

POPULATION DENSITY AND THE ZIPF'S LAW: INSIGHT INTO NEPALI CITIES

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Abstract

This paper is focused to show there is population agglomeration in the context of Nepal along with a brief insight into other countries of the South Asian region on population agglomeration, also suggests some policy recommendations to accept the population agglomeration wisely. This study is a qualitative study that is conducted majorly reviewing the available literature. The finding of this paper suggests the population density of the major cities of Nepal follows Zipf's Law closely with an R² value of 0.958. It is observed that the concentration of population in a certain city is very high. Due to this population concentration, a particular city may face numerous problems. And, such population concentration doesn't come only with problems, there are some benefits that we can obtain from this concentration also.

1. Background

The development of a good city has long been an engineering and economic consideration with rare focus on mathematical attributes of the city". Looking at the world through mathematical eyes is that we can see certain patterns that would otherwise be hidden. The mathematics of cities was launched in 1949 when George Zipf, a linguist working at Harvard, reported a striking regularity in the size distribution of cities. Which says, the population of a city is, too a good approximation, inversely proportional to its rank (Zipf, 1932). Why this should be true, no one knows. If this law is validating, it suggests agglomeration. Marshall (1920) in his book defines Agglomeration as, the clustering or concentration of economic activity in a specific geographic area. This can include the clustering of industries, businesses, and people in a particular region or city. The term is often used in the context of urban economics, as it describes the phenomenon of cities and metropolitan areas becoming centers of economic activity and growth. Agglomeration can also lead to positive externalities such as knowledge spillovers and economies of scale.

The indicator of modernization and one of the viable processes of development is Urbanization. Around 56.121% of people in the world live in urban areas similarly 21% population of Nepal live in the urban area (United Nations Population Division, 2020). In the context of Nepal soon after the eradication of malaria in the Terai Region of Nepal and the construction of the East-West Highway along the plain belt contributed

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to high internal migration from the mountain and hilly regions to the Terai region around 1950(Gurung, 2011). The rapid increase of economically active population in a rural area, improved literacy status and willingness for employment in the corporate sector also induced the rural-to-urban migration. The influx of people into urban areas, coupled with limited resources, has led to a variety of problems in these areas, including a shortage of water, difficulties managing waste, and issues related to slums, among others. Poverty reduction contributes to an increase in urbanization, and rapid urbanization ultimately results in urban poverty.

This paper sets the objective to check the validation of Zipf's law which suggests population agglomeration and recommends policy for maximum utilization of agglomeration. The organization of the paper is done in such a way that subsection 2 discusses the methodology followed by Sub-section 3 where detail on zipf's law is discussed then in Sub-section 4 results and discussion are incorporated and finally in Sub-section five Conclusion and Recommendations are given.

2. Zipf's Law

Zipf's law for cities is one of the most clearly visible empirical facts in the economics, or in the social. The linguist George Zipf (Zipf, 1932), noticed something strange about how people often use words in a given language. He found that only some small numbers of words are repetitively used while the vast majority are used rarely. Where he ranked the words in order of popularity, a pattern emerged. The number one rank word was always used twice as often as the second-ranked word, and three-time as often as the third-ranked. He called this Rank vs Frequency rule.

Zipf's law also worked on the sizes of the cities. The city with the largest population in any country is generally twice as large as the next biggest and so on. The appearance of the distribution in rankings of cities by population was first noticed by Felix Auerbach in 1913, which later on gained recognition due to Zipf 1949, whom law also owes name (Mansury & Gulyas, February 2007). Generally to validate to the Zipf,s law data should have statistical properties that are both stable and persistent. Stability refers to the tight fit of $R^2 \approx 1$ (Mansury & Gulyas, February 2007).

To visualize Zipf's law in cities we take cities area and order the cities by the population, where the city with highest population is ranked one then following the same trend other cities are also listed. We then draw the graph (log-log scatter plot) with log of rank in x axis and log of population in y axis. We then see a straight line, which rather surprising. Furthermore, we find its slope -1 and R^2 value nearly 1. This can be seen in Krugman (1996) where he took 135 American Metropolitan area listed in the Statistical Abstract of the United States for 1991 and plotted and run a regression which showed slope close to -1 and R^2 value 0.986 which is very close to 1.

Similarly, some more literature such as Dobkins & Ioannides (1998) verified this in U.S context, and for most country in modern period is checked by Rosen & Resnick (1980). Rozman(1990) checked for the china in Mid Nineteenth century.

(Gabaix, 1999) present the equation for the Zipf's law in his paper which is as below :

$$P(\text{Size} > S) = \alpha / S^{\zeta} \text{ with } \zeta \approx 1$$

Where, ζ is slope, Size is the size of the city, S is the rank of city and α is constant.

In terms of the distribution author means that probability that the size of a city is greater than some S is proportional to $1 / S$.

3. Methodology

This study is based on the theoretical framework based on the previous literatures such as Krugman (1996), Gabaix(1999) and other. The theoretical framework is mentioned as above. In the other studies size of the city is considered which included the population but in this study the population density of the city is considered. To check the population concentration, here population density is considered. This study is done using the data in context to the Nepal to check whether the cities follow it or not. Introduction to Zipf's law in size distribution is done with the help of the available literature. A simple illustration to show there is urban agglomeration a regression estimate is done and graph was drawn and checked whether it fits Zipf's law or not and validation to Zipf's law suggests population agglomeration. The required population data and area of cities of Nepal for plotting the graph were obtained from the respective websites of Metropolitan cities, Sub-metropolitan cities, and municipalities and cities with population more than 75000 were taken and there were 44 such cities. Among 44 Cities – 6 metropolitan cities, 11 sub metropolitan cities, 27 municipality. A scatter plot was drawn to show the validity of Zipf's law for the population density of cities of Nepal. For achieving the second objective, analysis, discussions, and conclusions were drawn through the help of literature reviews done.

4. Result and Discussion

Figure 1 shows log-log scatter plot, plotted against Log of population density of cities of Nepal to the Log of Rank according to their population density.² The cities included in study are metropolitan cities, sub-metropolitan cities and municipalities with population of more than 75,000. Population density of 44 cities is taken in consideration.

2 Population per Square kilometer

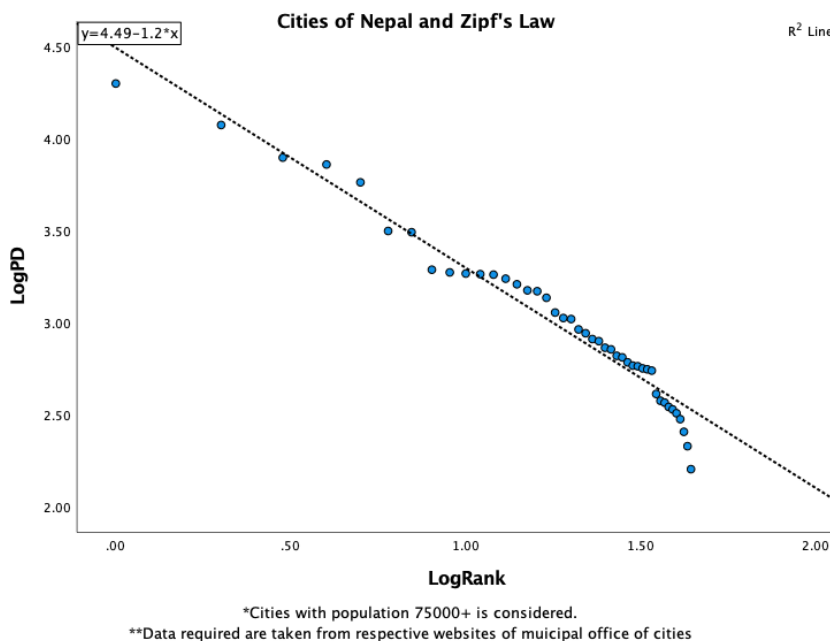


Figure 1. Cities of Nepal and Zipf's Law

The graph above approximately shows the validity of zipf's law. As(Mansury & Gulyas, February 2007) suggest, graph to statistically fitting $R^2 \approx 1$ validates zipf's law, in graph plotted for cities of Nepal with population more than 75000, fit line of $R^2 = 0.958$ is obtained which is approximately equal to 1. So, we can say that population density of the cities of Nepal follow this law.

The regression estimates of the analysis is:

$$\log PD = 3.6522 - 0.80126 \log Rank$$

In this estimate the slope parameter is highly significant and also near to 1 which validate the zipf's law. Looking to the data, the city with maximum population data is Kathmandu with population density of 19928.3/sq.km followed by population density of Bhaktapur-11861.8/sq.km. Similarly, Lalitpur being 3rd rank with population density of 7888.21/sq.km. We can observe a pattern: The population density of 2nd rank city is approximately half as 1st rank city also population density of 3rd rank city is approximately one third as of 1st rank city. Zipf's Law is intellectually exciting because it appears to be both powerful and mysterious. Gabaix in 1999 tried it with the size distribution to Metropolitan cities in United States and found that it fits with $R^2 = 0.986$ (Gabaix, 1999). Also, similar results was found in the study done by Mansury & Gulyas, for size distribution to metropolitan cities in US (Mansury & Gulyas, February 2007).

Zipf's Law is all about the agglomeration i.e., the attraction of people to more people. An initial population attracts more people who live nearby. That is, maximum concentration of people toward particular city. Study of Rosen and Resnick show that Zipf's law holds better the more carefully agglomerations are constructed (Rosen & Resnick, 1980). Similarly Gabaix also advocated the same (Gabaix, 1999). In the case of Nepal based on the above chart, cities of Nepal is approximately validating Zipf's law and suggesting agglomeration phenomenon.

4.1 Urban Population and Agglomeration

The United Nations defines an urban agglomeration as the buildup of the densely populated area containing the city proper, suburbs, and continuously settled commuter areas. It may be smaller or larger than a metropolitan area; it may also comprise the city proper and its suburban fringe or thickly settled adjoining territory. Urbanization is the process where an increasing percentage of the population lives in cities. It is projected that till 2050 the percentage of the population living in the urban area would be 68% and also reported that high concentration of urban population would be in certain countries only - India, China, and Nigeria; projected to accommodate 35% of the world's urban population.³ In 2020, the urban population for Nepal was 20.6%. The urban population of Nepal increased from 4% in 1971 to 20.6% in 2020 growing at an average annual rate of 3.40%.⁴ This shows the affinity of rural population to urban area rapidly in the Nepal.

4.2 Policy Context on Urban Development in Nepal

In Nepal, the Department of Urban Development and Building Construction (DUBDC) implements urban development plans and programs whereas the Ministry of Federal Affairs and Local Development (MoFALD) is responsible for administering the programs.

Though not enough to regulate urbanization, the first periodic plan has mentioned the resettlement and government housing policy. Nagar Panchayat Act 1962 was enacted during the second plan. Along with the Decentralization approach incorporated to coordinate with local-level activities, Town planning and building construction was the target of the Third Plan. The fourth Plan mentioned Housing plans for new settlements and also addressed the occurrence of traffic congestion and inconvenience in human mobility.

The Seventh plan incorporated a concrete vision of urbanization and habitat policy

3 2018 Revision of World Urbanization Prospects produced by the Population Division of the UN Department of Economic and Social Affairs (UN DESA)

4 World Data Atlas, KNOEMA

as the concentration of population in the urban area testified to the rapid process of Urbanization. This plan aimed to properly manage urbanization, create opportunities for productive employment and increase income to develop urbanization as a supplement to rural development based on a multi-sectoral approach. To promote urbanization, policies proposals that paid greater attention to the role of local panchayats, non-farm employment centers, long-term and short-term investment plans, self-sufficiency in local urban development, clean and pleasant urban environment, and attraction for the private sector toward urban development were proposed. The eighth plan recognized growth in urbanization in Nepal as the expansion of physical facilities but also regarded as a major contributor to the national economy. Urban Development Programs with strong participation of the private sector were also emphasized by the eighth plan. The tenth Plan emphasized Digital maps of all municipalities, healthy city programs, urban environment improvement projects, and environmental improvement(Devkota, 2012).

Currently, the 15th Plan is in action, which mentions Urban development with the Vision of sustainable economic and social prosperity through systematic urbanization; Goal is to develop accessible, prosperous, sustainable, and beautiful cities. This plan target development of social, physical, and economic infrastructure for improving the environment of existing cities; To make a directed investment for the development of the national urban system by identifying and utilizing all kind of resources. And expects development of three smart cities; development/expansion of new cities in four places within Kathmandu valley.

With the overview of the policy context in Urban Development, it can be found that no policy or plan is there to address maximum utilization of the concentrated urban population or no proper plan for utilization of this agglomeration. Policy research on urbanization that links urbanization with local governance is a usual practice in Nepal (Devkota, 2012).

4.3 Population Agglomeration and South Asia

In the South Asian regions, cities are in developmental processes. The trend of increasing level of urbanization in all countries of this region is expected to be maintained in the future as well. Also (Ansari, 2009) reports that there is a trend of population concentration in large cities in this region hence the number of megacities with ten million-plus population is increasing. And it is generally observed that there is a concentration of population in certain cities only in South Asian Region.

As we look at the population data of India, we can see that the population in Mumbai and Delhi is above 10 million, and cities like Bengaluru, Kolkata, Chennai are less than 5 million and the same follows for others. Similarly, in the context of Pakistan, Karachi has a population of about 11 million and the next biggest city Lahore

has a population of about 6 million then comes other cities like Faisalabad, Rawalpindi, Multan with a population of less than 2 million. Looking at the population data of Bangladesh, Dhaka is with a population of 10 million, and then a city like Chittagong, Khulna has a population of around one million then cities like Rajshahi and other cities have a population of less than one million. Sri Lanka has Colombo with a population of around 648 thousand then next big city Dehiwala-Mount Lavinia is with a population of around 219 thousand then other cities like Moratuwa, Jaffna, Negombo have a population of around 100 thousand only. As we look at population data of Afghanistan, Kabul accommodates around 3 million population and then 2nd biggest city Kandahar is with a population around 390 thousand and cities like Mazar-e Sharif, Herat less than that. Thimphu the capital city of Bhutan has a population of around 98 thousand and the next biggest city Punakha has a population of around 20 thousand and other cities like Tsirang, Phuntsholing has a population of around 18 thousand and less. In the Maldives, the capital city Male is with a population of around 100 thousand and then other cities like Fuvahmulah, Hithadhoo has a population of around 10 thousand only.⁵

The data mentioned above suggest that there is a concentration of population in certain cities only. We can see that roughly the population of the city in rank one is very high as compared to other following cities, which gives us the idea that population agglomeration prevails in the South Asian region. And it may also continue in the future, so it is not wise only to view agglomeration as a problem hence, a way to maximize the utilization of agglomeration should be done.

4.4 Cause of Population Agglomeration

Migration from rural to urban areas due to various factors results in population agglomeration in an urban area. According to (Devkota, 2012), urbanization in Nepal happened in three ways – by natural population growth, by rural-to-urban migration, and by the reclassification of rural areas to urban. The rapid increase in the number of the economically active population in rural areas, their improved literacy status, and raising aspiration for employment in the non-agricultural sector has increased the rate of rural to urban migration in Nepal. The urban population has been increasing mainly because of people's movement to towns and cities in search of service, facilities, opportunities, and employment. According to (Thapa & Murayama, 2010), the dynamic pattern of urban growth in Kathmandu has been influenced by seven driving factors: physical condition, public service accessibility, economic opportunities, land market, population growth, political situation, and plans and policies.

The study of spatial clustering of the population of the cities dates back as early as the 1920s, to study agglomeration (Fang & Yu, 2017). The degree of concentration

5 Population data of the cities of South Asia is extracted from World Population Review. Which can be accessed from <https://worldpopulationreview.com/countries>

of economic activity is striking. Roughly 75% of Americans live in cities as defined by the Census Department, and yet cities occupy only 2% of the land area of the lower 48 states. A similar story could be told for any other developed county: labor and capital are both heavily concentrated in cities (Rosenthal & Strange, 2004).

The Study of Glaeser, Kolko, & Saiz, (2001) put forward four fundamental ways that opportunity to consume results agglomeration. First, there may be goods and services available in the urban city, such as opera, and restaurants, and not available elsewhere. Second, the urban city may provide aesthetic charms like climates, architecture, and religious beliefs. Third, Large cities may allow the provision of public goods that wouldn't be possible in smaller places such as specialized schools. Fourth, a dense city allows the speed of interactions that wouldn't be possible in a smaller city, such as social interactions.(Glaeser, Kolko, & Saiz, 2001).

4.5 Advantages and Disadvantages of Agglomeration

There may be various causes as discussed above to result in population agglomeration in a certain urban area. According to (Marshall, 1920), the benefits of agglomeration are Sharing, Matching, and Learning.

Some infrastructures have fixed costs regardless of the number of users. Hence, with agglomeration higher number of users can utilize infrastructure more efficiently. Such as, transport and telecommunications infrastructure require huge public investment regardless of the number of users and one-time public investments become self-sustaining due to agglomeration economics. Hence by sharing some infrastructure, the maximum long-run benefit can be obtained.

Due to agglomeration huge pool of workers are available which tighten the competition, and is easier for firms or institution to choose the workers and hence offer a better match between workers and their jobs. This competition in the labor market results in better efficiency in the labor too. Hence productivity of both firms and labor can upgrade through the best match.

Learning and innovation is another benefit of agglomeration, it decreases the cost of the generation of new ideas and exchange of information. First of all, agglomeration results in the best match and workers of the best match learn from each other more quickly. Secondly, the rate of technological change may be faster as an employer in larger labor markets are more likely to invest in technology because they know they can find the specialized employees need to work.

Furthermore, (Boyko & Cooper, 2011) list the economic advantages of agglomeration as Increasing productivity level; Improving a city's economic efficiency

and employment opportunities; Enabling the use and extension of necessary urban services in an efficient and economical matter; Making better use of resources and existing infrastructures; Allowing for the technological and economic viability of certain energy technologies and transportation systems.

Along with advantages (Boyko & Cooper, 2011) list out some of the disadvantages of agglomeration as Costing more to build and maintain high-density projects than a medium or low-density project; Negatively impact the economic development of surrounding rural areas; Increasing the relative prices for dwellings, goods and services, and land; Exacerbating pollution, possibly because of reduced space for trees and shrubs that purify the air and cool the area; Congestion and Disruption; Reducing the capacity to cope with domestic waste and to recycle.

5. Conclusion

Based on this work, it is clear that validation to the Zipf's law for city indicates agglomeration and in the context to Nepal, with $R^2 = 0.958$ fit line (prepared during the study) we can conclude approximate validity to Zipf's law which suggests agglomeration phenomenon is developing in Nepal. The rational choice of humans is to seek further for their progress. In the 21st century, it is not wise to restrict population flow towards the urban area. Surely, the affinity of the population towards a particular city will increase with the increased level of literacy, need for employment, and other causes of agglomeration as listed above. So, it is not enough only to view the problems induced by agglomeration. Agglomeration is not only problem-inducing, but it also has several advantages as mentioned above. In the context of Nepal, it doesn't seem we can better utilize agglomeration. Here are some policy recommendations for effective use of Sharing, Matching, and Learning benefits along with other advantages. Agglomeration or density doesn't only come with problems that are difficult to address, but also with some economic benefit if utilized wisely. So, it is not wise to view agglomeration as a burden only. After analyzing the literature, the policy recommendation for best utilization of agglomeration can be suggested as follows:

Specialization and Diversity: Policy should identify, to which extent a city's employment should be specialized and hence plans should be made to produce specialized manpower along with a proper framework to diversify that manpower.

Industrial organization and business culture: Policy to improve the corporate environment should be developed to enhance the wage rate as well as the quality of life of the population.

Developed Public Infrastructure: As the number of people is high who will use public infrastructure, long-term benefits can be obtained from public infrastructure

which needs a huge initial investment. Hence policy should be made addressing this.

The Urban Rat- Race: (Rosenthal & Strange, 2004) used this term, Urban Rat-Race to address the phenomenon that cities can either inspire or require the hard work of their residents, a kind of urban rat race. This model is based on the idea that competition encourages individuals to work longer hours, which will be beneficial among youth professionals. The policy should incorporate plans to address this.

Development of Nearby Cities to economies benefit of agglomeration: By the benefits obtained from one agglomeration, policy should incorporate plans to develop nearby cities to create new agglomeration there and hence diversification of service, as well as density, can be done.

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