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2 authors:

Emilio Casetti
The Ohio State University

J.P. Jones
The University of Arizona

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By **Emilio Casetti and John Paul Jones III**

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REGIONAL SHIFTS IN THE MANUFACTURING PRODUCTIVITY RESPONSE TO OUTPUT GROWTH: SUNBELT VERSUS SNOWBELT

Emilio Casetti and John Paul Jones III
Ohio State University

INTRODUCTION

According to Verdoorn's law, productivity tends to rise faster in economic sectors that are in the process of expanding. Does this law hold 'spatially', in the sense that greater productivity growth is experienced by expanding regions rather than by regions that stagnate or decline?

This research question is of major theoretical and practical significance. In many countries, including the US, population and jobs have been moving out of old established industrial cores into regions that previously declined or stagnated. Investigating the possible spatial occurrence of the Verdoorn law can shed light on the relation between these 'deglomerative' trends and productivity change.

In this paper, US manufacturing data by states spanning the 1954-1977 time horizon are used to study the relation between manufacturing productivity dynamics and Snowbelt Sunbelt 'shifts'. To this effect, first the validity of the Verdoorn law is investigated over the 1954-1977 time span and over subsets of it. Then, the spatial variation in the occurrence of the Verdoorn law is brought into focus by techniques for analysing spatially varying regression parameters.

The sections that follow will introduce the Verdoorn law and the literature on the Snowbelt Sunbelt shifts. Then empirical analyses concerning the spatial occurrence of the Verdoorn law will be discussed. Finally, the results of these analyses will be related to issues pertaining to the contemporary regional dynamics in the US.

VERDOORN LAW AND SNOWBELT SUNBELT SHIFTS

According to the Verdoorn law productivity grows faster in expanding economic sectors (Verdoorn 1948; Kaldor 1967, 1970). A mathematical formulation of the Verdoorn law can be arrived at as follows.

Let Y and L denote respectively output and labor inputs. Indicate labour productivity by y, where

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(1) $y = Y/L$

Let Y and L be smooth functions of time t. Denote by a quote superscript the logarithmic derivative of the superscripted variable, so that for instance

(2) $Y'' = d(\ln Y)/dt = (1/Y)(dY/dt)$

Hence, Y" is the instantaneous percentage rate of change of Y over time. The Verdoorn law can be represented as a y"(Y") functional relation, characterized by the restriction dy"/dY">0 for Y">0. Hence, for b>0 equation (3) is a linear specification of the Verdoorn law.

(3) $y'' = a + bY''$

Within a production function frame of reference the occurence of the Verdoorn law can be related to economies of scale. To show it, let

(4) $Y(t,L) = \exp(m+nt)L^{v}$

be a quasi production function in which L stands for physical labor inputs, while capital inputs and technological levels are represented by the expression exp(m+nt). For n>0 this expression implies that over time, same labor inputs produce increasing outputs as a result of capital accumulation and technological progress. v is a scale economies diseconomies parameter, since if the labor inputs are, say, doubled, it follows from (4) that

(5) $Y(t,2L) = 2vY(t,L)$

Namely, Y(t,2L) is greater than, equal to, or smaller than 2Y(t,L) respectively if v is greater than, equal to, or smaller than 1, which identifies v as a scale economies parameter. By taking the logarithmic derivatives of (1) and (4) we obtain equations (6) and (7)

(6) $y'' = Y'' - L''$

(7) $Y'' = n + vL''$

that combine to yield the following y"(Y") relation:

(8) $y'' = (n/v) + ((v-1)/v)Y''$

Equating the coefficients of (8) and (3) we have

(9) $a = n/v$

(10) $b = (v-1)/v$

which prove that within this frame of reference $b>0$ if $v>1$. In other words, the Verdoorn law holds if increasing returns to scale prevail.

The Verdoorn equation provides a convenient basis for estimating production functions parameters. Here, for instance, regression estimates of a and b of equation (3) can be obtained using data on percentage rates of change of labor productivity and of product. Then these estimates could be entered into equations (9) and (10) to obtain the structural parameters n and v of (4).

Within the production functions frame of reference, Verdoorn equations can be usefully employed to investigate the spatial components and determinants of productivity change. In such analyses, however, it is desirable to use production functions in which capital appears explicitly, and consequently also more general formulations of the Verdoorn equation. Two empirical analyses of this kind were carried out by Casetti (1981, 1982b) to investigate the spatial variation of production functions' parameters, and of components of productivity growth.

However, the Verdoorn relations can be also interpreted without reference to underlying production functions. Let us show how, using the linear specification of y"(Y") defined earlier. The meaning of the parameters a and b of equation (3) can be inferred from the following:

(11) $y''(0) = a$

(12) $dy''/dY'' = b$

Clearly, a denotes 'productivity change in the absence of output growth', and b denotes 'change in productivity growth produced by a unit of output growth'. Specifically, an estimate of b is a measure of the productivity response to output change. A high value of b indicates that productivity growth responds strongly to output growth, and vice versa. The spatial variation of b identifies the spatial differential in the productivity response to same output growth.

The term bY" of the Verdoorn equation measures the component of the percentage rate of change of productivity y" due the output growth Y". Let us call Verdoorn Ratio (VR) the ratio of the productivity growth due to an output growth of Y", divided by the total productivity growth y".

(13) $VR = bY''/y''$

Ordinarily, the productivity growth due to output growth will be a fraction of the total productivity growth, and in this case $0<VR<1$. However, in regions where stagnating economic sectors experience technological involution and decapitalization, bY'' could be greater than y'', which will produce a $VR>1$. Also, a negative productivity response to output growth, or a decline in output can produce a $VR<0$. Both b and VR refer to the effects of output change on productivity. However, b is the productivity effect of a unit of output growth, while VR identifies the relative weight of the productivity growth due to ouput growth.

This study rests upon a linear specification of the Verdoorn relation, and upon an interpretation of it that does not rely on a production function frame of reference. Its focus is upon empirical analyses of the spatial temporal variation of the productivity response to output growth, b, and of the ratio VR relating productivity change due to output growth to total productivity change.

The tendency for economic activities to disperse out of old established industrial cores has been investigated and documented for several countries (Richardson 1980; Vining, Pallone, and Yang 1980). The US counterpart of these trends is represented by shifts of population and jobs out of the Snowbelt into the Sunbelt, and also away from some larger metropolitan agglomerations into urban centers of intermediate size and into non urbanized areas (Beale 1977; Berry and Dahman 1977; Chinitz 1978; Rees 1979; Sternlieb and Hughes 1975, 1978). Some phases of these shifts predate the seventies. Others, such as the movement of population and economic activities into the South have been placed into focus only recently and constitute an unexpected reversal of long run trends that shaped the spatial structure of the American economic system (Sternlieb and Hughes 1975; Vining and Strauss 1977).

Empirical analyses of the relation between the Verdoorn law and the Snowbelt Sunbelt shifts, as well as their results and significance are presented in the sections that follow.

INTRODUCTORY EMPIRICAL ANALYSES

In order to investigate whether the Verdoorn law holds spatially in the contemporary US, first the parameters of equation (3) were estimated over a number of time intervals spanning the 1954-1977 time horizon. The data used are number of manufacturing production workers and manufacturing value added for the 48 conterminous States and the District of Columbia for the years 1954, 1958, 1963, 1967, 1972, and 1977. The 1954 through 1972 data are taken from the 1977 City and County data book. The 1977 data were extracted from the 1980 Statistical Abstract of the US. The value added data, were converted into constant 1967 dollars.

Denote the manufacturing employment and value added, in constant 1967 dollars for the year t and state i respectively by EMP(t;i) and VAD(t;i). Denote by $EMPH(t_0,t_1;i)$ and $VADH(t_0,t_1;i)$ respectively the percentage rate of growth of labor inputs and product, for the state i, over the time interval t_0, t_1. EMPH and VADH were generated from the source variables using the following equations

$$EMPH(t_0,t_1;i) = \ln(EMP(t_1;i)/EMP(t_0;i))/(t_1-t_0) \quad (14)$$

$$VADH(t_0,t_1;i) = \ln(VAD(t_1;i)/VAD(t_0;i))/(t_1-t_0) \quad (15)$$

The variables y" and Y" that appear in equation (3) were operationalized as follows:

$$Y'' = VADH \quad (16)$$

$$y'' = VADH - EMPH \quad (17)$$

Values of the y" and Y" variables were calculated for the time intervals 1954-1963, 1958-1967, 1963-1972, 1967-1977, and 1954-1977. Regression estimates of equation (3), VR ratios, and aggregate percentage rates of growth of productivity for these intervals are shown in Table 1. The decline in productivity growth that recently has been the object of so much discussion and concern (Denison 1979), is quite apparent from column 6 of Table 1. The data in this column document that the growth rates of productivity declined since the early sixties. The 1967-1977 figure shows a slight reversal of this trend.

The partial F's and R2's in columns 3 and 4 of the table show clearly that the Verdoorn relation is less significant over the 1954-1977 time horizon than it is over any of its four subsets. This result is contrary to what one might expect. Growth rate data tend to be contaminated by noise the more, the shorter is the time interval over which they are calculated (Morgenstern 1950). Consequently regression analyses based on growth rates spanning a larger time interval should yield results stronger than those based on shorter time intervals. However, this is only true to the extent that the relation investigated has not 'drifted'. Anticipating what will become apparent from the results reported later on, the weaker performance of the Verdoorn relation over the 1954-1977 time span can be explained by a spatial temporal drift in the parameters of the Verdoorn relation, that can itself be linked to the snowbelt sunbelt 'shifts'. Verdoorn relations that are strong over narrow spatial temporal contexts, offset each other and vanish from analyses encompassing wider contexts.

By contrasting the results in lines (1) through (5) of Table 1 it is apparent that F's and R2's are larger over time intervals characterized by higher productivity growth. Also, both the productivity response to output growth, b, and the ratio of the productivity change due to output growth to total productivity change, VR, tend to be larger during time intervals in which the productivity growth is higher. Namely, b and VR vary over time. Do they vary over space as well? And, do they vary spatially in a different fashion at different points in time? Are these spatial temporal differentials related to the Sunbelt Snowbelt shifts?

These questions were investigated using two complementary approaches. The first one constitutes a spatial application of the Drift Analysis of Regression Parameters (DARP) and is designed to identify different mixes of spatially local versus global components of parameter variation. The second approach involves expanding the parameters of the Verdoorn equation into trend surfaces, and then estimating the coefficients of a spatially expanded Verdoorn equation. Recently, this latter approach has been succcesfully applied to analyzing the spatial variation of the coefficients of an equation relating welfare participation rates to their determinants (Jones 1982). The two analyses and their results will be described in the sections that follow.

DARP

DARP stands for Drift Analysis of Regression Parameters. It is a technique designed to investigate in a systematic and controlled fashion, whether and to what extent the parameters of a regression relating a dependent variable Y to predictor variables X tend to change in response to attributes of the observations measured by a set of Z variables. The interested reader will find a general discussion and justification of the technique in Casetti (1982a). Here DARP will be only dealt with to the extent required by its application to analyzing the spatial variation of the Verdoorn equation.

In the data set used for estimating the parameters of the linear Verdoorn equation, the observations are states (plus the District of Columbia), and the variables are rates of change of productivity, y", and of product, Y". Suppose we complement these data by a Z matrix, with variables z1 and z2 that are geographical coordinates of the states. Specifically, the Z matrix has rows associated with states, and its two columns contain the coordinates of the states' centroids. Hence, each observation can be associated not only with a point in the conventional regression space, in which the axes are associated to the regression variables, but also with a second point in a Euclidean Z space, with axes associated to the Z variables.

Let z_{ij} denote the coordinate of the ith state with respect to the jth coordinate axis in Z space. Denote by r a 'reference point' with coordinates r_1 and r_2 with respect to the Z axes. r may or may not coincide with an observation. Let D(r,i) be the distance between the ith observation and the reference point r, and w(D) denote a non increasing functions of D used to assign 'weights' to the observations. Specifically, an observation's weight is the value assumed by the function w(D) at the observation's point image in Z space. In this study, a Gaussian specification of w(D) was used:

$$(18) \quad w = \exp(-hD^2) \qquad h>=0$$

h is a 'distance decay' or simply, 'decay' factor controlling the extent to which the weight of an observation declines with its distance from the reference point in Z space. Indicate by w(i,r,h) the weight of the ith observation when a reference point r and a decay factor h are given. Namely

(19) $w(i,r,h) = \exp(-hD^2)$

If an observation's point image in Z space coincides with the reference point r the weight of the observation equals one, irrespective of the value of h. For any given value of h>0, observations that do not coincide with r will have a weight the smaller, the larger their distance from the reference point. If h=0, all the observations will have a weight of one irrespective of their distance from the reference point, and also irrespective of the location of the reference point. When a value of the decay factor h, and the coordinates of a reference point are specified, a set of weights for all the observations in the data set becomes also defined. These weights can be used to calculate weighted regression estimates of the equation to be investigated for possible parameter drift.

In order to clarify how the procedure described can be used to analyze parameter drift consider the following. Any point in Z space can be a reference point. Consequently, as soon as a value of the decay factor h is defined, any point in Z can be associated with a set of 'regression results'. The differences among the regressions associated with different locations in Z space can indicate the occurrence and extent of drift in regression parameters, and also in measures of regression strength such as R^2.

Suppose that each observation in turn is defined as a reference point, and is associated with a specific regression result. Then we will have as many estimates of the regression parameters, of R^2, and so on, as there are observations. Alternatively, points that are representative of substantively meaningful clusters of observations can be selected as reference points and associated with regression results. The latter course of action was employed here, since it allows scanning meaningful regions in Z space for regression drifts, but at considerably reduced computational costs. Specifically, reference points associated with census divisions' centroids were investigated. The coordinates of each division's centroid were obtained by averaging the coordinates of the centroids for the states in the division.

Let us now discuss the role of the decay factor h. It was pointed out earlier that when a value of h is given, any point in Z can be associated with a set of regression results. If h=0 all results are equal to one another, and to an ordinary non DARP regression. h controls the extent to which observations closer to the current reference point in Z space are weighted more than the observations more distant from it. A large h deemphasizes the observations more distant from the reference point, so that the regression associated with the reference point reflects to a greater extent the immediate neighborhood of the reference point in Z space.

Summing up, large values of h bring into the forefront the neighborhood of the current reference point; smaller values of h cause the regression at each reference point to be influenced by the more distant observations. Each h produces regressions reflecting a mix of local versus global influences in Z space. Small h's deemphasize the local influences, large h's deemphasize the global influences. On the other hand, the sum of the 'weights' grows smaller as h grows larger, which places a limit on the extent to which local effects can be brought to the surface. In this study DARP is applied to investigating the Verdoorn equation in a geographical Z space. However, the technique is of a general applicability to any Z space (Casetti 1982a).

DARP REGRESSIONS

Analyzing the spatial drift of the Verdoorn equation's parameters via DARP requires a Z matrix and meaningful values of the decay parameter h. The Z matrix used includes the coordinates of the centroids of the observations with respect to two arbitrary axes. These coordinates were scaled so that '1' would represent one hundred miles.

The h values employed in the analyses were arrived at as follows. Equation (18) implies that the weight w* of a state centroid located 100 miles from a reference point, namely at unit distance from it because of the scaling used, is given by the expression

(20) $w^* = \exp(-h)$

Which in turn implies that

(21) $h(w^*) = -\ln(w^*)$

Equation (21) means that, for instance, h(.99) denotes the value of h that would give a weight of .99 to a state centroid at a distence of exactly 100 miles from a reference point. After some explorations h(.99), h(.97), h(.95), h(.93), h(.91), and h(.89) were selected for use in this study.

Two DARP analyses were carried out. The first one, exploratory in nature, was designed to evaluate which values of h if any, would reveal substantively significant spatial variations in the parameters of the Verdoorn equation. It employed the 1967-1977 data and the full range of h values specified earlier. The focus of the second analysis instead was upon the change over time in the spatial variation of the productivity response to manufacturing growth. It was based on an intermediate value of h, and on the 1954-1963 and 1967-1977 data.

Tables 2A, 2B, and 2C show the results of DARP regressions for reference points corresponding to the Census Divisions's centroids, and for h(.99), h(.97), h(.95), h(.93), h(.91), and h(.89). These h values correspond to increasing local effects. For the sake of clarity, let us reiterate that here local effects mean the influence of the states near a Census Division centroid on the regression results for the division. A greater intensity of local effect signifies that the states more distant from a given division's centroid would be weighted less, and hence would contribute less to the regression for the division. The b coefficients of the Verdoorn equation by division, and for the specified range of h's are given in Table 2A. Tables 2B and 2C show respectively the coefficients of determination and the degree of freedom (DOF) for the DARP regressions that yielded the b estimates shown in Table 2A.

A comparison of the DOF's for the various h's documents the reduction in degrees of freedom that is associated with a greater emphasis on local effects. The degrees of freedom for h(1) has a value of 49, and corresponds to the number of observations in the analysis. More precisely, 49 is the sum of the weights of the observations in the analysis, when every observation has a weight of one. As the local effects increase, the weights of the observations more distant from divisional reference points grow smaller. Consequently, also the sum of the weights truncated to the nearest integer, that constitutes the DOF, grows smaller. The analysis was carried out down to h(.89) because beyond this h value regressions incomputable due to insufficient DOF's started to appear.

The increase in the spatial differentiation of the productivity response to output growth, associated with higher local effects becomes readily apparent by comparing the columns in Table 2A. As we move in the direction of increasing local effects, namely, from left to right, the b's in the columns are increasingly different from one another. On the other hand, the changes in b's by division are considerably different. The b's of the Snowbelt divisions change only to a minor extent. Specifically, those for New England and Middle Atlantic increase moderately, while those for the East North Central and West North Central decline moderately. Instead, the b's for the South and the West show a wider range of behaviour. The East South Central, West South Central and Mountain divisions display a strong increase in b as local effects are emphasized. The b for the Pacific declines and becomes negative and the b for the South Atlantic division displays slight oscillations around a seemingly horizontal trend.

The single most significant result of this analysis is represented by the striking increases in b in the East South Central, West South Central and Mountain divisions when local effects are emphasized. In other words, the 1967-1977 productivity response to output growth for these three divisions is strongly flattened out when global effects are prominent. Also, Table 2B shows that the coefficients of determination for East South Central, West South Central, and Mountain divisions increase strongly when the intensity of the local effects is increased: higher local effects are associated with stronger Verdoorn relations as well.

The next set of DARP analyses investigate whether a spatial shift of the productivity response to output growth occurred between the 1950's and the 1970's. They are based on an intermediate decay factor of h(.97), that enhances to a sufficient degree local effects, while retaining resonably high DOFs for all the divisions. In a capsule, these analyses involve DARP regressions for h(.97), for reference points associated with the Divisions' centroids, and for the time periods 1954-1963 and 1967-1977.

These intervals cover the end points of the 1954-1977 time span. The years 1963 and 1967 were selected because Census of Manufacturing data are available for them. The fact that the research design adopted leaves the 1963-67 period uncovered was regarded to be unimportant, since here the issue dealt with is whether a spatial drift of the Verdoorn relation had taken place between the 1950's and 1970's.

The results of the second set of DARP analyses are shown in columns 1 through 4, lines 1 through 9 of Table 3. Specifically, the b coefficients for the two time periods are given in columns 1 and 3 of the Table. As we compare these columns two obvious patterns of change become apparent. First, the b values of the Snowbelt divisions (New England, Middle Atlantic, East North Central, and West North Central) show a clear decline. Second, some divisions of the Sunbelt (East South Central, West South Central and the Mountain) show just as clear a tendency to increase. Unlike other southern divisions, the b values of the South Atlantic and Pacific divisions decline.

The results of the analyses in this section can be summarized as follows. The productivity response to output growth exhibits spatial variation that changed over time. From the 1950's on, it declined in the Snowbelt divisions, and it increased in some of the Sunbelt divisions. Recently this response has been highest in some Sunbelt divisions. In the 1950's it was highest in the Snowbelt divisions.

TREND SURFACE EXPANSIONS

The analyses that follows were carried out to determine whether an hypothesis testing frame of reference would reveal shifts over time in the spatial variation of b comparable to those uncovered by the second set of DARP regressions. These analyses are based on trend surface expansions of the Verdoorn equation and constitute an application of the Expansion Method (Casetti 1972).

The Expansion Method is a technique for building more complex 'terminal' models from simpler 'initial' ones. The method involves redefyning at least some of the parameters of the initial model as functions of other variables which may or may not appear in the initial model. The expanded parameters are then substituted back in the initial model to produce a terminal model. For appropriate initial models and functional specification of the expansions, the terminal model is intrinsically linear, and its parameters can be estimated by ordinary multiple regression.

Here the Verdoorn equation was taken as the initial model. The parameters a and b of the Verdoorn equation were expanded into third degree polynomials in the z coordinates of the observations' centroids. The application of trend surface expansions to investigating spatial parameter variation is more fully described in Jones (1982). The z variables used in these expansions are the same employed in the previous DARP analyses. The expansion of a and b parameters of the Verdoorn equation are:

$$a = a_0 + a_1 z_1 + a_2 z_2 + a_3 (z_1)^2 + a_4 (z_2)^2 + a_5 z_1 z_2 + a_6 (z_1)^3 + a_7 (z_2)^3 + a_8 z_1 (z_2)^2 + a_9 z_2 (z_1)^2 \quad (22)$$

$$b = b_0 + b_1 z_1 + b_2 z_2 + b_3 (z_1)^2 + b_4 (z_2)^2 + b_5 z_1 z_2 + b_6 (z_1)^3 + b_7 (z_2)^3 + b_8 z_1 (z_2)^2 + b_9 z_2 (z_1)^2 \quad (23)$$

By substituting (22) and (23) into (3) an expanded Verdoorn equation is obtained. Regression estimates of the parameters of this equation were obtained by backward selection. Backward selection involves the following. First, all variables are forced into the regression equation, and then they are removed from it in a stepwise fashion. At each step the variable with the lowest F value is removed. The removal process is terminated when all the F coefficients of the variables still in the regression are significant at, say, the 5% level or better.

The estimates of the expanded Verdoorn equation obtained for the 1954-1963 and 1967-1977 time periods are given in lines 1 and 2 of Table 4. The corresponding expansion equations, in lines 3 and 4 of Table 4 were obtained by replacing the coefficients of (23) and (24) with the corresponding numerical values appearing in lines 1 and 2 of the table. The equations in lines 3 and 4 of Table 4 were used to evaluate b coefficients at the census divisions centroids for the 1954-63 and 1967-77 time intervals. The b values obtained are given in columns 5 and 6 of Table 3.

A comparison of these estimates with the DARP estimates in columns 1 and 3 of Table 3 shows the following. Between 1954-1963 and 1967-1977, in both sets of estimates the productivity response to output growth, b, increases in the East South Central, West South Central and Mountains divisions, and declines in the New England, and Middle Atlantic divisions. In the East North Central, West North Central and South Atlantic however, b declines according to the DARP estimates, and increases according to the trend surface expansion estimates.

This discrepancy is perhaps due to the fact that the East North Central, West North Central, and South Atlantic divisions are located at the boundary between a core of Snowbelt divisions with sharply declining b's (New England and Middle Atlantic) and a core of Sunbelt divisions with sharply increasing b's (East South Central, West South Central, and Mountain). The different sensitivity of the two analyses to local effects brings these boundary divisions under the dominance of the core with declining b's, in the case of the DARP regressions, and under the dominance of the core with growing b's, in the case of the trend surface expansions.

The New England and Middle Atlantic divisions, on one hand, and the East South Central, West South Central, and Mountains divisions, on the other, display a consistently similar behaviour in their productivity response to output growth in both analyses. Consequently, these two clusters of census divisions will be respectively regarded as cores of the Sunbelt and Snowbelt as far as the phenomena investigated in this study are concerned. It seemed useful to label these clusters Group A and Group B. Mean b's for the Group A and Group B divisions are shown in lines 10 and 11 of Table 3. They indicate very clearly that the highest productivity responses to manufacturing output growth shifted between 1954-63 and 1967-77 from the Snowbelt core to the Sunbelt core.

The Verdoorn ratios (VR) reported in Table 5 were calculated using the b values by division shown in Table 3. The entries in lines 10 and 11 of the table are mean values for the divisions in Group A and in Group B. The VR's in columns 1 and 2 are based on the b's produced by DARP regressions. Those in columns 3 and 4 are calculated from the b's produced by trend surface expansion regressions. As noted earlier in this paper VR denotes the ratio between the productivity change due to change in output, bY", divided by the total productivity change, y". We leave to the interested reader to scan the VR's by division, in lines 1 through 9 of Table 5, to note the close match between the spatial temporal shifts of the VR's and those of the b's. Instead, we will confine ourselves to point out that between 1954-63 and 1967-77 the fraction of productivity change associated with change in output declined in the Snowbelt core and increased to a major extent in the Sunbelt core (lines 10 and 11 of Table 5).

INTERPRETATION OF THE FINDINGS

It is generally presupposed that in an economic system with a strong free enterprise component, such as that of the US, human resources and capital would flow to where they are most productive. Table 6 is intended to give us a feel as to whether resources can be presumed to have moved into or out of the regions that in terms our findings, displayed high/low productivity response to output growth. The first two columns of the table contain the average annual percentage rate of change of population for the periods 1950-1960, and 1970-1979. Column 3 shows the percentage rate of growth of manufacturing capital, and is based on data appeared in Browne (1979).

Let us leave once more to the interested reader a line by line comparison of the data in Tables 3 and 6. Here we will concentrate instead on Group A and Group B results. Clearly, the declines/increases in b's between 1954-1963 and 1967-1977 match declines/increases in percentage rate of growth of population. Also, circa in the 1970's in the Snowbelt core (Group A) the low productivity response to output growth is matched by a low rate of capital formation, while in the Sunbelt core (Group B) the high productivity response to output growth is matched by a rate of capital formation more than twice as large as that of Group A.

The relation between productivity response to ouput growth and resources flows deserves a more exhaustive treatment and discussion. However, we will confine ourselves to noting that Tables 3 and 6 certainly suggest the occurence of resources flows to where the expansion of the economic fabric is associated with greater productivity gains.

Why did the productivity response to output growth decline in the Snowbelt core and increase in the Sunbelt core between the 1950's and the 1970's? Only some introductory remarks are possible here.

The productivity response to output growth is measured by the b coefficients of the linear Verdoorn equation. The Verdoorn Ratio also requires b for its calculation. In the introductory sections of this paper it was shown that within a production function frame of reference b is related to scale economies. Consequently, explanations of the changes in b could be sought in factors and circumstances with a potential for affecting the scale economies of 'community' production functions. Indeed, this line of inquiry can be usefully pursued, especially considering how many generalizations of the concept of scale economies can enter into it.

On the other hand, it was also noted that the b coefficient of the Verdoorn equation can be simply taken as a measure of productivity response to output growth. Spatial temporal variations of this measure can be directly related to corresponding variations in 'business climate'. Hence, an explanation of the changes in b can be also be sought along the following lines. The environment in which business is carried out contains aspects affecting positively and negatively productivity growth. Manpower's and infrastructures' quality are prominent positve factors. Instead, the sociopolitical pressures for the protection of workers, citizens, natural environment, and consumers, and the business costs that they bring about, affect the business climate in a predominantly negative manner, irrespective of the positive role that these pressures may have in the long run, or along other dimensions of collective life.

After the 1950's the negative factors of the business climate increased in intensity. The increase had a prominent role in the well publicized decline in productivity growth in this country. However, it could be argued the pressure of these negative factors operated with spatial differentials and was stronger in the Snowbelt than in the Sunbelt. At the same time the quality of manpower and infrastructures changed, again along spatial differentials to the benefit of the Sunbelt. At some point during the 1960's the conbined spatial dynamics of these factors reversed the comparative attractiveness to business of the Sunbelt and Snowbelt, and channeled into the Sunbelt a much larger portion of new and more productive capital. These occurences are reflected by the observed shifts in the productivity response to output growth and in the Verdoorn ratios.

CONCLUSION

The research questions, analyses, and findings discussed in this paper can be summarized as follows. The Verdoorn law suggests that the rate of productivity growth of an economic sector is positively related to its rate of expansion. Does the Verdoorn law hold spatially? Is the rate of growth of productivity in a region positively related to the rate of the regions' growth? This and related issues were investigated using manufacturing data. It was found that in the US the Verdoorn law does not hold over the 1954-1977 time horizon, but holds instead over subsets of it.

Between the 1950's and the 1970's, the US geographic poles characterized by highest economic growth shifted from the Snowbelt to the Sunbelt. These shifts explain why the Verdoorn law holds at the beginning and at the end of the 1954-1977 time interval, but not across it. The relation between Snowbelt Sunbelt shifts and the spatial validity of the Verdoorn law is the focal point of this paper.

The expression 'productivity response to output growth' is here used to denote the change in the rate of productivity growth produced by a unit change in the output growth. The spatial temporal changes in the productivity response to output growth were investigated using techniques for the detection of regression parameters' drifts. It was found that between the 1950's to the 1970's the productivity response to output growth increased in a Sunbelt 'core' and decreased in a Snowbelt 'core'. In the fifties it was highest in the Snowbelt core, in the seventies it was highest in the Sunbelt core. A shift in the comparative attractivenes of the 'business climate' in the two regions is suggested as the explanation of these findings.

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TABLE 1
Introductory Analyses

Line No.	Time Interval	a (1)	b (2)	F (3)	R^2 (4)	y" (5)	VR (6)
1)	1954-63	.0329	.2124	16.58	.261	4.22	.205
2)	1958-67	.0214	.2141	13.02	.217	3.24	.346
3)	1963-72	.0173	.1091	2.13	.043	2.19	.165
4)	1967-77	.0195	.1022	2.73	.058	2.27	.094
5)	1954-77	.0286	.0594	1.91	.039	3.03	.068

Cols 1 and 2: a and b are the regression parameters of the linear Verdoorn relation y"=a+bY"
Col 3: partial F's associated with the b coefficients
Col 4: coefficients of determination
Col 5: percentage rates of growth of US manufacturing productivity
Col 6: VR stands for Verdoorn ratio, where VR=bY"/y"

TABLE 2A
DARP Regressions for 1967-1977: b coeffients

Line No.	Area Code	h(.99) (1)	h(.97) (2)	h(.95) (3)	h(.93) (4)	h(.91) (5)	h(.89) (6)
1)	NEN	.1355	.1818	.2241	.2458	.2556	.2601
2)	MAT	.1352	.1444	.1616	.1758	.1867	.1957
3)	ENC	.1363	.1405	.1341	.1291	.1235	.1152
4)	WNC	.1424	.1756	.1667	.1523	.1399	.1304
5)	SAT	.1438	.1393	.1355	.1401	.1474	.1548
6)	ESC	.1528	.2146	.2612	.2990	.3312	.3600
7)	WSC	.1557	.2241	.2646	.2942	.3164	.3345
8)	MTN	.1866	.3970	.5634	.6963	.7986	.8739
9)	PAC	.1983	.1103	-.0519	-.1754	-.2541	-.3010

In this and in subsequent Tables the area codes above identify the following Census Divisions:
NEN = New England MAT = Middle Atlantic
ENC = East North Central WNC = West North Central
SAT = South Atlantic ESC = East South Central
WSC = West South Central MTN = Mountain
PAC = Pacific

TABLE 2B
DARP Regressions for 1967-1977: R^2 coefficients

Line No.	Area Code	h(.99) 1)	h(.97) (2)	h(.95) (3)	h(.93) (4)	h(.91) (5)	h(.89) (6)
1)	NEN	.120	.117	.141	.156	.167	.175
2)	MAT	.129	.0974	.095	.094	.091	.088
3)	ENC	.138	.171	.147	.125	.109	.094
4)	WNC	.107	.204	.260	.289	.305	.315
5)	SAT	.141	.114	.103	.108	.118	.129
6)	ESC	.150	.261	.331	.389	.438	.482
7)	WSC	.115	.207	.271	.313	.331	.331
8)	MTN	.082	.205	.332	.451	.555	.639
9)	PAC	.071	.016	.003	.037	.075	-

TABLE 2C
DARP Regressions for 1967-1977: Degrees of Freedom

Line No.	Area Code	h(.99) (1)	h(.97) (2)	h(.95) (3)	h(.93) (4)	h(.91) (5)	h(.89) (6)
1)	NEN	21	13	10	9	8	7
2)	MAT	25	16	13	11	10	9
3)	ENC	29	15	10	7	6	5
4)	WNC	25	11	8	6	4	4
5)	SAT	26	16	11	9	7	6
6)	ESC	27	15	10	8	6	5
7)	WSC	23	10	6	5	4	3
8)	MTN	17	8	6	4	3	3
9)	PAC	11	5	4	3	3	2

TABLE 3
Estimates of b by DARP Regressions for h(.97)
and by Trend Surface Expansions

Line No.	Area Code	DARP 1954-1963 b (1)	R^2 (2)	DARP 1967-1977 b (3)	R^2 (4)	TSE 1954-63 b (5)	TSE 1967-77 b (6)
1)	NEN	.3755	.394	.1818	.117	.3357	.1300
2)	MAT	.3140	.337	.1444	.097	.2544	.2290
3)	ENC	.1809	.127	.1405	.171	.2226	.2479
4)	WNC	.2322	.257	.1756	.204	.2287	.2720
5)	SAT	.2306	.242	.1393	.114	.1789	.3706
6)	ESC	.1473	.094	.2146	.261	.2125	.4015
7)	WSC	.1354	.078	.2241	.207	.2090	.4693
8)	MTN	.2379	.359	.3970	.205	.2370	.2893
9)	PAC	.3160	.432	.1103	.016	.4672	.3786
10)	GRA	.3447	---	.1331	---	.2950	.1795
11)	GRB	.1735	---	.2786	---	.2195	.3867

In this Table and in subsequent ones GRA and GRB stand for Group A and Group B Divisions, that constitute respectively the Snowbelt core and the Snowbelt core.

TSE stands for Trend Surface Expansion.

TABLE 4
Trend Surface Expansion Equations

(1) Time Interval:1954-63 R=.583 R^2=.340

$$y'' = .0340 - \underset{(5.09)}{.0049(z_1)^2 z_2} + \underset{(16.27)}{.2190Y''} + \underset{(5.26)}{.0854(z_1)^2 z_2 Y''}$$

(2) Time Interval:1967-77 R=.587 R^2=.345

$$y'' = 0130 + \underset{(13.00)}{.0044z_1} + \underset{(9.20)}{.0438(z_2)^3} + \underset{(14.05)}{.2740Y''} - \underset{(5.77)}{.1415z_1 z_2 Y''} + \underset{(7.93)}{.9260(z_2)^3 Y''}$$

(3) Time Interval:1954-63

$$b = .2190 + .0854(z_1)^2 z_2$$

(4) Time Interval:1967-77

$$b = .2740 - .1415z_1 z_2 - .9260(z_2)^3$$

TABLE 5
Verdoorn Ratios

Line No.	Area Code	DARP Coefficients 1954-63 (1)	DARP Coefficients 1967-77 (2)	TSE Coefficients 1954-63 (3)	TSE Coefficients 1967-77 (4)
1)	NEN	.27	.03	.24	.02
2)	MAT	.21	.00	.17	-.01
3)	ENC	.14	.10	.18	.17
4)	WNC	.23	.21	.23	.32
5)	SAT	.30	.20	.23	.52
6)	ESC	.21	.38	.31	.72
7)	WSC	.17	.42	.27	.88
8)	MTN	.40	1.32	.40	.96
9)	PAC	.41	.16	.61	.56
10)	GRA	.24	.01	.21	.01
11)	GRB	.26	.71	.33	.85

TABLE 6
Average Percentage Rate of Change
of Population and Manufacturing Capital

Line No.	Area Code	Percentage Change of Population 1950-60 (1)	Population 1970-79 (2)	Capital 1970-76 (3)
1)	NEN	1.2	.44	2.6
2)	MAT	1.2	-.2	1.7
3)	ENC	1.8	.3	2.2
4)	WNC	.9	.5	4.1
5)	SAT	2.0	1.5	4.7
6)	ESC	.5	1.1	1.6
7)	WSC	1.5	1.7	5.9
8)	MTN	3.0	2.8	6.8
9)	PAC	3.4	1.5	2.9
10)	GRA	1.2	.1	2.15
11)	GRB	1.7	1.9	5.8

Cols (1)-(3) from "State and Metropolitan Area Data Book," US Bureau of the Census, 1979, Washington, D.C., 1980, p3.

Col (4) from "Regional Capital Formation", Lynn E. Browne, New England Ec. Indicators, June 1979, pp.A3-A8,