationship between urbanization and economic performance.

However, relatively little research has examined whether the association between urbanization and economic growth changes systematically with the amount of

basic-service infrastructure available across nations. A significant portion of the literature either examines the urbanization-growth relationship or the infrastructure-growth relationship independently. Most studies that have examined both urbanization and infrastructure in relation to each other have treated them as separate explanatory factors or have studied how urbanization influences the supply of infrastructure. In contrast, very few studies directly investigate the extent to which the availability of infrastructure modifies the economic consequences of urbanization. One notable exception is Lewis (2014), who shows, using subnational data from Indonesia, that local infrastructure expenditure moderates the relationship between population growth and economic performance. However, this evidence concerns infrastructure expenditure within a single-country context rather than realized access to essential services across countries.

This study aims to fill this research gap by analyzing if the relationship between urbanization and economic growth differs systematically according to differences in infrastructure availability among a large number of countries internationally. Instead of measuring the quality or quantity of infrastructure by way of expenditure or a single structural element, this study assesses real access to three fundamental services -- electricity, drinking water and sanitation -- that collectively form the base-service environment in which households function and economic activities occur. The study also considers digital connectivity (as measured by Internet usage) separately since it is an alternative dimension of infrastructure that operates primarily through informational, communicational, knowledge-dissemination, and market-access channels.

These hypothesized moderating relationships can be explained through the mechanisms previously described. Concentration of persons in urban areas can lead to greater specialization, better labor market matching, better transfer of knowledge and better efficiency of scale. However, realizing these potential benefits requires an environment that can accommodate and serve more concentrated household units and economic activities. Improved levels of access to electricity, water and sanitation may help alleviate some of the infrastructure constraints and improve the underlying service foundations that support urban-based economic activity. As such, the urbanization-growth relationship may then be more favorable as basic service infrastructure improves.

In addition, improved digital connectivity represents another possible moderating mechanism. Increased access to the Internet can facilitate the flow of information, communication, dissemination of knowledge and connection to larger markets, possibly influencing how firms and individuals realize benefits from urban concentration. However, previous literature did not consistently demonstrate sufficient evidence to predict whether this moderating relationship would be positive. Therefore, digital connectivity was treated as a separate potential moderator but without presuming directionality.

Therefore, based on these arguments the following hypotheses were developed:

H1: The relationship between urbanization and economic growth varies with the level of basic-services infrastructure, such that the urbanization-growth

association becomes more favourable as access to basic infrastructure increases.

H2: Digital connectivity moderates the relationship between urbanization and economic growth.

3. Methodology

3.1 Research Design and Data

This study employs a cross-country panel-data framework to examine whether the relationship between urbanization and economic growth varies with the level of infrastructure. Annual country-level data covering the period 2000–2024 were obtained from the World Bank's World Development Indicators (WDI) database (World Bank, 2026).

In this study, the dependent variable is economic growth, measured as the annual percentage change in real GDP per capita. Urbanization is measured as the percentage of the total population living in urban areas. Infrastructure is represented by two dimensions. Basic-services infrastructure comprises access to electricity, urban drinking water and urban sanitation, while digital connectivity is represented by the percentage of individuals using the Internet.

In addition to these infrastructure concepts, two macroeconomic variables are included as controls. Trade openness is measured as total trade in goods and services as a percentage of GDP, while inflation is measured as the annual percentage change in the Consumer Price Index. These variables capture important aspects of external economic integration and domestic macroeconomic conditions while maintaining a parsimonious baseline specification.

The initial country-level dataset covered 217 economies over the 2000–2024 period, corresponding to 5,425 potential country-year observations. After merging the indicators and restricting the baseline estimation sample to observations with complete data for the required variables, the final sample contains 3,438 country-year observations from 158 economies. The resulting dataset is therefore an unbalanced panel. Retaining the unbalanced panel allows available cross-country and time-series information to be used without restricting the analysis to economies with complete observations for every year. The overall empirical procedure followed in the study is summarized in Figure 1.

3.2 Construction of the Basic Services Infrastructure Index

Electricity access, urban drinking water access, and urban sanitation access represent closely related dimensions of basic-services infrastructure. In the principal estimation sample, the correlation between electricity access and urban drinking water access was 0.838, between electricity access and urban sanitation access was 0.887, and between urban drinking water access and urban sanitation access was 0.810. Including all three indicators independently in the regression could therefore introduce substantial multicollinearity and make their individual coefficients difficult to interpret.

Principal component analysis (PCA) was therefore employed to construct an aggregate Basic Services Infrastructure Index. Prior to conducting PCA, electricity

access, urban drinking water access, and urban sanitation access were standardized to prevent differences in their distributions from disproportionately influencing the resulting index.

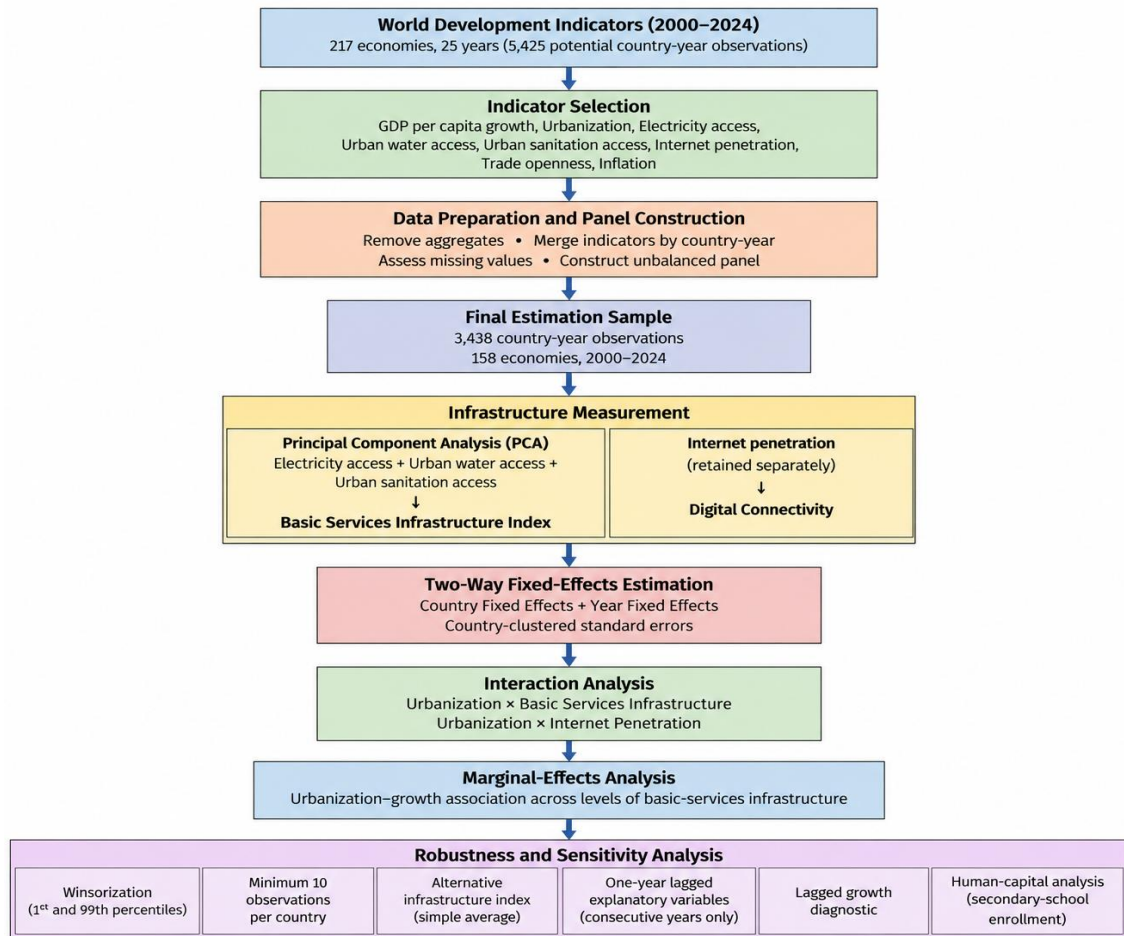


Figure 1. Empirical Research Workflow

The first principal component explained 89.67% of the variance in the three standardized basic-services infrastructure indicators. The component loadings were positive and similar in magnitude: 0.585 for electricity access, 0.568 for urban drinking water access, and 0.579 for urban sanitation access. The first principal component was therefore retained as the Basic Services Infrastructure Index, with higher values indicating greater access to basic infrastructure services.

The resulting index was strongly correlated with each of its constituent indicators: 0.960 with electricity access, 0.931 with urban drinking water access, and 0.950 with urban sanitation access. These results provide empirical support for representing the three indicators through a common basic-services infrastructure dimension.

Internet penetration was retained as a separate indicator rather than being incorporated into the Basic Services Infrastructure Index. Conceptually, electricity, water, and sanitation represent essential basic-services infrastructure, whereas Internet penetration represents digital connectivity. Internet penetration also exhibits substantially greater variation across countries and over time than the three basic-services indicators. Separating these dimensions makes it possible to examine whether basic-services and digital infrastructure play different moderating roles in the relationship between urbanization and economic growth.

3.3 Baseline Panel Model

The empirical analysis begins with a two-way fixed-effects model examining the associations between urbanization, infrastructure, and economic growth, while controlling for country and year fixed effects. The baseline specification is expressed as follows:

$$\text{Growth}_{it} = \beta_1 \text{Urbanisation}_{it} + \beta_2 \text{BasicInfrastructure}_{it} + \beta_3 \text{Internet}_{it} + \beta_4 \text{Trade}_{it} + \beta_5 \text{Inflation}_{it} + \alpha_i + \lambda_t + \varepsilon_{it}$$

where i represents the country, and t represents the year. Growth_{it} is defined as annual real Gross Domestic Product per capita growth; $(\text{Urbanisation})_{it}$ represents percentage of the total population living in urban areas; $(\text{BasicServicesInfrastructure})_{it}$ defines the Basic Services Infrastructure Index generated through Principal Component Analysis; $(\text{Internet})_{it}$ represents Internet penetration; $(\text{Trade})_{it}$ represents trade openness; and $(\text{Inflation})_{it}$ represents the rate of consumer price inflation.

Country-specific fixed effects, denoted α_i , capture time-constant differences between countries. Yearly fixed effects, denoted λ_t , represent influences that affect all countries in a given year, such as global economic conditions and simultaneous shocks affecting multiple economies. The error term, denoted ε_{it} , captures idiosyncratic variation not explained by the model.

The inclusion of country fixed effects focuses the estimation on changes occurring within countries over time rather than on cross-sectional differences between countries. Year fixed effects account for common temporal influences affecting countries in a given year. Standard errors are clustered at the country level to account for heteroscedasticity and within-country dependence over time.

3.4 Infrastructure as a Moderator of the Urbanization–Growth Relationship

The central proposition of the study is that the relationship between urbanization and economic growth may vary with the infrastructure environment in which urbanization occurs. The baseline model is therefore extended by introducing interaction terms between urbanization and the two infrastructure dimensions.

Before constructing the interaction terms, urbanization, the Basic Services Infrastructure Index, and Internet penetration are mean-centered. Mean-centering facilitates interpretation of the constituent coefficients in the interaction model. In particular, the coefficient on urbanization represents its estimated association with economic growth when the infrastructure variables are at their respective sample means.

We define the principal interaction model as follows:

$$\begin{aligned} \text{Growth}_{it} = & \beta_1 \text{Urbanisation}_{it}^c + \beta_2 \text{BasicInfrastructure}_{it}^c + \beta_3 \text{Internet}_{it}^c \\ & + \beta_4 (\text{Urbanisation}_{it}^c * \text{BasicInfrastructure}_{it}^c) \\ & + \beta_5 (\text{Urbanisation}_{it}^c * \text{Internet}_{it}^c) + \beta_6 \text{Trade}_{it} + \beta_7 \text{Inflation}_{it} + \alpha_i \\ & + \lambda_t + \varepsilon_{it} \end{aligned}$$

where the superscript c denotes mean-centered variables.

The coefficient β_4 captures whether the relationship between urbanization and GDP-per-capita growth varies with the level of basic-services infrastructure and therefore provides the principal test of H1. A positive β_4 indicates that the estimated urbanization–growth association becomes more favourable as basic-services infrastructure increases. Similarly, β_5 captures whether the urbanization–growth relationship varies with the level of digital connectivity and provides the test of H2.

3.5 Marginal Effects

An interaction coefficient indicates how the estimated relationship between urbanization and economic growth varies with infrastructure, but it does not directly show the estimated marginal association between urbanization and growth at specific infrastructure levels. Marginal effects are therefore calculated to examine how the estimated urbanization–growth association changes across different levels of basic-services infrastructure.

For this analysis, mean-centered Internet penetration is held constant at zero, corresponding to its sample mean. The marginal association between urbanization and GDP-per-capita growth is then calculated as follows:

$$\text{Marginal Effect of Urbanisation} = \beta_1 + \beta_4 \text{BasicInfrastructure}_{it}^c$$

The marginal effect is evaluated at the 10th, 25th, 50th, 75th, and 90th percentiles of the Basic Services Infrastructure Index. Standard errors and 95% confidence intervals are calculated using the estimated variance–covariance matrix of the interaction model.

The marginal effect is also evaluated continuously across the observed range of the infrastructure index to determine how the estimated urbanization–growth association and its confidence interval change as the level of basic-services infrastructure increases. This analysis is used to interpret the interaction rather than to impose or estimate a predetermined infrastructure threshold.

3.6 Robustness and Sensitivity Analysis

A series of robustness and sensitivity analyses was undertaken to assess the sensitivity of the principal interaction result to particular observations, sample-selection rules, infrastructure measurement, and temporal specification. First, GDP-per-capita growth and inflation were winsorized at the 1st and 99th percentiles to assess whether extreme observations disproportionately influence the principal interaction estimate. Second, economies with fewer than 10 usable annual observations were excluded, while the remaining sample retained its unbalanced-panel structure. This specification assesses whether the principal

interaction result is sensitive to the inclusion of economies with relatively short time series.

Third, the PCA-based Basic Services Infrastructure Index was replaced with an alternative index constructed as the equally weighted mean of the standardized electricity-access, urban drinking-water-access, and urban-sanitation-access indicators. The interaction model was then re-estimated using this alternative measure to assess whether the principal result is sensitive to the method used to construct the infrastructure index.

Lastly, the temporal robustness of the original results was tested by replacing the contemporaneous values of the explanatory variables with lagged ones. Lags were constructed within each economy only when an observation was available for the immediately preceding calendar year, thereby avoiding the treatment of observations separated by multiple years as consecutive annual observations. The dependent variable remained GDP-per-capita growth in year (t), while the explanatory variables were measured in year ($t - 1$).

$$\begin{aligned} \text{Growth}_{it} = & \beta_1 \text{Urbanisation}_{i,t-1}^c + \beta_2 \text{BasicInfrastructure}_{i,t-1}^c + \beta_3 \text{Internet}_{i,t-1}^c \\ & + \beta_4 (\text{Urbanisation}_{i,t-1}^c * \text{BasicInfrastructure}_{i,t-1}^c) \\ & + \beta_5 (\text{Urbanisation}_{i,t-1}^c * \text{Internet}_{i,t-1}^c) + \beta_6 \text{Trade}_{i,t-1} \\ & + \beta_7 \text{Inflation}_{i,t-1} + \alpha_i + \lambda_t + \varepsilon_{it} \end{aligned}$$

This specification contains 3,265 observations from 157 economies over 2001–2024. As an additional sensitivity check, lagged GDP-per-capita growth was added to the lagged specification.

$$\begin{aligned} \text{Growth}_{it} = & \rho \text{Growth}_{i,t-1} + \beta_1 \text{Urbanisation}_{i,t-1}^c + \beta_2 \text{BasicInfrastructure}_{i,t-1}^c \\ & + \beta_3 \text{Internet}_{i,t-1}^c + \beta_4 (\text{Urbanisation}_{i,t-1}^c * \text{BasicInfrastructure}_{i,t-1}^c) \\ & + \beta_5 (\text{Urbanisation}_{i,t-1}^c * \text{Internet}_{i,t-1}^c) + \beta_6 \text{Trade}_{i,t-1} \\ & + \beta_7 \text{Inflation}_{i,t-1} + \alpha_i + \lambda_t + \varepsilon_{it} \end{aligned}$$

This specification is treated as a supplementary robustness diagnostic rather than as a causal dynamic-panel estimator. Finally, the secondary-school gross-enrollment ratio was considered as an additional proxy for human capital. Because education data were substantially less complete than the variables used in the baseline model, including this control reduced the estimation sample. To distinguish the effect of adding the human-capital control from the effect of changing the sample composition, two models were estimated using the same restricted sample of observations for which secondary-enrollment data were available. The first excluded secondary enrollment, while the second included it as an additional control. Comparing these specifications makes it possible to assess whether changes in the principal interaction estimate arise primarily from the inclusion of the human-capital control or from the reduced estimation sample.

4. Results

4.1 Descriptive Statistics and Preliminary Analysis

The primary estimation sample contains 3,438 country-year observations from 158 economies over the period 2000–2024. The dataset forms an unbalanced panel because indicator availability varies across economies and years. Table 1 presents descriptive statistics for the variables used in the primary analysis.

Table 1: Descriptive Statistics of the Main Estimation Sample

Variable	N	Mean	Std. Dev.	Minimum	Median	Maximum
GDP per capita growth (%)	3,438	2.256	4.979	-55.294	2.394	74.921
Urban population (%)	3,438	58.206	21.856	11.641	60.619	100.000
Electricity access (%)	3,438	80.296	29.072	1.300	98.700	100.000
Internet users (%)	3,438	40.019	32.463	0.006	34.300	100.000
Urban basic drinking water (%)	3,438	93.644	8.405	48.064	97.388	100.000
Urban basic sanitation (%)	3,438	78.944	24.655	8.996	91.539	100.000
Trade (% of GDP)	3,438	88.456	55.569	15.282	75.951	442.620
Inflation (%)	3,438	6.207	17.446	-16.860	3.595	557.202

Average annual real GDP-per-capita growth was 2.26%, with a median of 2.39%. Growth varies substantially across observations, ranging from -55.29% to 74.92%. These extreme observations are retained in the main analysis, while their potential influence is examined through the winsorized robustness specification. The mean urban population share is approximately 58.21%, with a standard deviation of 21.86 percentage points. Values range from 11.64% to 100%, indicating substantial heterogeneity in urbanization across the sample.

The infrastructure indicators also display substantial variation. Average access to electricity is approximately 80.30%, while average Internet penetration is 40.02%. Mean urban drinking-water access is approximately 93.64%, and mean urban sanitation access is approximately 78.94%. Despite relatively high average levels of the basic-services indicators, considerable variation remains across country-year observations, particularly at the lower ends of their distributions.

Trade openness averages approximately 88.46% of GDP, with substantial variation across the sample. Inflation averages approximately 6.21% and also displays considerable variation across country-year observations.

Correlations between indicators reveal a very close relationship among the three basic-service indicators. Correlation between electricity access and urban access to clean drinking water is 0.838; correlation between electricity access and urban access to sanitation is 0.887; and correlation between urban access to clean drinking water and urban access to sanitation is 0.810. Therefore, the fact that

there are three indicators that measure essentially the same thing empirically supports combining them into a single indicator measuring basic-services infrastructure.

Principal component analysis provides further support for this structure. The first principal component explains 89.67% of the variance in the three standardized indicators. The corresponding loadings are positive and similar in magnitude: 0.585 for electricity access, 0.568 for urban drinking-water access, and 0.579 for urban sanitation access. This pattern indicates that the first principal component reflects a broad basic-services infrastructure dimension rather than being dominated by a single indicator.

Table 2 reports the findings from the principal components analysis of the three indicators of basic-services infrastructure. The Basic Services Infrastructure Index is strongly correlated with each of its constituent indicators: 0.960 with electricity access, 0.931 with urban drinking-water access, and 0.950 with urban sanitation access. Internet penetration exhibits substantially greater within-country variation over the study period than the Basic Services Infrastructure Index. The mean within-country standard deviation of the Basic Services Infrastructure Index is approximately 0.234. This relatively limited within-country variation is relevant when interpreting the subsequent fixed-effects estimates, which are identified primarily from changes within economies over time.

Table 2. Principal Component Analysis of Basic-Services Infrastructure Indicators

Infrastructure Indicator	PC1 Loading	Correlation with Basic Services Infrastructure Index
Electricity access (%)	0.585	0.960
Urban basic drinking water (%)	0.568	0.931
Urban basic sanitation (%)	0.579	0.950
Variance explained by PC1 (%)	89.67	—

Note: The Basic Services Infrastructure Index is the first principal component obtained from standardized electricity access, urban basic drinking-water access, and urban basic sanitation access. Higher index values indicate stronger provision of basic infrastructure services.

The Basic Services Infrastructure Index is strongly correlated with each of its constituent indicators: 0.960 with electricity access, 0.931 with urban drinking-water access, and 0.950 with urban sanitation access. Internet penetration exhibits substantially greater within-country variation over the study period than the Basic Services Infrastructure Index. The mean within-country standard deviation of the Basic Services Infrastructure Index is approximately 0.234. This relatively limited within-country variation is relevant when interpreting the subsequent fixed-effects estimates, which are identified primarily from changes within economies over time.

4.2 Baseline Two-Way Fixed-Effects Results

The baseline two-way fixed-effects model examines the relationship between urbanization, infrastructure, and GDP-per-capita growth before introducing the

interaction terms that constitute the central empirical test. The estimation results are presented in Table 3.

Table 3. Baseline Two-Way Fixed-Effects Estimates of GDP per Capita Growth

Variable	Coefficient	Clustered Std. Error	t-statistic	p-value	95% Confidence Interval
Urban population (%)	-0.0008	0.0518	-0.016	0.988	[-0.1025, 0.1008]
Basic Services Infrastructure Index	0.3105	0.4375	0.710	0.478	[-0.5474, 1.1683]
Internet users (%)	-0.0438***	0.0113	-3.870	<0.001	[-0.0660, -0.0216]
Trade (% of GDP)	0.0331***	0.0084	3.941	<0.001	[0.0166, 0.0496]
Inflation (%)	-0.0265***	0.0056	-4.736	<0.001	[-0.0375, -0.0155]
Observations	3,438				
Countries	158				
Within R²	0.0504				
Country fixed effects	Yes				
Year fixed effects	Yes				
SE clustered by country	Yes				

Note: The dependent variable is annual real GDP per capita growth (%). Country and year fixed effects are included in all estimates. Standard errors are clustered at the country level. *** indicates statistical significance at the 1% level.

The baseline estimates show no statistically significant association between urbanization and real GDP-per-capita growth. The estimated coefficient is -0.0008 ($p = 0.988$), indicating that the urbanization coefficient is statistically indistinguishable from zero.

The coefficient on the Basic Services Infrastructure Index is positive (0.3105) but statistically insignificant ($p = 0.478$). This result should be interpreted in the context of the relatively limited within-country variation in the index, since the fixed-effects estimator relies primarily on changes occurring within economies over time.

Internet penetration is negatively and statistically significantly associated with GDP-per-capita growth (-0.0438, $p < 0.001$). This coefficient represents a conditional within-country association and should not be interpreted as evidence that increased Internet use causes slower economic growth. The estimate may reflect unobserved factors, common development trends, the timing of digital

adoption, non-linear relationships, or other dynamics not captured by the baseline specification.

Trade openness is positively and statistically significantly associated with GDP-per-capita growth (0.0331, $p < 0.001$), while inflation is negatively and statistically significantly associated with growth (-0.0265 , $p < 0.001$). The model has a within R^2 of 0.0504. Thus, the model explains approximately 5% of the within-country variation in annual GDP-per-capita growth.

4.3 Moderating Role of Infrastructure

The central empirical question is whether the relationship between urbanization and economic growth varies with the level of infrastructure within a country. Table 4 presents the estimates from models incorporating interactions between urbanization and the two infrastructure dimensions.

Table 4. Infrastructure Moderation of the Urbanization–Growth Relationship

Variable	(1) Basic Infrastructure Interaction	(2) Digital Infrastructure Interaction	(3) Combined Interaction
Urbanization (centered)	-0.0100	-0.0015	-0.0166
	(0.0508)	(0.0520)	(0.0514)
Basic Services Infrastructure Index	1.2454**	0.2823	1.2229**
	(0.6126)	(0.4784)	(0.6106)
Internet penetration (centered)	-0.0561***	-0.0434***	-0.0552***
	(0.0126)	(0.0118)	(0.0127)
Urbanization × Basic Infrastructure	0.0330 **	—	0.0390**
	(0.0133)	—	(0.0148)
Urbanization × Internet	—	-0.00005	-0.0003
	—	(0.0003)	(0.0003)
Trade (% of GDP)	0.0342***	0.0332***	0.0349***
	(0.0084)	(0.0084)	(0.0083)
Inflation (%)	-0.0263***	-0.0265***	-0.0263***
	(0.0055)	(0.0056)	(0.0054)
Observations	3,438	3,438	3,438
Countries	158	158	158
Within R²	0.0481	0.0504	0.0473
Country fixed effects	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes

Note: Clustered standard errors are reported in parentheses. Country and year fixed effects are included in all specifications. Standard errors are clustered at the country level. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

The interaction between urbanization and basic-services infrastructure is positive and statistically significant ($\beta = 0.0390$, $SE = 0.0148$, $p = 0.0085$), with a 95% confidence interval of approximately [0.010, 0.068]. This result indicates that the estimated relationship between urbanization and GDP-per-capita growth becomes more favourable as the level of basic-services infrastructure increases.

The coefficient on centered urbanization is -0.0166 and is statistically insignificant ($p = 0.747$). Because the variables are mean-centered, this coefficient represents the estimated association between urbanization and growth when both basic-services infrastructure and Internet penetration are at their respective sample means. Thus, at average levels of infrastructure represented in the sample, urbanization has no statistically detectable association with GDP-per-capita growth.

The coefficient on centered basic-services infrastructure is positive (1.2229) and statistically significant at the 5% level ($p = 0.045$). However, because this coefficient is estimated within an interaction model, it represents the association between basic-services infrastructure and growth when centered urbanization equals zero—that is, when urbanization is at its sample mean. It should therefore not be interpreted as an in contrast, the interaction between urbanization and Internet penetration is negative but statistically insignificant ($\beta = -0.0003$, $p = 0.271$). Thus, the results do not provide evidence that digital connectivity moderates the relationship between urbanization and economic growth. Overall, the findings indicate a distinction between the two infrastructure dimensions examined in this study: the estimated urbanization–growth association varies systematically with basic-services infrastructure, whereas a similar moderating relationship is not identified for digital connectivity.

4.4 Marginal Effects of Urbanization Across Basic-Infrastructure Levels

The positive interaction coefficient indicates that the estimated relationship between urbanization and economic growth varies with the level of basic-services infrastructure. However, the interaction coefficient alone does not show the magnitude or statistical significance of the estimated urbanization–growth association at specific levels of infrastructure. Marginal effects are therefore examined across the distribution of the Basic Services Infrastructure Index.

Using data from the interaction model, we can calculate marginal effects of urbanization as follows:

$$\text{Marginal Effect of Urbanization} = \beta_1 + \beta_4 \text{BasicInfrastructure}^c + \beta_5 \text{Internet}^c$$

where β_1 is the urbanization coefficient; β_4 is the coefficient on urbanization x basic-services infrastructure; β_5 is the interaction coefficient of urbanization and Internet-penetration; $(\text{BasicInfrastructure})^c$ is centered basic-services infrastructure; and $(\text{Internet})^c$ is centered Internet-penetration.

Since we set Internet-penetration at its sample mean during our marginal-effects analysis, we may simplify the previous equation as:

$$\text{Marginal Effect of Urbanization} = \beta_1 + \beta_4 \text{BasicInfrastructure}^c$$

Using the previously mentioned estimates from the combined model:

$$\text{Marginal Effect of Urbanization} = -0.0166 + 0.0390(\text{BasicInfrastructure}^c)$$

As illustrated above, this equation illustrates how the estimated urbanization-growth slope changes with increasing amounts of basic-services infrastructure. For the marginal-effects analysis, centered Internet penetration is held at zero, corresponding to its sample mean. Using the estimates from the combined interaction model, the marginal association between urbanization and GDP-per-capita growth therefore changes with the level of centered basic-services infrastructure. Table 5 reports the estimated marginal effects at representative percentiles of the infrastructure distribution.

Table 5. Marginal Effects of Urbanization at Different Levels of Basic-Services Infrastructure

Infrastructure Percentile	Centered Basic Infrastructure Index	Marginal Effect of Urbanization	Std. Error	95% Confidence Interval	p-value
10th	-2.776	-0.125	0.073	[-0.268, 0.018]	0.087
25th	-1.023	-0.056	0.057	[-0.168, 0.055]	0.321
50th	0.838	0.016	0.050	[-0.082, 0.114]	0.748
75th	1.217	0.031	0.050	[-0.068, 0.130]	0.541
90th	1.304	0.034	0.051	[-0.065, 0.134]	0.499

At the 10th percentile of the basic-services infrastructure distribution, the estimated marginal association between urbanization and GDP-per-capita growth is negative (-0.125), with a 95% confidence interval of [-0.268, 0.018]. The point estimate becomes less negative at the 25th percentile (-0.056) and turns positive at the median (0.016), increasing further to 0.031 at the 75th percentile and 0.034 at the 90th percentile. Thus, the point estimates become progressively more favourable as basic-services infrastructure increases. However, the 95% confidence intervals at all five representative percentiles include zero. Consequently, these estimates do not provide evidence of a statistically significant positive association between urbanization and GDP-per-capita growth at the higher representative levels of basic-services infrastructure.

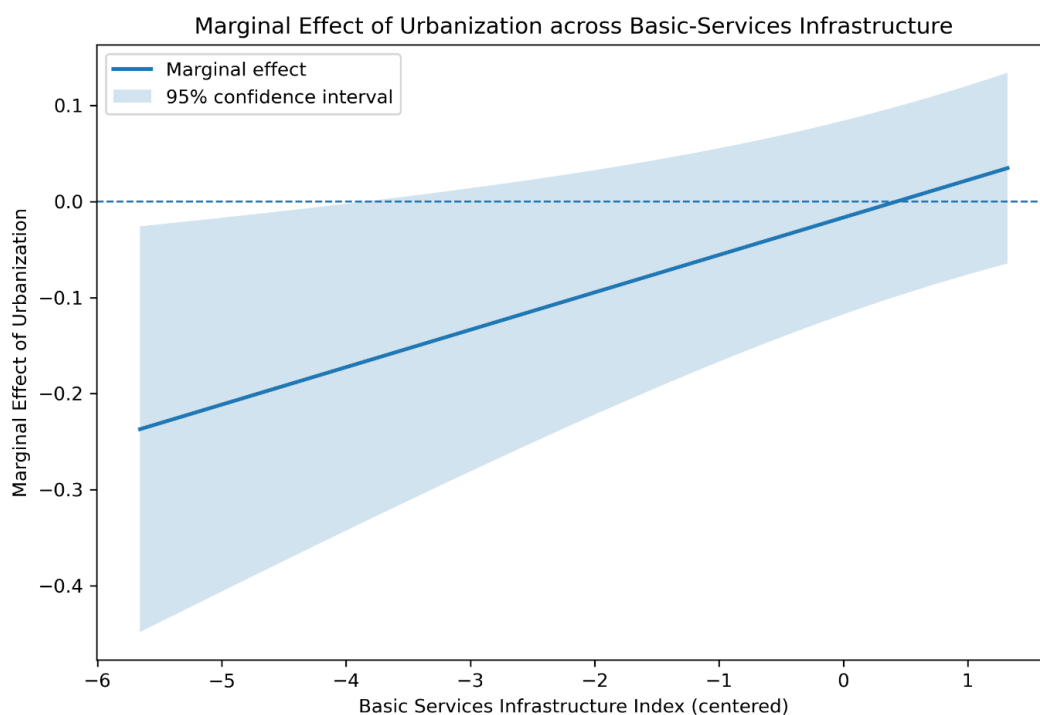


Figure 2. Marginal Effect of Urbanization on GDP per Capita Growth across Basic-Services Infrastructure

Note: The solid line represents the estimated marginal effect of urbanization from the combined two-way fixed-effects model. The shaded area represents the 95% confidence interval. Internet penetration is held at its sample mean.

The continuous marginal-effects analysis provides further qualification. The estimated marginal association between urbanization and GDP-per-capita growth is statistically negative only over a very low range of the centered Basic Services Infrastructure Index, approximately -5.66 to -3.87 . This region contains 107 observations, representing approximately 3.1% of the main estimation sample and 13 economies. Above this range, the confidence interval includes zero, and no observed level of basic-services infrastructure produces a statistically significant positive marginal association.

The results do not identify an infrastructure threshold beyond which urbanization becomes positively associated with economic growth. Rather, the positive interaction coefficient indicates that the estimated urbanization–growth association becomes progressively more favourable as basic-services infrastructure increases. However, the marginal-effects analysis identifies a statistically significant negative association only at extremely low infrastructure levels and does not identify a statistically significant positive marginal association anywhere within the observed infrastructure range.

4.5 Robustness and Sensitivity Analysis

A series of robustness and sensitivity tests was conducted to assess the sensitivity of the positive interaction between urbanization and basic-services

infrastructure to extreme observations, countries with short time series, the construction of the infrastructure index, and the temporal specification of the model. Table 6 reports the estimated interaction coefficient across the alternative specifications.

Table 6. Robustness and Sensitivity of the Urbanization–Basic Infrastructure Interaction

Specification	Interaction Coefficient	Std. Error	p-value	Observations	Countries
Main combined FE model	0.0390	0.0148	0.0085	3,438	158
Winsorized growth and inflation	0.0383	0.0142	0.0070	3,438	158
Countries with ≥ 10 observations	0.0403	0.0147	0.0062	3,361	145
Alternative standardized-mean infrastructure index	0.0675	0.0257	0.0087	3,438	158
One-year-lagged explanatory variables	0.0368	0.0148	0.0129	3,265	157
Lagged explanatory variables + lagged GDP growth	0.0340	0.0149	0.0222	3,265	157

Note: The dependent variable is annual real GDP per capita growth. All specifications include country and year fixed effects and country-clustered standard errors. The reported coefficient is the interaction between urbanization and basic-services infrastructure. The coefficient in the alternative-index specification is not directly numerically comparable with the other coefficients because the infrastructure index is measured on a different scale.

In the main combined fixed-effects model, the interaction between urbanization and basic-services infrastructure is positive and statistically significant, with a coefficient of 0.0390 ($p = 0.0085$). The coefficient remains stable when GDP-per-capita growth and inflation are winsorized at the 1st and 99th percentiles, with an estimate of 0.0383 ($p = 0.0070$). This similarity indicates that the principal interaction result is not driven by extreme observations in these variables.

When economies with fewer than 10 usable annual observations are excluded, the remaining sample contains 3,361 observations from 145 economies. The estimated interaction coefficient remains positive and statistically significant at 0.0403 ($p = 0.0062$). This indicates that the principal interaction result is not driven by economies represented by relatively short time series.

The PCA-based Basic Services Infrastructure Index was also replaced with an alternative index constructed as the equally weighted mean of the standardized electricity-access, urban drinking-water-access, and urban-sanitation-access indicators. The resulting interaction coefficient is positive and statistically significant at 0.0675 ($p = 0.0087$). Its magnitude is not directly comparable with the main estimate because the alternative index has a different scale. The two infrastructure measures are nevertheless almost perfectly correlated (approximately 0.99999), indicating that the principal interaction result is not sensitive to the method used to construct the infrastructure index.

Temporal robustness was evaluated through the introduction of lagged explanatory variables into the model. The urbanization-basic infrastructure interaction remains positive and statistically significant using explanatory variables lagged one year, with an estimated coefficient of 0.0368 ($p = 0.0129$). This estimated coefficient is very close to the contemporaneous coefficient of 0.0390, which indicates that the principal interaction estimate remains stable when the explanatory variables are lagged by one year.

As an additional sensitivity check, lagged GDP-per-capita growth was added to the lagged specification. The coefficient on lagged GDP-per-capita growth is 0.0681 and is statistically insignificant ($p = 0.295$). The urbanization-basic-infrastructure interaction remains positive and statistically significant at 0.0340 ($p = 0.0222$).

Across the outlier, panel-composition, infrastructure-measurement, and temporal robustness specifications, the interaction coefficient remains positive and statistically significant. Among the specifications using the PCA-based infrastructure index, the estimated coefficient lies within a relatively narrow range of approximately 0.034 to 0.040. This stability indicates that the central moderating relationship is robust across the alternative specifications examined here.

4.6 Human-Capital Control and Sample Sensitivity

As an additional sensitivity analysis, secondary-school gross enrollment was introduced as a proxy for human capital. Because education data are substantially less complete than the variables used in the main specification, restricting the analysis to observations for which secondary-enrollment data are available reduces the estimation sample from 3,438 to 2,560 observations across 154 economies. To distinguish the effect of adding the human-capital control from the effect of changing the sample composition, the main interaction model was first re-estimated on this restricted sample without including secondary enrollment. Table 7 presents the results.

Table 7. Human-Capital Control and Sample Sensitivity

Specification	Urbanization × Basic Infrastructure	Std. Error	p- value	Observations	Countries
Full estimation sample	0.0390	0.0148	0.0085	3,438	158

Specification	Urbanization × Basic Infrastructure	Std. Error	p-value	Observations	Countries
Education-available sample, excluding education control	0.0214	0.0193	0.2670	2,560	154
Education-available sample, including education control	0.0204	0.0196	0.2974	2,560	154

Note: The education variable is gross secondary school enrollment. Models 2 and 3 use exactly the same restricted sample, allowing the effect of adding the human-capital control to be distinguished from the effect of sample restriction. All specifications include country and year fixed effects and country-clustered standard errors.

In the full estimation sample, the interaction between urbanization and basic-services infrastructure is positive and statistically significant, with a coefficient of 0.0390 ($p = 0.0085$). When the same model is estimated using only observations for which secondary-enrollment data are available, but without including secondary enrollment as a control, the interaction coefficient declines to 0.0214 and is no longer statistically significant ($p = 0.2670$). Adding secondary enrollment to exactly the same restricted sample changes the interaction coefficient only slightly, from 0.0214 to 0.0204 ($p = 0.2974$). The coefficient on secondary enrollment itself is 0.0070 and statistically insignificant ($p = 0.5999$).

This matched-sample comparison indicates that most of the attenuation in the interaction estimate occurs when the sample is restricted to observations for which education data are available, rather than when the education control itself is introduced. The loss of statistical significance should therefore not be interpreted as evidence that the inclusion of the human-capital control explains the urbanization–infrastructure relationship estimated in the main model.

The education-available sample also differs systematically from the excluded observations on several characteristics relevant to the analysis. Mean urbanization is approximately 60.4% in the education-available sample compared with 51.9% among excluded observations. The corresponding mean values of the Basic Services Infrastructure Index are approximately 0.30 and -0.87 , while mean Internet penetration is approximately 44.5% and 27.0%, respectively. These differences indicate that education-data availability is not random with respect to several observable characteristics relevant to the analysis.

The human-capital specification therefore provides an important sensitivity check but is based on a more selective sample than the main estimation. The weaker interaction estimate in this restricted sample should be regarded as a

qualification to the otherwise robust results reported in Section 4.5, rather than as evidence that the attenuation is attributable to the inclusion of the human-capital control itself.

5. Discussion

5.1 Interpretation of the Main Findings

The empirical results indicate that the relationship between urbanization and economic growth varies with the level of basic-services infrastructure. The baseline two-way fixed-effects model identifies no statistically significant association between urbanization and GDP-per-capita growth. However, once the interaction between urbanization and basic-services infrastructure is introduced, a more nuanced relationship emerges. The positive and statistically significant interaction indicates that the urbanization–growth association becomes more favourable as access to electricity, urban drinking water, and urban sanitation increases.

Urbanization can create opportunities for agglomeration economies, labour-market specialization, and other productivity-related benefits, but the realization of these opportunities may depend partly on adequate supporting infrastructure. Where electricity, water, and sanitation services are limited, increasing population concentration may place additional pressure on existing service systems. Conversely, greater access to basic services may provide a more supportive environment for accommodating urban concentration and realizing the potential economic benefits associated with urbanization.

The marginal-effects analysis further qualifies this interpretation. As the Basic Services Infrastructure Index increases, the estimated marginal association between urbanization and economic growth becomes less negative and eventually positive. However, none of the marginal effects evaluated at the 10th, 25th, 50th, 75th, or 90th percentiles is statistically significant at the 5% level. The continuous analysis identifies a statistically significant negative association only at very low levels of basic-services infrastructure and does not identify a statistically significant positive marginal association anywhere within the observed range. The results therefore do not identify a specific infrastructure threshold beyond which urbanization becomes positively associated with economic growth. Rather, they indicate that the estimated urbanization–growth association becomes progressively more favourable as basic-services infrastructure increases.

An important distinction also emerges between basic-services infrastructure and digital connectivity. Internet penetration exhibits a negative conditional association with GDP-per-capita growth in the fixed-effects models, but its interaction with urbanization is statistically insignificant. Thus, the analysis does not identify a statistically significant moderating role for Internet penetration in the relationship between urbanization and GDP-per-capita growth. This contrasts with the significant moderating relationship identified for basic-services infrastructure and suggests that different infrastructure dimensions should not necessarily be treated as interchangeable in analyses of the urbanization–growth relationship.

The robustness analyses provide additional support for the central interaction result. The positive interaction between urbanization and basic-services infrastructure remains statistically significant when extreme observations are addressed through winsorization, economies with fewer than 10 usable observations are excluded, the PCA-based infrastructure index is replaced with an alternative standardized-mean measure, explanatory variables are lagged by one year, and lagged GDP-per-capita growth is included as an additional diagnostic. The stability of the interaction estimate across these specifications indicates that the central moderating relationship is robust to the principal alternative specifications examined in the study.

The human-capital sensitivity analysis, however, provides an important qualification. Restricting the analysis to observations for which secondary-school enrollment data are available produces a smaller and statistically insignificant interaction estimate. The matched-sample comparison shows that most of this attenuation occurs when the estimation sample is restricted, before secondary enrollment is introduced as an additional control. The result therefore indicates that the estimated moderating relationship is sensitive to the composition of the estimation sample rather than showing that the inclusion of the human-capital control itself explains the attenuation.

Taken together, the findings support a conditional rather than universal interpretation of the relationship between urbanization and economic growth. Urbanization is not uniformly positively or negatively associated with GDP-per-capita growth across the sample. Instead, the results suggest that the relationship between increasing urban concentration and economic growth varies with the level of basic-services infrastructure. This perspective shifts attention from urbanization solely as a demographic process toward considering the infrastructure environment within which increasing urban concentration occurs.

5.2 Relationship with Previous Literature and Hypothesis Assessment

The current study's findings support the broader literature questioning the idea of a universally positive and straightforward link between urbanization and economic growth. Turok and McGranahan (2013) point out that the economic advantages associated with urbanization rely upon the total environmental circumstances of urbanization. Turok et al. (2023) note that there exists a trade-off between agglomeration economies and congestion/overcrowding/service constraints that occur during urbanization when urban expansion is inadequately supported. The present findings provide empirical support for this broader perspective by showing that the association between urbanization and economic growth varies systematically with the level of basic-services infrastructure.

These findings also extend previous empirical work examining the role of infrastructure in the economic relationship associated with urbanization. Lewis (2014), using subnational data from Indonesia, reports a positive interaction between local infrastructure expenditure and population growth, indicating that higher infrastructure expenditure is associated with a weaker negative relationship between rapid local population growth and subsequent economic growth. The present study examines a related proposition from a different empirical perspective. Whereas Lewis considers local-government infrastructure

expenditure within a single country, the present study examines realized access to electricity, urban drinking water, and urban sanitation across a large cross-country panel. The positive interaction between urbanization and the Basic Services Infrastructure Index therefore provides cross-country evidence consistent with the broader proposition that infrastructure is relevant to the economic relationship associated with urbanization.

In addition, the findings can be compared to other studies indicating that urbanization and infrastructure evolve together, yet neither uniformly nor simultaneously. El-Bouayady et al. (2024) demonstrate that the relationships among urbanization and infrastructure development vary across types of infrastructure in African countries. Pandey et al. (2025) report continued inequality and, in many instances, growing inequality in the distribution of infrastructure as well as urbanization and economic development. Both studies underscore the importance of considering the infrastructure environment within which urbanization occurs. The present study extends this perspective by examining whether the urbanization–growth relationship varies with the level of access to basic services.

The distinction between basic-services infrastructure and digital connectivity is also relevant to the existing literature. Although communication infrastructure is widely recognized as an important component of economic development, the present analysis does not identify a statistically significant moderating role for Internet penetration in the urbanization–growth relationship. This finding does not imply that digital connectivity is economically unimportant. Rather, its economic role may operate through mechanisms different from those captured by the urbanization interaction examined here. Basic services such as electricity, water, and sanitation can support the functioning and capacity of urban settlements, whereas the economic benefits associated with digital connectivity may depend more strongly on complementary capabilities and the ways in which digital technologies are used.

The empirical results support H1, which proposes that the relationship between urbanization and economic growth varies with the level of basic-services infrastructure, such that the urbanization–growth association becomes more favourable as access to basic infrastructure increases. The positive and statistically significant interaction between urbanization and basic-services infrastructure is consistent with this hypothesis. However, this finding should be interpreted alongside the marginal-effects analysis. The evidence indicates a systematic change in the slope of the urbanization–growth relationship rather than identifying a specific infrastructure level at which urbanization has a statistically significant positive marginal association with economic growth.

H2, which proposes that digital connectivity moderates the relationship between urbanization and economic growth, is not supported by the empirical findings. The interaction between urbanization and Internet penetration is statistically insignificant, providing no evidence of a systematic moderating role for digital connectivity within the present sample and specification. This result should not be interpreted as evidence that Internet access has no economic significance; rather, the analysis does not identify a statistically significant moderating role for

Internet penetration in the relationship between urbanization and GDP-per-capita growth.

5.3 Economic and Policy Implications

The findings have implications for understanding the relationship between urbanization and economic development. Urbanization is frequently viewed as an indicator of structural transformation; however, the empirical results suggest that its economic association should be considered alongside the infrastructure environment within which urban concentration occurs. The statistically significant interaction between urbanization and basic-services infrastructure indicates that the urbanization–growth association becomes more favourable as access to essential services increases. This finding highlights the relevance of considering basic-service capacity alongside the extent of urbanization when examining differences in economic performance across economies.

From a policy perspective, the findings highlight the relevance of considering urban development and basic-infrastructure provision together rather than viewing them as entirely separate policy domains. Increasing urban concentration can place additional demands on electricity, water, and sanitation systems, while the capacity of these systems may be relevant to how urban economies accommodate population and economic activity. For rapidly urbanizing economies in particular, the results highlight the relevance of basic-service provision alongside urban expansion. The evidence should not be interpreted as establishing that infrastructure improvements will necessarily cause higher economic growth; rather, it indicates that basic-service capacity is systematically related to the economic relationship associated with urbanization. The distinction between basic-services infrastructure and digital connectivity also has implications for the measurement and assessment of infrastructure. Although digital connectivity is increasingly important for communication, information access, and economic participation, the present study does not identify a statistically significant moderating role for Internet penetration comparable to that identified for basic-services infrastructure. Treating different types of infrastructure as a single composite dimension may therefore obscure differences in how particular infrastructure components relate to the urbanization–growth relationship.

The findings do not imply a universal level of basic-services infrastructure that economies must achieve before urbanization becomes economically beneficial. The marginal-effects analysis does not identify a statistically significant positive infrastructure threshold within the observed range. The policy implication is therefore not a specific infrastructure target derived from the present estimates, but the broader relevance of considering basic-service capacity in relation to the pressures and opportunities associated with urbanization.

5.4 Limitations and Directions for Future Research

The findings should be considered in light of several limitations. First, the analysis identifies associations rather than causal effects. Although the two-way fixed-effects framework controls for time-invariant country characteristics and common year-specific influences, time-varying country-specific omitted variables and potential reverse causality remain possible. The estimates should therefore

not be interpreted as establishing causal effects of urbanization or infrastructure on economic growth.

Second, the infrastructure indicators measure access rather than the quality, reliability, or capacity of infrastructure services. National-level measures may also conceal substantial subnational inequalities in service provision. In addition, some basic-services indicators, particularly urban water and sanitation access, change gradually over time, limiting the within-economy variation available for identification in the fixed-effects models.

Third, the availability of human-capital data represents an additional limitation. Restricting the analysis to observations for which secondary-school enrollment data are available produces a smaller and systematically different sample in which the urbanization–basic-infrastructure interaction is no longer statistically significant. The matched-sample analysis indicates that most of this attenuation is associated with the change in sample composition rather than with the inclusion of the education control itself. Nevertheless, this result indicates that the estimated moderating relationship is sensitive to the composition of the estimation sample.

Future research could extend the analysis by incorporating richer measures of infrastructure quality, reliability, and capacity; more comprehensive measures of human capital; and subnational data capable of capturing differences in infrastructure provision and economic outcomes within economies. Longer time horizons and alternative empirical strategies that permit stronger causal inference could also provide further evidence on the mechanisms linking urbanization, infrastructure, and economic growth.

6. Conclusion

This study examined whether the relationship between urbanization and economic growth varies with the level of infrastructure using a cross-country panel of 158 economies over the period 2000–2024. The results show no statistically significant direct association between urbanization and GDP-per-capita growth. However, the positive and statistically significant interaction between urbanization and access to electricity, urban drinking water, and urban sanitation indicates that the urbanization–growth association becomes more favourable as basic-service provision improves. The marginal-effects analysis, however, does not identify a statistically significant positive infrastructure threshold within the observed range.

In contrast, Internet penetration does not exhibit a statistically significant moderating relationship with urbanization, highlighting the importance of distinguishing between basic-services infrastructure and digital connectivity when examining the economic role of infrastructure. The principal basic-services interaction remains stable across several robustness specifications, although it weakens and loses statistical significance in the restricted sample for which human-capital data are available. The matched-sample analysis indicates that this attenuation is associated primarily with the change in sample composition rather than with the inclusion of the human-capital control itself.

Because the analysis is based on observational data, the findings should be interpreted as associations rather than causal effects. Nevertheless, the study contributes to the urbanization literature by showing that the economic relationship associated with urban concentration should be considered alongside the basic infrastructure environment within which urbanization occurs. The broader implication is that understanding urbanization as a process of economic transformation requires attention not only to the concentration of people and activity, but also to the basic services available to support increasing urban concentration.

Data Availability

The data used in this study are publicly available from the World Bank's World Development Indicators (WDI) database. The variables and corresponding indicator codes used in the analysis are reported in the manuscript. The data can be accessed through the World Development Indicators database.

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Competing Interests

The author declares no competing interests.