A New Method for Measurement of Urban Decentralization

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Abstract

The standard model used in studies of urban decentralization is the monocentric model with its implication of an exponential density gradient. Exponential density gradients have been estimated for the cities of many countries. The exponential, however, does not easily facilitate the study of jurisdictional effects on suburbanization. This led Edwin Mills in 1991 to propose a new function for measuring suburbanization and analyzing its determinants [2].

While Mills has used his function to study jurisdictional effects in decentralization of U.S. cities, there are no known cases of its application for measurement of suburbanization patterns over time. This paper reports measures of suburbanization obtained for the post-war decades in the two Germanys, and comments briefly on the suitability of Mills' function for this purpose.

1 The Exponential as a Means of Measuring Suburbanization

Suburbanization is generally studied in terms of trends in densities between the central city and the suburbs. The functional form most often used is

$$D(x) = D_0 e^{-\theta x} \tag{1}$$

$D(x)$ is the density at a distance x from the central business district (CBD), D_0 is the density at the CBD, and θ is a measure of how sharply density falls with distance from the center, i.e. it gives the percentage decline in density with each mile from the CBD. θ is therefore a measure of suburbanization; the smaller θ, the flatter the gradient.

With census tract data and knowledge of D_0, it is possible to use values of density at varying distances from the center to yield an estimate of θ for a given city. For many countries, however, only central city and metropolitan area populations and city land areas are available to the U.S. researcher.[1] Two values of density can be calculated from this data and a regression can be performed over a sample of such data derived from a number of cities. D_0 then becomes a general constant for the purpose of the regression, with no physical significance. For comparison of results among samples, smaller D_0 or θ implies more decentralization.

The exponential does not, however, permit the separate examination of the roles of central city size and city population in determining the dominance of the central city. A further flaw is that the exponential treats the population at the city center as exogenous when it is more reasonable to assume that it is endogenous, determined by the relationship between the central city and its suburbs and other jurisdictional effects, such as central city school quality, employment location and ease of commuting, and urban blight.

2 A New Means of Measuring Suburbanization

It is this last reason, the consideration of jurisdictional effects in determining the population and hence the dominance of the city center, which led Mills to propose

$$P_c = AL_c^{\alpha} P^{\beta} \qquad \alpha \leq 1,\ 0 < \beta,\ \alpha + \beta > 1 \tag{2}$$

[1] For a brief discussion of the difficulty in finding adequate data, see the appendix on page 11.

as a functional form for use in the measurement of suburbanization. P_c is the central city population, P is the total metro area population, and L_c is the land area of the central city. A is a constant with no direct physical interpretation. As with the exponential, in a comparison of results, smaller A, α, or β implies more decentralization.

Mills presents six criteria he feels a "reasonable measure of suburbanization" should satisfy (I quote each from [2]):

1. It should identify central city and suburban jurisdictions... and should contain parameters that permit estimation of effects of central city and suburban conditions on suburbanization.

2. It is reasonable to assume that L_c and P, but not P_c or L_s, are exogenous.

3. The measure should accommodate the fact that central cities vary enormously relative to metropolitan areas both as to land areas and as to populations.

4. P_c should be an increasing function of P and L_c, but $\frac{P_c}{L_c}$ should be a decreasing function of L_c, i.e. $\frac{\partial P_c}{\partial L_c}\frac{P_c}{L_c} < 1$. This criterion represents the facts that central city population is greater the greater the metropolitan population or the greater the central city land area, but central city population density decreases as central city land area increases, other things equal.

5. P_c should increase more than proportionately with a proportionate increase in P and L_c. This criterion specifies that a given percentage increase in the metropolitan area's population and the central city's land area should result in an increase in the central city's population density. This characteristic reflects the fact that average metropolitan density, and thus density of any central proportion of the metropolitan area, is greater the larger the metropolitan area.

6. The measure should accommodate a variety of specific density patterns....

Clearly, (2) satisfies 1 and 2. Permitting P_c to vary separately with P and L_c satisfies 3. The conditions on α and β satisfy 4 and 5 [2].

An interesting feature of this model is that it resembles the standard production function, although unlike the Cobb-Douglas function, $\alpha + \beta > 1$

here. This, in conjunction with the explicit presence of P_c, P, and L_c, makes the interpretation of trends in terms of the relevance of city size, population growth, etc. very straightforward. Since the model is founded on the expected effects of jurisdictional factors, Mills' function provides a superior method for the measurement of urban decentralization. An added bonus is that the available data, i.e. P_c, P, and L_c, can be plugged straight into the formula, without the need for conversion to suit (1).

3 Results

I examine trends in suburbanization for two countries: East and West Germany. Non-U.S. nations were chosen because the U.S. has been studied extensively.[2] As discussed in the appendix on page 11, data—even merely population and land area for the central city and the metro area—is remarkably difficult to find; as a result, data for the Germanys was the only non-U.S. data accessible. Nevertheless, a study of the two countries not only permits examination of application of Mills' method, but also yields some interesting results.

Before examining the results, a brief aside on the nature of the German data is in order. Both nations report statistics for central cities and for the suburban rings. This data is reported in the statistical yearbook. An unfortunate difficulty is that some suburban rings' names in the tables do not correspond to the central cities' names.

For each nation, postwar data is reported in more-or-less ten-year intervals. For both East and West Germany, the arbitrary criterion of cities with central city populations of 100,000 or greater for which the suburban ring is identifiable is used to select the samples.

3.1 West Germany

Eighteen cities in West Germany meet the specified criteria. Note that due to the jurisdictional peculiarities of Berlin, Hamburg, and Bremen[3], they are not included in the sample. The cities are listed in Table 1; they comprise a fairly good distribution in terms of geographic location within

[2]In addition, a study of U.S. cities using Mills' method has apparently been done by a graduate student in Rice University's Department of Economics, but the author could not be reached.

[3]Hamburg and Bremen are separate states, with no distinction between central city and metro area.

West Germany, but due to the omission of Berlin, Hamburg, and Bremen, there is a moderate bias toward smaller cities. Munich and Hanover were the only cities with metro populations exceeding 1 million. The population data are found in [7, 8, 9, 10].

West German Cities	
City	Metro Population, 1988 (in thousands)
Aachen	519
Augsburg	439
Darmstadt	387
Erlangen	208
Freiburg im Breisgau	387
Hanover	1044
Heilbronn	367
Karlsruhe	630
Kassel	411
Koblenz	296
Ludwigshaven am Rhein	289
Mainz	339
Munich	1460
Nuremberg	627
Oldenburg	240
Osnabrück	446
Regensburg	265
Würzburg	265

Table 1: *West German cities used in measurement of West German suburbanization, with their metro populations. Only those cities with a central city population over 100,000 for which the city ring was identifiable in the statistical yearbook are included.*

A regression using Mills' formula for this sample for intervals from 1960–1990 yields the results in Table 2.

The statistics are in a sense unremarkable. The variations in α and β are not statistically significant; they can be treated as remaining essentially unchanged. A, on the other hand, is declining, especially over the period

West Germany						
Census Date	A	σ (*log A*)	α	σ	β	σ
06/30/59	.3015	.0970	.3534	.1798	.8552	.1643
06/30/69	.2258	.0888	.4081	.1821	.8515	.1604
06/30/79	.1340	.1052	.3463	.4334	.9387	.3133
06/30/88	.1132	.1061	.5110	.4523	.8287	.3398

Table 2: *West German statistics, 1960–1990, calculated using Mills' model. The standard error for each value is reported as σ, except in the case of A, for which the standard error of $\log A$ is reported.*

1960–1980. Since West Germany is a modern, Western country, we expect to see some decentralization, despite the stronger orientation toward the central city which exists in most European nations [1].

3.2 East Germany

Only eleven cities meet the specified criteria. Again, Berlin is not included. A list of the cities can be found in Table 5. Two sets of population were available: populations from 1950 and 1970–1990, based on 1990 jurisdictions projected backwards to previous years [6]; and populations based on boundaries in effect at that time for 1960–1990 [3, 4, 5, 6]. Again, the distribution of cities is fairly good in terms of location and population distribution.

The regression using Mills' formula on the sample with fixed boundaries yields the results in Table 3, and the regression on the sample with evolving boundaries yields the results in Table 4.

The results are not significantly different between the two. What is notable is that, in both cases, while A is rising, α is falling, with β essentially stable, implying contradictory trends. A closer look at the city data, however (in Tables 5, 6, 7), reveals that the three largest cities—Dresden, Karl-Marx-Stadt, and Leipzig—shrunk rapidly in central city population as well as in metro population over the period studied, whereas the other 8 cities all had increasing metro populations. The quite large populations of these three cities causes this fact to skew the data.

Another regression was performed, with these three cities removed from the sample. The new results appear in Table 8.

Now the variations in α, as well as β, are not statistically significant. A,

East Germany: Fixed Boundaries						
Census Date	A	σ (*log A*)	α	σ	β	σ
08/31/50	.1950	.0426	.2359	.0790	1.0194	.0607
01/01/71	.2808	.0561	.2162	.1118	.9815	.0911
12/31/81	.3690	.0528	.1919	.1119	.9633	.1008
12/31/89	.4128	.0513	.1676	.1134	.9667	.1082

Table 3: *East German statistics, 1950–1990, based on 1990 city boundaries. The standard error for each value is reported as σ, except in the case of A, for which the standard error of log A is reported.*

East Germany: Evolving Boundaries						
Census Date	A	σ (*log A*)	α	σ	β	σ
01/01/61	.1902	.0434	.3015	.0831	.9821	.0504
12/31/69	.2400	.0535	.2336	.1056	.9919	.0819
12/31/79	.2763	.0558	.2197	.1114	.9815	.0903
12/31/89	.4128	.0513	.1676	.1134	.9667	.1082

Table 4: *East German statistics, 1960–1990, based on evolving city boundaries.*

East Germany: Central City Populations				
City	08/31/50	01/01/71	12/31/81	12/31/89
Cottbus	60.874	83.996	116.092	128.943
Dresden	494.187	502.432	521.060	501.417
Erfurt	188.650	196.528	212.012	217.035
Gera	98.576	111.535	126.792	132.257
Jena	81.134	88.130	104.946	105.825
Karl-Marx-Stadt †	293.373	299.432	318.578	301.918
Leipzig	617.574	584.412	559.574	530.010
Potsdam	118.180	111.336	132.543	141.430
Rostock	133.591	198.713	236.011	252.956
Schwerin	93.990	97.389	122.264	129.492
Zwickau	138.844	126.988	121.283	118.914

†Now Chemnitz

Table 5: *Central city populations (in thousands) for East German cities. Only those cities with a central city population over 100,000 for which the city ring was identifiable in the statistical yearbook are included.*

East Germany: Urban Ring Populations				
City	08/31/50	01/01/71	12/31/81	12/31/89
Cottbus	58.323	48.645	45.570	42.768
Dresden	137.589	126.657	113.498	103.821
Erfurt	64.532	51.801	47.976	47.108
Gera	76.359	69.333	61.316	57.418
Jena	42.191	37.631	35.594	33.679
Karl-Marx-Stadt †	145.218	122.411	107.591	99.126
Leipzig	195.579	170.047	145.831	131.734
Potsdam	93.963	102.507	99.051	99.031
Rostock	45.817	38.927	36.565	38.558
Schwerin	46.677	36.726	34.482	34.291
Zwickau	119.250	98.290	87.538	80.225

†Now Chemnitz

Table 6: *Urban ring populations for East German cities.*

East Germany: Metro Area Populations				
City	08/31/50	01/01/71	12/31/81	12/31/89
Cottbus	119.197	132.641	161.662	171.711
Dresden	631.776	629.089	634.558	605.238
Erfurt	253.182	248.329	259.988	264.143
Gera	174.935	180.868	188.108	189.675
Jena	123.325	125.761	140.540	139.504
Karl-Marx-Stadt †	438.591	421.843	426.169	401.044
Leipzig	813.153	754.459	705.405	661.744
Potsdam	212.143	213.843	231.594	240.461
Rostock	179.408	237.640	272.576	291.514
Schwerin	140.667	134.115	156.746	163.783
Zwickau	258.094	225.278	208.821	199.139

†Now Chemnitz

Table 7: *Total metro area populations for East German cities.*

East Germany: Fixed Boundaries—Modified Data						
Census Date	A	σ (*log A*)	α	σ	β	σ
08/31/50	.2487	.0518	.2443	.1018	.9649	.1531
01/01/71	.5001	.0676	.2393	.1437	.8496	.2298
12/31/81	.7619	.0635	.2321	.1491	.7913	.2776
12/31/89	.7363	.0626	.2050	.1554	.8255	.2799

Table 8: *East German statistics, 1950–1990, with Dreseden, Karl-Marx-Stadt, and Leipzig removed; based on 1990 city boundaries.*

however, shows a very strong increasing trend. The immediate conclusion is that East German cities have been *centralizing* since the war, instead of decentralizing.

An examination of the suburban ring data in Table 6 shows that suburban populations show a uniform falling trend. On the other hand, with the exception of Dresden, Leipzig, and Zwickau, central city populations have been rising, sufficiently except in the case of these three cities plus Karl-Marx-Stadt to offset the suburban declines, so that metro populations actually rose over the period studied. The conclusion that East German cities have been centralizing appears, based on the data, to be a valid one.

Is this a reasonable conclusion? Cities in European, communist countries are likely to exhibit a strong orientation toward the center for all the reasons mentioned in [1], but to a stronger degree, as the communist cites tend to be more strictly planned, with more emphasis toward the center, more officed employment toward the center, and a greater lack of dependence on private transportation. Furthermore, the communist nations are known for their vast, staid apartment buildings, which are usually centrally located. I contend that as the East German cities were rebuilt after the war, and more residences became available closer to the center, the strong center-orientation of the East German cities drew employees from the suburban rings into the central cities, thus actually increasing the dominance and density of the central cities.

4 Conclusions

Mills' function is extremely straightforward in its application to two-point data, and the intuitive nature of its functional form makes interpretation of results straightforward.

An analysis of population data for West Germany leads to the expected conclusion that West German cities have experienced suburbanization in the past 30 years, whereas the analysis for East Germany indicates its cities have centralized in the post-war era.

As topics for further study, a more detailed examination of East German cities seems warranted in order to pinpoint the source of the centralization. Also of interest would be a study of other Soviet-bloc nations to see whether, as suggested above, the trend toward centralization can be expected as a general rule in such countries.

5 Acknowledgements

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The regressions were performed using Borland's **Quattro Pro SE**, version 3.0, and this document was prepared with Eberhard Mattes' **emTeX**, an implementation of LaTeXfor the IBM PC.

A The Data Problem

My original intent was to calculate measures of suburbanization for a number of western European countries, but a lack of available data in the end forced me to focus solely on West and East Germany. This appendix briefly examines the nature of the data shortage.

A.1 Needed Data

As a minimum of information for a given country, populations for the central city and metropolitan area as well as the land area of the central city for several cities are needed in order to perform a meaningful regression using Mills' function. As a rule of thumb, at least 10 cities, and preferably 20 or more, constitutes a satisfactory sample size. In addition, a time series for these values of 30 or preferably at least 40 years is desirable in order to obtain a picture of suburbanization trends.

A.2 Available Data

I found two potential sources for the needed data for non-U.S. countries: the U.N.'s Demographic Yearbook and individual countries' statistical yearbooks. Curiously, the Demographic Yearbook only reports separate statistics for central city and metro area populations for 37 nations [11], reporting only one figure for all other countries. A further difficulty is that many of the nations for which separate statistics exist are small and only have a handful of cities with populations over 100,000. Finally, the Demographic Yearbook does not report any land areas.

The only evident source of land areas for individual cities are countries' statistical yearbooks, which if they have areas are likely to have population statistics as well. These are not available in translation, and many do not provide separate statistics for central city and metro area. A final difficulty is that such yearbooks are in short supply except, presumably, at a top-notch library, meaning that finding a nation for which data exists for an adequate span of time is quite difficult. For example, the only countries for which Rice's library possessed yearbooks for 30 years or more were France, West Germany, East Germany, and Poland; and for 25 years or more were Italy, the Netherlands, and Yugoslavia. The French volumes only report separate statistics for the last decade or so, and I am unable to read any of the other languages except German.

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