Power Law Signature in Indonesian Population
Empirical Studies of Kabupaten and Kotamadya Population in Indonesia

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Abstract

The paper analyzes the spreading of population in Indonesia. The spreading of population in Indonesia is clustered in two regional terms, i.e.: kabupaten and kotamadya. It is interestingly found that the rank in all kabupaten respect to the population does not have fat tail properties, while in the other hand; there exists power-law signature in kotamadya. We analyzed that this fact could be caused by the equal or similar infrastructural development in all regions; nevertheless, we also note that the first 20 kabupaten are dominated in Java and Sumatera. Furthermore, the fat tail character in the rank of kotamadya could be caused by the big gap between big cities one another, e.g.: Jakarta, Surabaya, and others. The paper ends with some suggestions of more attention to infrastructural development in eastern regional cities.

Keywords: power law, self-organized criticality, cities, population, urbanization, Indonesia

1. Background on Population Studies

We analyze cities in Indonesia but only concern most on respective population. In some countries, the population occasionally discussed on the cities (Gabaix, 1999; Anderson & Ge, 2003; Blank & Solomon, 2000, Henderson & Wang, 2003; Overman and Ioannides, 2000), however every country have their own criterion-defining on cities and any other regional areas to discuss the population with. For example, in the United States, an area called city when the population reached at minimum 2.5 million (U.S. Census Bureau, 2000).

Based on Indonesian law (Undang-Undang Republik Indonesia 22/1999) about regional autonomy, Indonesia region is composed by:

a) Daerah Tingkat I (Provinces)
b) Daerah Tingkat II or Kabupaten (Regionals)
c) Kotamadya (Municipals)

Daerah Tingkat I, kabupaten, and kotamadya have autonomy and without hierarchy among one another. In the rest of the paper we analyze the populations of Indonesia based on the latest two items, i.e.: kotamadya and kabutapen. According to the Indonesian law (Undang-Undang Republik
Indonesia 22/1999 chapter 1 section 1q), kotamadya is as an area, which its main activities are not agriculture and kabupaten is an area, which its main activities are agriculture.

According to the state governmental act (Peraturan Pemerintah 129/2000), the considerations of area to becoming kabupaten or kotamadya are:

i) Economic ability, such as GDP
ii) Potential sources, such as man-power, health facility, transportation facility, etc.
iii) Socio-cultures, e.g. number of theatre buildings
iv) Socio-politics, e.g. participation rate in general election
v) Populations number
vi) Area size

2. Basic Model
2.1 Mechanism of Creating Power Law

Power law is a function of the form:

\[ f(x) = f(1)x^{-\tau} \quad \ldots \quad (1) \]

where \( \tau \) is a constant. As analyzed in Situngkir & Surya (2003), power laws are known to occur at critical point on phase transition in physics. There are some circumstances emerging the power laws, e.g.: the self-organized criticality, the phase transition phenomena, and the highly optimized tolerance. In short, the discussion on the existence of power-laws in many occasions is opening the further advancement on the complex adaptive system (Per Bak, 1987).

We rank cities based on its respective population. Suppose a certain quantity \( x \) has a power law distribution, as in equation (1). The integral under the distribution from \( x \) to \( \infty \) is:

\[ R(x) = f(1) \int_{x}^{\infty} y^{-\tau} dy = \frac{f(1)}{1-\tau} x^{-\tau + 1} \quad \ldots \quad (2) \]

This quantity is recognized as the rank. If \( f(x) \) is the appropriate histogram of \( x \), then \( R(x) \) is a number of measurements that had a value greater than or equal to \( x \). In other words, if we number \( n \) measurements from 1 (greatest) to \( n \) (smallest), then the number given to a measurement \( x \) is \( R(x) \). We see that if \( f(x) \) is power law, then so is \( R(x) \). Often people plot a so-called rank plot, i.e.: \( R(x) \) is plotted versus \( x \). This is better than making a histogram, because it does not require us to bin the data - each data point is counted separately. In some circumstances, the rank plots can be also sometimes recognized as the cumulative distribution function (CDF).

Regarding to the Indonesian population, we recognize that the social system has the property of self-organized. People want to satisfy themselves (rather than maximize it; see Paul Ormerod, 2000:125). This fact leads to the urbanization on big cities, e.g. Jakarta, which is believed to offer more satisfactions and opportunities. Suppose there are \( i_1, i_2, \ldots, i_N \) individuals live in kabupaten or kotamadya. In Indonesia, there are \( M \) kabupaten and \( O \) kotamadya. Each individual \( i \) has experiental spaces of \( s_i \), thus the total experiental space is \( S = \{s_1, s_2, \ldots, s_N\} \), representing knowledge about places.
to live in. Decision of each individual \( i \) in time steps \( t \), \( D_i = \{d_i^1, ..., d_i^N\} \), could be whether to stay or to migrate. The decision is much influenced by the pay-off function as the function within experiential spaces and the decisions, \( \omega_i = f_i(S_i, d_i^t) \). Individual decides whether to live or to migrate in order to be satisfied, or mathematically \( d_i^t = \max \omega_i^t \). If individual \( i \) is not satisfied when living in kabupaten or kotamadya, he organize himself to migrate to another kabupaten or kotamadya until find the most satisfaction.

Let \( P_{kabupaten} = \{I_1, I_2, ..., I_M\} \) is a set of populations living in \( m \) kabupaten and they are ranked based on number of populations, index 1 for the biggest, \( M \) for the smallest. For kotamadya, we denote \( P_{kotamadya} = \{I_1, I_2, ..., I_O\} \), index 1 for the biggest, \( O \) for the smallest.

### 2.2 Analysis of Indonesian Population Data

Now, we analyze Indonesian cities population to see how many populations live in Indonesian cities. Here, we make a rank of kabupaten and kotamadya according to its population; the biggest population gets rank 1, the second biggest gets rank 2, and so on until the smallest. In this case, we will consider Jakarta as kotamadya since its main activities are non-agriculture. We make \( P_{(1)} \) the biggest, \( P_{(2)} \) the second, and so on, to have:

\[
P_{(r)} \approx r^{-\alpha}
\]

\[
P_{(r)} = P_1 r^{-\alpha}
\]

It is interesting that the rank plots of kabupaten do not show power law signature (see figure 1). Since it does not have the fat tail properties, we can consider it to be Gaussian in every census year (with \( \alpha \approx 0.5 \)), summarized in Table 1.

| Census Year | \( \alpha \) |
|-------------|-------------|
| 1961        | 0.5968      |
| 1971        | 0.4981      |
| 1980        | 0.5239      |
| 1990        | 0.598       |
| 2000        | 0.5706      |
In figure 2, we see that the ranked cities show power law signature. The coefficient $\alpha$ rises in the period of 1961-1990, but in 2000, it is below 1. For all $\alpha$ in each year, we summarized in Table 2.

| Census Year | $\alpha$   |
|-------------|------------|
| 1961        | 1.107      |
| 1971        | 1.14       |
| 1980        | 1.227      |
| 1990        | 1.072      |
| 2000        | 0.9882     |

In Figure 1, populations living in kabupaten per census year.

In Figure 2, populations living in kotamadya per census year.
From Figure 1, we can say that most populations in kabupatens are not only concentrated in few kabupatens only. It is contrasted to the result we have in kotamadya showing the power law signature. It means that most populations live in few kotamadyas only, i.e.: Jakarta, Surabaya, and Bandung and only small populations live in the rest of kotamadyas. Thus, we can say there is a big gap among kotamadyas in Indonesia. This probably comes from the gap of infrastructural development becoming the major factor that makes people migrate to Jakarta, Surabaya, and other major big cities. The gap, however, turns out to be the critical points among people that self-organizing to have better living. That is why we can recognize the self-organizing in critical points among people become the major reason of the emerging power-laws among cities in Indonesia.

Furthermore, beside economic reasons, there could be another reason explaining why people urbanize, e.g.: city attraction on the lifestyles within (see: Louis Wirth, 1938; George Simmel, 1971; Claude Fischer, 1975), the major development on transportation sector ease people (see: D.F Batten, 1995), or a myth that in cities there are many job opportunities. In the case of Indonesia, it is often heard that urbanized people were asked by their relatives to help running their business in cities.

3. Discussions

To see dynamics of population in more micro view, we plot kabupaten or kotamadya on its rank (increase or decrease), population, in respective years (from 1961 to 2000).

In figure 3, Kabupaten Bandung seems to dominate the 1st rank. We take Kabupaten Tangerang and Kabupaten Purwakarta as examples because they show fascinating phenomenon. Kabupaten Purwakarta in 1961 was the 6th, but in period 1971-2000, its rank dropped to around 80’s. It might be caused by the division of Kabupaten Purwakarta became two i.e.: Kabupaten Subang and Kabupaten Purwakarta; before the separation, most population lived in Subang. Another possible explanation is Purwakarta is a regional connecting three big
cities (Jakarta, Bandung, and Cirebon). Most lands in Purwakarta are used for farming, cultivation, and forestry. Instead of becoming farmer, people prefer to urbanize to Jakarta, Bandung, and Cirebon in order to seek another job opportunities. In other case, Kabupaten Tangerang, its ranks always hike in the period of 1961-2000, the main factor was the opening of many industries, such as shoes, fashions, et cetera. The openings of those industries attract many people to migrate.

In figure 4, we can see that big-three cities always hold the same positions from 1961 to 2000. None gives interesting pattern compared to Kabupaten Purwakarta and Tangerang. The big gap of development in Jakarta and other kotamadya leads people to urbanize to Jakarta, for it is the so called fact that people looking better opportunities that can only be offered by Jakarta.

How is the spreading of population among cities in Indonesia according to the facts of decentralized and centralized governance? We can see this property by plotting the evolution of cities normalized to Jakarta respect to the distance. Let Jakarta be a center of Indonesia \((d=0)\), and we plot the cities \((kotamadya)\) then plot the population according to its distance \(d\).

As showed in figure 5, we may divide the distances \((d)\) from Jakarta to several kotamadya into three emerging groups, i.e.:

A. \(0 < d < 500\) miles
B. \(500 < d < 1000\) miles
C. \(> 1000\) miles

Kotamadya in-group A \((0<d<500\) miles) shows the decreasing trend (1961-2000), e.g.: Bandung, Surabaya. It is convenient to hypothesize that many people urbanized to Jakarta looking for better living and opportunities, while the transportation facilities from Bandung, Surabaya to Jakarta ease people to urbanize. If we look back to our assumption, the self-organized criticality, then it is clear that Jakarta offer more attractions and opportunities on most people
to migrate, $d_i^j = \max \omega_i^j$. Kotamadya in group-B ($500<d<1000$ miles) is more interesting; some kotamadya' populations decrease, while in some places increase, e.g.: Medan. Medan is known as the biggest kotamadya in the island of Sumatera, and the economic activities are better than in others in the whole big island. In short, we can say that Medan is a major city in Sumatera and most people in Sumatera prefer to migrate to Medan than Jakarta because of the transportation cost is less while in the same time the culture in Medan is more related and similar to them. The kotamadya in group C ($d>1000$ miles); the trend of normalized population is relatively constant. We cannot justify that population in-group C are happy to stay there or the development is magnificent. It is much sound if we think that people have to spend expensive cost to migrate to Jakarta while not many people can do that – based on the minimum transportation development in these areas. We can say, in kotamadya C, there is local $\max \omega_i^j$ in each kotamadya that does not drive people to migrate to inter-kotamadya iii or to Jakarta. Interestingly, we can see that most cities in the group C is in the eastern region of Indonesia – a point showing the lack of infrastructural development in the period.

4. Concluding Remarks

We show that power law signature in kotamadyas of Indonesia that assumed to be caused by the self-organized criticality among people. People decide whether to stay or to migrate in order to be satisfied. If people live in kotamadya, but they are not satisfied, they would organize to migrate to another kotamadya offering better living according to their experiential spaces. In this case, the self-organization tends to place the critical situations among people to migrate or to stay to have a better living.

The population ranked in kabupaten-manner does not have fat tail properties, contrasted to the kotamadya, the power-law exists. The gaussian of

![Figure 5](image-url)

The distance and the populations living in several kotamadya
the rank of kabupaten shows that the major problem is not among regional but among cities. The power-law signature among kotamadya can be understood in accordance of big gap development amongst; believed to have better living, people urbanize to Jakarta. There is no way to stop the flow of the urbanization, since the attraction of big city will always promise better living. Regarding the discussions in the paper, we suggest that the government can break the migration flow by paying attention to the infrastructural development in other (remote) kotamadyas. Probably, a good project on this is the project of accelerating development in Eastern Indonesia.

**Further Works**

In further works, we want to make agent based modeling of regional mobility and poverty trap connected with population distribution in Indonesia. By looking at the micro level (agent) behavior, we want to see the result in macro level as aggregate. By doing this, we could make proper suggestion technical policies.

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