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# The application of expanded rank-size model in Turkish urban settlements

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# THE APPLICATION OF EXPANDED RANK-SIZE MODEL IN TURKISH URBAN SETTLEMENTS

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The objective of this paper is to analyze the structure of urban system in Turkey from 1980 to 1997 by using expanded rank-size model. The former studies related to rank-size model in Turkey have illustrated important hierarchical regularities in rank-size relationships. In these studies changes in city- size distributions over time examined noting differences in slope and intercept at the different points in time. Then, these results are interpreted to indicate growth (decline) in entire system of cities and the relative rates of growth (or decline) of large and small areas. However, according to the studies by Casetti, Maleki, Stephens and Holly, Strickland and Aiken, such casual inspection of coefficients can be misleading: First one is the insufficient of criteria related to identify statistically significant changes in coefficient. Second one is the obscurity of the particular dynamics of city-system change by the simple inspection of coefficients. In order to examine to strictly change in rank –size coefficient over time. In this paper, the expanded rank-size model is applied all of cities in Turkey and separately each regional level.

## I. INTRODUCTION

The rank-size distribution represents a model for evaluating a system of settlements that are undergoing changes in population (9). Although Auerbach (1) was the first to formulate the rank-size distribution, Zipf (12) popularized the model and his applications have led to many of the problems that persist in empirical rank-size research. The other studies related to rank-size rule have been continued by Berr and Garrison (3) and Beckman (2), etc.

The direction of slope and intercept value in rank size rule indicates growth (or decline) or within urban system. But Malecki (7), Stephens and Holly (10), Strickland and Aiken's studies (11) have pointed out that only rank-size model is not sufficient in explaining statistically significant changes in the coefficients and the particular dynamics of city system change. In city system intercept value and slope can change

over time for instance, the slope and intercept value can vary because larger cities have the most rapid growth with constant growth in smaller cities or intercept value can vary while slope remains constant because of an uniform rate of growth (or decline) in the city system. These situations are not easily explained by rank-size model. So, the expanded rank-size method was improved by Cassetti (4) in order to examine strictly the changes in coefficients over time. This model reformulated the rank-size model to include a time parameter so as to assess change in rank-size relations.

The main objective of this paper is to examine strictly the changes in coefficient in rank-size model of Turkey and its seven regions in between 1980-1997 periods.

## II. THE STANDARD LOGARITHMIC RANK SIZE AND EXPANDED RANK-SIZE MODEL OF CITIES OVER TIME

Since the 1950's, Turkey has undergone rapid urbanization and has developed a more integrated city system. The extent of this integration, the form in which is expressed, and the way in which it has changed over time provide useful insights into the nature and regularities of urban growth. In the period between 1945-1975 the patterns of distribution of cities in Turkey are quite regular when the other developing countries (5,6). Also, the development of city size distribution between 1980 and 1997 illustrated further adjustment to the rank-size rule (8).

The most normally used formulation of rank-size model is expressed as below:

$$\text{Log } P_i = \text{Log } C - q \text{Log } r_i$$

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$P_i$  = Population of center  $i$ ;

$r_i$  = rank of center  $i$ ;

$C$  = a constant approximately equal to the population of the center of rank 1;

$Q$  = the slope coefficient.

The plot of rank against size on double logarithmic paper should give a straight line with a slope of  $-q$ . The slope coefficient expresses the degree of concentration or dispersion of population within the urban system.

The standard logarithmic rank-size function (2) was fit to the data for 1980, 1985, 1990 and 1997. The results are given in Table 1 with  $t$ - values shown below each regression coefficient. The regression results exhibit an increasing intercept values, from 6.404 in 1980 to 6.770 in 1997. In addition to the slope of rank-size distribution has increase in four periods. From this analysis it is indistinct whether the change because of increasing population in larger cities faster than smaller ones or to an increase in populations of larger cities alone or decrease in the population of smaller cities.

Table 1 : Regression Equations, 1980-1997 for Turkish cities

Year	LogC*	Q*	R	R <sup>2</sup>
1980	Log P <sub>i</sub> =6.407 (902.265)**	-0.960 logr (284.430)**	0.998	0.996
1985	LogP <sub>i</sub> =6.521 (849.098)	-0.976 logr (277.889)	0.998	0.995
1990	LogP <sub>i</sub> =6.639 (943.387)	-0.991 logr (317.972)	0.998	0.996
1997	LogP <sub>i</sub> =6.770 (782,210)	-1.007 logr (271.325)	0.996	0.993

\*Values for log C and q are significant at the 0.05 levels for all years.

\*\* t values

Source: State Institute of Statistics Republic of Turkey, Census of Population 1980,1985,1990 and 1997

In order to make a better examination of changes in the rank-size coefficients over time “expanded model ” was developed by Casetti (4). The method expresses the parameters of the logarithmic form of the rank-size function to account for changes in the rank –size structure over time.

The values for log C and q remain constant only for given point in time. Since log C and q vary temporally, they can be expressed as a functions of time (10).

The expanded linear function for the intercept becomes and q;

$$\text{LogC}=\text{LogC}_0+\text{LogC}_1t \quad (3)$$

$$q=q_0+q_1t \quad (4)$$

Where

C<sub>0</sub> = constant at the initial point in time;

q<sub>0</sub> = slope at the initial point in time;

t = time

Incorporating these linear functions with standard rank-size model (2), the expanded rank-size model becomes;

$$\text{LogP}_i=\text{LogC}_0+\text{LogC}_1t-q_0\text{logr}_i \quad (5)$$

In equation, logC<sub>1</sub> and q<sub>1</sub> can be tested. The logC<sub>1</sub> term shows significant growth (or decline) over time in the system of cities, while a term q<sub>1</sub> demonstrates a significant difference in the rates of growth (or decline) between larger and smaller urban areas. In addition to the logical inclusion of the temporal dimension of the urban rank-size distribution allows for more precise identifications of stability and change over time, and, in the case of change, a more rigorous assessment of the locus of such city-system change (11).

In this study the expanded logarithmic rank-size model determines source of change in the Turkish city system. According to the results, on the basis of t-test (0.05 level), log C is significantly greater than zero but q is not. The results are given in Table 2.

Table 2: Expanded regression equation, 1980-1997 for Turkish Urban System

Equation	LogC <sub>0</sub>	Log C <sub>1</sub>	q <sub>0</sub>	Q <sub>1</sub>	R	R <sup>2</sup>
1980-1997	6.090* (174.66)**	0.0455 (14.208)	-0.814 (50.273)	-0.01368 (9.496)	0.931	0.867

\*Significant at the 0.05 level.

\*\* t-values.

Source: See Table1

It can be concluded that for Turkish rank-size distribution, all city centers have increased at approximately at the same rate and change in population is statistically significant. Figure 1 shows parallel rank-size curves in over this time. In addition, it can be said that cities have experienced either no shift in population rank at all.

### III. THE STANDARD LOGARITHMIC RANK SIZE AND EXPANDED RANK-SIZE MODEL OF CITIES ACCORDING TO REGIONS

#### III.1 Marmara Region

Table 3 : Regression Equations, 1980-1997 for Marmara Region

Year	LogC*	Q*	R	R <sup>2</sup>
<b>1980</b>	Log P <sub>i</sub> =5.924 (123.448)**	-1.141 log <sub>r</sub> (32.355)**	0.977	0.954
<b>1985</b>	LogP <sub>i</sub> =6.043 (123.789)	-1.146 log <sub>r</sub> (34.391)	0.974	0.948
<b>1990</b>	LogP <sub>i</sub> =6.119 (137.190)	-1.117 log <sub>r</sub> (38.504)	0.975	0.950
<b>1997</b>	LogP <sub>i</sub> =6.226 (165.280)	-1.099 log <sub>r</sub> (47.650)	0.979	0.958

\*Values for log C and q are significant at the 0.05 level for all years.

\*\* t values

Source: State Institute of Statistics Republic of Turkey, Census of Population 1980,1985,1990 and 1997

The standard logarithmic rank-size function (2) fit to the data for 1980, 1985, 1990 and 1997. The results are given in Table 3 with t values shown below each regression coefficient. The regression results exhibit an increasing intercept values, from 5.924 in1980 to 6.226 in 1997. In addition to the slope of rank-size distribution has increase from 1.141 in 1980 to -1.146 in 1985 and then q value has decrease from -1.146 in 1985 to -1.099 in 1997. From this analysis it is indistinct whether the change because of increasing population in larger cities faster than smaller ones or to an increase in populations of larger cities alone or decrease in the population of smaller cities.

Table 4: Expanded regression equation, 1980-1997 for Marmara Region

Equation	LogC <sub>0</sub>	Log C <sub>1</sub>	q <sub>0</sub>	Q <sub>1</sub>	R	R <sup>2</sup>
1980-1997	5.758* (128.762)**	0.02611 (6.502)	-1.053 (32.110)	0.0018 (0.661)	0.967	0.935
1985-1997	5.456* (79.789)**	0.0496 (9.073)	-0.906 (18.148)	0.0134 (3.563)	0.972	0.944

\*Significant at the 0.05 level.

\*\* t-values.

Source: See Table3

When the same data fitted to the expanded rank-size model according to two periods, it can be concluded that for Marmara region rank-size distribution, all city centers have increased at approximately at the same rate and change in population is statistically significant.

### III.2 The Central Anatolian Region

Table 5 : Regression Equations, 1980-1997 for Central Anatolian Region

Year	LogC*	Q*	R	R <sup>2</sup>
1980	Log P <sub>i</sub> =5.741 (152.927)**	-1.058 logr (36.720)**	0.984	0.969
1985	LogP <sub>i</sub> =6.114 (176.125)	-1.245 logr (50.415)	0.989	0.978
1990	LogP <sub>i</sub> =6.125 (199.955)	-1.194 logr (57.576)	0.990	0.980
1997	LogP <sub>i</sub> =6.171 (221.886)	-1.174 logr (64.898)	0.991	0.982

\*Values for log C and q are significant at the 0.05 level for all years.

\*\* t values

Source: State Institute of Statistics Republic of Turkey, Census of Population 1980,1985,1990 and 1997

The standard logarithmic rank-size function (2) was fit to the data for 1980, 1985, 1990 and 1997. The results are given in Table 5 with t- values shown below each regression coefficient. The regression results exhibit an increasing intercept values, from 5.741 in 1980 to 6.171 in 1997. In addition to the slope of rank-size distribution has increased from 1.058 in 1980 to -1.245 in 1985 and then q value has decreased from -1.245 in 1985 to -1.174 in 1997.

Table 6: Expanded regression equation, 1980-1997 for Central Anatolian Region

Equation	LogC <sub>0</sub>	Log C <sub>1</sub>	q <sub>0</sub>	Q <sub>1</sub>	R	R <sup>2</sup>
1980-1997	5.860* (199.181)**	0.0221 (8.104)	-1.130 (52.305)	-0.0046 (2.412)	0.987	0.975
1985-1997	6.076* (139.688)**	0.0055 (1.542)	-1.258 (41.594)	0.00512 (2.103)	0.990	0.980

\*Significant at the 0.05 level.

\*\* t-values.

Source: See Table5

When the same data fitted to the expanded rank-size model according to two periods, it can be concluded that for Central Anatolian region rank-size distribution, all city centers have increased at approximately at the same rate and change in population is statistically significant.

### III.3 The Aegean Region

Table 7 : Regression Equations, 1980-1997 for the Aegean Region

Year	LogC*	Q*	R	R <sup>2</sup>
1980	Log P <sub>i</sub> =5.653 (167.850)**	-0.997 logr (39.081)**	0.986	0.971
1985	LogP <sub>i</sub> =5.777 (168.719)	-1.018 logr (42.007)	0.984	0.969
1990	LogP <sub>i</sub> =5.836 (197.077)	-1.006 logr (50.387)	0.987	0.974
1997	LogP <sub>i</sub> =5.906 (220.854)	-0.091 logr (56.576)	0.988	0.977

\*Values for log C and q are significant at the 0.05 level for all years.

\*\* t values

Source: State Institute of Statistics Republic of Turkey, Census of Population 1980,1985,1990 and 1997

The standard logarithmic rank-size function (2) is fit to the data for 1980,1985,1990 and 1997. The results are given in Table 7 with t- values shown below each regression coefficient. The regression results exhibit an increasing intercept values, from 5.653 in 1980 to 5.906 in 1997. In addition to the slope of rank-size distribution has increase from -0.997 in 1980 to -1.018 in 1985 and then q value has decrease from -1.018 in 1985 to -1.006 in 1990. There is again an increase from -1.006 in 1990 to -0.091 in 1997.

Table 8: Expanded regression equation, 1980-1997 for the Aegean Region

Equation	LogC <sub>0</sub>	Log C <sub>1</sub>	q <sub>0</sub>	Q <sub>1</sub>	R	R <sup>2</sup>
1980-1997	5.674* (218.457)**	0.0147 (6.057)	-1.004 (53.054)	0.000312 (0.184)	0.986	0.973
1985-1997	5.775* (123.513)**	0.0020 (0.523)	-1.001 (30.483)	0.00066 (0.238)	0.984	0.968

\*Significant at the 0.05 level.

\*\* t-values.

Source: See Table7

When the same data fitted to the expanded rank-size model according to two periods, it can be concluded that for the Aegean region rank-size distribution, all city centers have increased at approximately at the same rate and change in population is statistically significant.

### III.4 Mediterranean Region

Table 9 : Regression Equations, 1980-1997 for the Mediterranean Region

Year	LogC*	Q*	R	R <sup>2</sup>
1980	Log P <sub>i</sub> =6.095 (142.703)**	-1.286 logr (37.469)**	0.987	0.974
1985	LogP <sub>i</sub> =5.795 (179.911)	-1.026 logr (42.600)	0.987	0.975
1990	LogP <sub>i</sub> =6.063 (349.907)	-1.152 logr (92.9467)	0.997	0.994
1997	LogP <sub>i</sub> =6.172 (290.708)	-1.161 logr (82.036)	0.995	0.990

\*Values for log C and q are significant at the 0.05 level for all years.

\*\* t values

Source: State Institute of Statistics Republic of Turkey, Census of Population 1980,1985,1990 and 1997

The standard logarithmic rank-size function (2) is fit to the data for 1980, 1985, 1990 and 1997. The results are given in Table 7 with t values shown below each regression coefficient. The regression results exhibit a decreasing intercept values, from 6.095 in 1980 to 5.795 in 1985, then an increase from 5.795 in 1985 to 6.172 in 1997. In addition to the slope of rank-size distribution has decrease from -1.286 in 1980 to -1.026 in 1985 and then q value has increase from -1.026 in 1985 to -1.161 in 1997.

Table 10: Expanded regression equation, 1980-1997 for the Mediterranean Region

Equation	LogC <sub>0</sub>	Log C <sub>1</sub>	q <sub>0</sub>	Q <sub>1</sub>	R	R <sup>2</sup>
1980-1997	5.941* (218.119)**	0.0111 (4.436)	-1.173 (55.953)	0.00233 (1.286)	0.989	0.979
1985-1997	5.689* (164.562)**	0.003 (10.610)	-1.003 (39.806)	0.0130 (5.166)	0.993	0.986

\*Significant at the 0.05 level.

\*\* t-values.

Source: See Table9

When the same data fitted to the expanded rank-size model according to two periods, it can be concluded that for the Mediterranean region rank-size distribution, all city centers have increased at approximately at the same rate and change in population is statistically significant.



### III.5 The South-Eastern Anatolian Region

Table 11 : Regression Equations, 1980-1997 for the South-Eastern Anatolian Region

Year	LogC*	Q*	R	R <sup>2</sup>
1980	Log P <sub>i</sub> =5.589 (170.743)**	-1.020 logr (35.538)**	0.989	0.978
1985	LogP <sub>i</sub> =5.707 (156.786)	-1.040 logr (33.995)	0.986	0.973
1990	LogP <sub>i</sub> =5.875 (136.633)	-1.095 logr (32.213)	0.982	0.964
1997	LogP <sub>i</sub> =6.086 (177.567)	-1.160 logr (29.578)	0.975	0.951

\*Values for log C and q are significant at the 0.05 level for all years.

\*\* t values

Source: State Institute of Statistics Republic of Turkey, Census of Population 1980,1985,1990 and 1997

The standard logarithmic rank-size function (2) is fit to the data for 1980,1985,1990 and 1997. The results are given in Table 9 with t values shown below each regression coefficient. The regression results exhibit an increasing intercept values, from 5.589 in 1980 to 6.086 in 1997. In addition to the slope of rank-size distribution has increased from -1.020 in 1980 to -1.160 in 1997.

Table 12: Expanded regression equation, 1980-1997 for the South-Eastern Anatolian Region

Equation	LogC <sub>0</sub>	Log C <sub>1</sub>	q <sub>0</sub>	Q <sub>1</sub>	R	R <sup>2</sup>
1980-1997	5.626* (175.301)**	0.0145 (5.040)	-1.028 (37.759)	0.00179 (0.0.797)	0.985	0.969

\*Significant at the 0.05 level.

\*\* t-values.

Source: See Table11

When the same data fitted to the expanded rank-size model according to one period, it can be concluded that for the South-Eastern Anatolian region rank-size distribution, all city centers have increased at approximately at the same rate and change in population is statistically significant.

### III.6 Eastern Anatolian Region

Table 13 : Regression Equations, 1980-1997 for the Eastern Anatolian Region

Year	LogC*	Q*	R	R <sup>2</sup>
1980	Log P <sub>i</sub> =5.490 (178.972)**	-0.991 logr (38.826)**	0.989	0.979
1985	LogP <sub>i</sub> =5.605 (199.909)	-1.023 logr (45.418)	0.991	0.982
1990	LogP <sub>i</sub> =5.630 (224.225)	-0.979 logr (51.815)	0.992	0.983
1997	LogP <sub>i</sub> =5.801 (218.759)	-1.019 logr (55.055)	0.990	0.981

\*Values for log C and q are significant at the 0.05 level for all years.

\*\* t values

Source: State Institute of Statistics Republic of Turkey, Census of Population 1980,1985,1990 and 1997

The standard logarithmic rank-size function (2) is fit to the data for 1980, 1985, 1990 and 1997. The results are given in Table 9 with t values shown below each regression coefficient. The regression results exhibit an increasing intercept values, from 5.490 in 1980 to 5.801 in 1997. In addition to the slope of rank-size distribution has an increase from -0.991 in 1980 to -1.023 in 1985, then a decrease -1.023 in 1985 from -0.979 in 1990, an increase again from -0.979 in 1990 to -1.019 in 1997.

Table 14: Expanded regression equation, 1980-1997 for the Eastern Anatolian Region

Equation	LogC <sub>0</sub>	Log C <sub>1</sub>	q <sub>0</sub>	Q <sub>1</sub>	R	R <sup>2</sup>
1980-1997	5.493* (236.176)**	0.0173 (8.101)	-0.996 (52.948)	0.0008 (0.504)	0.990	0.981
1985-1997	5.494* (144.424)**	0.0172 (5.562)	-1.001 (33.890)	0.0005 (0.225)	0.991	0.981

\*Significant at the 0.05 level.

\*\* t-values.

Source: See Table13

When the same data fitted to the expanded rank-size model according to one period, it can be concluded that for the Anatolian region rank-size distribution, all city centers have increased at approximately at the same rate and change in population is statistically significant.

### III.7 Black Sea Region

Table 15 : Regression Equations, 1980-1997 for Black Sea Region

Year	LogC*	Q*	R	R <sup>2</sup>
<b>1980</b>	Log P <sub>i</sub> =5.405 (233.391)**	-0.759 log <sub>r</sub> (45.863)**	0.987	0.975
<b>1985</b>	LogP <sub>i</sub> =5.519 (248.888)	-0.793 log <sub>r</sub> (52.782)	0.988	0.977
<b>1990</b>	LogP <sub>i</sub> =5.612 (230.798)	-0.817 log <sub>r</sub> (51.681)	0.986	0.972
<b>1997</b>	LogP <sub>i</sub> =5.681 (224.970)	-0.826 log <sub>r</sub> (51.294)	0.984	0.969

\*Values for log C and q are significant at the 0.05 level for all years.

\*\* t values

Source: State Institute of Statistics Republic of Turkey, Census of Population 1980,1985,1990 and 1997

The standard logarithmic rank-size function (2) is fit to the data for 1980, 1985, 1990 and 1997. The results are given in Table 9 with t values shown below each regression coefficient. The regression results exhibit an increasing intercept values, from 5.405 in 1980 to 5.681 in 1997. In addition to the slope of rank-size distribution has increase from -0.759 in 1980 to -0.826 in 1997.

Table 16: Expanded regression equation, 1980-1997 for the Black Sea Region

Equation	LogC <sub>0</sub>	Log C <sub>1</sub>	q <sub>0</sub>	Q <sub>1</sub>	R	R <sup>2</sup>
1980-1997	5.422* (265.743)**	0.0164 (8.548)	-0.765 (53.984)	0.0042 (3.240)	0.986	0.972

\*Significant at the 0.05 level.

\*\* t-values.

Source: See Table15

When the same data fitted to the expanded rank-size model according to one period, it can be concluded that for the Black Sea region rank-size distribution, all city centers have increased at approximately at the same rate and change in population is statistically significant.

#### IV. CONCLUSION

This study analyses logarithmic rank-size rule and expanded rank-size rule in whole of Turkey and seven regions between 1980-1997 and it demonstrates that city size distribution adjusted more to the logarithmic straight-line. When the same data fitted to the expanded rank-size model, it can be concluded that for Turkish cities and seven regions rank-size distribution, all city centers have increased at approximately at the same rate and change in population is statistically significant. The rank size distributions of cities maintain a stable equilibrium in a national scale and regional scale.

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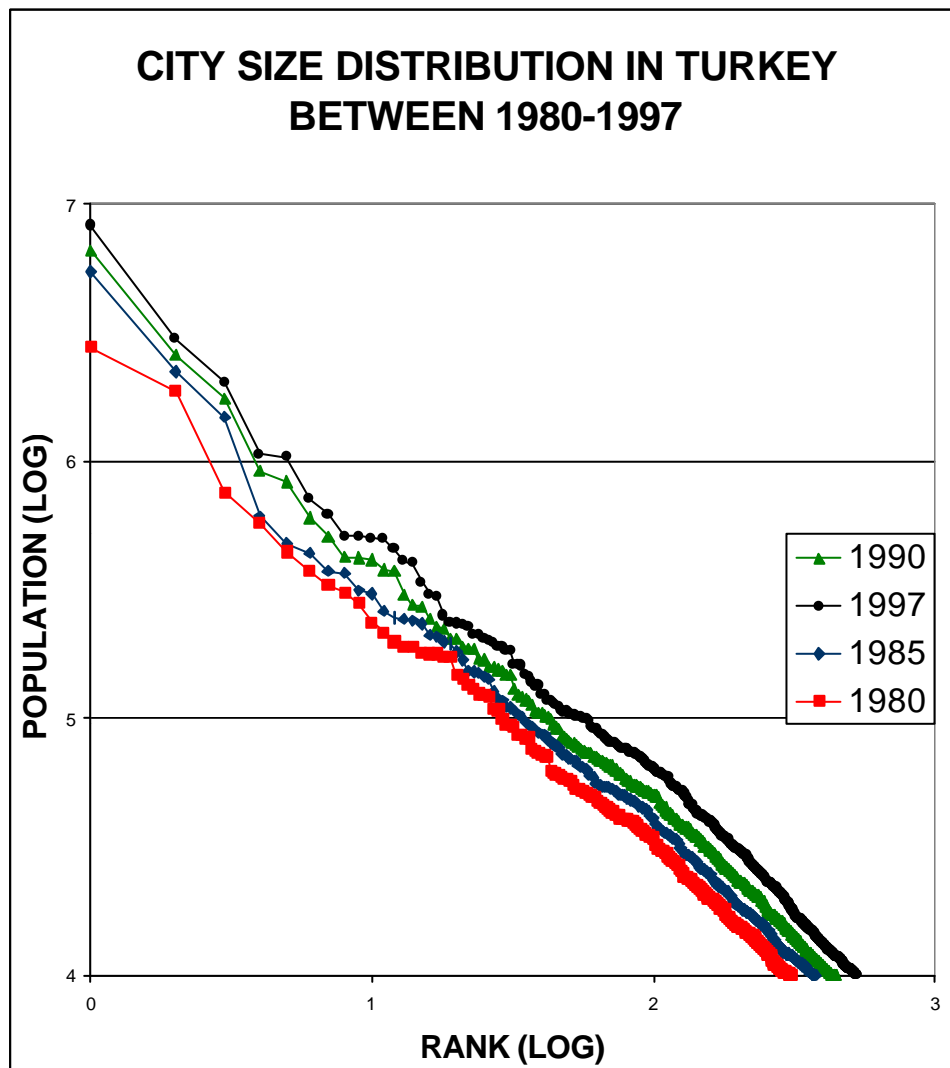


Figure 1. Rank Size of Cities in Turkey between 1980-1997