The Impact of Settlement Structure on the Tertiary Sector of the Regions of the Federal Republic of Germany

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Introduction

Following the development theory of J. Fourastié, the number of employees in the tertiary sector in relation to the number of inhabitants has been widely used as an indicator for discribing the stages of the development of an economy. This concept has also proved to be fruitful in regional development theory. However, the discussion about an adequate and operational definition of the term "stage of development" often seems to be circular: On the one hand, the number of employees in the tertiary sector is used to define the term "stage of development", while, on the other hand, the "stage of development" is used to explain the interregional differences in the relative number of employees in the tertiary sector.

In this article, the number of tertiary employees of a region is treated as a dependent variable which is to be explained by other variables. Whether the explained variable or the explaining variables used are appropriate measures for terms like "stage of development" is not examined.

In the following, it will be shown that there exists a relatively simple way of estimating the number of tertiary employees in a region as a function of the distribution of the number of inhabitants among cities of different size classes.

The main hypothesis of this article is derived from a Christaller-type model. An alternative seems to be to base the hypothesis on assumptions similar to those used in central place theory developed by Lösch, Beckmann, McPherson and others. But the main object of this article is not to examine the logical relationships between central place theory and the *population oriented approach* proposed here. Rather, the aim is to show that there exist assumptions which allow for an efficient way of explaining regional differences in the proportion of the tertiary sector – assumptions which are less restrictive than those used in central place theory.

A population-oriented approach to explaining regional differences in the proportion of tertiary sector to total population

To state the basic hypothesis, the following abbreviations and definitions are used:

P_i^r = number of inhabitants which live in cities of size class i in region r

T_i^r = number of employees in the tertiary sector which work in cities of size class i in region r

The following size classes are defined:

Size Class	*Number of Inhabitants*	*Variable*
class 1:	less than 2,000	P_1^r
class 2:	2,000 – 5,000	P_2^r
class 3:	5,000 – 20,000	P_3^r
class 4:	20,000 – 100,000	P_4^r
class 5:	more than 100,000	P_5^r

It is assumed that for every region r the number of employees in the tertiary sector which work in cities of size class 1 is a constant proportion β_1 of the number of inhabitants which live in these cities:

$$(1) \qquad T_1^r = \beta_1 P_1^r, \qquad 0 < \beta_1 < 1$$

The variable T_1 includes population related tertiary activities, e. g. retail and other low order services.

Furthermore, it is assumed that the cities in size class 2 have tertiary employees which provide services of the kind found in class 1 plus *additional* employees which produce services of hierarchy level 2 which are not found in cities of class 1, but which are used by the inhabitants in the cities of size classes 1 *and* 2 (low order office activities, low order business services). In general it is assumed that the number of tertiary employees in class i, T_i^r, is not only a function of the population in class i, P_i^r, but also of the number of inhabitants $P_1^r, P_2^r, \ldots, P_{i-1}^r$ in the lower classes:

$$T_1^r = \beta_1 P_1^r$$

$$T_2^r = \beta_1 P_2^r + \beta_2 (P_1^r + P_2^r)$$

(2) $$T_3^r = \beta_1 P_3^r + \beta_2 P_3^r + \beta_3 (P_1^r + P_2^r + P_3^r)$$

$$T_4^r = \beta_1 P_4^r + \beta_2 P_4^r + \beta_3 P_4^r + \beta_4 (P_1^r + \dots + P_4^r)$$

$$T_5^r = \beta_1 P_5^r + \beta_2 P_5^r + \beta_3 P_5^r + \beta_4 P_5^r + \dots + \beta_5 (P_1^r + \dots + P_5^r)$$

Summation of (2) yields:

$$T^r = \sum_i T_i^r = \beta_1 (P_1^r + \dots + P_5^r) + \dots + \beta_5 (P_1^r + \dots + P_5^r)$$

(2.1) $$= (\beta_1 + \dots + \beta_5) \sum_i P_i^r = \sum_i \beta_i \sum_i P_i^r = \beta^* P^r,$$

where $\beta^* = \Sigma \beta_i$ and $P^r = \Sigma P_i^r$.

We can state that an implication of the assumptions made in (2) is that the ratio of tertiary employees to population T^r/P^r is the same in all regions, namely β^*. In the following, equation (2) is referred to as *hypothesis A* (Model A).

An alternative way of setting up a population – oriented model is to assume that the number of tertiary employees in cities of level 1 is the same as in Model A, namely

$$T_1^r = \alpha_1 P_1^r \qquad 0 < \alpha_1 < 1$$

But contrary to model A it can be assumed that second order tertiary activities provided in cities of level 2 are not a function ot the population in the cities of level 1 *and* 2 but only a function of the population in cities of level 2:

$$T_2^r = (\alpha_1 + \alpha_2) P_2^r \qquad 0 < \alpha_1, \alpha_2 < 1 \quad 0 < (\alpha_1 + \alpha_2) < 1$$

In general: The cities of size class i provide all services of the classes 1, 2, ..., i but no services of the higher classes $i + 1$, $i + 2$, ...

(3) $$T_i^r = (\alpha_1 + \dots + \alpha_i) P_i^r; \qquad 0 < \alpha_1, \dots, \alpha_i < 1 \quad 0 < (\alpha_1 + \dots + \alpha_i) < 1$$

This assumption is reffered to as *Model B.*

The differences between Models A and B are due to different assumptions on the consumption patterns: In Model A it assumed that the inhabitants in the low order cities have the same consumption pattern as those in the cities of higher rank, whereas in Model B it is assumed that, for example, the population in the small communities do not visit the theatres, universities museums and all other high level tertiary activities to the same extent as the inhabitants in the cities where these activities are located.

From the assumptions of Model B we can derive the following equation which describes the number of tertiary employees in the region as a function of the *intra*-regional population distribution (summation of equation (3)):

(4) $$T^r = \sum_i T_i^r = \alpha_1 P_1^r + (\alpha_1 + \alpha_2) P_2^r + \dots + (\alpha_1 + \alpha_2 + \dots + \alpha_5) P_5^r$$

Using the following abbreviations

(5) $$a_1 = \alpha_1$$
$$a_2 = \alpha_1 + \alpha_2$$
$$\vdots$$
$$a_5 = \alpha_1 + \alpha_2 + \dots + \alpha_5$$

we can rewrite equation (4) as

(6) $$T^r = a_1 P_1^r + a_2 P_2^r + \dots + a_5 P_5^r.$$

In the following test computations it will be shown that Model B is in correspondance with reality whereas Model A does not correspond with the empirical data to the same extent. The two Models have different implications which can be summarized as follows.

From *Model B* we can conclude that the relationship between the number of employees in the tertiary sector and the number of inhabitants is not the same in all regions: Dividing equation (6) by P^r, we obtain

(7) $$\frac{T^r}{P^r} = a_1 \frac{P_1^r}{P^r} + \dots + a_5 \frac{P_5^r}{P^r},$$

which shows that the ratio T^r/P^r is a function of the relative shares of the population classes in the total population of the region. Another consequence is that the amount of supplied services of level i is not a function of the number of the inhabitants in cities of lower size classes but of the number of inhabitants in the cities of size class i only. If the assumptions of Model B hold, a region which has many inhabitants in the lower city-size classes and less in the higher size classes will supply fewer high level services than a region with many inhabitants in the larger cities and fewer in the smaller ones.

By comparison *Model A* suggests an equal interregional distribution of tertiary employees: From equation (2.1) it can be expected that the ratio T^r/P^r should be the same in all regions. Model B can be classified as the more *normative* one, because it suggests a more equal interregional and intercity-size class distribution of services. If we compare the characteristics of the models with the approach of contemporary central place theory we can state the following basic differences:

(1) In central place theory the frequency distribution of the population of cities of different sizes is treated as the *dependent* variable which is explained by using service ratios indicating how many people are required in a center to serve the population of the center and the population of the complementary area. Here the role of the variables is reversed: The distribution of the population in cities of various size classes and the inter-size class differences of the service ratios are treated as the *independent* variables in order to explain the interregional differences in the ratio T^r/P^r which can be interpreted as an overall service ratio.

(2) The assumptions about the service ratios made in central place theory are more similar to the normative assumptions of Model A than to those of Model B: Beckmann and McPherson assume, for instance, that the number of inhabitants in a center of the nth level, c_n, required to provide services of a certain level, is not only proportional to the population of the center itself but also to the population in the cities of the complementary area. For a detailed description of this assumption see Beckmann and McPherson (1970, p. 26, equation 2).

Empirical test results

Requirements for an adequate test

The Models stated in (2.1) and (6) can be tested by applying cross section analysis based on a sample of a sufficient number of regions. As both hypotheses are linear functions, linear regression procedures can be used.

In order to avoid biased test results the regions should be formed in such a way that, (1) the value of the dependent variable T^r of a region should not be influenced by either the values of the dependent nor of the independent variables of any other region, and, (2) the size classes of the cities should be properly defined in order to reflect the real hierarchy of the nested markets which offer services of various levels.

The condition (1) of minimal interaction between the sample regions can hardly be fulfilled: As central place theory shows, most settlement structures, and especially those in Germany, are hierarchical which means that cities of a high rank supply services not only for the population of the region but also for the population of other regions. If cross section analysis is used, a contradiction would arise, namely a contradiction between the test requirement of a minimal interregional interaction and the fact of market connections between the regions: Only regions which are completely separable in the sense that they supply all needed services within their own frontiers meet the test requirements. Evidently it is not possible to subdivide a developed economy into regions which strictly fulfill these conditions. One has therefore to choose between different regionalizations which are all more or less inadequate for test purposes.

In the case of the Federal Republic of Germany, the 79 Planning Regions seem to meet the test requirements best because they have been set up by the local planning authorities of the 11 States which conducted the regionalization task on the principle of functional regions (see the map at the end of the article).

Test results

For the computations, the variables T^r and $P^r_1, \ldots, P^r_5$ have been measured for each of the 79 regions using the statistics of the 1961 census.

The first multiple linear regression on the basis of the full sample of all 79 regions yields the following parameters for function (6), Model B (with u^r as disturbance term and the standard deviation of the parameters in brackets):

$$(6.1)\quad T^r = \underset{(9{,}219)}{-\,6{,}844} + \underset{(0.048)}{0.154}P^r_1 + \underset{(0.101)}{0.288}P^r_2 + \underset{(0.062)}{0.253}P^r_3 - \underset{(0.036)}{0.055}P^r_4 + \underset{(0.008)}{0.250}P^r_5 + u^r$$

$$\rho^2 = 0.947;\ \text{full test sample: } r = 1, \ldots, 79$$

It can be stated that the coefficient of determination is high ($\rho^2 = 0.95$), but the parameter of variable P^r_4 has not the expected positive sign. In addition, the theory leads us to expect an ascending order of the parameters

$$a_1 < a_2 < \ldots < a_5$$

which does not correspond with the computed values of a_3, a_4 and a_5.

It can be assumed that the test requirement of minimal interregional interaction is less fulfilled in regions with big cities which supply services not only for the regional population but also for the population of other regions. If these regions are excluded from the test sample in order to fulfill the test requirements the test results should improve.

The following computation is based on 42 regions (instead of all 79) which have cities only in the first 4 size classes but no cities in size class 5. The calculations show the expected improvements:

$$(6.2)\quad T^r = 187 + 0.116P_1^r + 0.103P_2^r + 0.179P_3^r + 0.203P_4^r + u^r$$
$$(3{,}910)\quad (0.021)\quad (0.058)\quad (0.036)\quad (0.031)$$

$\rho^2 = 0.904$; restricted test sample:
$r = \{1, 2, 5, 8, 10\text{–}13, 16, 18, 24, 28, 31, 33\text{–}35, 38, 39, 41, 42, 44, 46, 50, 53\text{–}57, 59\text{–}61, 64\text{–}66, 69\text{–}73, 76, 77\}$

The coefficient of determination is again high ($\rho^2 = 0.90$), all parameters have the expected sign, and the order

$$a_1 < a_2 < \ldots < a_4$$

is largely fulfilled.

An even higher coefficient of determination occurs when the test is restricted to the subsector trade and commerce (see sector 10 in the following table):

$$(6.3)\quad T^r_{T+C} = -812 + 0.046P_1^r + 0.045P_2^r + 0.052P_3^r + 0.076P_4^r + u^r$$
$$(1{,}165)\quad (0.006)\quad (0.017)\quad (0.011)\quad (0.009)$$

$\rho^2 = 0.937$; test sample as in test (6.2)

It may be that the markets of this subsector experience less interregional interactions than the market of the whole tertiary sector. If this assumption holds, this would be the most plausible interpretation for the test improvement.

The following table gives a survey of the parameters of the functions (6.2) and (6.3). They can be interpreted as the percentage of inhabitants employed in the tertiary sector. The figures show in general the rising order which is suggested by the theory:

size class of cities in the region		percentage of inhabitants employed in the tertiary sector	subsector trade and commerce
less than	2,000	11.6	4.6
2,000 –	5,000	10.3	4.5
5,000 –	20,000	17.9	5.2
20,000 –	100,000	20.3	7.6

Test computations for Model A (function 2.1) yield the following parameters[1]:

$$(2.2)\quad T^r = -1{,}886 + 0.148P^r + u^r$$
$$(3{,}772)\quad (0.008)$$

$\rho^2 = 0.889$; test sample as in tests (6.2) and (6.3)

Again, we can see a significant coefficient of determination and a low variance of the parameter a_1.

Table 1
Coefficients of Determination for Various Sectors, 1961
(estimation function 6.2)

	Production Sectors	ρ^2	
non tertiary sectors	1 Agriculture, forestry, fishing	0.72	
	2 Energy, mining	0.42	
	3 Chemicals, building materials	0.62	
	4 Iron and steel, non-ferrous metals	0.18	
	5 Constructional steel, machinery, vehicles	0.28	
	6 Electrical engineering, hardware and metal goods	0.21	
	7 Timber, paper, leather, textiles	0.58	
	8 Food, beverages and tobacco	0.79	
	9 Construction	0.93	
tertiary sectors	10 Trade and commerce	0.94	whole tertiary sector = 0.90
	11 Transportation, communications	0.76	
	12 Other services	0.79	
	13 Public sector	0.86	
	14 Private households, private organizations	0.53	

Which Model is best confirmed by the data? This question cannot be answered if the arguments are solely based on a comparison of the coefficients of determination. We can state that the coefficient of Model B is higher (0.904 in function (6.2) and 0.937 in function (6.3)) than that of Model A (0.889 in (2.2)), but the differences are minor. In discriminating between the competing hypotheses, the strongest argument seems to be for Model B in that the theoretical order of the parameters

$$a_1 < a_2 < \ldots < a_4$$

is almost completely in correspondence with reality.

Although these test results confirm Model B to a high degree, support for the results can be increased by a further *indirect* test procedure: If the results are substantial and not the reflection of a mere statistical correlation between variables, then the coefficient of determination should be significantly lower for those sec-

[1] To make the results comparable to the tests of functions (6.2) and (6.3), the cross-section analysis is based on the same sample of regions as in (6.2) and (6.3).

tors which cannot be classified as tertiary. As the following table shows, the coefficient of determination, which refers to the same test conditions as specified in the estimation function (6.2), is significantly lower in most non-tertiary sectors. Obviously the regional distribution of employees in the tertiary sector can be explained by a population-oriented approach whereas this approach is not adequate for other sectors (except for the construction sector where a high coefficient, $\rho^2 = 0.93$, has been found).

Alternative test computations

As the data requirements for testing the Models are not difficult to meet, it should be possible to test the Models in other countries as well. However, it is unlikely that the results will be as positive as for the FRG because the test condition for a cross-section test, low interregional interaction in the sense discussed above, may not be fulfilled to the same extent as in the case of the FRG. In the FRG there are a large number of evenly distributed centers and subcenters which provide all kinds of services in every part of the country. This is naturally due to political conditions, e. g. to a high degree of administrative and even legislative autonomy. Furthermore, the fact that West Germany has no real national capital improves the test conditions in preventing the concentration of various high level services in one single city. It may therefore be possible that the basic hypotheses holds in other countries as well but this cannot be tested by the use of cross-section analysis, if the respective countries cannot be subdivided into a sufficient number of regions without cutting hierarchically nested service markets.

In these countries, test calculations may be based on the following reformulation of Model B. From equation (3) and from definition (5) we obtain

(8) $$T_i = a_i P_i \qquad T_i/P_i = a_i$$

where the abbreviations

$$T_i = \sum_r T_i^r;\ P_i = \sum_r P_i^r$$

are used.

If Model B holds we can conclude that

(9) $$T_i/P_i > T_{i-1}/P_{i-1}$$

which means that $a_1 < a_2 < \ldots < a_5$.

In order to test the relationship (9), employment and population data have to be available for communities only at the national level: In (9) the index r for the regional level does not occur.

In the case of the FRG these data are available in the classification given in Table 2.

Whereas the parameters a_1, a_2 and a_3 in function (6.3) are above the corresponding value for the class "less than 20,000" in Table 2, the parameter a_4 lies in the intervall of the values for the classes 20,000 – 50,000 and 50,000 – 100,000 in Table 2. The differences may be due to the fact that Table 2 contains all cities in all regions whereas the calculations in (6.2) and (6.3) are based on a restricted sample of regions. In order to draw conclusions from these calculations with regard to the question of whether or not Model B is supported a more detailed classification of the cities with less than 20,000 inhabitants is required. Unfortunately, the statistics do not meet these requirements.

One point seems to be important for the interpretation of these results: The parameters in Table 2 follow the ascending order predicted by the theory, but it is not possible to conclude from these figures at the *national* level that this order should be followed by the parameters in the *regions* as well. We can only conclude that if the order $a_1 < a_2 < \cdots < a_n$ exists in the regions then it must exist at the national level too. If the order exists at the national level it need not necessarily exist at the regional level. In the case of the FRG, cross-section analysis shows that this order exists at both national as well as regional levels.

Table 2

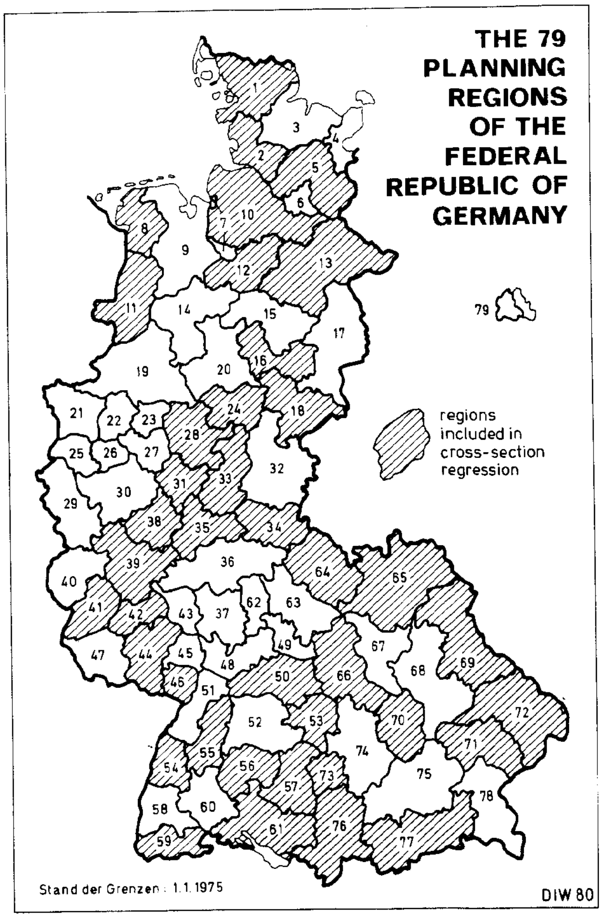
Distribution of Employees in the Sector Trade and Commerce ($T + C$) and of Population (P) by Size Classes of Cities in the FRG, 1961

Population class i	$T_{T+C,\,i}$ (1,000 persons)	P_i (1,000 persons)	$T_{T+C,\,i}/P_i$
less than 20,000	1,068	28,275	0.038
20,000 – 50,000	407	5,531	0.074
50,000 – 100,000	306	3,568	0.086
100,000 – 200,000	347	3,776	0.092
200,000 – 500,000	372	4,069	0.091
more than 500,000	1,081	10,956	0.099
Total	3,581	56,175	0.064

Source: Statistisches Bundesamt, Volkszählung v. 6. 6. 1961, Heft 12, p. 34;
Statistisches Jahrbuch deutscher Gemeinden, 1963, p. 29

Concluding remarks

An interesting interpretation of Model B, formulated in function (7), can be stated as follows: If there is a general shift of the population from small to larger cities, the regional T^r/P^r ratios and even the absolute number of employees in the tertiary sector may increase in all regions, even in those where the absolute number of inhabitants remains constant or declines. It is likely that a great deal of the frequently cited "tertiarization" trend, indicated by increasing *T/P*-ratios at the national level, is a reflection of the inter-class shift in population distribution.



Summary

In central place theory the frequency distribution of the population of cities of different sizes is explained by assumptions about service ratios for the cities of different rank and size. The model presented is not based on the restrictive assumptions of central place theory: The distribution of the regional population between size classes of cities is treated as a variable which is not explained but used as an explanatory variable in explaining regional differences in the relationship between the number of employees in the tertiary sector and total population. Using data of the 1961 census, it can be shown that the proposed population-oriented approach is effective in explaining the actual interregional differences in this relationship. The Model is confirmed by further computations for the nontertiary production sectors in the FRG.

References

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