Determinants of Urbanization: A Comparative Analysis Across Global Cities

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Abstract:
Rapid urbanization has catalyzed economic growth, especially for developing nations, and their urban populations have seen a dramatic rise, hence requiring an understanding of and policymaking on socioeconomic issues. The paper presents important factors that determine the population growth in major urban agglomerations around the world with over 5 million inhabitants. The determinants of urban population size in 2020 and population growth rates from 2010-2020 were analyzed using OLS and quantile regression models based on data with geographical, environmental, demographic, political, and infrastructural variables. The main results show that proximity to transportation infrastructure, annual temperature, initial population size, population density, and the number of educational institutions are essential facilitating factors for urban populations. In contrast, port city status, annual precipitation, and CO_2 emissions show negative impacts. Many of these same factors are also significant in population growth rates, though state capital status and congestion in traffic flow negatively relate to growth. The results indicate a complex variety of factors that shape global urban growth and imply some policy directions for sustainable urban development investments in education, environmental protection, and transport infrastructure. This research contributes to understanding the dynamics of global urbanization.

Keywords: Urban population growth, Demographic factors, Environmental variables, Infrastructure, Sustainable urban development.
JEL Classifications: O18, R11, R12

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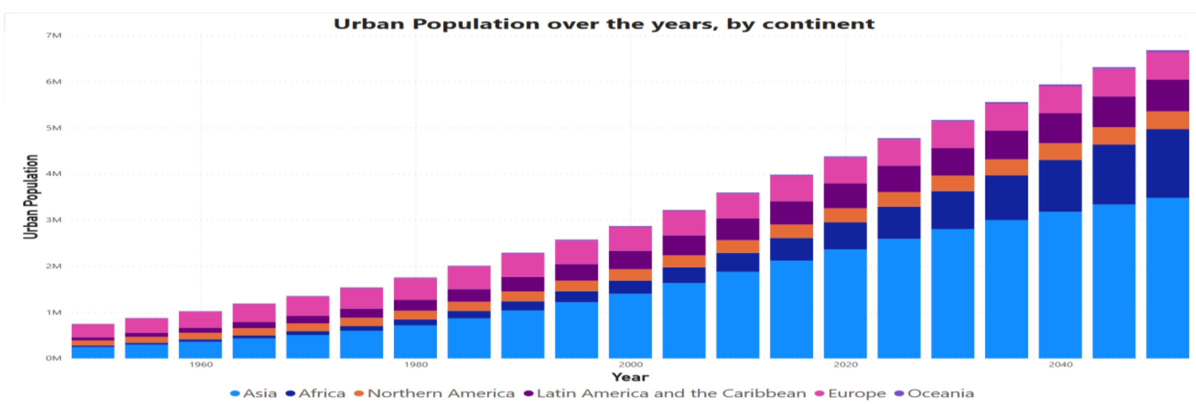
1. Introduction

Cities are usually the engine of economic growth. Over time, the world's urban population has grown steadily (Fig. 1). Today, cities are home to about 56% of the world's population, which equals 4.4 billion people and is expected to more than double by 2050.[1] Back in 2000, 371 cities worldwide had one million or more inhabitants. By 2018, this number grew to 548 cities, and projections suggest that by 2030, 706 cities will have at least one million residents.[2] Along with the increase in the number of cities, cities like Mumbai, Delhi, and Beijing are seeing a rapid rise in their urban population and changes in urban dynamics. However, there is a significant diversity in urbanization patterns across developing countries. For example, in Latin America and the Caribbean, 81% of the population lives in cities, and four megacities (Buenos Aires, Mexico City, Rio de Janeiro, and São Paulo) account for 17% of the combined urban population. The probable reason for the growth of these cities is globalization, which has transformed cities into global economic centres, attracting multinational corporations, international finance, and diverse workforces (Sassen, 2020). Though, rapid urbanization can lead to socioeconomic issues like overcrowding, environmental degradation, and infrastructure strain. Understanding key determinants of city growth can help policymakers implement policies for sustainable economic development and climate change mitigation. This understanding is crucial for developing effective environmental policies and addressing climate change.

Fig 1: Urban Population in the World over the years



Source: Author's calculation based on data from the World Urbanization Prospects, 2018

[1] https://www.worldbank.org/en/topic/urbandevelopment/overview. (Accessed on 6 January, 2024).
[2] https://www.un-ilibrary.org/content/books/9789210476102 (Accessed on 5 January, 2024).

The studies on urbanization contain three interlinked dimensions: growth in individual city population size, changes in city size distribution, and an increase in city numbers (Henderson & Wang, 2007; Abhishek et al., 2017). Changes in city size distribution indicate a shift in the pattern of urbanization and the structure of cities within a country; growth in individual city population size indicates an increase in the city's overall population; and an increase in city numbers indicates an increase in GDP, output, or other social and economic variables. Sridhar (2010) provides the following important distinction between population growth and economic growth of cities: a city may experience population growth while experiencing economic growth or may experience no economic growth at all. This perspective is rooted in general equilibrium analysis of optimal city size, which asserts that when cities exceed certain thresholds, they exhibit congestion and a reduction in overall economic output. This study examines the second aspect - the city's growth in terms of its overall population. This study aims to investigate the factors that influence city population.

Different studies have looked at different definitions of cities based on population size. For example, a population size of 5,000 (Abhishek et al., 2011), cities with populations over 750,000 (Tripathi, 2013), and cities with populations over 100,000 (Henderson & Wang, 2007) are considered. However, with the increasing urbanization, it becomes increasingly important to understand the growth dynamics of large cities and the factors that influence this growth. Therefore, in this study, we focus on cities with populations of over 500,000.

While several studies have looked into the factors that drive city growth, much of this research has focused on specific regions or countries (Baum-Snow, 2007; Sridhar, 2010; Tripathi, 2023; Mahey & Tripathi, 2016). These studies typically emphasize localized factors, such as infrastructure or migration, which can limit their applicability to different economic and social settings (Cheshire & Magrini, 2006; Duranton & Turner, 2012). Additionally, many cross-country studies on city growth are outdated, reflecting economic conditions from many years ago (Henderson & Wang, 2007). Most of the papers also neglected traffic congestion, which has become a more pressing issue in large cities worldwide. Therefore, it is critical to consider whether transportation inefficiencies, such as long commute times and congestion, impact urban growth. To address this, we incorporate transportation quality, as measured by the Inefficiency Index, in our analysis. By incorporating the Inefficiency Index alongside factors such as environmental conditions, geographical features, infrastructural, proximity factors, and so on, we hope to provide a more comprehensive understanding of how various factors influence urban growth dynamics. With the rapid evolution of economic structures, urbanization trends, and technological advancements in recent times, the dynamics of city growth have become increasingly complex. Therefore, there is a pressing need for more current cross-country analyses. This study seeks to fill this gap by performing an updated cross-country analysis incorporating these changing factors to offer a more thorough understanding of the drivers of city growth in recent times.

The paper is structured as follows. The next section presents the literature review to identify the research gap and develop the research hypothesis. Section 3 outlines the variables used in the analysis, their data sources and a brief description of the data. It also details the econometric specification adopted. The empirical framework and regression analysis are presented in Section 4, followed by the conclusion and policy recommendations in Section 5.

2. Literature review and research hypothesis

2.1 Literature review

According to Abhishek et al. (2017), the urban population is growing predominantly due to three reasons: first, natural births and deaths. Second, net migration and immigration. Third, the reclassification of rural land and expanding city boundaries. Of these three, the ability of individuals to migrate from rural areas to urban areas is the most prominent root cause of urbanization, where they are lured by the offering of improved economic opportunities, educational opportunities, and social aspirations (Liao & Yip, 2018). Duranton and Puga (2015) discussed the monocentric city model, which emphasizes the role of transportation cost and commuting as determinants of urban land use and population size. The model predicts that improvements in local transportation infrastructure can lead to a proportional increase in city population. Many studies have been conducted on urban growth and its driving forces. Proximity to key infrastructure is one of the most important influences affecting growth, according to Kantakumar et al. (2016), Grimes et al. (2014), and Zhang et al. (2013). The location of key infrastructure essentially drives spatial trajectories for urbanization. Kantakumar et al. (2016) concluded that proximity to key infrastructure had the highest explanatory value for urban growth in Pune, India, while Grimes et al. (2014) and Zhang et al. (2013) concluded that infrastructure expansion dramatically affects urban growth trajectories. Availability and quality of infrastructure may facilitate or constrain urban growth, depending on the context. The studies emphasized infrastructure's critical role in shaping urban development patterns and the importance of long-term, well-planned infrastructure development to support urban growth. They also found the significance of Proximity to transportation networks, industrial zones, and other critical services in determining the determinants of urban development. Duranton and Puga (2004) emphasized the role of connectivity in facilitating the movement of goods and people, thereby promoting economic activities and urban expansion.

Environmental factors are important in shaping urban population growth. Cheshire and Magrini (2006) found that warmer and drier weather conditions were linked to higher population growth rates in European cities. However, this effect did not apply to individual cities within those countries. Local factors, such as economic opportunities and environmental conditions, also significantly impact population growth in cities. Kahn and Walsh (2015) discovered that cities with higher environmental quality and lower disaster risk have higher population growth as people are drawn to liveable and sustainable urban areas. Abhishek et al. (2017) discovered that environmental degradation, such as air and water pollution, can deter urban population growth because people want to avoid adverse health and quality of life consequences. The geographical distribution of land and water resources can influence a city's growth patterns. Regions with abundant arable land and reliable water supplies, such as river basins and coastal areas, have historically attracted more people and urban development (Gao et al., 2015; Silva et al., 2017).

Conversely, areas with limited land or water scarcity have had difficulty accommodating urban expansion. Cities located along coastlines or major waterways frequently experience accelerated growth due to their strategic geographical locations. Coastal and port cities can access maritime trade routes, fisheries, and other marine resources to stimulate economic activity and population growth (Li et al., 2018; Thakur et al., 2020). Human capital and education are also important determinants of urban growth. In studies led by Popescu (2012) and Glaeser & Saiz (2003), cities higher in skilled individuals grow faster than their counterparts. Sridhar (2010) found that higher levels of education and literacy correlate with quicker urban growth in India. Simon & Nardinelli (2002) studied historical data on urban growth in the United States, examining the impact of human capital accumulation and analyzing census data to measure education attainment and assess the impact of human capital accumulation in the United States over the 20th century.

State power and administrative hierarchy play a vital role in driving urban growth globally. Han et al. (2015) discovered that urban land expansion in China correlates with administrative hierarchy, with cities at higher administrative levels expanding their urban land more rapidly. Lin and Yi (2011) argued that cities with provincial capital status have distinct advantages in attracting investment and resources, which drives urban expansion. The concentration of state power and resources in provincial capitals has resulted in uneven urban development across China, with higher administrative ranks and cities designated as provincial capitals or sub-provincial cities expanding much faster than lower-tier cities. However, the impact of administrative power on urban growth can differ across cities. According to Fang and Yu (2017), the growth-inducing impact of state power is most pronounced in medium-sized cities, whereas political factors less influence the largest metropolises. Duranton and Puga (2004) observed that city size positively correlated with urban growth, emphasizing the advantages of agglomeration economies. They discovered that larger cities benefit from diverse economic activities promoting innovation and productivity. Glaeser and Resseger (2010) discovered that larger cities grow faster due to increased human capital and innovation. Henderson (2003) investigated urbanization patterns in developing countries, learning that larger cities face unique challenges, such as congestion and inadequate infrastructure, but also have significant potential for economic development if managed effectively. Also, in developing countries, natural increase due to birth and death is one of the significant contributors to growth in the urban population (Lu et al., 2013; Abhishek et al., 2017).

Locations with higher population density are vital in idea generation, innovation, and growth (Carlino et al., 2007). According to Abhishek et al. (2017), population density positively affects the city size as locations with higher density play an essential role in generating new ideas, fostering innovations, and influencing growth in the city. Although many studies have been conducted to study the variables driving urban growth, they have often focused on a single city or country. There has been very little research on this topic in cities around the world. Given the increasing globalization and the importance of cities in promoting economic growth, it is vital to explore the sources of growth in cities around the world. Thus, we assessed urban agglomerations with more than 5 million populations and looked at the factors influencing population growth in these areas.

2.2. Research Hypothesis

The main objective of this study is to understand the factors that drive growth in urban agglomerations worldwide. The two independent variables considered for this study are population and population growth. The list of variables considered in this study and the expected outcome are mentioned in Table 1. Based on the previous literature, we hypothesize how these variables will likely affect growth indicators.

Table 1. List of independent variables used for the regression analysis

Factors	**Variable**	**Expected Sign**
Administrative power	State capital dummy	+ve
Geographical reasons	Port city dummy	+ve
Proximity to essential infrastructure	Distance to the nearest airport	-ve
	Distance to the nearest railway station	-ve
	Distance to the nearest highway	-ve
Environmental factors	CO2 emission Index (2019)	-ve
	Annual temperature (2019)	+ve
	Annual precipitation (mm) (2019)	-ve
Education	Number of higher educational institutions	+ve
Transportation	Inefficiency Index (2019)	-ve
Cultural heritage	Number of UNESCO World Heritage Sites in the city	+ve
Initial population	Population 2010	+ve
City size	Population density	+ve
Infrastructure	Built-up area per capita (m2 per person)	+ve

Source: Authors' calculation

H1.: Administrative power is crucial for urban population growth

Tripathi (2013) explores the role of administrative power in city development, highlighting the importance of capital-city favoritism in large Indian cities. Mayer et al. (2016) highlight the role of capital cities in forming distinct economic geography and facilitating government and private sector interactions. As Abhishek et al. (2017) suggested, an enhanced level of livability due to capital city favoritism could generate a higher demand for immigration, thereby helping urban populations grow. Therefore, this research expects to observe a positive relationship between the state capital dummy and the city population size.

H2.: Geographical reason drives urban growth

Port cities, often near maritime trade routes, offer numerous advantages, influencing economic activities, job opportunities, and population dynamics. A dummy variable represents port city status, with one value indicating state capital and zero otherwise. Urban growth is primarily driven by proximity to rivers due to favourable environmental conditions, convenient transportation, or fewer geographical barriers, as suggested by Li et al. (2018). We expect a positive relation of this variable with the dependent variables.

H3.: Proximity to essential infrastructure drives urban growth

Proximity to the airport can improve a city's access to domestic and international markets. This connectivity can attract businesses and residents, leading to urban growth. We hypothesize that the distance to the nearest airport will have a negative effect on the urban population. According to Suzuki & Muromachi (2010), population density is higher around a station than further away, with stronger trends as you get closer. A higher density remains in areas 2 to 3 kilometers from the station. Railroad service may be necessary in high-density areas, but it is insufficient. Railways are an essential source of transportation, and it may attract people and business. We expect that the distance to the nearest airport will negatively affect the urban population. According to *Duranton & Turner (2012)*, a 10% increase in a city's stock of roads causes about a 2% increase in its population and employment and a slight decrease in its share of poor households. Highways increase connectivity within the country and attract people and businesses because of the convenience of traveling. We hypothesize that the distance to the nearest highway will have a negative effect on the urban population.

H4.: Environmental reasons drive urban growth

According to NUMBEO, the CO2 Emission Index estimates CO2 emissions attributable to passenger daily commutes. The measurement unit is grams for the return trip. The amount of migration in cities with high pollution and CO2 emissions would be low as higher CO2 emissions can be associated with adverse health effects and reduced quality of life. We expect that the CO2 Emission Index will have a negative effect on the urban population. Beeson et al. (2001), Black and Henderson (2003), and Cheshire & Magrini (2005) all highlight the significant role of annual temperature in determining migration patterns to cities. Warmer temperatures, which encourage outdoor activities and higher living standards, are expected to attract more residents, thereby positively affecting the urban population, as Cheshire & Magrini (2005) supported. Climate and weather conditions significantly impact urban migration and population growth. Higher precipitation levels can impact agriculture, water supply and management, infrastructure, and quality of life. Excessive rainfalls might discourage people because of the potential risk of flooding, poor infrastructure resilience, and general inconvenience. Thus, we expect annual precipitation to impact the urban population negatively.

H5.: Educational factors drive urban growth

POPESCU (2012) highlights the significant impact of educational institutions on the economic and local demographics. These institutions attract students, staff, and faculty due to increased educational and job opportunities. They also contribute to city branding strategies and human capital, thereby positively affecting the urban population. The presence of educational institutions in cities is crucial for economic growth. We hypothesize that the number of higher educational institutions in the city will positively affect the urban population.

H6.: Transportation is an important factor affecting city growth

The most common problems with transport affecting cities in developing countries are congested roads and insufficient pedestrian facilities. It reduces productivity and quality of life (Habitat, 2013). We hypothesize that the Inefficiency Index, which shows the inefficiency caused by traffic and longer commute time, will negatively affect the urban population.

H7.: Cultural factors promote urban growth

The number of UNESCO *World Heritage Sites* in the City shows the number of sites that UNESCO has recognized for their cultural, historical, and natural significance. These sites can increase a city's attractiveness, boost tourism, and promote local pride, leading to increased population and urban growth. We expect a positive relationship between the urban population and the City's Number of UNESCO World Heritage Sites.

H8.: Initial Population positively impacts city growth

Cities with higher initial populations typically see faster growth that follows because of their well-established social networks, infrastructure, and employment prospects. Glaeser et al. (1995) also support this expectation. Thus, we expect that the initial population will positively affect the urban population.

H9.: Population density is a crucial factor determining city growth

Glaeser's (2011) research highlights the importance of urban population density in attracting new residents. High density indicates well-developed infrastructure, efficient public services, and thriving economic activity, attracting more people due to agglomeration benefits like better job opportunities and lower transportation costs. Glaeser (2011) states that dense urban areas can promote economic growth and innovation, attracting more people. Thus, we hypothesize that higher population density leads to higher population growth.

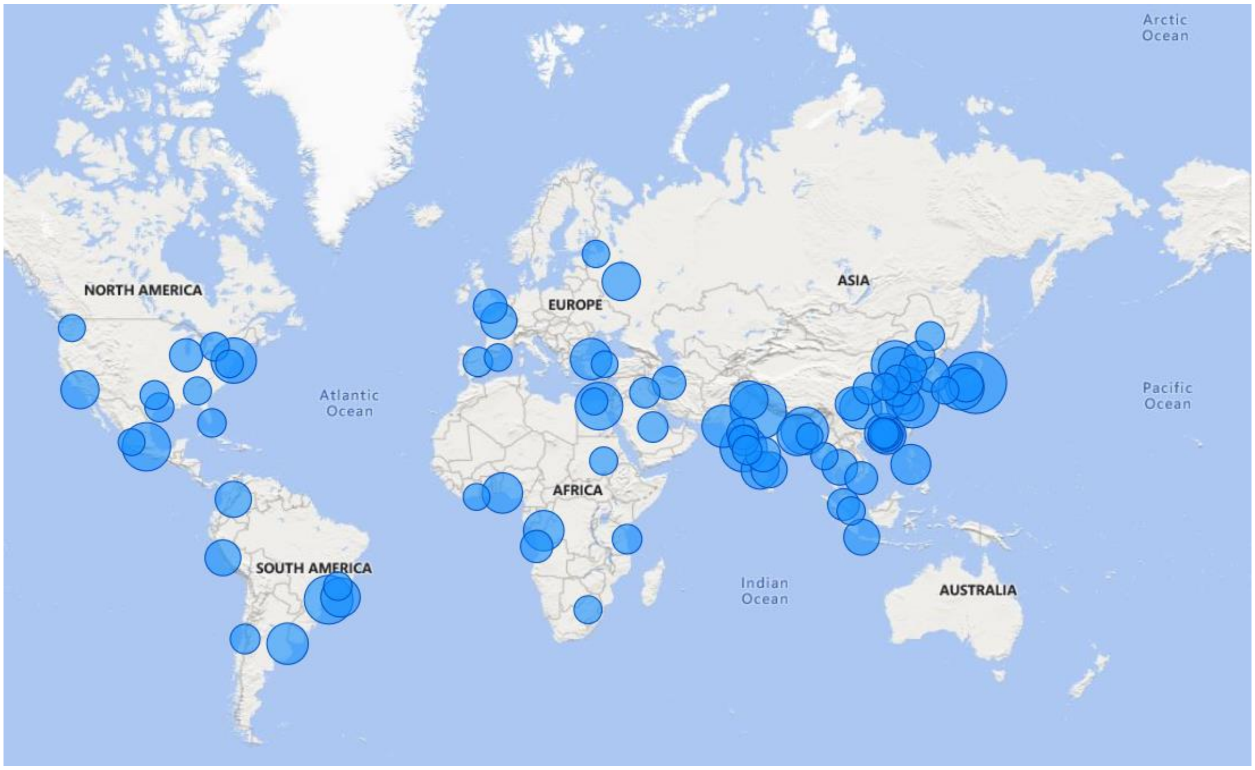
H10.: Better Infrastructural facilities promote city growth

The Built-Up Area Per Capita (m2 per person) measures a city's average land per person. This metric is important because it helps understand urban areas' spatial distribution and density. A high build-up area may suggest more living space, which may indicate better living conditions and quality of life, attracting more people and thus increasing the urban population.

3. Data and methodology

After discussing the potential factors that influence the growth of cities worldwide, the empirical framework and estimation methods are described. Simple OLS is used in this paper to analyze the factors influencing the growth in cities around the world. Data for the dependent variable and independent variables are collected from different sources. In this study, we look at cities with populations of more than 5 million to focus on large urban agglomerations that are experiencing significant demographic and economic changes. There are 85 cities that meet this criterion, and the complete list is provided in the Appendix Table 1. Figure 2 depicts a map of cities considered for the analysis. The bubbles represent the cities considered in the analysis. The larger the bubble, the higher the city's population.

Figure 2: Map of cities considered in the study



Source: Author's copilations based on data from the World Urbanization Prospects, 2018

The following regression model is used for the analysis.

Popi = a + b1AdmPowi + b2Geoi + b3Proximityi + b4Envi + b5Edui + b6Transi +b7Culi + b8IniPopi + b9Cityi + b10Infrai + ui ------(1)

Where *Popi* is the population of the urban area or population growth or the population density, *AdmPowi* is the administrative power, *Geoi* is the geographical factors, *Envi* is the environmental factors, *Proximityi* includes all the proximity variables, *Edui* is the educational factor, *Transi* is the transportation quality, *Culi* is the cultural heritage factor, *IniPopi* is the initial population of the city, *Cityi* is the city size of the city, and *Infrai* is the infrastructural reason. The explanation of the variable and the respective data source is given in Table 2. Population data for 2020 was considered for the analysis. Data for the independent variables was collected for the most recent data available before 2020. Population data for 2010 and 2020, as well as population growth rates, are taken from World Urbanization Prospects (2018). Proximity variables like distances to airports, railways, and highways are measured with Google Maps. Environmental factors, such as CO2 emissions, annual temperature, and precipitation, are derived from the World Meteorological Organization. Institutional and infrastructure-related variables, such as the number of educational institutions and UNESCO heritage sites, are obtained from uniRank, government sources, and UNESCO records, respectively. The Inefficiency Index, which measures traffic congestion and commuting inefficiencies, is sourced from Numbeo's Cost of Living Database. In addition, population density and built-up area per capita are derived from UN-Habitat's Urban Indicators Database and author calculations. Appendix Table 2 presents the variable definition and data sources for each variable.

4. Regression Results

Table 3 shows the summary statistics of each variable used in the analysis. The coefficient of variation (CV) indicates the dispersion of data points in a series (Tripathi, 2019). The Coefficient of Variation value of urban population, port city dummy, distance to the airport, annual temperature, annual precipitation, CO2 emission index, and inefficiency index are low, indicating a more symmetric distribution. However, the remaining values have a comparatively high CV value. Data on most of the variables is available. However, certain variables, such as CO2 emission Index, Inefficiency Index, and Build-Up area per capita, were not available for every city.

Table 3 Summary statistics

Variable	*N*	*Mean*	*SD*	*Min*	*Max*	*CV*
Population 2020	85	10645.918	6173.941	5020	37393	.58
State Capital Dummy (SCD)	85	.541	0.501	0	1	.926
Port City Dummy (PCD)	85	.765	0.427	0	1	.558
Distance to the nearest airport (DNAir)	85	20.714	11.709	1.3	64.9	.565
Distance to the nearest railway station (DNRail)	85	5.295	4.958	.1	23.3	.936

Distance to the nearest highway (DNHigh)	69	18.311	15.198	2.2	86.7	.83
Number of UNESCO World Heritage Sites in the city (UNESCOWH)	85	1.212	1.807	0	9	1.491
Annual temperature 2019 (ANTemp)	72	19.106	6.157	5.1	28.4	.322
Annual Precipitation 2019 (AnPrecip)	71	1070.269	611.213	13	2777	.571
Population 2010 (POP2010)	85	8801.538	5536.078	3629.582	36859.626	.629
Population growth 2010-2020 (POPGrowth20102020)	85	24.036	16.481	-.763	76.871	.686
Population density (POPDEN)	85	9199.895	8983.609	847.03	57081.522	.976
CO2 emission in 2019 (CO2Index)	49	6352.233	2626.360	1181.5	11284.8	.413
Inefficiency Index (INEFIndex)	50	221.054	58.304	120.7	366.8	.264
No. of educational institutions (EDU)	85	30.671	26.082	3	148	.85
Built-up area Per Capita (BAPC)	62	129.812	153.623	11.956	705.517	1.183

Source: Author's calculation

Table 4 shows the raw correlation matrix. The correlation coefficient values show the quantifies the strength and direction of the linear relation between the variables. The results show that the urban population has a positive correlation with the state capital dummy, port city dummy, distance to the nearest railway station, CO2 emission index, Inefficiency index, annual temperature, annual precipitation (mm), number of educational institutions, population 2010 and population density while it is negatively related to distance to the nearest airport, distance to the nearest highway and build-up per capita. Table 5 shows the regression results, including OLS results with robust standard errors (to correct for heteroskedasticity) in parentheses and any multicollinearity issues that may exist. Initially, we used the population of the urban area in 2020 as the dependent variable.

Table 4 Correlation coefficient of the determinants of urban population growth

Matrix of correlations																
	Population2020	SCD	PCD	DNAir	DNRail	DNHigh	UNESCOWH	ANTemp	AnPrecip	POP2010	POPGro~0	POPDEN	CO2Index	INEFIndex	EDU	BAPC
Population2020	1															
SCD	0.129	1														
PCD	0.1668	-0.1815	1													
DNAir	-0.0907	0.1532	-0.0133	1												
DNRail	0.2528	0.2326	0.0117	-0.174	1											
DNHigh	-0.2059	-0.4221	0.0592	-0.3293	-0.1908	1										
UNESCOWH	0.1333	0.0722	-0.09	0.0526	0.0295	-0.1508	1									
ANTemp	0.1272	0.1721	0.0507	0.0139	0.3051	-0.3358	-0.2534	1								
AnPrecip	0.0958	-0.0391	0.2793	0.0393	0.1825	-0.0788	-0.2443	0.5413	1							
POP2010	0.9773	0.1056	0.24	-0.1598	0.2432	-0.1982	0.1375	0.0645	0.0983	1						
POP~20102020	0.1332	0.0767	-0.2989	0.396	0.1979	-0.1154	-0.0543	0.4317	0.0692	-0.0583	1					
POPDEN	0.4388	0.2033	0.0981	-0.1056	0.4063	-0.2816	-0.0517	0.372	0.3351	0.3742	0.3036	1				
CO2Index	0.1413	0.0668	-0.234	0.1262	0.0827	0.1068	-0.3207	0.1544	-0.0369	0.1271	0.1997	-0.0764	1			
INEFIndex	0.5741	0.3004	0.1126	-0.1594	0.2283	-0.1152	-0.2552	0.2393	0.213	0.5774	0.0321	0.521	0.5251	1		
EDU	0.4881	-0.0969	0.1528	0.1343	0.0084	-0.2155	0.2391	-0.3161	-0.0299	0.4629	0.0909	0.2916	-0.1718	0.1674	1	
BAPC	-0.0577	-0.1211	0.0948	-0.0631	-0.2562	0.3705	-0.1359	-0.2785	-0.2731	-0.0366	-0.1401	-0.2549	0.4143	0.1284	-0.2031	1

Source: Authors' calculation
Note: See Table 3 for variable definitions

Table 5 displays the regression results with the urban population of 2020 and the population growth rate from 2010 to 2020 as the dependent variables. The mean VIF value of regression models 1-6 indicates that there is no multicollinearity in the models. In the regression analysis, we find that the port city dummy has a negative effect on the urban population, which contradicts our hypothesis. The port city dummy's negative impact on urban populations can be attributed to various factors such as environmental pollution, congestion, high living costs, industrial land use, health risks, etc. These factors may make port cities less appealing for residential living. Apart from that, another interpretation of this relation can be that the cities considered in this analysis have already reached a saturation point in terms of benefits received from being a port city or having administrative power. For example, Mumbai, a major port city in India, experienced rapid growth in the 20^{th} century due to its strategic location and proximity. However, in recent years, its growth has slowed down because of problems such as infrastructural constraints, high population density, increased cost of living, etc., which limit its economic expansion. The proximity variables, such as distance to the nearest airport and distance to the nearest highway, have a positive effect on the urban population. This relationship could be due to the negative externalities of living close to these locations. According to Zhang et al. (2013), airports, railways, and highways frequently cause a lot of air and noise pollution, which can lower the quality of life. In urban planning, areas near airports, railroads, and highways are typically zoned for industrial and commercial use rather than residential. These zones are intended to accommodate businesses that benefit from proximity to transportation hubs, which will result in less residential development in these areas.

Annual temperature is significant at 1%, and it shows that if the annual temperature rises by one unit, the urban population (in thousands) rises by 168 units. This result is consistent with our hypothesis that warmer climates attract more people and is supported by Cheshire & Magrini (2005). The findings indicate that an increase in annual precipitation leads to a decrease in urban population because increased rainfall poses a risk of food or other issues that may degrade the quality of life. As expected, the initial population positively affects the urban population, which is corroborated by the results obtained by Glaeser et al. (1995). Cities with a larger initial population may have better infrastructure, established connectivity, a higher standard of living, and so on. This may attract more people, thereby increasing the urban population. A one-unit increase in the initial Population can increase the urban population by approximately 1219 units. Population density, one of the most crucial variables, positively impacts the urban population. This result is consistent with our expectations and the findings of Abhishek et al. (2017). This positive relationship could be attributed to agglomeration benefits such as better job opportunities, social amenities, and lower transportation costs associated with higher population density. Further, a one-unit increase in the number of higher educational institutions in the city also increases the urban population by 118.9 units, which is significant at a one percent level.

Table 5 Regression output with Population and Population Growth as dependent variable

Variables	Dependent variable					
	Population in 2020			Population growth 2010 to 2020		
	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
SCD	236.0		265.6	-0.724	-3.274	4.036
	(441.5)		(1,790)	(3.492)	(2.783)	(3.418)
PCD	-1,325**	-1,359**		-9.472**		
	(608.7)	(492.8)		(3.564)		
DNAir	62.88**	65.01***		0.612***	0.519***	
	(23.43)	(17.20)		(0.173)	(0.125)	
DNRail	3.859		531.3**	0.430	0.561**	
	(46.77)		(262.7)	(0.435)	(0.232)	
DNHigh	54.71**	52.33**		0.399***		
	(21.06)	(21.25)		(0.117)		
UNESCOWH	-26.88		392.0	-0.135		0.508
	(95.07)		(463.1)	(0.903)		(0.662)
ANTemp	168.8***	169.2***		1.571***	0.843***	
	(45.85)	(43.17)		(0.349)	(0.236)	
AnPrecip	-0.663*	-0.679**		-0.00557*	-0.00928***	
	(0.355)	(0.307)		(0.00281)	(0.00267)	
POP2010	1.231***	1.227***		-0.000160	-0.000617***	
	(0.0803)	(0.0685)		(0.000409)	(0.000215)	
POPDEN	0.0460	0.0454**		0.000294	0.000423**	0.000834***
	(0.0290)	(0.0185)		(0.000243)	(0.000187)	(0.000194)
CO2Index	-0.143	-0.157	-1.056**	-0.000354		0.00351***
	(0.230)	(0.120)	(0.433)	(0.00141)		(0.000938)
INEFIndex	-1.750		56.64***	-0.0190		-0.126***
	(8.298)		(18.90)	(0.0662)		(0.0400)
EDU	29.33*	27.27**		0.237*		
	(14.86)	(12.47)		(0.121)		
BAPC	1.840	1.773		0.0110		
	(1.839)	(1.409)		(0.0107)		
Constant	-4,363***	-4,392***	2,940	-19.53**	6.352	14.44*
	(1,014)	(907.3)	(4,375)	(8.493)	(4.767)	(7.856)
Observations	35	35	49	35	71	49
Mean VIF	2.42	1.84	1.39	2.42	1.26	1.70
R-squared	0.984	0.984	0.302	0.714	0.472	0.344

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Note: See Table 3 for variable definitions

Source: Authors' calculation

Unexpectedly, the Inefficiency index correlates positively with the urban Population. This could be because inefficiency caused by traffic congestion or excessively long commutes are most common in a city's central or key areas, which are easily accessible and strategically important. Regardless of the inefficiency, the proximity to central business districts, commercial hubs, and other key locations can make these areas appealing. For example, in cities like New York, traffic congestion is a big issue. Still, it remains a highly desirable place to live because of the opportunities it offers because of its proximity to central business offices, job opportunities, high standard of living, etc. Similarly, in the case of Indian cities such as Mumbai and Bangalore, traffic congestion is rampant, and this leads to longer commute times. Still, because of reasons such as proximity to the financial institutions and the status of "IT hub," respectively, these areas continue to attract more population. Many people are willing to trade off the inconvenience for the benefit of living in a thriving, well-connected city. The advantages of living close to work, schools, and amenities may outweigh the negative externalities of traffic. Furthermore, the findings indicate that an increase in the CO_2 emission index value reduces the urban population. This suggests that an increased level of pollutants can drive people away from urban areas.

With the urban population growth rate as the dependent variable, the state capital dummy is significant at 5%, and the relationship between the dummy and the dependent variable is negative. The reason for this could be that the cities used in the analysis are mostly from developed countries, and these cities reach a saturation point in terms of population, development, economic growth, and so on over time, potentially limiting further growth due to spatial constraints and higher cost of living. For example, cities like Paris, Japan, which are capital cities, have seen slow population growth in recent years due to high real estate prices, spatial constraints, congestion, etc. The proximity variables, distance to the nearest highways and distance to the nearest railways, are significant at one percent and show a positive relationship, similar to when we used population as the dependent variable. Annual temperature, annual precipitation, population density, and the number of educational institutions in the city all have a significant relationship with the dependent variable, as expected. The initial population becomes significant at 1% and has a negative impact on population growth. This is because cities with a higher initial population tend to grow more slowly than cities with a lower initial population since they already have a certain amount of infrastructure and facilities. At some point, they may approach saturation. The scope of development in such cities may be less because of the spatial constrain. The results demonstrate that the inefficiency index negatively influences population growth, which is consistent with our expectations. An important observation is that the inefficiency index has a positive effect on the urban population in 2020, but a negative impact on population growth. This indicates that, given a higher standard of living and more economic opportunities, people are willing to put up with the short-term inefficiencies brought on by traffic and longer commutes. However, over time, the negative externalities associated with these inefficiencies outweigh the benefits of living in a city. The CO2 Emission Index shows a positive impact because as cities grow, the amount of CO2 emissions may rise. Thus, an increase in CO2 emissions may indicate that growth is happening in the city.

4.1 Robustness test: Quantile Regression

To test the robustness of the results, the study uses quantile regression to examine how the impact of various factors on urban population growth differs across cities with varying growth rates. Unlike the OLS regression, which provides an average effect of the independent variable on the dependent variable, quantile regression allows us to study whether certain factors are more important or have a different impact on slow-growing or fast-growing cities (Croxford, 2016). Population growth has been used as the dependent variable as it offers better cross-city comparability while also reflecting a city's long-term attractiveness, economic vitality, and livability, making it a strong indicator of urban development.

Table 6 Regression Output for 25th and 75th Quartiles

Variables	Dependent Variable			
	POPGrowth2010-2020			
	25th Quartile		75th Quartile	
	Model 7	Model 8	Model 9	Model 10
SCD	4.499	-4.891*	-8.808**	
	(2.774)	(2.755)	(3.621)	
PCD	-7.797**		-8.523**	
	(2.756)		(3.598)	
DNAir	0.666***		0.882***	
	(0.129)		(0.169)	
DNRail	0.159	0.0989	1.680***	
	(0.265)	(0.299)	(0.345)	
DNHigh	0.414***		0.710***	
	(0.106)		(0.139)	
UNESCOWH	0.113	0.817	1.312*	
	(0.577)	(0.597)	(0.753)	
ANTemp	1.235***		2.479***	
	(0.267)		(0.349)	
AnPrecip	-0.00618***		-0.0124***	
	(0.00208)		(0.00272)	
POP2010	-0.000468	-0.00124***	-0.000829**	
	(0.000292)	(0.000321)	(0.000381)	
POPDEN	0.000500***		9.82e-05	0.000949**
	(0.000174)		(0.000227)	(0.000360)
CO2Index	0.000688	0.00203***	-0.00190	0.00505***
	(0.000904)	(0.000734)	(0.00118)	(0.00163)
INEFIndex	-0.00460	0.0662*	0.0413	-0.156**
	(0.0392)	(0.0359)	(0.0512)	(0.0707)
EDU	0.165**		0.221**	
	(0.0727)		(0.0950)	
BAPC	0.00264	-0.0322***	0.00420	-0.0308
	(0.00988)	(0.0105)	(0.0129)	(0.0212)
Constant	-25.68***	1.846	-31.36***	25.05**
	(8.439)	(5.379)	(11.02)	(10.50)
Observations	35	39	35	39

Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Note: See Table 3 for variable definitions

Source: Authors' calculation

At the 25th quartile, transport connectivity variables such as proximity to highways and airports play an important role, but the impact is lower than that in high-growth cities. Furthermore, climate variables such as annual temperature have a positive effect on population growth, whereas annual precipitation has a small but significant negative effect. This suggests that rainfall may present challenges in cities that already experience low population growth. The number of educational institutions in the city and CO_2 emissions have a comparatively lower impact in slow-growing cities, suggesting that these challenges may not be as severe in cities with comparatively lower growth rates. At the 75^{th} quartile, proximity to transport infrastructure and climatic factors have a greater impact, suggesting that in rapidly growing cities, transportation and climatic conditions play a more significant role. Population density becomes significantly positive, indicating that higher-density cities attract new residents, majorly due to the economic opportunities and facilities that these cities provide. CO_2 Emission Index and Inefficiency Index have a greater impact at the 75^{th} quartile, confirming the hypothesis that rapid urbanization may lead to increased inconveniencies, which may eventually slow growth in the long run.

The results of the 50^{th} quartile (median regression) are mostly consistent with the OLS estimates, confirming the results of the OLS regression and the fact that the overall effects hold true across the distribution. However, certain factors, such as the proximity variables and climatic conditions, are different in terms of significance and the overall magnitude, suggesting that the OLS alone cannot capture the complexities in the urban growth patterns.

Table 7 Regression Output for 50th Quartile

Variables	Dependent Variable		
	POPGrowth2010-2020		
	Model 11	Model 12	Model 13
SCD	-1.132		
	(5.335)		
PCD	-11.85**		
	(5.301)		
DNAir	0.806***		
	(0.248)		
DNRail	0.290		0.732*
	(0.509)		(0.421)
DNHigh	0.563**		0.107
	(0.204)		(0.147)
UNESCOWH	-1.132	0.0285	2.423**
	(1.110)	(1.055)	(1.180)
ANTemp	1.708***		1.233***
	(0.514)		(0.404)
AnPrecip	-0.00797*		
	(0.00401)		
POP2010	0.000119		-0.00118**
	(0.000561)		(0.000452)
POPDEN	0.000248	0.00101***	
	(0.000335)	(0.000314)	
CO2Index	-0.00158	0.00484***	
	(0.00174)	(0.00142)	
INEFIndex	0.0282	-0.149**	
	(0.0755)	(0.0615)	
EDU	0.180		0.154
	(0.140)		(0.101)
BAPC	0.00147	-0.00439	
	(0.0190)	(0.0184)	
Constant	-24.32	13.58	-4.963
	(16.23)	(9.767)	(11.06)
Observations	35	39	64

Standard errors in parentheses
*** $p<0.01$, ** $p<0.05$, * $p<0.1$
Note: See Table 3 for variable definitions
Source: Authors' calculation

5. Conclusion

In our study, we sought to examine the urban population growth across all cities globally with several geographical, environmental, demographic, political, spatial, and other variables clearly indicated. Regression models were used to assess how selected variables influenced the urban population in the year 2020. OLS and qantile regression models are used to estimate the relationship between the selected independent variables and the urban population. An additional significant variable added to the study is the inefficiency index, which illustrates the inefficiencies brought on by longer commutes and traffic jams.

Summarizing the results of our analysis, the proximity variables, inefficiency index, annual temperature, the initial population, population density, and the number of educational institutions contribute to the increasing population in cities. There was no significant evidence showing that the capital state dummy, the number of UNESCO World Heritage sites within the city, and the built-up area per capita affect the urban population. Port city dummy, annual precipitation, and CO_2 emission have a negative effect on the urban population. In the case of population growth rate, proximity variables, CO_2 emission, annual temperature, population density, and the number of higher educational institutions increase population growth. In contrast, the inefficiency index, initial population, annual precipitation, and build-up area per capita have a negative effect on the population growth rates in cities. State capital dummy and the number of UNESCO world heritage sites in the city have no significant impact on the population growth rate of cities.

The study uses quantile regression to explore the impact of factors on urban population growth for cities with different rates of growth. It concludes that transport connectivity, climate variables, educational institutions and CO2 emissions have a different impact on cities. Transport connectivity and climate factors play a larger role in high-growth cities. Higher-density cities draw new residents due to economic opportunity. However, the CO2 Emission Index and Inefficiency Index were more influential, indicating a downside of rapid urbanization with increased discomfort and slow development. The findings for the 50th quartile were broadly consistent with those of OLS estimates.

Given the study's limited scope, the findings have various policy implications. The educational variable has a significant effect on urban populations. This suggests that for a city to grow, the government should aim to invest in education to stimulate innovation and aid in the city's growth. Another major recommendation is that, given the growing issue of climate change and environmental pollution, actions should be taken to ensure sustainable growth. Promoting urban green spaces and sustainable building methods can help to support this goal further. The government must encourage using green fuels and other renewable energy sources to reduce emissions. The government should also develop more effective public transportation systems to reduce traffic congestion, an increasing concern. Investing in public transportation will not only alleviate traffic congestion but will also boost economic activity by improving accessibility. The government should also encourage the usage of electric vehicles and provide the necessary infrastructure to support this transition.

Measuring urban economic growth is not possible because of data unavailability. Additionally, the study could not use panel data for the same reason. Furthermore, several potential urban growth drivers, such as economic opportunities provided by the city, cost of living-related factors, and availability of social and public infrastructure, are excluded from our study owing to a lack of data. Additional data on the independent variables may help better understand the influence of these factors on the urban population.

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Appendix

Appendix Table 1: List of cities included in the study

Tokyo, Delhi, Shanghai, São Paulo, Mexico City, Dhaka, Cairo, Beijing, Mumbai, Kinki M.M.A. (Osaka), New York, Karachi, Chongqing, Istanbul, Buenos Aires, Kolkata, Lagos, Kinshasa, Manila, Tianjin, Rio de Janeiro, Guangzhou, Lahore, Moscow, Los Angeles, Shenzhen, Bengalaru, Paris, Bogotá, Chennai, Jakarta, Lima, Bangkok, Hyderabad, Seoul, Nagoya, London, Chengdu, Tehran, Chicago, Nanjing, Ho Chi Minh City, Wuhan, Luanda, Ahmadabad, Xi'an, Kuala Lumpur, Hangzhou, Hong Kong, Dongguan, Foshan, Riyadh, Shenyang, Surat, Baghdad, Suzhou, Santiago, Dar es Salaam, Pune, Madrid, Haerbin, Houston, Dallas, Toronto, Miami, Belo Horizonte, Singapore, Khartoum, Atlanta, Johannesburg, Philadelphia, Qingdao, Dalian, Barcelona, Kitakyushu-Fukuoka M.M.A., Saint Petersburg, Jinan, Yangon, Zhengzhou, Washington, Alexandria, Abidjan, Guadalajara, Ankara, Chittagong.

Source: Authors' compilation

Appendix Table 2: Explanation of data used in the regression

Variable	**Description**	**Data Source**
Population 2020	Population of urban agglomerations	World Urbanization Prospects 2018
Population Growth	Growth of population in urban agglomerations from 2010 to 2020	World Urbanization Prospects 2018 and author's calculations
State Capital Dummy	State capital dummy is the dummy variable that shows whether the city is the capital of a certain province or not, where 1 means the city is a capital city, and 0 means the city is not a capital city.	Author's Calculations
Port city Dummy	The port city dummy shows whether the city is a port city, where 1 = city is a port city and 0 = city is not a port city.	Author's Calculations
Distance to the nearest airport	Distance to the nearest airport	Google Maps
Distance to the nearest railway station	Distance to the nearest railway station	Google Maps
Distance to the nearest highway	Distance to the nearest highway	Google Maps

CO2 Emission Index (2019)	The CO_2 Emission Index estimates CO_2 emissions attributable to daily commutes by passengers. The measurement unit is grams for the return trip. (*About Traffic Indexes*, n.d.)	Numbeo's Cost of Living Database.
Annual temperature (2019)	Annual temperature refers to the average temperature recorded in the city in a particular year.	World Meteorological Organization's World Weather Information Service and Climate-data.org
Annual Precipitation (mm) (2019)	Annual precipitation (mm) measures the total rainfall received in a year, expressed in millimeters.	World Meteorological Organization's World Weather Information Service and Climate-data.org
Number of Educational Institutions	The number of educational institutes includes the number of higher educational institutions in the particular city.	4icu.org (uniRank) and respective Government database.
Inefficiency Index (2019)	The Inefficiency Index estimates inefficiencies in a city's traffic system. High inefficiencies are usually a sign of excessively long commutes or a preference for private automobile use over public transit. It can be used to measure traffic components in economic analyses (*About Traffic Indexes*, n.d.).	Numbeo's Cost of Living Database.
Number of UNESCO World Heritage Sites in the city	Number of UNESCO World Heritage Sites in the city	UNESCO World Heritage Centre
Population 2010	Population 2010	World Urbanization Prospects 2018
Population density	Population density is the number of people living per unit area, typically expressed as residents per square kilometer. It is calculated as	Author's Calculation

	Population Density = Total Population / Total Area.	
Built-Up Area Per Capita (m2 per person)	"Built-up area" is defined as the presence of buildings (roofed structures). This definition largely excludes other parts of urban environments or human footprints, such as paved surfaces (roads, parking lots), commercial and industrial sites (ports, landfills, quarries, runways), and urban green spaces (parks, gardens). (OECD, 2024)	UN-Habitat- Urban Indicators Database

Source: Authors' compilation