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Are Cities in Vietnam Distributed According to Zipf?

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Abstract

In this paper we test for congruence with Zipf's Law among cities, towns, and communes in Vietnam. Zipf's Law prescribes a particular distribution of cities when ordered by population. Much of the extant literature testing for Zipf's Law utilizes a methodology that has been shown to produce biased estimates in small samples. Here we employ the techniques recommended by Gabaix and Ibragimov (2007, 2011), and focus on 2009 census data of 156 urban areas in Vietnam. We find support for a distribution consistent with Zipf's Law based on the full dataset, and two subsets: cities only, and cities and towns.

Keywords: City populations, ordinary least squares, Pareto form, Vietnam, Zipf's Law

1. Introduction

Dating to the year 1913, Felix Auerbach, a German geographer noted a very interesting empirical regularity regarding the distribution of the population of cites in a given geographic area. Let rank (R) represent the rank of the city population (that is, for the largest city, R = 1, and for the second largest city, R = 2 …). If S equals the size of the city population, and S is normalized to 1 for the largest city, then $R \cdot S = 1$, approximately. This means than the second largest city (R = 2), would have ½ the population of the largest city; the third largest city (R = 3) would have ⅓the population of the largest city; and so forth. If Auerbach's observation is correct and S is not normalized, then $R \cdot S = A$, where A is a positive constant (and in theory equal to the population of the largest city). This empirical regularity has become best known as Zipf's law for cities based on his 1949 work—though Zipf's original work was on the frequency with which individual words were used. The remainder of the paper is organized as follows: in the next section (2) we provide a brief review of the literature; section 3 presents a description of the methodology utilized for the regressions; section 4 defines cities, towns, and communes, and describes the data set.; section 5 presents tests of the Law for Vietnam based on three variations on the dataset; finally, section 6 offers modest conclusions.

2. Brief Literature Review

The literature is replete with empirical tests of Zipf's law. Nitsch's 2005 summary paper includes 29 previous studies in his meta-analysis. Nitsch claims that many studies do not confirm Zipf's law (though he finds the mean estimate to be approximately consistent with the law). Most scholars, however, generally agree that Zipf's law does hold, at least for the largest cities in a given geographical area. Krugman's often cited 1996 paper confirms that the largest 130 metropolitan areas in the United States as defined by the Census Bureau conform to Zipf's law. As Krugman noted and Rosen and Rennick (1980) show, the more carefully cities are defined, the better is the fit of Zipf's law to the data. Many researchers have pointed out that cities are administratively defined, whether by political boundaries or census methods. In response to this critique, Rozenfeld, et al., in a series of papers (see Rozenfeld, et al., 2008, 2009, 2011a, 2011b) have proposed a method for constructing cites from a "bottom up" approach. They term their method the City Clustering Algorithm (CCA).

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This method identifies a city as " … a maximally connected cluster of populated sites defined at high resolution." (Rozenfeld, et al., 2011a, p. 2206). Briefly, this method starts with 61,224 population points for the US as defined by the US Census Bureau in 2001. Each point is identified by a FIPS (Federal Information Processing Standards) census tract code.

These points consist of populations ranging from 1,500 to 8,000 people. Once a point is chosen, a circle is drawn of a prescribed radius (e.g., 3000 meters) and points with a given density threshold are added to the city. The process is repeated from the centroid of the newly included points, until no additional points are added. The result is, then, a city. If a minimum "city" size of 12,000 inhabitants and a radius of 3000 meters are chosen, this method produces 1,947 city clusters for the entire US. Jiang and Jia (2011), also noting that cities are usually administratively defined, propose another alternative method. They employ a process to detect clustering based on street nodes (including intersections and ends) to define what they term natural cities for the entire United States. The method does not depend on Census definitions at all; rather it is also a "bottom-up" approach. Utilizing different "resolutions" they define as many as 4 million natural cities for the US. They then find that the entirety of their defined cities (not just the upper tail) conforms to Zipf's law.

We were able to find two papers that reference Vietnamese cities and test for Zipf's Law. Soo (2004), in a cross country investigation, finds against a Zipf distribution in a traditional test, and in favor based on the "Hill estimator." Soo's results differ from those we report here in several ways. First, those results are based on 1989 data—our data (2009) are much more recent. Second, our data set contains 156 observations, versus 54 cities in Soo's paper. Third, Soo does not utilize the methods suggested by Gabaix and Ibragimov (2007, 2011) to correct for bias in the estimation process. Jiang, Yin, and Liu (2014) define cities world-wide based on nighttime satellite imagery producing another version of natural cities. They define these "cities" in three time frames, 1992, 2001, and 2010. These authors find in favor if Zipf's Law for the entire world, most continents, and many individual nations. For Vietnam, however, they reject the hypothesis of a Zipf distribution for all three time frames. Below we present contrary evidence.

2.2 Attempts at Theory

Krugman also raises another important point regarding economic theory and empirical results. Generally, economic theory is most always simple and neat, whereas economic reality is often messy and complicated. With regard to Zipf's law, this relationship between theory and reality is reversed—in Krugman's words, "… we have complex, messy models, yet reality is startlingly neat and simple." Put plainly, there is (still) no convincing economic explanation (even with messy theory) of city populations' adherence to Zipf's law. Numerous attempts have been made to provide economic explanation for the frequently found regularity of Zipf's law applied to cities. Here we list only a few. Krugman (1996) employs Simon's (1955) urban growth model and is able to show that city populations could be consistent with a power law, but that model has difficulty in predicting with theory the coefficient of 1 that would represent a Zipf distribution. In short, the convergence process is infinitely long and requires unrealistic growth rates for some cities (see Gabaix, 1999, pp. 754-55 for a summary). Axtell and Florida (2006) apply a micro-foundations model capable of explaining a Zipf distribution of firm size and cities. The intuition of their model is that people co-operate to form firms and firms co-locate to form cities with the resulting population distribution conforming to Zipf's law. These authors admit that other models could be imagined that would give rise to similar results. Other research related to Zipf's law has proceeded in interesting directions. Some have suggested a connection to Benford's law, and, perhaps more productively, to Gilbrat's rule. That rule states that the size of a firm and its growth rate are independent. The result of such a process gives rise to a log-normal distribution. The upper tail (here largest cities) of a log-normal distribution conforms to Zipf's law (see Eeckhout, 2004 for more detail).Despite these and other attempts to match economic theory to the empirical evidence that confirms Zipf's law, it is fair to say that the general conclusion still holds: no theory has as of yet provided a definitive explanation for the congruence of city populations to Zipf's law.

3. Methodology

3.1 A General Approach

Given the proposition offered by Auerbach and Zipf, many empirical tests have been conducted seeking to verify (or contradict) Zipf's law. These tests usually take the following form. Repeated from the introduction, let $R_i \cdot S_i = A$, where i references the individual city, the following equation is estimated by ordinary least squares:

$\ln R_i = \ln A - \alpha \ln S_i$. (1)

If Zipf's law holds approximately, the estimate of α is close to 1. A represents the population of the largest city in the data set.

The form in (1) can (of course) be re-formulated with S on the left-hand side, with the coefficient to be estimated attached to R, clearly however, that coefficient would be expected also to be near 1 as well (it is the reciprocal of α) if Zipf's law were to hold. Nitsch (2005) calls equation (1), the "Pareto" form and the other formulation, the "Lotka" form. The existing literature includes many estimates of each type.

3.2 Hill's Method

As noted above with reference to Soo (2004), some papers, including Dobkins and Ioannides (2000) as well as Soo, utilize a method generally referred to as Hill's Estimator (see Hill, 1975) when testing for Zipf's Law. This method is a maximum likelihood estimator that produces an estimate of what we've called α under the hypothesis that population in a given urban area distribution follows perfectly a power law. However, the Hill method has also been shown to produce strongly biased estimates in small samples and also to underestimate the standard errors (Veneri, 2013, p 5, and Gabaix and Ioannides, 2004, p. 2349).

Because the ordinary least squares approach is both simple and robust, it has been the method utilized in the vast majority of studies testing for Zipf's Law. We also choose this method with the adjustments described in the immediately following sub-section.

3.3 A Methodology Adjustment

In their 2007 and 2011 papers, Gabaix and Ibragimov show that for small samples, the estimates of α in OLS regressions based on (1) are strongly biased, and the standard errors are underestimated. They further show that modifying rank by subtracting the constant ½ from each rank is an optimal remedy for the bias. These authors demonstrate this result numerically and offer a systematic explanation of the optimality of the rank − ½ adjustment in reducing the bias in the estimation of α to a leading order (see Gabaix and Ibragimov, 2011, p 26, Theorem 1).

They further show that the standard error of the α coefficient can be estimated (asymptotically) as

$$S_e = \sqrt{\frac{2}{n}} * \hat{\alpha}_n \, .$$

Gabaix and Ibragimov recommend that one should always use the rank − ½ adjustment (and the standard error just described) in OLS tests of Zipf's Law. In this paper we follow their recommendation and utilize these refinements for all of our estimations. Thus equation (1) simply becomes

$\ln (R_i - ½) = \ln A - \alpha \ln S_i$, (1′)

and is estimated by OLS.

4. Definitions and Data For Vietnam

In this section we describe the definitions of cities, towns, and communes in Vietnam and the data set we employ in the empirical tests.

4.1 Definitions

Vietnam is a Southeast Asian country with an estimated population of 90.5 million as of 2014. It is administratively divided into 58 provinces (Vietnamese: tỉnh) and 5 municipalities (thành phố trực thuộc trung ương) existing at the same level as provinces. The provinces are divided into districts (huyện), provincial cities (thành phố trực thuộc tỉnh), and district-level towns (thị xã), which are subdivided into commune-level towns (thị trấn) or communes (xã). The municipalities are divided into rural districts (huyện) and urban districts (quận), which are subdivided into wards (phường).

According to Vietnamese Government Decree No. 42/2009/NĐ-CP promulgated in 2009, urbanized areas (Vietnamese: đô thị) are categorized into 6 types: special type, and type I – V. The basic standards utilized to categorize urbanized areas are specialty (economics, military, culture…), population size (at least 4000 people), population density, non-agriculture employment rate (must be at least 65% employment rate), infrastructure system, and architecture and urban landscape.

Urbanized areas are ranked by scores. The higher the score of that area, the more urbanized the area. These scores are calculated based on the following categories: population size, area size, special factors such as poverty, ethnic group, religion. Government Decree No. 15/2007/NĐ-CP authenticates municipalities are ranked as urbanized areas special type and type I without scores due to their important roles. These cities have significant roles in economy growth and culture as well as important positions related to the military. They are Hà Nội [Hanoi] (capital), Hồ Chí Minh City, Hải Phòng, Cần Thơ, and Đà Nẵng. Provincial cities are usually urbanized areas type II, III. Towns are urban areas type IV while communes are type V.

4.2 The Data Set

The data used in this paper were obtained from the website, Thomas Brinkhoff: City Population, http://www.citypopulation.de. This site contains population statistics for many countries, administrative areas, cities and agglomerations dating from 1998 to the present. The full data set is contained in the Appendix.

We use the most recent census data (2009) containing the populations of 156 Vietnamese cities, towns and communes with more than 18,000 urban inhabitants. The 2009 data on City Population website actually originates from the General Statistics Office of Vietnam. Interestingly, Soo (2004) in his investigation also obtained data from this website (though obviously not the 2009 data), and he tested the data reliability by cross-checking with official statistics published by other statistics agencies such as UN Demographic Yearbook. For our purposes, the data set was later divided into subsets: cites only, and cities and towns.

In our initial data search, we encountered several sources with significant differences in population figures. For example, some sources have the population of Hanoi ranging from about 2.5 – 3 millions depending on the year of record while others have roughly 7 – 8 millions. As mentioned earlier, Hanoi is one of the municipalities, which are ranked at the same level with provinces. Subdivisions in Hanoi include one town (Sơn Tây), 12 urban districts and 17 rural districts, so that the total population of all subdivisions would reach up to approximately 8 millions. However, since Zipf's law focuses on urbanized areas, our census data set would match quite well with the basic requirements of Zipf's law. Hanoi's population in this census data contains only 12 urban districts. More urbanized areas in rural districts of Hanoi, such as Xuân Mai (commune in Chương Mỹ District, one of rural districts in Hanoi), Sơn Tây (town), Đông Anh (commune), Từ Liêm (commune), were included separately in the data set.

5. Results

Given the definitions presented above, we estimate 1′ for the entire dataset consisting of cities, towns, and communes. That data encompasses the population of all Vietnamese cities, towns and communes with more than 18,000 urban inhabitants according to census results. Since the original formulation of Zipf's law refers to cities, we also test for Zipf's law for a subset of the data containing cities only. Finally, we test cities and towns—excluding from the data communes as described above.

5.1 Cities, Towns, and Communes

The estimated equation for the full sample of 156 cities, towns, and communes is as follows:

$$\ln (R_i - ½) = 14.52 - 0.9621 \ln S_i \quad (2)$$
$$(0.1089)$$
$$\overline{R}^2 = 0.981$$
$$n = 156$$

The fit is impressive and the estimate of α is very near 1, indicating support for Zipf's Law for the full dataset.

The formal test for congruence with Zipf's Law is simply:

Ho: α = 1.00 (Zipf's Law holds)

Ha: α ≠ 1.00 (Zipf's Law does not hold)

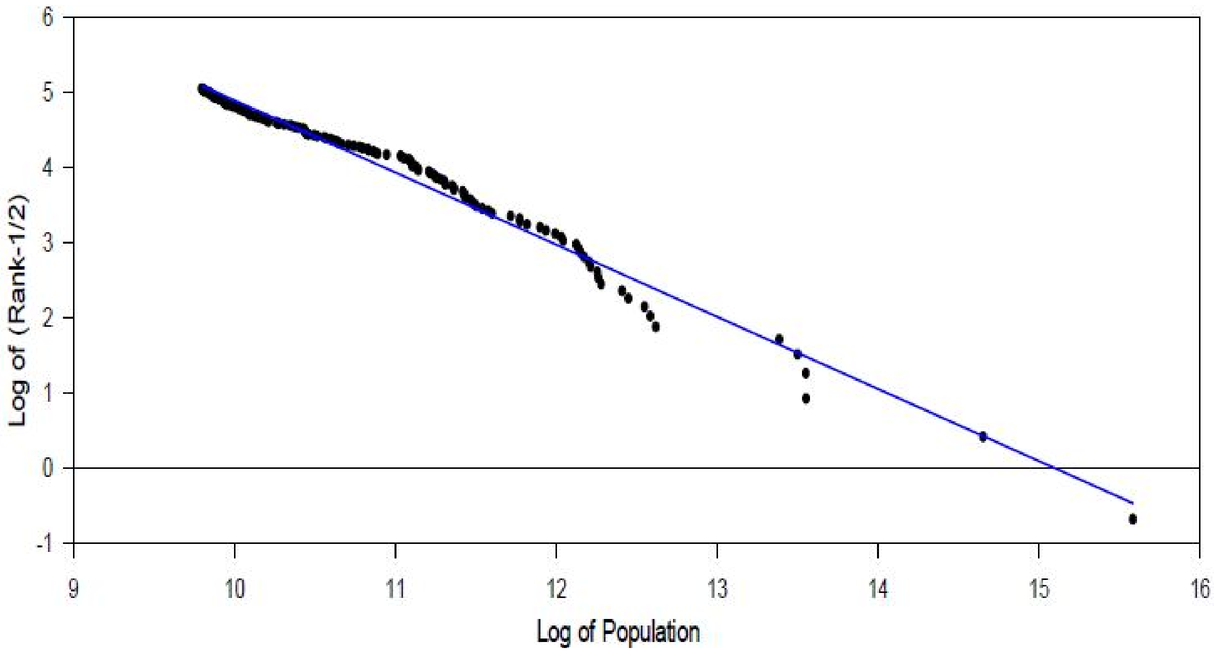
$$t = \frac{\hat{\alpha} - 1}{\sqrt{\frac{2}{n} * \hat{\alpha}}}$$

$$t = \frac{0.9621 - 1}{\sqrt{\frac{2}{156} * 0.9621}} = \frac{-0.0379}{0.1089} = -0.347$$

The null hypothesis is not rejected; thus Zipf's Law is confirmed for the full data set.

Figure 1 is the graphical representation of the regression.

Figure 1: Log of (Rank-1/2) vs. Log of Population, Vietnamese Cities, Towns, Communities



5.2 Cities Only

Here we present the results for the 60 Vietnamese cities, eliminating towns and communes from the estimation.

$$\ln (R_i - ½) = 15.956 - 1.0810 \ln S_i \quad (3)$$
$$(0.1974)$$

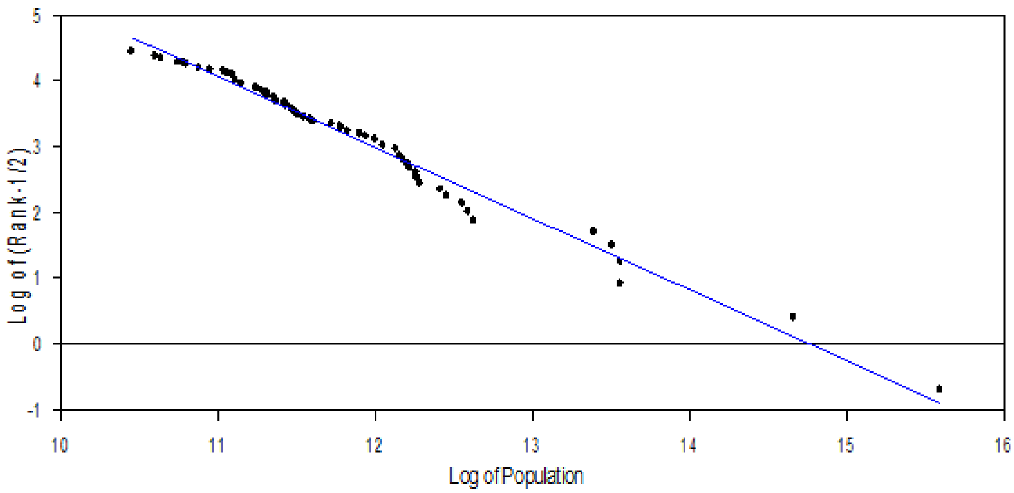
$$\overline{R}^2 = 0.981$$

n = 60

Again, the hypothesis that α = 1 for this regression is not rejected. The 60 cities from the data set in Vietnam conform to Zipf's law.

Below is Figure 2, the graphical representation of the cities only regression.

Figure 2: Log of (Rank-1/2) vs. Log of Population, Vietnamese Cities



5.3 Cities and Towns

The results for cities and towns are shown in equation 4.

$\ln (R_i - ½) = 15.059 - 1.0065 \ln S_i$ (4)

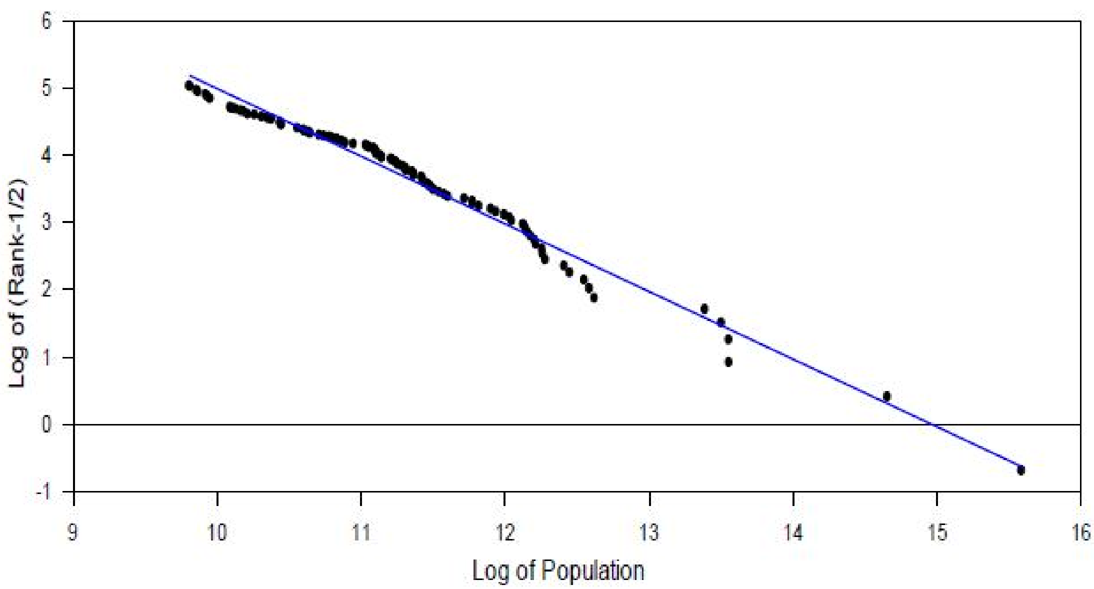
(0.1409)

$\overline{R}^2 = 0.979$

$n = 102$

Clearly, Zipf's law is again confirmed for cities and towns. The estimated coefficient is almost exactly 1, and of course does not differ from 1 in the statistical sense. Figure 3 shows the results of the regression for the combination of Vietnamese cities and towns.

Figure 3: Log of (Rank-1/2) vs. Log of Population, Vietnamese Cities and Towns



6. Conclusions

In this paper we test census data from Vietnam cities, towns and communes for congruence with Zipf's Law. Cities, town and communes are large urban areas within the nation.

Applying the corrections for bias suggested by Gabaix and Ibragimov (2007, 2011), we find strong evidence in favor of a Zipf distribution of these urban areas whether the test is for the full data set, or segregated into cities alone, or cities and towns. These conclusions differ in some respects to those found by Soo (2004) and Jiang, et al. (2015). The differences in our results and theirs can be ascribed to differences in methods and data, and in the case of Jiang, et al., very different data sources.

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Appendix: Population of Cities, Towns, and Communes (2009 Census)

City/Town/Commune	POP_2009	Rank	Status
Thành Phố Hồ Chí Minh [Saigon]	5,880,615	1	City
Hà Nội [Hanoi]	2,316,772	2	City
Đà Nẵng [Da Nang]	770,911	3	City
Hải Phòng [Haiphong]	769,739	4	City
Cần Thơ [Can Tho]	731,545	5	City
Biên Hòa [Bien Hoa]	652,646	6	City
Huế	302,983	7	City
Nha Trang	292,693	8	City
Vũng Tàu	282,415	9	City
Qui Nhơn	255,463	10	City
Long Xuyên	245,699	11	City
Vinh	215,577	12	City
Buôn Ma Thuột (Lạc Giao)	211,891	13	City
Rạch Giá	210,784	14	City
Hạ Long (Hòn Gai)	201,990	15	City
Thái Nguyên	199,732	16	City
Nam Định	193,768	17	City
Phan Thiết	189,619	18	City
Thủ Dầu Một	187,379	19	Town
Đà Lạt	184,755	20	City
Hải Dương	170,420	21	City
Cẩm Phả	168,196	22	Town
Pleiku (Plây Cu)	162,051	23	City
Phan Rang-Tháp Chàm	152,906	24	City
Thanh Hóa	147,559	25	City
Sóc Trăng	136,018	26	City
Mỹ Tho	130,081	27	City
Cà Mau (Quản Long)	129,896	28	City
Tuy Hoà	122,838	29	City
Bạc Liêu (Vinh Lợi)	109,529	30	City
Thái Bình	106,915	31	City
Vinh Long	103,067	32	City
Việt Trì	99,147	33	City
Tân An	98,157	34	City
Bạc Ninh	96,408	35	City
Quảng Ngãi	95,537	36	City
Châu Đức	92,667	37	Town
Ninh Bình	92,111	38	City
Bảo Lộc	92,036	39	City
Cao Lãnh	91,218	40	City
Kon Tum	86,362	41	City
Từ Sơn	86,289	42	Town
Cam Ranh (Ba Ngòi)	85,507	43	City
Đông Hà	81,951	44	City
Trà Vinh (Phú Vinh)	81,549	45	City
Tam Kỳ	81,396	46	City
Vinh Yên	79,547	47	City
Thuận An (Lái Thiêu)	77,406	48	Town
Lào Cai	76,836	49	City
Đồng Hới	76,058	50	City
Uông Bí	74,678	51	Town
Di An	73,859	52	Town
Hội An	69,222	53	City
Tây Ninh	68,979	54	Town
La Gi	68,562	55	Town
Bắc Giang	66,678	56	City
Son Tây	66,517	57	Town
Sa Đéc	66,485	58	Town
Bà Rịa	66,341	59	Town
Lạng Sơn	65,754	60	City
Hòa Bình	65,377	61	City
Hà Tĩnh	63,415	62	City
Yên Bái	62,441	63	City
Bến Tre (Trúc Giang)	61,968	64	City
Sơn La	56,848	65	City

Phúc Yên	53,795	66	Town
Tuyên Quang	52,927	67	City
Buôn Hồ	52,409	68	Town
Đồng Xoài	50,827	69	Town
Long Khánh	50,615	70	Town
Móng Cái	48,986	71	City
Hưng Yên	48,019	72	City
Điện Biên Phủ	46,362	73	City
Chí Linh	44,805	74	Town
Liên Nghĩa (Đức Trọng District)	42,898	75	Com
Hồng Ngự	42,101	76	Town
Vị Thanh	41,713	77	City
An Khê	41,523	78	Town
Bỉm Sơn	40,424	79	Town
Phủ Lý	40,139	80	City
Long Hải (Long Điền District)	39,000	81	Com
Cửa Lò	38,522	82	Town
Phan Rí Cửa (Tuy Phong District)	37,000	83	Com
Chu Sê	36,227	84	Com
Dương Đông (Phú Quốc District)	35,000	85	Com
Hà Giang	34,486	86	City
Tam Điệp	34,440	87	Town
Tân Châu	34,198	88	Town
Tịnh Biên	34,191	89	Com
Cao Bằng	34,165	90	Town
Mạo Khê (Đông Triều District)	34,000	91	Com
Mỹ Phước (Bến Cát District)	33,763	92	Com
Kiên Lương	32,837	93	Com
Sầm Sơn	32,184	94	Town
Hồng Linh	31,582	95	Town
Ngã Bảy	31,163	96	Town
Hà Tiên	30,077	97	Town
Liên Hương (Tuy Phong District)	29,000	98	Com
Sông Đốc (Trần Văn Thời District)	29,000	99	Com
Gia Nghĩa	28,609	100	Town
Gò Công	27,293	101	Town
Long Thành	27,084	102	Com
Từ Liêm	27,045	103	Com
Xuân Mai (Chương Mỹ District)	27,000	104	Com
Thái Hoà	26,472	105	Town
Sông Công	25,919	106	Town
Gò Dầu	25,865	107	Com
Diêu Trì (Tuy Phước District)	25,213	108	Com
Phước Long	24,994	109	Town
Bắc Kạn	24,344	110	Town
An Châu (Châu Thành District)	24,214	111	Com
Phú Thọ	24,204	112	Town
Phước Dân (Ninh Phước District)	24,144	113	Com
Núi Sập (Thoại Sơn District)	24,000	114	Com
Cai Lậy	23,974	115	Com
Buôn Trấp (Krông Ana District)	23,495	116	Com
Nhà Bè	23,463	117	Com
Mộc Châu	23,000	118	Com
Phú Mỹ (Phú Tân District)	23,000	119	Com
Đông Anh	22,757	120	Com
Vinh An (Vinh Cửu District)	22,505	121	Com
Bến Lức	22,474	122	Com
Phước Hải (Đất Đỏ District)	22,000	123	Com
Cái Vồn (Bình Minh District)	21,742	124	Com
Nam Phước (Duy Xuyên District)	21,641	125	Com
Tân Phú	21,050	126	Com
Ninh Hòa	21,013	127	Town
Bình Định (An Nhơn District)	21,000	128	Com
Tân Thành	20,901	129	Com
Thuận An (Phú Vang District)	20,671	130	Com

Ayun Pa	20,664	131	Town
Diên Khánh	20,659	132	Com
Minh Lương (Châu Thành District)	20,609	133	Com
Mỹ Xuyên	20,537	134	Com
Lai Châu	20,391	135	Town
Hoà Bình	20,054	136	Com
Đất Đỏ	20,000	137	Com
Phú Phong (Tây Sơn District)	19,930	138	Com
Củ Chi	19,573	139	Com
Định Quán	19,487	140	Com
Bình Long (An Lộc)	19,321	141	Town
Phước Long	19,307	142	Com
Tân Hiệp	19,299	143	Com
Nghĩa Lộ	19,111	144	Town
Trảng Bom	19,068	145	Com
Vạn Giã (Vạn Ninh District)	18,966	146	Com
Ea Drang (Ea H'leo District)	18,948	147	Com
Di Linh	18,912	148	Com
Mỹ An (Tháp Mười District)	18,706	149	Com
Long Điền	18,500	150	Com
Năm Căn	18,480	151	Com
Quảng Trị	18,254	152	Town
Cái Dầu (Châu Phú District)	18,244	153	Com
Sông Cầu	18,208	154	Town
Dầu Tiếng	18,196	155	Com
An Thới (Phú Quốc District)	18,000	156	Com