

RESEARCH NOTES/NOTES DE RECHERCHE

COMPARING URBAN SYSTEMS: MEASUREMENT
CRITERIA AND EMPIRICAL EVALUATIONS*

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Introduction

Despite the emergence of a substantial literature on urbanization, there has been relatively little discussion and even fewer applications of consistent criteria for measuring the spatial structure of urban systems in an international comparative context. Without such criteria, attempts at cross-national analyses of urban systems are unlikely to be successful.

This paper reports briefly on the first phase of a longer-term comparative study of the characteristics and changing spatial structure of national urban systems in both developed and developing countries. The paper first introduces a set of measurement criteria and then evaluates a series of hypotheses designed to identify and account for observed differences in the geometry of urban systems. These hypotheses are tested against data for twenty-eight countries, including those with centrally-planned as well as market-based economies. The empirical analysis to date has not been extended to incorporate countries from the Third World.

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Measurement Criteria

In effect, all empirical studies of urban systems employ measurement criteria in one form or another. What is surprising is that there has not been an explicit attempt to bring those varied criteria together in one study or to assess their relative merits and disadvantages. The need to do so is particularly evident when one is involved in an international project involving researchers from several countries using widely different data bases and varying research styles [10;8;4].

With these considerations in mind, and as the starting point for the comparative analysis, the following set of measurement criteria was proposed:

1. *level* (or degree) of urbanization: the proportion of total population resident in geographic areas classified as urban;
2. *rate* of urbanization (or deurbanization): the rate of change in the proportion in 1;
3. *degree of concentration/deconcentration*, as measured by:
 - i) the hierarchical distribution of population by city size classes;
 - ii) the geographical distribution of population by region and size classes;
4. the level of *disorder* or unevenness in the distribution of population by size classes: the entropy of the system;
5. *variability of growth relationships*: the variation of growth rates by population size, among size classes and/or regions;
6. *interaction effects*: measured in terms of:
 - i) the nature and intensity of *linkages* (by city and sector);
 - ii) the geographical spread and local *multiplier* effects;
 - iii) network configurations and *connectivity*;
7. *lead-lag effects*: the temporal variability in growth and change among urban areas, and among the individual components of growth;
8. *subsystem differentiation*: the degree to which an urban system (national) operates as a more or less tightly integrated set of regional urban subsystems;
9. *urban growth and decline*: the specific spatial and temporal pattern of aggregate urban population change (among individual urban areas);
10. *functional differentiation*: differences in the economic base, service activities and functional mix of each member city.

Variables other than population (for example, employment, capital investment, and so forth), can of course be substituted as needed and available.

These broad measurement criteria in turn may be translated into specific parameters for purposes of statistical analysis, as is done in

Table 1 for the first eight criteria in this set. In the following analysis only the first three of these criteria are actually applied, given the serious limitations of the data available [16].

Empirical Evaluation: A Case Study of Developed Countries

Any comparative analysis of urbanization, and of the structure of urban systems at an international scale, faces immense difficulties. Not only are comparable data for urban areas based on the same scale, spatial units and time periods simply not available for more than a few countries; even among those countries with relatively comprehensive data files the definitions of relevant variables are so diverse that most comparative studies are limited to population data. Commonly, data for other critical sectors are either not collected (for example, on employment) for urban areas, or are a decade or more out of date. The data utilized at this stage derive primarily from World Bank [16] files, and despite their limitations are still the best available.

The initial empirical analysis reported briefly below has two specific objectives. First, it undertakes to test a series of broad hypotheses designed to account for variations in levels and rates of urbanization, the distribution of urban population by size, and the degree of concentration and primacy within the urban systems of developed countries. The data set includes twenty-eight countries in Western and Eastern Europe, North America and Australasia. A second objective is to identify avenues for future research as part of the longer term project on comparative urban systems. The concluding discussion also draws a parallel to the well-known Jansen-Paelinck [7] model of the determinants of urbanization in Third World countries.

The Variables

The variables chosen for inclusion in the analysis, listed in Table 2, fall far short of what would be desirable to test the initial hypotheses. Given the data deficiencies noted earlier, this should not be surprising.

Although the definitions of most of the variables in Table 2 are obvious, a few warrant brief elaboration here. In addition to measures of the level of urbanization and the size distribution of urban centres, the data set includes variables descriptive of each country's demography, labour force, employment structure (particularly in services and manufacturing), production levels (GNP), international trade volumes and levels of specialization by product type (for example, primary products and energy), population size and density, and (where possible) measures of change over the decade 1970-80 inclusive. Also

Table 1
STATISTICAL MEASUREMENTS OF URBANIZATION, SPATIAL
ORGANIZATION AND URBAN GROWTH: A SUMMARY

Concepts	Definition/Description	Statistical Measures
(1) Level of urbanization	% of national population resident in geographically-defined urban areas	$\alpha(t) = (u/T)_t$ where u = urban population T = Total population
(2) Rate of urbanization (or deurbanization)	the rate of change in the proportion in (1) above over a given time period	$\Delta\alpha(t_0-t_1) = \Delta(u/T)_{t_0-t_1}/(u/T)_{t_0}$
(3) Degree of concentration/deconcentration	(a) hierarchical: % distribution of urban population by city size classes (b) geographical: % distribution of urban population by size class and region	$\sum_i^n (u_i/u) = 1$ complete concentration or $(u_i/u) = 1/n$ complete evenness where i = size class u = total population n = number of classes $\sum_{ij}^{nk} (u_{ij}/u_i) \leq 1$ ≥ 0 for $j = 1 \dots k$ regions
(4) Entropy (degree of disorder)	level of order or disorder (unevenness) in the distribution of population by size classes (or regions).	$H = - \sum_i^n (u_i/u) \ln(u_i/u)$ where \ln is natural logarithm, and $H = \max = \ln(n)$ when all probabilities are equal to $(1/n)$ and n is the number of size classes and $H = 0$ with complete concentration in one class (or region).
(5) Variability of urban growth	the variability of urban growth rates by size class (and region)	$r_{\Delta P_i/u_i} \quad S^2_{\Delta P_i/u_i}$ where r is the zero-order correlation coefficient of population growth (ΔP) across i size classes and S^2 is the variance
(6) Interurban interaction and integration	the extent of interdependence (I) within a spatial system among n urban areas; including quantities of interaction and the multiplier effects of given structural/area configurations, in matrix form or as one index: $1 - \sum_j \sum_i I_{ij}/I_{ij}$	$\bar{S}_{n \times n}$ a matrix summarizing n^2 linkages within an urban system, which transforms a vector of inputs $\bar{X}_{1 \times n}$ into a vector of outputs $\bar{Y}_{n \times 1}$ or $(\bar{X} + \bar{X}') \cdot \bar{S} = (\bar{Y} + \bar{Y}')$ as in the case of an open system where \bar{X}' and \bar{Y}' are external determinants
(7) Temporal leads and lags (periodicity)	the temporal behaviour of the urban system, as reflected in cyclical (or quasi-cyclical) paths of development, and specifically of leads and lags.	$U_t = \alpha(U_{t-1})(U_{t-2}) \dots = \sum a_i U_{t-i}$ where U is the urban statistic of interest, and $t-1$, etc. are the temporal lags
(8) System differentiation (subsystems) and economic specialization	the degree to which an urban system is spatially differentiated, into either regional subsystems or specialized economic clusters or subgroups.	where the matrix $\bar{S}_{n \times n}$ or the index I at the national level, are effectively partitioned into j subregions of intense integration, based on k subgroups of economic activity.

included on a purely speculative basis are estimates of the size (and date) at which each country would reach a stationary or equilibrium population. The latter variables were intended to identify the future growth path of that nation's population and thus its long-term urban development profile.

Table 2
LIST OF VARIABLES: COMPARATIVE STUDY OF URBAN SYSTEMS

Dependent Variables
V12 - % population urban (1980)
V2 - % urban population in cities over 500,000 (1980)
V4 - % urban population in largest city (1980)
V8 - % average annual growth rate of urban population (1970-80)
Explanatory Variables
V14 - % population of working age (1980)
V17 - total national population (1980)
V19 - birth rate (1979)
V21 - % population growth 1970-80
V23 - % labour force in industry (1980)
V25 - average annual growth rate in manufacturing employment, 1970-79
V26 - G.N.P. per capita (1980)
V28 - terms of trade (1979)
V30 - trade in resource/energy sector (1979)
V32 - trade in other primary products (1979)
V34 - average annual growth of labour force, 1970-80
V36 - hypothetical size of stationary population
V37 - year reaching stationary population
V39 - % population change, 1970-80
V43 - % labour force in services (1979)
V45 - share of primary exports in total registered merchandise exports (1979)
V48 - average annual population growth, 1970-80
AGTRADE - (exports plus imports)/GNP \times 100
DEN - average population density (persons/km ²)
D1 - (dummy) Mediterranean countries
D2 - (dummy) Eastern Europe

Sources: World Bank and U.N. Statistics, various publications.

Four dependent variables were selected, based on the preceding list of criteria, to test a set of explicit hypotheses on the structure of urban systems. The first measures the degree of urbanization, while the second and third relate to the hierarchical dominance of the urban system and the relative degree of primacy, respectively. The fourth relates to the average annual rate of growth of the urban population. The regression analyses were then repeated with dummy variables differentiating between the three broad regions or groupings of countries within the sample group: the Mediterranean countries (D1), Eastern Europe (D2) and all other countries.

Research Hypotheses

Urbanization and urban growth are complex processes and the spatial geometries of the urban systems which emerge from these processes defy simplistic generalizations. Consequently, one must start with the most modest of possible explanations and proceed carefully to increasingly more elaborate and robust explanations.

First, it is hypothesized that variations in the *level* of urbanization among developed countries reflect differences in:

- i) the stage or level of economic development (G.N.P. per capita (+);
- ii) the level of industrialization (percent of labour force in industry) (-);
- iii) The size of the service sector (percent of labour force in services) (+);
- iv) the volume of international trade (aggregate volume of trade/GNP) (+);
- v) the degree of dependence on primary exports in international trade (-);
- vi) average population density (persons/km²) (+); and
- vii) specific regional variables (binary), identifying a country's location in:
 - a) the Mediterranean region (-); or
 - b) Eastern Europe (-).

In other words we would expect that levels of urbanization would be higher in countries with mature economies, high incomes, service-based economies, high levels of international trade, and higher average population densities. Conversely, urbanization would be less prevalent in manufacturing economies, in countries which show a dependence on exports of primary products, and in those countries located in Eastern Europe and the Mediterranean region. The specific variable used to measure the relationship and the hypothesized sign of the coefficient are given in parentheses.

The origins and rationale for most of these hypotheses are well known; indeed they have been extracted from a decade or more of writing on urbanization and urban growth, and thus need not be repeated here (see, for example, [1;8;4]). The regional dummy variables, however, have been added to incorporate the effects of urban development controls and decentralization policies in Eastern Europe and the uniformly lower levels of urbanization among Mediterranean countries.

Further, it is hypothesized that variations in the degree of population concentration, by size class and in the level of primacy, should reflect differences in:

- i) the size of the country and total national population (-);
- ii) the level of economic development (GNP per capita) (-);
- iii) the degree of dependence on primary exports in foreign trade (+);
- iv) aggregate trade levels (-);
- v) the level or degree of urbanization (-).

Again the signs in parentheses identify the anticipated direction of the relationship.

These hypotheses were tested through least squares regression procedures using both transformed (log) and untransformed data. Several different versions of each analysis were undertaken, each seeking the best fit combination of variables. Others provide a replication of the regression models reported in the Jansen-Paelinck [7] study for developing countries. In the latter study only two urbanization indices were used as dependent variables: the level of urbanization and the proportion of the population resident in a nation's largest city.

Regression Results

Examples of the results of the regression analyses, with accompanying statistical parameters, are reported in Tables 3 through 6. Despite the reservations expressed earlier on the quality of the data, the results are relatively consistent and intuitively plausible, although the R^2 are generally not very high.

As expected, differences among countries in the level of urbanization (% population urban in 1980) are positively associated with the stage or level of economic development (GNP per capita), as well as with volumes of foreign trade and average population densities (Table 3). In the log transformed example (not reported here), the population density variable was negative and the scalar variable (total population) entered the equation.

Table 3
LEVELS OF URBANIZATION: REGRESSION RESULTS
Dependent Variable - V12 (% Population Urban, 1980)

Variable	R	R ²	R ² change	Simple R	B	Beta
V26 (GNP per capita)	.544	.296	.296	.544	.236D-3	.054
D1 (dummy, Mediterranean)	.574	.330	.034	-.483	-19.626	-.538
AGTRADE (aggregate trade)	.600	.360	.030	.020	-.286	-.488
D2 (dummy, Eastern Europe)	.626	.392	.032	-.150	-16.463	-.422
DEN (density)	.652	.425	.033	.181	.173D-1	.316
V45 (primary exports)	.668	.447	.022	-.011	.299	.408
V48 (average annual pop. growth 1970-80)	.707	.500	.054	-.253	-11.346	-.413
(CONSTANT)					80.401	

At the same time, differences in the level of urbanization, as hypothesized, are inversely related to the two regional dummy variables (D1, Mediterranean; D2, Eastern Europe). These results reflect the lower levels of GNP per capita in both Mediterranean and Eastern European countries as well as the imprint of planning, particularly rural industrialization programs and controls on the growth of large cities in the latter. In addition, those countries with high levels of urbanization also tend to have the lowest rates of growth in urban population and marginally lower levels of dependence on the export of primary products. The latter relationship emerges even though several of the more highly developed countries in the sample (for example, USA) have high ratios of primary exports.

The conditions of metropolitan dominance and primacy in urban size distributions, which remain points of interest for many researchers, are measured here by the simple variable, percent urban population in the largest city. A second measure, the percent of urban population in cities of 500,000 or more, is included at a later phase. The basic arguments are that metropolitan dominance reflects the combined result of an earlier stage of national development and a high degree of external economic dependency. The latter relationship, for example, should be picked up by the variable denoting the level of primary exports, while the former should be expressed through low levels of GNP per capita. Given the underlying differences in political ideology and geographic scale cited earlier, one would also expect that primacy would be inversely related to national population size and density as well as to the regional dummy variable for Eastern Europe.

All of these relationships appear with the correct signs in the regression results (Table 4), but with widely varying degrees of statistical significance. In the untransformed case the degree of primacy is negatively associated with total population size (the continental scale factor), population density, an Eastern Europe location, and GNP per capita, and is positively related to the proportion of exports in primary products, a Mediterranean location, and higher rates of population growth. These same relationships hold under log transformation, including the size variable.

In evaluating the degree of metropolitan concentration within an urban system, measured as the proportion of urban population resident in all cities over 500,000 in 1980, the same hypotheses should apply. Indeed, the same variables emerge as significant (Table 5), but in a different order, and the R^2 is considerably lower. The degree of concentration is positively related to the extent of specialization in primary exports, total population size, rates of population growth, and a Mediterranean location, and inversely related to levels of trade, GNP per capita, and an Eastern European location.

Table 4
DEGREE OF PRIMACY: REGRESSION RESULTS
Dependent Variable - V4 (% Urban Population in Largest City, 1980)

Variable	R	R ²	R ² change	Simple R	B	Beta
V17 (population)	.427	.183	.183	-.427	-.646D-3	-.318
DEN (density)	.509	.259	.076	-.249	-.942D-2	-.206
D2 (dummy, Eastern Europe)	.549	.302	.043	-.281	-.18.008	-.551
V26 (GNP per capita)	.599	.359	.057	-.188	-.234D-2	-.644
D1 (dummy, Mediterranean)	.623	.389	.030	.189	-.8.216	-.269
V48 (average annual pop. growth 1970-80)	.649	.421	.032	.082	-.8.690	-.378
V45 (primary exports)	.663	.440	.019	.272	.132	.214
(CONSTANT)					52.928	

Comparing these results with those obtained by Jansen and Paelinck [7] highlights some of the similarities and differences in the determinants of urbanization between developed and developing countries. Both the level of urbanization and the degree of primacy, in their study, were strongly associated with level of economic development and, surprisingly, negatively associated with primary-exports specialization and population growth rate. The dummy variables introduced into their analysis, denoting Asian and Latin American cities, also improved the goodness of fit of their equations. In each case the regional component in urbanization was shown to be as significant in accounting for differences in the structure of urban systems as the functional determinants.

Table 5
URBAN SIZE CONCENTRATION: REGRESSION RESULTS
Dependent Variable - V2 (% Urban Population in Cities Over 500,000, 1980)

Variable	R	R ²	R ² change	Simple R	B	Beta
V45 (primary exports)	.319	.102	.102	.319	.289	.292
V17 (population)	.442	.195	.093	.299	.813D-3	.301
D2 (dummy, Eastern Europe)	.547	.300	.104	-.296	-.26.894	-.620
AGTRADE (aggregate trade)	.579	.336	.036	-.244	-.185	-.285
V26 (GNP per capita)	.592	.351	.015	-.112	-.171D-2	-.354
V48 (average annual pop. growth 1970-80)	.607	.369	.018	.309	-.7.458	-.244
D1 (dummy, Mediterranean)	.612	.375	.006	.215	-.5.904	-.146
DEN (density)	.613	.376	.001	-.230	-.189D-2	-.030
(CONSTANT)					61.537	

Finally, the hypotheses relating to the correlates of urban population growth (average annual growth rate 1970-80) are also borne out in the final set of regressions, but with some revealing differences

(Table 6). The principal determinant of differential urban growth rates is of course the rate of national population growth. Beyond that, however, growth rates are positively associated with levels of specialization in primary exports and a Mediterranean location, and inversely associated with GNP per capita, levels of international trade, and population density. Interestingly, the Eastern European dummy variable does not enter into this equation, nor does total national population.

Table 6
URBAN GROWTH RATES: REGRESSION RESULTS
Dependent Variable - V8 (% Average Annual Growth Rate of Urban Population, 1970-80)

Variable	R	R ²	R ² change	Simple R	B	Beta
V48 (average annual pop. growth 1970-80)	.750	.562	.562	.750	.983	.550
V26 (GNP per capita)	.814	.662	.100	-.635	-.488D-4	-.173
DEN (density)	.848	.720	.058	-.493	-.103D-2	-.290
D1 (dummy, Mediterranean)	.859	.738	.018	.538	.508	.214
V17 (population)	.861	.741	.003	.024	-.907D-5	-.057
D2 (dummy, Eastern Europe)	.862	.742	.002	-.002	.201	.079
V45 (primary exports)	.862	.743	.001	.529	-.214D-2	-.045
AGTRADE (aggregate trade)	.862	.743	.000	-.342	.127	.033
(CONSTANT)					1.495	

Equally important are the other variables which do not appear in the regression results, either because they are not correlated with the dependent variables or because they were eliminated due to multicollinearity. The demographic variables (see Table 2), including birth rates, age structure (percent of working age) and the hypothetical size of the stationary population, were excluded because of weak correlations. Clearly, at least in the industrialized world, demographic differences among countries are not directly and consistently related to levels of urbanization nor to changes in the hierarchical structure of their urban systems.

More surprisingly perhaps is the failure of those variables denoting industrial structure (percent of the labour force in industry) and changes in manufacturing employment (percent annual growth 1970-80) to remain in the equations. This result may be attributable in part to the widely varying definitions of industrial structure and manufacturing employment used in each country, and in part to the fact that such highly aggregated data obscures substantial shifts within the manufacturing sector. In any case, there is little evidence in this data set to support the assertions that slow growth (or even a decline) in manufacturing has at this point altered the structure of urban systems. These relationships, however, remain to be more fully explored as additional data become available.

Conclusions

This study has demonstrated that systematic differences in levels of urbanization, in the hierarchical structure of national urban systems, and in the degree of metropolitan concentration and primacy, can be identified, measured and analyzed in a comparative framework. Moreover, the hypotheses advanced to account for these differences, with a few exceptions, were substantially confirmed. The results suggest that further cross-national comparisons of urban systems are indeed warranted.

Four criteria or measures of urbanization and urban system structure were examined in this paper. Differences in the level of urbanization, as hypothesized, are positively associated with levels of economic development and the density of the existing settlement base and are negatively associated with a national dependency on primary exports and with a centrally-planned economy. Primacy, crudely measured as the proportion of the population resident in the largest city, tends to be greater in smaller countries (in both population and area) and less in those with lower population densities and lower levels of development. The widely-cited relationship between high degrees of primacy and a dependence on the export of primary products did not emerge, presumably because many of the higher-income countries in the sample also show high proportions of primary exports in their trade profiles. In addition, high rates of change in urbanization correlated inversely with GNP per capita and population density but positively with specialization in primary exports.

Although few of these results are entirely new, they do offer an unusual empirical test of several long-standing hypotheses on urbanization as well as useful empirical criteria for further comparative research on urban systems. It should be recognized, however, that such simplistic analyses of urban systems must give way to more detailed examinations of urban system structure and growth. It is necessary, for example, to examine the complex variations in urban growth over space and time and the degree to which these mirror broad structural processes of economic, demographic and technological change. These are the subjects of future research.

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