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Rank Size Rule Analysis on the Urban Population Distribution of Indonesia for the Year 2020

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Abstract
The rank-size rule which is known as Zipf``s law is an interesting research topic in the field of urban and regional studies. Conclusions are drawn based on the parameters that examine people and their economic activities in a particular city. this study aims to assess the unique urban development and population distribution of Indonesia by taking into account the complex socioeconomic system and geographically different archipelago. This study uses demographical data from various cities in Indonesia to understand the hierarchal pattern of population distribution in urban areas. Furthermore, Indonesia is an interesting case study regarding urban economics since it has a vast geographical area and contains different cultures and economic activities. The main objective of this research is to understand the population distribution and to evaluate the accuracy of the rank-size rule model in this country. This research also aimed to identify the main factors that deviate the population distribution from the rank-size rule distribution. It is particularly important to develop practical policies on the urban development issues. The minor variations of population distribution in Indonesia from the rank-size rule model are a good tool for decision-makers to allocate resources, develop infrastructure, and contribute to sustainable urban expansion. In addition, this study is significant for understanding how the urban centers developed in Indonesia and how they interact with broader socio-economic perspectives which is essential for further urban development and wise decision-making.

Keywords: Zipf`s Law, Rank-size rule, urban hierarchy, Indonesia, population distribution, economic activity, urban studies, socioeconomic dynamics, city size distribution, sustainable urban development, infrastructure investment, urban planning, policymaking.

Introduction

The rank-size rule model is a significant topic in urban development. It explains that urban development follows a predictable pattern in which the largest city is twice the second largest city and three times the third city. Despite the earlier criticisms and vast differences in the geographical areas, the rank size rule is followed with little variations in Indonesia. The main objective of this research is to understand the population distribution pattern in Indonesia's urban centers and assess whether or not it gives us valuable information about population distribution.

Indonesia is made up of more than 17000 islands with different cultures and languages. The ranking size rule is put into doubt in Indonesia which reflects the diversity of this country. Despite lots of issues like geographical restrictions, historical reasons, and regional variations, the population distribution of Indonesia is more balanced in contrast to the anticipated pattern. Planners and politicians need to take into consideration the population distribution in the urban centers of Indonesia when addressing some major demographical and socioeconomic challenges.

The rank-size rule is significantly important to Indonesia, especially in this period of rapid technological advancement, economic growth, and urban development. Although the model`s simplified predictions are acknowledged and accepted with little variations in Indonesia still Jakarta emerges as a primate city in this country and needs further planning and policy-making decisions to balance this issue. To understand how the rank-size rule gives us valuable insights into urban planning, this research looked from a normative perspective. This study significantly contributes to the existing literature by examining the population

distribution pattern in Indonesia and providing policymakers and politicians with useful insight into the regional population distribution of this archipelago.

This study aims to answer two primary research questions comprehensively: does the urban population distribution adhere to Zipf`s law? Furthermore, what are the major factors affecting the urban population distribution across the country?

This research aims to address the disparities between previous researches about the suitability of the rank-size rule model in Indonesia. Previous researches indicates that the rank size rule is not followed by the population distribution in Indonesia. Therefore, this study is aimed to evaluate the suitability of the urban population of Indonesia to Zipf`s law. Contrasting to the previous studies, the current data shows that the rank size rule is met by the population distribution of Indonesia.

This variation reveals that urban development is a dynamic phenomenon, so consistent analysis is essential to assess the suitability of this model in the context of Indonesia. The contradiction of previous studies and recent data indicates that the urban environments of Indonesia are dynamic and they are shifting to the rank size rule. To handle this issue a thorough analysis of the urban population distribution is necessary. To accomplish such kinds of analysis, the most recent data, potential shifts in the trends of urbanization, and methodological improvements are essential. Hence, this study aims to fill the gap between previous studies and the most recent data and identify the main contributing factors that assist Indonesia in following the rank-size rule model.

This study explores the alluring dynamics of urban development in Indonesia by examining the country`s urban hierarchy through the presentation of two competing ideas. The first hypothesis which is the null hypothesis (H0), reveals that the urban hierarchy of Indonesia is not consistent with the pattern of the rank-size rule. This hypothesis put into question the accuracy of the rank-size rule in the context of Indonesia. On the other hand, the alternative hypothesis states that the rank size rule is followed in the population distribution of Indonesia, denoting a strong correlation between the hierarchy pattern of cities and the population distribution.

H0: the rank-size rule model is not followed in Indonesia.

HA: in Indonesia, urban development adheres to the rank-size rule model.

The main objective of this research is to assess the applicability of the rank-size rule in Indonesia. Therefore, this study is aimed to evaluate whether or not the rank-size rule model is applicable in Indonesia and explain factors that assist Indonesia in balancing urban development. The following points show the main objectives of this study:

- A thorough analysis of the rank-size rule model will be carried out by using the demographical data.
- This study identifies the major cultural, socioeconomic, and political factors that impact the population distribution in this country.
- Lastly, the findings' broader implications are evaluated in terms of policy suggestions for urban planning and development as well as their contribution to the Indonesian academic debate on urban studies.

This research aims to accomplish these objectives to further knowledge of Indonesian urban circles and offer insightful insights into the country's urban development.

Literature Review

When the distribution function with a given cost approximates logarithmically, as in the case of a gamma distribution with a small shape parameter, the Law of Zipf for metropolitan regions applies under central place hierarchies. Interestingly, the size distribution exhibits a tiny concavity, another widely recognized feature of the city size distribution. The same rules apply to firms under Zipf's law. This theory also predicts the NAS rule, confirming the observation of Mori et al. (2007) that Zipf's law and the NAS rule are identical under the hierarchy property (Hsu, 2008). Moreover, there is a claim that expressly links a central location hierarchy to Zipf's law. In other words, when there are enough levels and almost equal fractional increases in the goods supplied by two nearby city layers, Zipf's law is applicable. Even if more research uncovers different economic mechanisms for establishing the central location hierarchy, Zipf's law is still valid.

A key concept in urban geography and economics, the rank-size rule model has generated a lot of debates and attracted attentions in academic literature. According to the paradigm, which dates back to Zipf's observations in the 1940s, there is a steady and strong relationship between city rank and size, meaning that the largest city in a country or a geographical area is much larger than the second-largest city, and so on,

resulting in a hierarchical distribution of urban cities (Zipf, 1949). According to this theory, there should be an accepted pattern in urban systems where there are more smaller cities than larger ones in a country (Batty, 2006).

Some studies have evaluated the correlation between the rank-size rule and population distribution by considering the historical and geographical contexts. For instance, a study by Fotheringham and Wong in 1991 revealed that the rank size rule is different among the borders and political, economic, and historical variables affecting the urban population distribution. The intricate correlation between urban development and economic activities is further evaluated in a study by Bettencourt et al. (2007) and Arcaute et al. (2015) in which they evaluated the correlation between city size distribution and economic efficiency. They concluded that higher city-size distribution is accompanied by higher efficiency.

Urban centres and the population distribution in urban areas display a hierarchical pyramidal pattern in terms of size and spatial distribution (McCan, 2001). The city area with the highest rank ordering is referred to as the primate city, and it has the largest number of population. According to the hierarchy pattern of urban sizes, the next group of cities with comparable sizes is classified as the second largest city, the following group as the third city with the largest number of population, and so on.

In comparison to other developing countries, Turkey's rank-size distribution of cities is generally rather regular. Since 1945, the country's urban areas has evolved to become more compatible with the rank-size rule, particularly in light of the emergence of middle-sized cities from 1945 to 1975 that fell short of the rank-size rule's expectations. This change has occurred in due to the nation's economic growth and inclusion. The shift from an agrarian to an industrial and service economy has resulted in certain small cities being smaller in size and population, according to a recent analysis of city size distribution between 2000 and 2012. However, it is rationale to suppose that recent remarkable urban development and infrastructure development projects in Istanbul's centre and suburbs will significantly contribute to the city's "primacy" to be raised both today and in the future as it gets more appealing in the country (Kundak & Dökmeci, 2018).

According to a research by Asadi in 2019, The irregular city development dynamism and diverse population distribution in Iran's urban structure and geographical areas are confirmed by the reality that the country's urban growth process does not follow Zipf's law. Tehran, the capital city of Iran, has a population density that is much higher than other urban areas primarily because of its highly concentrated economy relative to other regions and its centralized administration, which extends beyond country borders.

According to a research by Bajracharya & Sultana in 2020, Developmental planning and policy enhancement in Bangladesh have historically neglected spatial techniques in favour of sectoral models. Using a spatial aspect could help create specific goals, execute SMART policies, and reveal development concerns that are particularly related to a given location. This approach will enhance cooperation and collaborations throughout governments. Nevertheless, there is frequently a lack of theoretical probes and poor execution of spatially precise ideas. Strong theoretical bases like Zipf's law could improve Bangladesh's urban development framework's spatial component and result in concentrated policies like Urban Growth Boundaries.

District Bundi is not subject to the regulations of rank-size rule model. The Zipf's rank-size rule is not followed by the expected or actual population of the Tehsil Headquarters in District Bundi. Because of its larger population than the other tehsil headquarters, the primate city of district Bundi contributes as the home of the Bundi tehsil headquarters. The other five remaining tehsil headquarters do not make any sense in terms of their population-to-rank ratio. Several geographical factors influence a region's population density and population distribution. Based on their actual population, Bundi and Keshoraipatan tehsils rank first and second in district Bundi. Additionally, these two tehsils have an established socioeconomic system. The variation in the distribution of population in district Bundi can be attributed to several factors, including different natural resources, agricultural output, industrial development, transportation infrastructure, job opportunities, and other socioeconomic opportunities. according to the ideal pattern of rank-size rule, the reason for Nainwa, Indergarh, and Hindoli tehsils' lower population is their relative lagging in relation to these facilities and opportunities (Dr. Gautam, 2022).

Likewise another research by Vishnu Pore in 2019 using Chi square test states that in Hatkangale, Shirol, Radhanagari, Bavda, and Shahuwadi tahsils, as well as in a larger number of observed rural settlements in tahsils, large settlement areas have fewer people than expected in terms of population rank. This gap is filled by middle-sized settlement areas, which have more people than expected, and a small number of smaller settlements, which have fewer people than expected by the rank size rule. Topographical differences have an

impact on this phenomenon's tahsil level variation, which culminates to socioeconomic diversity. Hence, the Kolhapur district of Maharashtra does not entirely contribute to the rank size rule; yet, the district's population distribution is still beneficial.

Another study which is done by Muhammad Firdaus & Annisa Fitria in 2010 states that the value of the Pareto exponents is not equal to 1, indicating that the rank-size rule is not followed in Indonesia. The concentration of city sizes is influenced by the level of agglomeration economies, local government spending, and the number of administrative cities. Participation in the labour force and the openness of the region have an impact on the distribution of city sizes in this country.

Methodology, Data, And Econometric Model Specification

This study evaluates the appropriateness of the rank-size rule on Indonesia's population distribution using the quantitative research approach. Regression analysis has been used to evaluate the complex relationship between city development and rank size-rule. The intricate relationship between the population of cities and their ranking is methodically interpreted through the use of cross-sectional data.

A. Data Source

In order to assess the fit between the population distribution of Indonesia and the validated rank-size rule model, data has been gathered from Badan Pusat Statistik (BPS). BPS is a trustworthy source of information on demographic factors. Because it uses the BPS as a data source to assess the link between the population distribution of Indonesia and the ranking of the cities, this study provides insightful information to academics, policymakers, and urban planners. We can learn a great deal about the complex relationship between Indonesian urban growth and the rank-size rule thanks to this methodology.

B. Data Analysis

Effective data calculation is made simple by the use of Excel for the rank-size rule computation. Furthermore, regression analysis has been performed using STATA in order to assess the complex association between the population distribution and the ranking size model. With the use of this method, we are able to thoroughly examine Indonesia's urban development characteristics. It is crucial that relevant methods be put into practice in order to advance the development of Indonesia's urban regions. This study aims to advance urban development and offer evidence-based recommendations for sustainable development in Indonesia through the application of this.

C. Variables and Econometric Equation

The dependent variable in this study is the corresponding population sizes, whereas the independent variable is the rank-size of Indonesian cities. The econometric equation models show the correlation between these two variables. This equation interprets and analyzes the effect of city ranking on the population distribution using the regression analysis approach. This gives us important information on Indonesia's population distribution in its urban areas. Through the analysis of this relationship, the equation contributes to our understanding of the factors influencing population distribution in urban regions and provides evidence in support of the development of evidence-based strategies for the extension of sustainable urban areas across the nation.

In the area of urban economics, Xi represents a city's rank, Yi denotes its population, allowing for an econometric exploration of the relationship between city size and rank in Indonesia.

The following is an explanation of the econometric equation.

$$\ln(Yi)=\beta_0+\beta_1\ln(X_i)+\varepsilon i$$

in the above-stated econometric equation;

- ln stands for the natural logarithm.
- β_0 is the intercept term.
- β_1 denotes the coefficient of the natural logarithm of the rank.
- εi is the error term

A common association between the equation $\ln(Yi) = \beta0 + \beta1\ln(Xi) + \varepsilon i$ and the rank-size rule is seen in economics and urban studies. According to the rank-size rule, when cities or businesses are ranked in declining order, their sizes typically exhibit a predictable pattern.

The natural logarithm of the size (population or revenue) of the ith city or enterprise is represented by the symbol ln(Yi) in the equation. The intercept term, denoted as β0, represents the predicted value of ln(Yi) in the case where ln(Xi) (the rank) is zero. The coefficient of ln(Xi), β1, represents the way in which a city's or firm's size varies with rank. The difference between a city's or firm's actual size and what the rank-size relationship predicts is captured by the error term εi.
This formula is useful for comprehending the distribution of market share among businesses or the sizes of cities within a nation. It enables scholars to measure the correlation between size and rank, offering valuable information on the distribution or concentration of economic activity in a particular setting.

Findings And Discussions

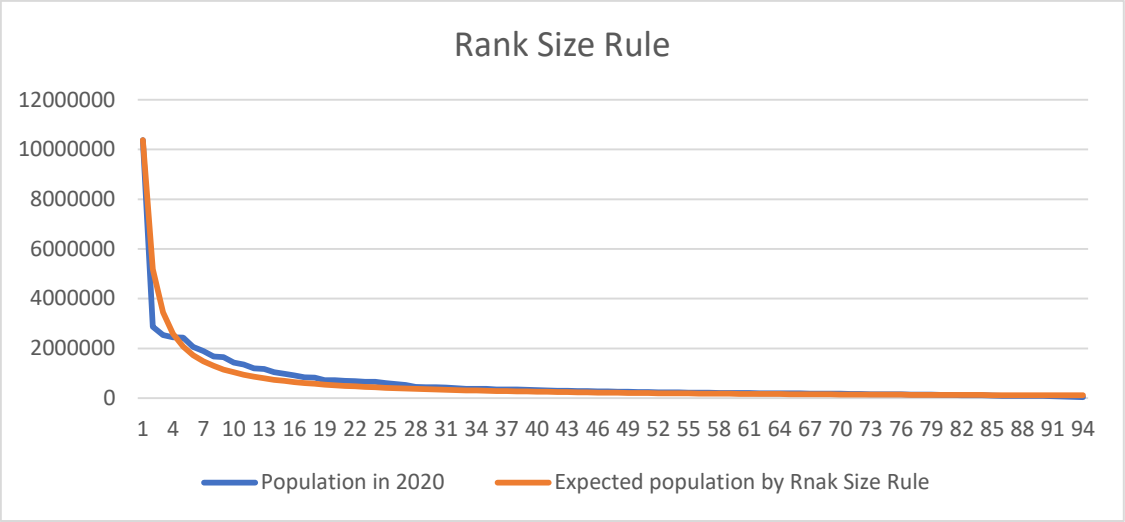
A. Calculation of rank-size rule

The graphical representation elucidates notable patterns in urban population distribution across various cities in Indonesia. Jakarta emerges as the city with the highest anticipated population, projected at 10373088 as expected population. Subsequently, Surabaya ranks as the second most populous city, boasting an urban population of 2874314 and an expected population of 5186544. The difference in population distribution between Jakarta and Surabaya denotes Jakarta as the primate city in this country. while Bekasi secures the third position with an actual population of 2543676 and the Expected population of 3457696. Bandung follows suit as the fourth city in terms of urban population, accounting for 2444160 people as its population and 472,776 as the expected population. The subsequent cities in descending order include Medan with a population of 2435252 and an expected population of 2074617.6, and Depok with 2056335 as the actual population and an expected population of 1728848. Considering the aforementioned figure, we can conclude that there are modest variations between the actual and expected populations, which account for the rank rule size being followed rather regularly in Indonesia's population distribution.

Table 1: calculation of rank-size rule

Calculation table for rank size rule				
City	**Population in 2020**	**Rank**	**1/Rank**	**Expected population by Rank Size Rule**
Jakarta	10373088	1	1.00	10373088
Surabaya	2874314	2	0.50	5186544
Bekasi	2543676	3	0.33	3457696
Bandung	2444160	4	0.25	2593272
Medan	2435252	5	0.20	2074617.6
Depok	2056335	6	0.17	1728848
Tangerang	1895486	7	0.14	1481869.714
Palembang	1668848	8	0.13	1296636
Semarang	1653524	9	0.11	1152565.333
Makassar	1423877	10	0.10	1037308.8
South Tangerang	1354350	11	0.09	943008
Batam	1196396	12	0.08	864424
Bandar Lampung	1166066	13	0.08	797929.8462
Bogor	1043070	14	0.07	740934.8571
others	**< 1 million**			
Total	**58160774**	**Sum(1/Rank)**	**5.13**	**53170583.64**

Graph 1: Real population vs expected population by rank size rule



Source: Authors Calculation

B. Regression analysis

Subsequent examination of the regression analysis yields insights into the Indonesia rank size rule model

Table 2: regression analysis of rank-size rule

Source	SS	df	MS	Number of obs	=	94
				F(1, 92)	=	1568.09
Model	75.1862644	1	75.1862644	Prob > F	=	0.0000
Residual	4.41118631	92	.047947677	R-squared	=	0.9446
				Adj R-squared	=	0.9440
Total	79.5974507	93	.855886567	Root MSE	=	.21897

logrank	Coefficient	Std. err.	t	P>|t|	[95% conf.	interval]
logpopulation	-.8899603	.0224742	-39.60	0.000	-.9345961	-.8453245
_cons	14.8771	.2862486	51.97	0.000	14.30858	15.44561

Source: Author`s Calculation

- Here we see that the p-value is close the zero which shows that the coefficient is statistically significant.
- and we also find out that t-value is t=(1-0.8899603)/.0224742) = 4.8962677 which shows that our model is statistically significant.

With a coefficient of roughly -0.8899603, the rank-size rule distribution in Indonesia is remarkably close to the theoretical predictions, demonstrating strong conformance to the model. This number, which is virtually equal to one, indicates that Indonesian city populations exhibit a hierarchical pattern that is quite similar to what is predicted by the rank-size rule. Following the rule indicates a structured distribution, mirroring a common pattern seen in many countries, with larger cities being much more populous despite being relatively fewer in number than smaller ones.

The value of the coefficient is also significantly important which is close to 1. This research gives us valuable information about the population distribution of Indonesian cities. The value of 1 for the coefficient describes the city population distribution, which indicates an efficient utilization of the resources. This efficient allocation of resources indicates a wise use of the resources and maximizes the potential of Indonesia in terms of urban development and planning.

The value of the coefficient essentially highlights a significant pattern in the Indonesian rank-size law model, indicating both the expected inverse relationship and the optimal distribution and use of resources as a result of the observed population diversity among ranks. This comprehensive analysis provides valuable information to policymakers and researchers to make wise decisions regarding urban development which greatly contribute to the environmental preservation and sustainability of this country as well.

Determinants Of City Size Distribution In Indonesia

A. Economic Factors

In Indonesia, several key economic factors are influential on the city size distribution. GDP per capita is a good indicator of urban development in Indonesia. It reflects economic growth and attracts more people seeking job opportunities and searching for higher standards of living. Cities with higher GDP growth attract more people and that will result in urban development. In addition, in the urban areas, several types of job opportunities are available which is another contributing factor in urban development. Cities which are the centers of economic activities provide people with a wide range of job opportunities in different sectors which in turn affect the movement of people in search of jobs and financial progress.

We can get a detailed understanding of the intricate correlation between economic dynamics and urban development from the interaction of these economic dynamics with the city ranking size. This study is also important to policymakers, urban planners, and politicians.

B. Socio-Cultural Factors

Among the most significant socio-cultural elements influencing urban development are employment prospects, cultural affinity, and lifestyle preferences. Furthermore, urban areas have a greater diversity of cultures, which influences this occurrence by drawing and keeping more people. Cities can choose their democratic models and processes of growth by serving as multicultural hubs and fostering inclusivity and diversity. In order to promote sustainable urban development in Indonesia, it is imperative to comprehend these social and cultural aspects. Through an analysis of the relationship between cultural variety indicators, migration trends, and the classification distribution of cities, this research aims to investigate the social and cultural elements that influence urbanization in Indonesia. This advances our knowledge of the variables influencing the distribution of city sizes.

C. Political Factors

Political considerations pertaining to government development programs and rules and regulations on urban planning also influence the size distribution of cities and urban development. Government laws and regulations shape resources, build infrastructure, and finance development initiatives, all of which have an impact on urban growth. An important way to learn about how cities react to laws, rules, and regulations is to assess the success of policies related to urban planning, economic development, and regional innovation. Furthermore, a nation's urban growth can be significantly influenced by the government's decision to carry out development initiatives in a given area. the ranking of cities and urban areas is greatly different as a result of the development of urban planning, infrastructure projects, and policies for economic development. The purpose of this study is to examine the political factors shaping urbanization in Indonesia by examining how regional planning and government policies affect the distribution of city sizes. This will help policymakers and urban planners to control the sudden change in urban development in the country.

Policy Implications

The result and the findings of this research have important policy implications for the urban development and planning of Indonesia. In order to develop plans and policies that support sustainability in Indonesia, policymakers take advantage of understanding the economic, sociocultural, and political elements that contribute to urban development.

- Currently, most economic activities are concentrated in the city centers. In order to balance urban development, more attention is needed to the expansion and development of smaller cities. Providing incentives and subsidies to companies based in smaller cities may help promote economic development, job opportunities, and balanced growth. this action will result in a balanced distribution of the population among the cities and help to achieve sustainability.
- Considering the highly influential factors of urbanization such as cultural diversity and migration patterns, politicians and policymakers should prioritize the development of inclusive societies. Programs such as cultural exchanges, community participation in basic works, preservation and care of cultural assets, and infrastructure development are all factors that contribute to the vibrancy of urban centers, and planners must include all of these simultaneously when working on urban development planning.

- The plans and efforts of the government to expand the infrastructure and economic activities between different regions will contribute to the balanced growth of cities, reducing the focus on urban centers and thus it will help the government to achieve its objective which is balanced and inclusive urban development.
- Strategic investments in infrastructure such as communication services, transportation, and other fundamental projects are among the solutions that help the governments support smaller cities and improve sustainable urban development. This gives the majority of people access to services, reduces inequalities, and contributes to balanced development
- Establishing resilient and ecologically friendly urban centers needs attention and investment in the regulatory frameworks for sustainable urban development. Land-use planning and environmental preservation organizations are all contributing factors to achieve this objective.

Conclusion

Finally, based on the findings of the regression analysis, the rank-size rule model provides us with valuable information about urban development, contributing factors to the population distribution and sustainable development of Indonesia. Through comprehensive research with statistical modeling, we now fully understand how economic, social, cultural, and political elements contribute to the current development of urban centers. Policymakers, urban planners, and researchers should know this information because it provides a framework for understanding migration patterns, urban growth, and demographic changes in many regions of Indonesia.

The Rank-Size Rule model's ability to illustrate the intricate connections between the various factors driving urbanization is what makes it so important. Economic factors like GDP per capita, employment possibilities, and income distribution largely affect how people are distributed in urban areas. Urban growth is also impacted by migratory patterns and cultural variety, which are the primary sociocultural factors. Additionally, political choices and government regional planning have an impact on population distribution and city development.

Future research and analysis on the variables influencing Indonesia's urban growth and the rank-size rule model are crucial. This necessitates examining regional variations, evaluating the impact of policy changes, and comprehending how global trends—like climate change and technological advancements—may influence patterns of urbanization. We can create more effective policies and initiatives to support resilient, inclusive, and sustainable urban growth in Indonesia by developing a deeper knowledge of these dynamics.

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