THE CUMULATIVE CAUSATION THESIS OF REGIONAL GROWTH: A THEORETICAL AND EMPIRICAL ANALYSIS

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LIST OF SYMBOLS

E_i: Total employment in region i.

E_B: Basic employment region i.

E_{NB}: Nonbasic employment in region i.

k: Export base multiplier.

e_i: Regional employment in region i.

E_{ni}: National employment in industry i.

E_n: National employment.

E_g: Geographical-oriented employment.

E_c: Complementary-oriented employment

E_u: Urban-oriented employment.

x_i: Regional export employment in industry i.

P: Regional population.

m_i: Net migration in region i.

n_i: Rate of natural increase in the labor force in region i.

L_i, l_i: Labor supply in region i and its growth rate.

Y_i, y_i: Real income in region i and its growth rate.

K_i, k_i: Capital stock in region i and its growth rate.

s_k: Capital's distributive share of real income.

I_D: Net Investment from regional sources.

I_x: Net investment from sources other than regional.

I_t: Net investment expentures at time t.

t: Time.

T_i: Rate of technical progess in region i.

r_i, r_n: Rate of return to capital in region i and nation.

w_i, w_n: Wage rate in region i and nation.

W_t, w_t: Wage rate and its growth rate.

V, v: Average product of capital and its growth rate.

R_t, r_t: Average product of labor and its growth rate.

P_{dt}, p_{dt}: Domestic price and its growth rate.

P_{ft}, p_{ft}: Competitor's price and its growth rate.

e_1: Own-price elasticity of export demand.

e_3: Cross-price elasticity of export demand with respect to the competitor's price.

Z_t, z_t: World income and its growth rate.

e_2: Income elasticity of export demand.

$E_{i,j}$: Elasticity of j with respect to i.

EK, EL: Elasticity of output with respect to capital and labor respectively.

G_t, g_t: Quantity of output and its growth rate.

X_t, x_t: Quantity of exports at time t and its growth rate.

γ: Constant output elasticity with respect to exports.

M_t, m_t: 1 + % mark-up on unit labor cost and its growth rate.

R_a, r_a: autonomous labor productivity and its growth rate.

λ: Verdoorn coefficient, i.e., the elasticity of the average product of labor with respect to output.

TOTEM: Growth rate of total employment.

MANU: Growth rate of manufacturing employment.

NOMAN: Growth rate of nonmanufacturing employment.

BMANU: Growth rate of basic manufacturing employment.

CHAPTER I

RESEARCH PROBLEM

Introduction

Samuelson (1974) begins his classic work by quoting Moore's principle of generalization by abstraction which states:

> The existence of analogies between central features of various theories implies the existence of a general theory which underlies the particular theories and unifies them with respect to those central features (p.3).

Accepting this proposition, the similarities in many of the theoretical explanations of regional growth imply the existence of a general theory. Although this study is not so bold as to suggest it represents the general theory of regional growth, the particular version of the cumulative causation model of regional growth developed and analyzed in this study synthesizes the chief regional growth theories. This unification represents a step towards a more general theory of regional growth.

The cumulative causation thesis questions the appropriateness of the concept of a stable equilibrium in the study of a dynamic social system. Instead, the appropriate view is one of a social system making quantum jumps from one state of economic activity to another. The originator of the cumulative causation thesis, G. Myrdal (1957), states:

> The system is not moving toward any sort of balance between forces but is constantly on the move away from such a situation. In the normal case, a change does not call forth countervailing changes, but instead, supporting changes, which move the system in the same direction as the first change but much further. Because of such circular causation a social process tends to become cumulative and gathers speed at an accelerating rate (p. 13).

If there are forces which cause supportive change instead of countervailing change, the social system may be inherently unstable because exogenous change induces endogenous change, perhaps starting a process of cumulative change.

Statement of Problem

To be a valid, the cumulative causation thesis must be able to explain the historical patterns of regional growth. In particular, the thesis must explain the historical patterns in the growth of regional per capita income and returns to factors of production. For the United States the actual record of these growth rates has been mixed.

Easterlin (1961) found that with the exceptions of the 1840-1850 and 1920-1940 periods, regional per capita income showed a marked tendency to converge to the national average during the 1840-1950 period. This finding supports Perloff's (1957) earlier study, but Perloff also found that the rate of convergence did not occur as rapidly in regions with per capita income below the national average. Borts (1960) also investigated the historical growth patterns in wages, capital, and employment for a later period, 1919-1953. He found divergent growth rates in wages for the 1919-1929 and 1948-1953 periods while they converged in the 1929-1948 period. Recently, Jackson (1982) reported a continued convergent trend in per capita income and wages due to differences in the growth rates of employment, income, and population across regions for the 1960-1980 period. Thus, the evidence does not give strong support to theories of regional growth that emphasize either convergence or divergence of real per capita income and returns to factors of production across regions.

While there have been periods which show a marked convergence, the evidence also suggest that the process has not been continuous or steady. There have been periods when the rate of convergence in per capita income and returns to factors of production have varied across regions as well as actually diverging. These various patterns of regional activity make one wonder if the regional growth process is equilibrating in the sense of achieving equality in regional per capita income and returns to homogenous factors of production. As Easterlin (1958) concludes:

> . . . its by no means certain that convergence of regional income levels is an inevitable outcome of the process of development. For while migration and trade do appear to exert significant pressure towards convergence, they operate within such a changing environment that dynamic factors may possibly offset their influence. One may agree, of course, that migration and trade may become progressively more important during

> growth, as a result, for example, of improvements in transportation, and hence that the pressures towards convergence will tend increasingly to predominate. But whether this is generally the case cannot be settled on a priori grounds (p. 325).

With regard to urban and regional growth, cumulative change could explain the differences in these growth rates. Growth requires an economy to solve simultaneously a large number of allocation and distribution problems concerning the flow of resources so that external and internal demands for goods and services are satisfied. When the economy solves these problems, additional allocation and distribution problems are created; when these problems are solved with greater efficiency, cumulative growth may occur. The process of growth or the increasing level of economic activity may become endogenous depending on current and past levels of economic growth. Once such a process starts, this endogenous dependence may result in a cumulative growth process and a continuing variation of growth rates across regions.

Purpose of Study

An express purpose of Samuelson's study was to attempt "to show that there exist meaningful theorems in the diverse fields of economic affairs" (Samuelson, 1974, p. 5). To Samuelson (1974), a meaningful theorem is:

> . . . a simple hypothesis about empirical data which could conceivably be refuted, if only under

> ideal conditions. A meaningful theorem may be false. It may be valid but of trivial importance (p.4).

A purpose of this study is to determine whether the cumulative causation thesis can generate meaningful theorems of regional and urban growth. In particular, it seeks to ascertain whether the source of the variations in the growth rates of output and employment across a sample of urban and regional economies can be attributed to the process of cumulative change. The theoretical content of the study concentrates on formularizing the thesis into a dynamic model of growth and investigating the dynamic properties of the model. In the empirical part of the study, the validity of the cumulative causation thesis is tested by analyzing its ability to explain the economic growth of employment using time-series data from a sample of urban and regional economies.

The study proceeds in the following manner. Chapter II surveys the literature on urban and regional growth theories and shows that a cumulative causation model can synthesize many of the chief theories. Chapter III formulizes the thesis, investigates comparative static properties of the model as well as its dynamic properties, and develops testable hypotheses. Chapter IV undertakes the empirical analysis using California, Michigan, Missouri, Oklahoma, and Texas as the regional economies and Detroit, Kansas City, Houston, Joplin, and Springfield as urban economies. Chapter V summarizes and concludes the study.

CHAPTER II

SURVEY OF THE LITERATURE

Introduction

What are the various explanations for differences in the growth rates of spatial economic activity? Why are there some periods that have a convergent pattern and other periods that have a divergent pattern in the growth of returns to homogeneous factors of production and of per capita income? These questions are different aspects of a broader area of inquiry that focuses on whether regional and urban growth is an equilibrating or a disequilibrating process. These topics have fascinated many researchers. As a result, an extensive body of literature exists. Three distinct economic models offer explanations for the variations in spatial economic activity. The first model is the export-base theory that emphasizes exports and export-related employment as the primary determinant of growth (North, 1955; Stabler, 1968). It is a demand side theory of growth, since it relies upon interregional variations in export demand to explain the differences in regional and urban economic activity. The second model is based on supply side theories that draw upon propositions from a neoclassical theory of production and distribution to explain the variations in economic activity (Richardson, 1972; Borts and Stein, 1962, 1964). These theories concentrate on factor supplies, interregional factor flows, and agglomeration economies. The third model is derived from growth pole theory. It centers on differences in industrial mix across regions plus intraregional and interregional linkages to explain the growth process (Hansen, 1967). A number of hybrid models have synthesized some of the different aspects of these various approaches (Muth, 1968; Guccione and Gillen, 1980; Ghali, Akiyama, and Fujiwara, 1981).

Regional and urban models based upon the cumulative causation thesis also synthesize various elements of the alternative approaches (Kaldor, 1970; Dixon and Thirlwall 1975). These models are distinguished by an endogenous growth process where variations in the growth economic activity naturally occur due to forces internal to the economy that are embodied in the growth process itself.

This chapter surveys regional and urban economic growth theories and supporting evidence. The focus of the survey is on competing hypotheses that offer alternative explanations for the variations in the rates of economic activity across regional economies.[1] This examination bears fruit

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[1]Henceforth, the use of the terms regional, regional economy, and regional growth will be used in the inclusive sense so that it will refer to the corresponding urban activity.

when it becomes time to examine the explanatory power of the cumulative causation thesis, since these alternative explanations must also be studied in order to come to grips with the divergent and convergent patterns of regional growth.

Export-Base Theory

Export-base theory emphasizes the role of exports or the income derived from exports as the primary determinant of economic activity (Richardson, 1972). According to North (1955):

> The importance of the export base is a result of its primary role in determining the level of absolute and per capita income in a region, and therefore in determining the amount of residentary, secondary, and tertiary activity that will develop (p. 47).

Export-base theory dichotomizes the economy into basic and nonbasic sectors. The exogenous basic (export) sector leads and determines the overall performance of the economy, while the nonbasic sector responds to the activity in the basic sector. The export-base model can be formulated as

$$E_i = E_B + E_{NB},$$

$$E_{NB} = f(E_B), \; dE_{NB}/dE_B > 0,$$

where

E_i : total employment in region i,

E_B : basic employment,

E_{NB}: nonbasic employment.

By postulating a stable relationship between employment in the basic and nonbasic sectors, an employment multiplier, the ratio of the change in total employment to the change in basic employment, can be derived for this simple model. The base multiplier, k, is given as

$$k = \frac{dE_i}{dE_B}$$

but

$$dE_B = dE_i - dE_{NB},$$

so that

$$k = \frac{dE_i}{dE_B} = \frac{dE_i}{dE_i - dE_{NB}} = \frac{1}{1 - \frac{dE_{NB}}{dE_i}} .$$

If the employment multiplier is assumed to be stable, it can be used to predict the effects of an exogenous change in basic employment. However, its predictive powers and, thus, its ability to explain the regional growth process are questionable on theoretical grounds.

A fundamental criticism of export-base theory concerns its validity as an exclusive theory of regional growth. Non-export-led growth is a distinct possibility. Growth can occur through increases in local expenditures that are unrelated to the growth in the basic sector. Intrabasic employment shifts due to wage differentials can cause the growth of income, and therefore, economic activity. Labor-saving technical progess can also lead to rising levels of economic activity relative to the level of employment. As

Meyer (1963, p. 37) has observed "it is quite obvious, moreover, that an economy can exist without exports and grow without the growth of exports, as must be true for the world economy taken together."

Hartman and Seckler (1967) have used a Keynesian growth model to analyze the dynamic properties of the export-base model. They concluded that the economic-base approach to regional growth may be in error when non-export-led growth is possible.

Williamson (1975) reviews a number of studies that analyze the causal relationship postulated by export-base theory. These studies have had mixed results and do not conclusively prove the existence of the causal relationship postulated by export-base theory. Williamson does point out, however, that the studies reveal the existence of a statistical correlation between basic activity and total economic activity, implying some empirical validity.

Even if the causality postulated by export-base theory is accepted, its predictive powers are questionable since no a priori grounds exist to assume a constant relationship between basic and nonbasic activities. Consequently, the predictive powers of the theory have been a subject of controversy. The issue centers on a debate initiated by North (1955, 1956) who maintained that the theory provides a long-run explanation of economic growth, and the rebuttal by Tiebout (1956a, 1956b) who maintained that it represents a short-run explanation of economic fluctuation. Empirically, this issue is related to the appropriate lag structure between autonomous changes in basic activity and its impact on nonbasic activity. The empirical research on this subject has been contradictory.

Sasaki (1963) regressed total employment on export employment and found a significant relationship for unlagged variables but not lagged variables in a study of Hawaii. Sasaki concluded that adjustments were quite rapid with the full impact realized in approximately one year. Moody and Puffer (1970), in their study of the employment multiplier of San Diego, California, concluded that the full impact will not be felt for decades. McNulty (1977) analyzed a cross-sectional sample of 41 Standard Metropolitan Statistical Areas (SMSA's) and concluded that the long-run interpretation but not the short-run explanation fits the facts very well. Gerking and Isserman (1981) maintained that McNulty misinterpreted his results and that they do not support the long-run view. In addition, they argued that the source of the contrary observations between these studies has been the methods of defining basic and nonbasic sectors and present evidence supporting the short-run interpretation.

Isserman (1980) analyzed such methods of estimating export-related employment as using the location quotient approach, the minimum requirements approach, assignment method, and econometrics. His main conclusion was that each was problematic and has conceptual flaws. However, he suggested on empirical and theoretical grounds that the location quotient method yields employment estimates that are biased downward. The location quotient (LQ) used in this study is given by

$$LQ = \frac{\dfrac{e_i}{E_i}}{\dfrac{E_{ni}}{E_n}},$$

where

e_i: regional employment in the i^{th} industry,

E_{ni}: national employment in the i^{th} industry,

E_i: total regional employment,

E_n: total national employment.

The LQ measures the concentration of employment in the region's i^{th} industry relative to national employment in the i^{th} industry. When its value exceeds unity, the region is relatively concentrated in the i^{th} industry. If the number of workers that cause the LQ to exceed unity are assumed to be engaged in export activity, then it can be used to calculate export employment. Thus, for the i^{th} industry

$$x_i = ((LQ - 1)/LQ)e_i \quad (LQ>0),$$

$$= (1 - 1/LQ)e_i,$$

$$= \left(1 - \frac{\dfrac{e_i}{E_i}}{\dfrac{E_{ni}}{E_n}}\right)e_i,$$

$$x_i = \left(\frac{e_i}{E_i} - \frac{E_{ni}}{E_n}\right)E_i,$$

where x_i represents export employment in the i^{th} industry. This method of estimation assumes that labor productivity and consumption expenditures should be the same geographically. This enables (e_i/e_T) to approximate the region's share of total national output, and (E_i/E_T) to approximate the region's share of national consumption. Thus, their differences approximate the region's contribution to national production over and above local consumption if it is assumed that all local consumption comes from local production and that all national consumption comes from national production. By assuming the absence of imports, the location quotient estimates net exports rather than gross exports; thus, it results in the underestimate of export-related employment.

Factor-Price Adjustment in Export-Led Growth and Decline

According to export-base theory, differences in spatial economic activity result from interregional variations in exports and export demand. Can this explanation also account for interregional differences in the real returns to factors of production? Since export-base models maintain that increases in the volume of exports determine the rate of regional growth, they implicitly assume the availability of resources for the expansion of the economy and, thus, are either less than full employment models of growth or they rely upon extensive factor mobility. Any prolonged export-led growth will encounter the full employment constraint retarding further growth unless the region imports resources from other regions. To acquire the use of these resources, unemployment must exist in other regions of the nation or real returns must be increasing relatively. The influx of imported resources will likely turn the initial export-led surplus in the current account of the region's balance of payments into a deficit (Borts, 1960; Whitman, 1967).

In both Bort's and Whitman's analyses, the basic sector produces capital-intensive goods and the nonbasic sector produces labor-intensive goods. Both sectors have constant returns to scale production functions that are identical across regions. Under these assumptions, an increase in the volume of exports has the dual impact of generating an income boom and causing a relative increase in the marginal efficiency of investment (MEI) within the region. The increase in the MEI induces an inflow of capital which increases the production capacity of the economy enabling it to circumvent the full employment constraint. In addition, if the accumulation of capital raises the region's capital-labor ratio, the marginal product of labor will increase leading to higher real wages and the immigration of labor. Depending on the immigrant's propensities for imported goods, the volume of imports into the region will have an additional increase over and above the initial increase due to the income boom. The net impact of the inflows of resources turns the initial surplus in the region's current accounts into a deficit. Whitman (1967, p. 6) has termed this process as one of "prosperity-cum-deficit."

A number of conditions must be satisfied in order to achieve prosperity-cum-deficit. An acceleration type link between exports and real investment expenditures or an increase in the price of export goods is necessary to have an increase in the MEI (Whitman, 1967). For the immigration of labor, the real wage must increase relative to other regions, which requires that the price of the labor-intensive goods increases relative to the capital-intensive goods (Borts, 1960). Export-led decline essentially reverses the above conditions. An exogenous decline in exports leads to declines in regional income and real factor returns by a "recession-cum-surplus process" (Whitman, 1967, p. 6). When export-led growth via prosperity-cum-deficit process or decline via a recession-cum-surplus occurs in different regions simultaneously, resources will flow from the declining region to the expanding region, resulting in diverging growth rates in economic activity across the regions.

The Crowding-Out Hypothesis and Export-Led Growth

Regional export-led growth via a prosperity-cum-deficit process requires an inflow of resources to sustain the growth process. If export-led growth does not result in capital inflows financed by a current account deficit, the full employment constraint will prevent overall expansion by the economy.[2] When this occurs, continued growth in the basic sector will be at the expense of growth in the nonbasic sector since resources will be flowing from the latter to the former. In particular, the intersector reallocation of labor will mean that the employment growth in the basic sector will be crowding-out nonbasic employment. Thus, one way to test the validity of export-led growth is to test for the absence of crowding-out of nonbasic employment.

Czamanski (1965) has developed a variant of the export-base model which Luttrell and Gray (1970) and Moriarty (1976) have utilized to test the crowding-out hypothesis. In this approach industries are classified according to their locational factors as geographically-oriented, complementary, and urban-oriented industries. Geographically-oriented industries are those whose locational factors are geographic and conditioned by the environment.[3] Complementary-industries' main locational factors are "the presence of other industries" (Czamanski, 1965, p. 184). Urban-oriented industries' main locational

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[2]This assumes that the determinants of the full employment constraint are constant.

[3]Geographically-oriented industries include extractive industries and raw materials oriented industries.

factor is "the existence of the city" (Czamanski, 1965, p. 183).[4]

Using this industrial classification scheme, Czamanski's (1965) model of urban population growth has the following structural form:

$$P = a_1 + b_1 E_i$$
$$E_i = E_g + E_c + E_u$$
$$E_c = a_2 + b_2 E_g$$
$$E_u = a_3 + b_3 P$$

where

P : population in the area,

E_i: employment in the area,

E_g: geographical-oriented employment,

E_c: complementary-oriented employment,

E_u: urban-oriented employment.

Although Czamanski's model does not conform strictly to the export-base model, the geographic industries may be interpreted as the basic sector. They are the engines for population and employment growth. This can be explicitly seen by solving Czamanski's structural equations for their reduced-form equation

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[4]Urban-oriented industries not only include market-oriented industries but also industries attracted to urban locations by the availability of a labor force, public services, and industries that produce non-transportable services.

$$P = \frac{a_1 + b_1(a_2 + a_3)}{1 - b_1 b_3} + \frac{b_1(1 - b_3)}{1 - b_1 b_3} E_g.$$

Changes in employment in geographically-oriented industries induce a $b_1(1-b_3)/(1-b_1b_3)$ change in population, a b_2 change in employment in complementary industries, and a $b_3b_1(1-b_3)/(1-b_1b_3)$ change in employment in urban-oriented industries.

Moriarty (1976) and Luttrell and Gray (1970) used a polynomial distributive-lag adaptation of Czamanski's methodology to analyze urban growth. Luttrell and Gray analyzed employment growth in seven SMSA's in the Central Mississippi Valley for the period 1960 to 1968. Moriarty analyzed annual employment growth in a sample of 16 SMSA's for the period 1959-1970. The empirical results of both studies were mixed. Neither gave strong support for accepting geographically-oriented industries as the basic sector or as the engine of urban growth. Both studies found that crowding-out could retard export-led growth because in a number of SMSA's, employment in the geographically-oriented industries was negatively related to employment in the complementary-industries. The existence of employment crowding-out shows that a major drawback of export-base theory is its neglect of the supply side of the growth process. Neoclassical theories, on the other hand, recognize the role of the supply of factors of production in the growth process.

Neoclassical Regional Growth Models

Concentration on the supply side aspects of the growth process distinguishes neoclassical models from other theories of urban and regional growth. Two aspects of neoclassical analysis are applicable to this study. One aspect adapts the standard neoclassical model of national growth to regional growth and emphasizes interregional factor movements in response to earning differences across regions. The second aspect concerns the impact of agglomeration economies on the distribution of money income across city size.

Steady-State Regional Growth Models

Following in the tradition of aggregate neoclassical models, regional neoclassical analysis investigates the conditions that enable the economy to achieve long-run steady-state growth. Following Richardson's (1972) analysis, neoclassical models assume an aggregate production function relating real income or real output to the inputs of capital, labor, and technical progress, the latter being a function of time. For the i^{th} region, this production function is specified as

$$Y_i = f(K_i, L_i, t), \tag{2.1}$$

where Y_i, K_i, L_i and t represent real income, capital stock, labor supply, and time respectively. By assuming constant returns to scale in production and perfect competition in all markets, inputs will be paid the value of their marginal products; due to Euler's Theorem, the sum of these payments will equal the value of the total product (Chiang, 1974, pp. 406-407). These properties allow the derivation of the growth rate of real income,

$$y_i = s_K k_i + (1-s_K)l_i + T_i, \qquad (2.2)$$

where y_i, k_i, l_i, and T_i are the proportional rates of growth in real income, capital stock, labor supply, and the rate of technical progress respectively and s_K represents capital's distributive share of real income.[5]

Long-run equilibrium growth requires full employment, which can be achieved by flexible interest rates that equate saving and planned investment. Given the determination of the interest rate in a national market, each region will have the same interest rate that equals the marginal product of capital due to profit maximization. The marginal product of capital, in turn, equals capital's distributive share of income times the reciprocal of the capital-real income ratio. Thus, for the i^{th} region

$$MP_K = s_K \frac{Y_i}{K_i} = r_i,$$

where the new variables are MP_K and r_i, the marginal product

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[5]For the derivation of equation (6) see Meade, J., A Neoclassical Theory of Economic Growth (London, 1961), pp. 8-12.

of capital and the interest rate respectively. Since the interest rate is given and the equilibrium condition for capital accumulation is MP_K equal the interest rate, the growth rate in income must equal the growth rate of capital, that is, steady-state growth requires $y_i = k_i$. Substitution of this condition into equation (2.2) and simplifying yields

$$y_i = k_i = l_i + \frac{T_i}{1-s_K} , \tag{2.3}$$

the equilibrium growth condition for steady state growth. Real income and capital accumulation must proceed at the same rate equal to the growth in the labor force plus the rate of technical progress divided by labor distributive share.

In the absence of technical progress ($T_i = 0$), the growth rates in real income, capital accumulation, and the labor force must be equal for steady state growth. This represents the case of pure supply-determined growth. It cannot be inferred, however, that income of all regions must grow at the same rate. Borts and Stein (1964) have demonstrated that when regions have different growth rates in the labor force, due to either differences in natural increases or migration, the equilibrium growth rates of income across the regions do not have to be equal. They argued that given a perfectly elastic demand for labor and common wages across regions, due to perfect adjustments in labor market, the effects of higher rates of growth in output upon wages can be offset by the growth in the labor force. This could allow some regions to have a higher growth rate in output without higher wages in steady state growth.

In the presence of technical progress and national capital markets, equation (2.2) requires the growth in real income in each region be equal. Thus, for two regions, i and j, the following conditions must hold:

$$l_i + \frac{T_i}{1-s_{ki}} = l_j + \frac{T_j}{1+s_{kj}} \quad . \tag{2.4}$$

Steady-state regional growth across regions depends upon the growth rates of labor supply and technical progress as well as a constant distributive share of capital.

Capital's share and the rates of growth in labor supply and technical progess need not be equal across regions if differences in these variables are offset by differences in other variables. In general, the offsetting differences can be accommodated by differences in the distributive share of capital or, equivalently, differences in the capital-real income ratio across regions. Nor does the rate of growth in the capital stock need to be limited to the rate of regional saving if the region that exports capital has a higher propensity to save or if capital receives a smaller distributive share than the region that imports. Thus, capital will flow from regions with high marginal propensities to save or low distributive shares of capital to regions with low marginal propensities to save and high distributive shares of capital. This is a significant result since it indicates the necessary direction of capital flows between regions to maintain steady-state growth.

The neoclassical steady-state model of regional growth makes several contributions to the issue of convergent and divergent growth. It illustrates the possibility of long-run equilibrium growth where the growth rate of income remains identical across regions while other growth rates can vary within the limits set by the feasible capital-real income ratios of the economy. The model also represents the intermediate case between divergent and convergent growth. It is convergent in that along the long-run equilibrium growth path the relative positions of regions with respect to real income will not change. In the absolute sense, however, it is divergent because initial real income differences will widen.

Convergent Growth in the Neoclassical Model

As an economy develops, regions of the nation have a greater degree of interdependence because of improvements in communications, transportation, and the broadening of regional markets into national markets. These events enhance the mobility of resources through increased information flows and reductions in travel cost. The net impact of these developments promotes the equalization of real returns to homogeneous factors of production across regions. In the neoclassical theory of regional growth, factor-price equalization represents a major force for the convergence in real income across regions.

Borts (1960) has analyzed the conditions for factor-price equalization across regions. In his model of regional economic activity, he assumes that regions have a fixed labor supply, produce a single homogeneous good with identical constant returns to scale production functions, and have a zero cost of converting the output into capital. In addition, he assumes zero transportation costs and perfect competition. Under these conditions factor flows will equalize real returns to homogeneous factors of production across regions. In a two-region case each region produces a homogenous good with a different capital-labor ratio. Due to constant returns to scale, labor will have a higher marginal product and, thus, higher real wage while capital will have a lower marginal product and lower return in the region with the larger capital-labor ratio. If labor and capital are mobile and respond to factor-price differences across regions, labor will migrate from the low wage region to the high wage region while capital will flow in the opposite direction. This interregional reallocation of factors of production between regions will cause the capital-labor ratios in each region to converge resulting in factor-price equalization. Although his analysis dealt with a single good two-region case, with additional assumptions it can be generalized to a multiple good case and to the equalization of real returns across regions.

In the multiple good case, the possibility of factor-price equalization under the conditions of free trade has been extensively studied in the theory of international trade. Mundell (1957) has shown factor-price equalization when factors of production are mobile, but commodities are not. Samuelson (1948, 1949) has demonstrated it in the absence of factor mobility but in the presence of free trade in commodities.

Although factor and commodity price equalization theorems make important contributions to the theories of international and interregional trade, complete factor-price equalization is unlikely. At most, the theorems illustrate a tendency toward factor-price equalization rather than absolute equalization. There are many reasons for believing that absolute factor-price equalization will not occur. In regards to regional economies, the assumption of linearly homogeneous production functions rules out increasing and decreasing returns to scale, but the agglomeration of economic activities at various locations requires the existence of these scale economies. Also, the act of transporting factors of production and commodities requires inputs of resources that must be paid their market prices. These transportation costs act as a wedge between the cost, insurance, freight price, and free-on-board price. Prices for factor and commodities will vary at least by the per unit transportation cost between regions. Even if complete factor-price equalization occurs, per capita incomes across regions need not equalize. Regional variation in labor force participation rates, skill levels, occupational mix, and differences in property ownership can cause variation in income per capita.

To integrate interregional factor flows in response to differences in factor returns across regions, the growth in the regional capital stock and labor supply must be specified. Richardson (1978a) gives a standard specification for the i^{th} region as

$$y_i = s_k k_i + (1-s_k) l_i, \tag{2.5}$$

$$k_i = I_D + I_x, \tag{2.6}$$

$$l_i = n_i + m_i, \tag{2.7}$$

$$I_x = f_1(r_i - r_n),\ dI_x/d(r_i - r_n) > 0, \tag{2.8}$$

$$m_i = f_2(w_i - w_n),\ dm_i/d(w_i - w_n) > 0, \tag{2.9}$$

where in addition to the previous variables

I_D: net investment from regional sources,

I_x: net investment from sources other than the region,

n_i: rate of natural increase in the labor force,

m_i: net migration,

r_i, r_n: rate of return to capital in i^{th} region and nation respectively,

w_i, w_n: wage rate in i^{th} region and nation respectively,

Equations (2.6) and (2.7) modify the determinants of the production function, equation (2.5), to reflect the influence of interregional factor flows. Equations (2.8) and (2.9) assume that factors flow in response to interregional factor return differences, and that factor flows are directly related to these differences so that they will promote factor price equalization. This extended neoclassical model has been subject to empirical analysis by Ghali (1981) and Smith (1975).

Ghali estimates the neoclassical growth model using cross-sectional data from 48 states and the District of Columbia between the years 1958-1963. Smith uses aggregate cross-sectional state data between 1880-1953. In both studies the propositions of neoclassical growth cannot be rejected. Output growth is influenced by the rate of growth in inputs. Capital and labor growth rates are sensitive to interregional factor-price differences and respond to these differences to promote convergent growth.

Divergent Neoclassical Growth

Incorporating perverse factor flows into the neoclassical model creates the conditions for divergent growth across regions. In the earlier discussion of the Bort and Whitman models, the conditions under which capital and labor migrate from slow-growing regions to fast-growing regions were analyzed. This represents one possible scenario for divergent growth. Another source of perverse labor flows is migration selectivity.

Selective migration occurs because some people are more prone to migrate than others. Evidence suggests that migrants are usually young adults with higher educational levels and occupational status than nonmigrants (Sjaastrad, 1962; Greenwood, 1976; Hoover, 1975). This induces greater income growth in the receiving region and reduces income growth in the sending region because migrants are more productive than nonmigrants in both regions. Even if factor-prices equalize across regions, regional per capita income can widen due to the impact of migration on the composition of the regions' labor forces.

The possibility that selective migration invalidates factor-price equalization must also be considered. If immigrants are truly more productive, the schedule representing the marginal product of labor will be shifting outward in the receiving region and declining in the sending region. Given the capital stocks and the price levels, the relative shifts in the marginal product of labor schedules imply a rising real wage in the receiving region and a falling real wage in the sending region which prevents factor-price equalization. Of course, this effect could be offset on the supply side. Moreover, factor-price equalization theorms are based on homogenous factors of production while selective migration implies the presence of heterogenous factors of production.

Interregional capital flows can also be perverse and prevent factor-price equalization. A possible reason for perverse capital flows would be the imperfect capital markets. High-income regions with higher rates of savings due to high propensities to save may be reluctant to invest in low-income regions due to agglomeration economies and psychic income associated with home investment (Richardson, 1972). Even if capital markets are perfect, a historically low-average return on investment in the low-income region can cause uncertainty and risk differentials to be imposed, preventing equalization of returns to capital (Richardson, 1972).

Agglomeration Economies and the Distribution Of Money Income Across City Size

Neoclassical production theory has been used to analyze productivity differentials across cities and regions. One source of productivity differentials is agglomeration economies, which refer to the advantages of size and concentration. These advantages exist for both household and business sectors. The greater varieties of goods and services available in large cities are beneficial to consumers. Also, allocative efficiency in the provision of public goods appears, to some extent, to improve with city size. The per unit cost curves are "U-shaped" with respect to city size (Alsono, 1971, p. 68). Business agglomeration economies have been extensively analyzed, especially in manufacturing.

Business agglomeration economies are attributed to indivisibilities and specialization in the use of factors of production and production processes that result when firms locate in clusters (Carlino, 1978). Being technical in nature, business agglomeration economies reduce the per unit cost of production with respect to city size. The sources of these savings are the reduction "in uncertainty which comes about from locations in a large city in close proximity to many possible sources of information" and "the availability of a variety of specialized facilities and services in large cities" (Evans, 1972, p. 56). Nourse's (1968) classification divides business agglomeration economies into transfer economies, internal economies, locational economies, and urbanization economies.

Transfer economies refer to the reductions in transportation cost to households and firms when they locate together. Internal economies refer to the likelihood that a firm will have greater output levels in the larger markets of large cities enabling the firm to realize economies of scale. Locational economies characterize economies external to the firm but internal to the industry (Carlino, 1978). They arise when the clustering of firms result in the lower cost for all firms. This cost reduction concerns, for example, the development of a skilled labor force accessible to clusters of industrial activity that reduces the cost of filling vacancies and increases the skill levels of new employees. In addition, when the market becomes sufficiently large, specialization in the production of subparts and production techniques becomes feasible (Stiegler, 1951). Urbanization economies extend the idea of locational economies to interindustry relationships. Firms in many industries clustering together can benefit from a flexible labor force, the provision of public goods, and specialization.

The opposite of economies of agglomeration is diseconomies of agglomeration which can be pecuniary or nonpecuniary in nature. Chief among the pecuniary diseconomies are the diseconomies of transportation associated with the using transfer networks. Negative nonpecuniary externalities, such as pollution and crime rates, are also related to concentration and size. Both types of agglomeration diseconomies offset agglomeration economies and prevent a city from growing without limit.

Although the forces of agglomeration economies and diseconomies oppose each other with respect to city size, they complement each other with respect to money wages and nominal income. Falling total cost of production associated with agglomeration economies implies increasing average and marginal products of workers and, hence, higher money wages. Agglomeration diseconomies that result in compensatory payments to acquire and maintain factors of production also imply higher money wages and nominal income (Hoch, 1972). The existence of agglomeration economies implies that large cities have a natural competitive advantage resulting in higher wages, an inflow of labor, and increasing population. Money income also increases with city size due in part to compensatory payments for disamenities associated with city size.

Syntheses of Demand and Supply Theories

Studies by Guccione and Gillen (1980) and Ghali, Akiyama, and Fujiwara (1981) are noteworthy because they report the comparative explanatory powers of the demand type and supply type models of growth. In addition, both studies develop and test hybrid models that synthesize the major elements of both theories.

Guccione and Gillen's study interprets the export-base model as a short-run theory of growth. Drawing upon the studies by Muth (1968) and Borts and Stein (1964), long-run equilibrium conditions are imposed to derive a supply side theory of growth. In the short run, an exogenously determined wage and an inelastic supply of labor enable the level of demand for labor in the basic sector to determine the level of total employment. If unemployment occurs, disequilibrium adjustments take place through changes in the supply of labor brought about by migration. In the long run, the demand for labor becomes perfectly elastic in the relevant range implying full employment and the predominance of the supply of labor as the major determinant of employment growth. The empirical model consists of two equations specifying the disequilibrium adjustment process for employment and the determinants of population size. The supply of labor is assumed to be a constant fraction of the population. Using time-series data from the metropolitan area of Windsor, Canada, for the period 1939 to 1977, Guccione and Gillen found the hybrid model out performed both the supply type and demand type models. The labor market moved from a short-run export-base solution to a long-run supply solution in a "reasonable period of time" in the absence of disturbances (Guccione and Gillen, 1980, p. 709).

Ghali, Akiyama, and Fujiwara (1981) construct an econometric model of regional income determination where the interaction of regional aggregate demand and aggregate supply determines the equilibrium solution. Essentially, the model corresponds to a macro growth model for an open economy. Aggregate demand is determined by exogenous export expenditures and endogenous domestic demand which is the sum of local consumption, investment, and government expenditures. Aggregate supply is the sum of endogenous imports and a domestic endogenous output resulting from a Cobb-Douglas production technique relating output to exogenous inputs of capital and labor.[6] Personal income depends on output while population depends on interregional wage and output differentials. Using a cross-sectional time-series sample of 48 states and the District of Columbia, the

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[6]Capital stock is approximated by property income.

estimated model explained most of the variations in output, capital formation, and migration. Migration conformed to the neoclassical hypothesis of factor mobility by responding to factor price differentials to promote factor price equallization. In simulations of the disequilibrium adjustments, where the adjustments were assumed to occur entirely on the demand side or supply side, the growth paths of output and per capita output generate by the models were similar. Therefore, the short-run specification did not affect the long-run behavior of the model.

Growth Pole Theory

The origin of growth pole theory can be traced to the classical paper by Perroux (1955). Since the publication of this paper, growth pole theory initially regarded as "a panacea for solving regional problems" has fallen from grace due to the dissatisfaction associated with its growth strategies (Richardson, 1978b, p. 28).

Perroux develops the idea of growth pole theory in the context of economic space. From earlier work Perroux (1950) defines economic space as:

> . . . consists of centers (or poles or foci) from which centrifugal forces emanate and to which centripetal forces are attracted. Each center, being a center of attraction and repulsion, has its proper field, which is set in the field of other centers (p. 124).[7]

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[7]Perroux, F., 'Economic Space: Theory and Applications, Quarterly Journal of Economics, Vol. 64 (1950), quoted in

Perroux's growth process, by its very nature, is unbalanced, originating at certain poles and spreading outward from these poles. According to Perroux (1955):

> . . . growth does not appear everywhere at the same time; it becomes manifest at points or poles of growth, with variable intensity; it spreads through different channels, with variable terminal effects on the whole of the economy (p. 94).

Underlying the growth pole theory is a motor or propulsive industry that has the capability to generate dynamic change throughout the economy by its interindustry linkages (Perroux, 1955, p. 95). Changes in the output of the motor industry are transmitted to its resource suppliers and other industries by backward and forward type linkages. These technologically linked industries are called a cluster of industries. The expansion of output by a motor industry and, therefore, its cluster can have favorable and unfavorable effects on other clusters it dominates. The favorable effects, known as trickling-down or spread effects, encourage the growth of other clusters. The sources of this encouragement are usually cited as the diffusion of investments, innovation, and attitudes from the dominant cluster. Polarization, or backwash effects, refer to the unfavorable effects of the growth of the motor industry.

N. Hansen, 'Development Pole Theory in a Regional Context,' in D. C. McKee et al., Regional Economic Theory and Practic0, (New York, 1970), p. 124.

Chief among these effects are the migration selectivity, loss of investment funds, and loss market areas to the dominant cluster. The net impact of the spread and backwash effects determines the dominant cluster's impact on other clusters.

Growth pole strategy refers to economic growth policies in geographical space that identify growth poles and encourage their economic growth and development. The net impact of the spread and backwash effects on the hinterland is presumably favorable. Thus, growth pole strategies emphasize unbalanced regional growth concentrated in urban centers, where long-run spread effects can be substained by structural change so the region can become a center of innovation and technical efficiency.

Policy-makers and planners who have relied upon growth pole strategies have become disillusioned with the results. Richardson believes that the major reason for this disenchantment has been lack of anticipated spread effects to the hinterland (Richardson, 1978a). Studies of the results of growth pole strategies in Spain and Brazil indicate some success in raising output levels in the growth poles, but failure to raise the standard of living and welfare for the hinterland's population (Richardson, 1978b). However, the disenchantment with growth strategies may be premature due to the unrealistic time horizon concerning the impact of the spread effects (Richardson, 1978a).

Summary

A common theme in the various explanations for variations in the rates of economic activity emerges from the literature. Since the evidence reveals mixed periods of convergent and divergent growth, it may be that convergent growth is the equilibrium state in the steady-state sense and divergent growth exists in departures from the equilibrium growth path. Whether the regional economy returns to an equilibrium growth path once disturbed depends on the stability of the equilibrium and the disequilibrium adjustment path. To enable divergent regional growth to persist, the regional economy must import resources in order to circumvent the full employment constraint imposed by limited regional resources. Nontransferable factor-saving technological progress in the use of regional resources could also enable persistent divergent growth. To maintain an inflow of resources, neoclassical and prosperity-cum-deficit export-base models require the relative growth of factor returns while growth pole theory emphasizes the domination of polarization effects.

The cumulative causation thesis explains regional growth as a disequilibrium growth process where the cumulative growth results in an explosive nonoscillating adjustment path. Regional models based on the cumulative causation thesis synthesizes the divergent growth explanations of neoclassical, export-base, and growth pole theories. The demand side explanation of divergent growth initiates the cumulative growth process. The disequilibrium factor flows suggested by a neoclassical growth model provide the resources to enable the growth pole to substain the growth process and backwash other areas. A detailed development and formulization of the cumulative growth process remains, and it is taken up in Chapter III.

CHAPTER III

THE CUMULATIVE CAUSATION THESIS OF REGIONAL GROWTH: A THEORETICAL DEVELOPMENT

Introduction

The cumulative causation thesis maintains that economic activity can be characterized by disequilibrium models based upon supportive forces that have the potential to cause explosive change. This approach has been used to study the financial problems of cities, urban decay, and the flight to the suburbs as well as regional growth (Baumol, 1967; Oates, Howrey, and Baumol, 1971; Bradford and Kelejian, 1973). This chapter develops and extends the cumulative causation model of regional growth suggested by Myrdal (1957), Kaldor (1970), Dixon and Thirlwall (1975). This model has the capability of generating cumulative regional growth and incorporates the chief ideas of export-base and neoclassical regional models. The model's analytical properties provide the hypotheses to test the empirical validity of this particular formulation of the cumulative causation thesis.

The Cumulative Causation Thesis

At its very core, the cumulative causation thesis of regional growth attempts to explain the causes of regional disparities in the level of economic activity. Myrdal (1957), the originator of the thesis, views the chief cause as backwash effects generated in the expanding area that result in the stagnation of other areas. The expanding area denudes other areas of their skilled workers and managers. The banking system absorbs savings from other areas for investment in the expanding region, enabling its industries to become more efficient than their counterparts in the other regions. Although conceding the existence of spread effects, supporters of Myrdal maintain the net effects of the movement of capital, labor, and goods between regions will retard the growth of some regions (Hirschman, 1958). In a sweeping generality, Myrdal (1958) states his view as follows:

> The main idea I want to convey is that the play of the forces in the market normally tends to increase, rather than decrease, the inequalities between regions (p. 26).

Salvatore (1972) believes Myrdal's thesis lacks theoretical justification and testable hypotheses. He contends that concern with the net outflow of resources overlooks the real issue of whether the "resources could and would have been used in the poor region and that their use would have caused an increase in per capita income" (Salvatore, 1972, p. 521). He also maintains that Myrdal did not give any indication of how to apply the theory; therefore, the theory lacks testable and measurable causal relationships to validate its propositions (Salvatore, 1972).

Kaldor (1970) has extended Myrdal's idea that trade will widen inequalities between regions through a cumulative process. Unlike Myrdal, Kaldor has testable hypotheses. To Kaldor, the cumulative causation thesis represents "nothing else but the existence of increasing returns to scale--using the term in its broadest sense--in processing activities" Kaldor N., 1970, p. 340). The type of increasing returns Kaldor refers to are those associated with the Verdoorn effect (Verdoorn, 1949). This effect postulates a positive correlation between the rates of growth in the scale of the activity and the rate of growth in productivity. The cumulative causation growth process Kaldor develops relies on the Verdoorn effect to sustain the growth process.

Accoding to Kaldor the processing sector achieves a competitive advantage in national markets because of movements of the efficiency wage. The efficiency wage is the ratio of an index of money wages to an index of productivity, and its movement depends directly on movement of the index of money wages relative to the index of productivity. Kaldor believes the efficiency wage will be falling in the fast-growing region relative to the slow-growing region. He assumes a constant exogenous money wage, arguing that money wages in both regions are approximately equal and remain so due to institutional features and labor mobility. The efficiency wage, however, is endogenous and depends on the

Verdoorn effect. In the fast-growing region, as the scale of the activity increases, the Verdoorn effect increases productivity and reduces the efficiency wage. The Verdoorn effect and movements of the efficiency wage are Kaldor's endogenous mechanisms that may cause cumulative growth and decline. To complete the cumulative growth model, Kaldor uses an export-base type model to link these endogenous mechanisms to a regional model so that exogenous changes in export act as a trigger for cumulative regional growth.

In Kaldor's scenario there are two regions, say A and B, each with an agriculture sector and a processing sector. Although each region's processors supply their agriculture sector, region's A's processing sector is more developed than region B's. Presumably, the cause of this initial difference could be differences in natural resource and capital endowments. According to Kaldor, however, these differences do not have the capability of explaining the observed disparities in industrial development. The differences are too great to attribute to differences in natural resource endowments. Capital endowments are dismissed on the grounds that they confuse cause and effect since industrial development results in capital formation which, in turn, causes industrial development. Instead, the disparities in industrial development are due to a cumulative growth process.

The opening of trade between A and B enables A's processing sector to dominate B's. As the activities of A's processing sector increase, the Verdoorn effect causes a falling efficiency wage, which causes A's exports to become more competitive relative to B's. In similar product lines A's industries capture B's home markets, backwashing B's processing sector. Effectively, the cumulative growth mechanisms cause exports to become endogenous. The multiplier implies the domestic sector of A will also be expanding as income rises in the export sector. Thus, Kaldor's model of cumulative growth has changes in exogenous export demand triggering the cumulative growth process in A and cumulative decline in B. The Verdoorn effect and movements of the efficiency wage perpetuate and accentuate the process. The multiplier spreads the growth process initiated by the export sector to the remaining sectors of the economy.

Formulization of the Regional Cumulative Growth Model

Dixon and Thirlwall (1975) utilize a simultaneous system of equations to formulize Kaldor's cumulative growth process. Their structural equations are

$$G_t = X_t^{\gamma} \quad (\gamma > 0), \tag{3.1}$$

$$X_t = P_{dt}^{e_1} P_{ft}^{e_2} Z_t^{e_3} \quad (e_1 < 0,\ e_2 > 0,\ e_3 > 0), \tag{3.2}$$

$$P_{dt} = \frac{W_t}{R_t} M_t \tag{3.3}$$

$$R_t = R_a G_t^{\lambda} \quad (\lambda > 0), \tag{3.4}$$

where

G_t	:	quantity of output,
X_t	:	quantity of exports,
	:	constant output elasticity with respect to exports,
P_{dt}	:	domestic price
P_{ft}	:	competitor's price,
W_t	:	wage rate,
Z_t	:	world income,
e_1	:	own price elasticity of export demand,
e_2	:	cross price elasticity of export demand with respect to the competitor's price,
e_3	:	income elasticity of export demand,
R_t	:	average product of labor,
M_t	:	1 + % mark-up on unit labor cost,
R_a	:	autonomous labor productivity,
λ	:	Verdoorn coefficient, i.e., the elasticity of the average product of labor with respect to output,
t	:	in time t.

Transforming the model into discrete growth rates by taking the derivatives of the logarithmic specifications of the equations with respect to time, yields the system of equations

$$g_t = \gamma x_t, \qquad (3.1')$$

$$x_t = e_1 p_{dt} + e_2 p_{ft} + e_3 z_t, \qquad (3.2')$$

$$p_d = w_t - r_t + m_t, \qquad (3.3')$$

$$r_t = r_a + \lambda g_t, \qquad (3.4')$$

where the lower case letters refer to the growth rates of the variables.

The first two equations of each specification represent the multiplier and the trigger mechanism respectively. In equations (3.1) and (3.1'), the level and growth rate of output depends on the level and growth rate of exports respectively. In equations (3.2) and (3.2'), the quantity and growth rate of exports depend upon the endogenously determined domestic price plus the exogenously determined competitor's price and world income. Taken in isolation, these equations represent an export-base explanation of regional growth because the level and growth of output is attuned to the level and growth of exports.

Equations (3.3) and (3.3') provide the pricing mechanism and supply adjustments of the model. In Kaldor's (1970) model producers in the processing sector are willing and able to sell more at the prevailing price in response to increases in demand. Their ability to respond to an increase in demand depends on the level of wages, productivity of workers, and the unit mark-up on per unit labor cost. Thus, equation (3.3) provides the supply adjustments of the model with the wage reflecting labor market conditions and the average product of labor reflecting aspects of the production function. With this interpretation of equation (3.3), the growth rate of domestic prices in equation (3.3') is equivalent to Kaldor's efficiency wage concept since, its movements depends in part on the growth rates of wages and labor productivity.

Equations (3.4) and (3.4') specify the Verdoorn effect. The level and rate of growth of labor productivity are determined by the level and rate of growth of output.

The cumulative growth aspects of this specification are illustrated by considering an exogenous increase in the growth rate of exports. Equation (3.1') translates the increase in exports to an increase in the growth rate of output. The Verdoorn effect in turn results in an increase in the growth rate of labor productivity, which implies a falling efficiency wage, given the constant level of wages and percentage mark-up on unit labor cost. A falling efficiency wage implies falling domestic export prices which increases the quantities of exports, and therefore, output. Whether the growth rate of output diverges from or converges to an equilibrium growth rate depends on the stability conditions of the growth path.

Dixon and Thirlwall investigated the stability conditions of their model by specifying a one-period lag in the response of exports to its determinants. Their specification for the quantity of exports becomes in absolute terms

$$x_t = P_{dt-1}^{e_1} P_{ft-1}^{e_2} z_{t-1}^{e_3}, \tag{3.5}$$

and in terms of discrete growth rates

$$x_t = e_1 p_{dt-1} + e_2 p_{ft-1} + e_3 z_{t-1}. \tag{3.5'}$$

Using the appropriate lagged structural equations and repeated substitution, they derive the reduced form equation

$$g_t = e_1(w_{t-1} - r_a + m_{t-1}) + e_2 p_{ft-1} + e_3 z_{t-1} - \gamma e_1 \lambda g_{t-1}. \tag{3.6}$$

Equation (3.6) is a first-order difference equation in terms of the growth rate of output with all other variables exogenously determined or constant. If $e_1 \neq -1$, its solution is

$$g_t = (g_o - g_e)(-\gamma e_1 \lambda)^t + g_e \tag{3.7}$$

where

$$g_e = \frac{e_1(w_{t-1} - r_a + m_{t-1}) + e_2 p_{ft-1} + e_3 z_{t-1}}{1 + \gamma e_1 \lambda},$$

and g_o equals the initial growth rate of output (Dixon and Thirlwall, 1975, p. 205). The equilibrium growth rate of output is given by g_e, and the stability of equation (3.7) is determined by $(-\gamma e_1 \lambda)$. If $(-\gamma e_1 \lambda)$ exceeds unity, there will be cumulative divergent growth from the equilibrium growth rate of output; otherwise, the growth rate of output will converge to the equilibrium growth rate of output. Taking the former case as representing cumulative growth, Dixon and Thirlwall have shown that cumulative growth depends upon structure of the economy reflected in the value of certain parameters. In particular, cumulative growth depends on the product of the output elasticity with respect to export, the price elasticity of exports, and the Verdoorn coefficient.

The endogenous mechanisms are the linchpins of the cumulative growth process. The Verdoorn effect, efficiency wage, and multiplier are Kaldor's preconditions for cumulative growth. Also required is a trigger mechanism to start the cumulative growth process. Thus, the Verdoorn effect, efficiency wage, multiplier, and trigger mechanism must be taken together to have conditions favorable for cumulative growth. These conditions, however, do not guarantee a cumulative growth process, since they do not ensure dynamic instability in the growth of output. The cumulative growth model is a disequilibrium model; therefore, dynamic instability of the model is an additional condition for cumulative growth. Dynamic instability is more likely the larger the Verdoorn effect, the price elasticity of output, and the elasticity of output with respect to exports.

Guccione and Gillen (1977) have extended Dixon's and Thirlwall's (1975) model to include two regions. In their model regional interaction comes about by defining the rate of growth of the competitor's prices as the other region's domestic price and the growth rate of world income as the growth rate of the other region's output. Under these assumptions, their model is a system of two identical second-order difference equations. Their solution shows that the stability of a region's growth rate of output depends on the number of regions under consideration as well as the structures of the regional economies.[1]

Empirical Evidence Of The Verdoorn Effect

Of the endogenous mechanisms, the Verdoorn effect has the central role since it determines the movements of the efficiency wage when wages are exogenous. The Verdoorn effect has been tested empirically at the regional and national levels.

In a 1966 Inaugural lecture, Kaldor (1966) maintained that the poor economic performance of the British economy was due to a limited supply of labor for industrial growth that prevented the exploitation of the productivity advan-

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[1]The effect of the number of regions on the stability condition was a source of contention between Dixon and Thirlwall and, Guccione and Gillen. The issue centered on the impact of adding regions to the value of the dominant characteristic root derived in the solution to the system of equations. As identical regions are added to the system of equations, the value of the dominant characteristic root rises, thus, increasing the likelihood of instability since it is necessary and sufficient for stability that the characteristic roots be less than unity. However, if the regions are not identical, the effect of adding regions depends upon the parameters. Dixon, R. and Thirlwall, A., "Growth Rate Stability in the Kaldorian Model," Scottish Journal of Political Economy (February 1978), pp. 97-99. Guccione, A. and Gillen, W., "Growth Rate Stability in the Kaldorian Model: The Characteristic Roots," Scottish Journal of Political Economy (June 1978), p. 211. Dixon, R. and Thirlwall, A., "A Reply to Gucccione and Gillen," Scottish Journal of Political Economy (June 1978), p. 212.

tages of large scale production. Kaldor cited evidence from a cross-sectional study of 12 countries that revealed a positive relationship between productivity growth and output growth in manufacturing, construction, and public utilities. In the study, a 1 percent increase in the growth of output caused a 1/2 percent increase in the growth of productivity. Cripps and Tarling (1973) substantiated Kaldor's results in manufacturing for the period 1951-1965 in 12 advanced capitalist countries. However, no such relationship was found in construction, and a negative statistically significant relationship was found for public utilities. Also for the 1965-1970 period, no relationship between productivity growth and output growth was found.

The relationship between productivity growth and output growth is mathematically equivalent to a relationship between productivity growth and employment growth.[2] Using the same sample as Cripps and Tarling (1973), Rowthorn (1975) found a positive relationship between productivity growth and employment growth, but he maintained the results were due to the inclusion of Japan, an extreme observation. When Japan was dropped from the sample, the relationship was no longer statistically significant. In a reply, Kaldor

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[2]If r, e, g are productivity growth, employment growth, and output growth respectively, then $r = g - e$ or $g = r + e$. The Verdoorn effect asserts

$$r = r_a + \lambda g \quad (r_a > 0, \lambda > 0).$$

Therefore,

$$r = r_a + \lambda(r+e), \text{ or } r = r_a/(1-\lambda) + (\lambda/1-\lambda)e.$$

(1975) maintained that the relationship between employment and productivity growth does not say anything about the Verdoorn effect. Kaldor takes output as an exogenous variable while employment and productivity are dependent endogenous variables. Any disturbance in employment growth is reflected with an opposite sign on productivity growth. A regression of productivity growth on employment growth would therefore generate spurious negative correlation. The rssue between Rowthorn and Kaldor concerns whether output of employment growth should be treated as exogenous when specifing the Verdoorn effect. However, neither variable is exogenous; they are both endogenous. Output growth is as much a result of, as a cause of, employment growth.

Parikh (1978) maintains the single equation estimates utilized in these studies are subject to a simultaneous equation bias due to the endogenous nature of output and employment growth. To overcome this bias, Parikh formulated a simultaneous model that determines the growth rate of output, employment, and productivity. Using the same 12 countries in a cross-sectional analysis, Parikh's (1978) results were sensitive to the inclusion of Japan, and neither Rowthorn's or Kaldor's versions of the Verdoorn effect were supported.

Casetti (1981) has incorporated the Verdoorn effect into his empirical study of the differences in manufacturing labor productivity growth across the United States, especially the sunbelt and snowbelt for the 1967-1976 time interval. In his study, the growth rate of labor productivity was regressed on the growth rates of output (Verdoorn effect), capital's distributive share (a capital deepening variable), and neutral disembodied technological progress (the constant term in the regressions). His findings support the implication of the Verdoorn effect that productivity tends to increase faster in regions that are experiencing economic growth. The Verdoorn effect was significant and positive in the United States and the sunbelt but not the snowbelt. Labor productivity growth in the snowbelt was attributed to neutral disembodied technological progress. In no regression was the capital deepening variable significant.

Another aspect of the empirical investigation of the Verdoorn effect, although not explicitly recognized as such, has been attempts to measure agglomeration economies to determine the validity of the hypothesis that large cities have productivity advantages. In order to determine the extent of contribution of agglomeration economies to productivity differences, their impact must be disentangled from other potential sources of productivity differentials. Among these sources are the demographic characteristics of the population, climate differences, regional effects, differences in industry mix, capital intensity, and technology in production. A common approach in many studies has been to estimate a production function such as

$$G = g(A)f(K,L)$$

$$\frac{\partial G}{\partial K} > 0, \frac{\partial G}{\partial L} > 0, \frac{\partial^2 G}{\partial L^2} < 0, \frac{\partial^2 G}{\partial K^2} < 0,$$

$$\frac{\partial G}{\partial g(A)} \frac{\partial g(A)}{\partial A} > 0,$$

where

G: urban output,

g(A): Hicks-neutral productivity,

K, L: capital stock and labor force respectively.

The Hicks-neutral productivity parameter, g, acts as a shifter with its specification controlling city characteristics.

The production function approach can either estimate productivity differences by industry across a sample of cities or urban area production across cities. Both methods are controversial due to the lack of adequate data. Disaggregation along industry lines reduces the number of city observations across regions; so, to enable a large number of observations, the sample universe has generally been restricted to two-digit industries in the Standard Industrial Classification (SIC) system. Unfortunately, capital stock and service data do not exist for this sample, which means indirect methods of estimating productivity advantages must be used. The estimation of urban area production functions also requires estimating capital stock data, and this can induce errors in measurements biasing the estimated parameters of the production function.

The indirect methods of estimating productivity advantages have attempted to determine the variation in labor productivity by industry across SMSA's by using techniques suggested by Dhrymes (1965) and Arrow, Chenery, Minhas, and Solow (1961). Sveikauskas (1975) argues that the productivity advantages of large cities are due to urban concentration so that these productivity advantages increase with city size. Thus, Hicks-neutral productivity depends upon city size. Population increases shift the production function such that, at a given capital-labor ratio, output of the larger city exceeds that of smaller cities. The absence of data on g(A) forced Sveikauskas to use value-added per unit of labor as a measure of labor productivity. Controlling for labor quality and regional effects, he found that for the 14 manufacturing industries in his sample labor productivity increased by 6 percent with each doubling of city size. Moomaw (1981) takes objection to these results. He suggests the method of estimating is subject to a specification error that imparts an upward bias. Moomaw also objects to the omission of a capital intensity variable. According to Moomaw, Sveikauskas' omission of this variable implies it is taken to be independent of the variables in the estimating equation, but it is not independent of population. Futhermore, higher wages in larger cities imply higher capital intensity. This dependence suggests that Sveikauskas' results have an upward bias since they implicitly include the effects of differences in capital intensity across SMSA's.

In another study relying upon indirect estimates, Shefer (1973) estimated returns to scale parameters using two labor-oriented production functions. These production functions take the form

$$w = AG^{b}L^{c} \tag{3.8}$$

and

$$G/L = Aw^{d}G^{z(1-d)}, \tag{3.9}$$

where w equals the wage rate; G, L, are as before; and b, c, z, d are constants. The returns to scale parameter for these equations are (1+c)/(1-b) and (1+z) respectively. Shefer fitted these equations to observations from 25 industries from 1958 and 1963 in a sample of 65 SMSA's. Both equations indicated significant returns to scale parameters (locational economies) for most industries. Combining manufacturing industries by SMSA and reestimating the equations, the returns to scale parameters (1.14 and 1.27 respectively) were significant indicating urbanization economies. Carlino (1978) used equation (3.8) to estimate returns to scale parameters for manufacturing industries in 65 SMSA's covering the periods 1957-1972. Taking the estimated scale parameter as a dependent variable, he then regressed measures of internal scale economies, locational economies, urbanization economies and diseconomies on the returns to scale parameter. His results were mixed, but they did give support to the importance of urbanization economies and diseconomies. Both Shefer's and Carlino's results are questionable since neither control for regional effects, demographic effects, capital intensity, and the interdependence between the wage, population, and capital intensity.

Segal (1976) has computed urban capital stock data for 65 SMSA's which allow a direct estimation of the production function. Assuming a Cobb-Douglas production function, controlling for labor quality, city characteristics, and price differences, Segal finds SMSA's with population of two million or greater are 8 percent more productive than SMSA's with population ranging from 250,000 to two million. Moomaw (1981) argues that Segal introduced a bias into his computations of the capital stock by omitting initial capital stocks of older cities. Correcting for this bias, Moomaw's revised estimates were significantly smaller than Segal's.

There appears to be some statistical evidence for the role of agglomeration economies and productivity advantages of larger cities. However, due to methodological problems and imperfect data, the evidence is not completely convincing.

Extension of the Cumulative Regional Growth Model

An outcome of the theoretical development of the Kaldorian regional growth model has been various explanations for the observation that long-run explosive regional growth does not usually occur. There must be constraints preventing the workings of the cumulative growth process. Kaldor (1966, 1970) suggests a labor supply constraint, national governmental redistribution policies, and the diseconomies associated with growth. Dixon and Thirlwall (1975) stress product innovation. These possibilities suggest that the other theoretical explanation of regional growth might be offsetting the cumulative growth process. This is a significant conclusion since it means that the other explanations must be synthesized with the cumulative causation thesis before its validity can be determined. In particular, interaction between the production of different goods in the regional economy must be considered to allow for the possibility of crowding-out. In addition, the capital stock and its rate of growth in the regional growth process must be incorporated into the cumulative growth process. With these additions, the process of cumulative regional output growth can be generalized.

Assume a two-sector regional economy that produces only export goods and local consumption goods with two factors of production, capital and labor. Export goods are solely for export and sold in competitive national markets. Capital goods can be obtained from either the output of local goods or export goods without incurring additional cost. In addition, the importation of capital goods is possibile. For simplicity, assume also that the capital stock does not depreciate. Labor and capital are perfectly mobile and respond to interregional and intersectoral factor price differences. Wages and the return on capital are thus determined in the national markets.

The growth rate in regional output, g_t, depends on the growth rates in the production of export goods, x_t, and goods for local consumption, d_t. The growth rate in regional output can be specified as

$$g_t = a_1 + a_2x_t + a_3d_t \quad (a_1>0,\ a_2>0,\ a_3>0), \qquad (3.10)$$

where a_i, i = 1, 2, 3, are respectively a constant, the elasticity of regional output with respect to export goods, and the elasticity of regional output with respect to local goods.

The specification of the growth rate in the production of export goods has the same form as Dixon and Thirlwall's (1975) model. The growth in the production of export goods is given by

$$x_t = e_1+e_2p_{dt}+e_3p_{ft}+e_4z_t \quad (e_1>0,e_2<0,e_3>0,e_4>0), \quad (3.11)$$

where e_i = 1, 2, 3, 4 are respectively a constant, the own price elasticity of exports, the elasticity of exports with respect to the foreign price and the income elasticity of exports.

The growth of the production of local goods, d_t, is assumed to depend upon the growth rate of the production of the export goods and the region's population, n_t. The interaction between the production of exports and local goods allows for the possibility of crowding-out of local production by the production of export goods. The growth rate in the production of local goods is specified as

$$d_t = d_1 + d_2 x_t + d_3 n_t \quad (d_1 > 0,\ d_3 > 0), \tag{3.12}$$

where d_i, i = 1, 3 are respectively a constant and the elasticity of the output of local goods with respect to population. The coefficient of x_t, d_2, is the elasticity of the output of local goods with respect to the production of exports. Henceforth, this coefficient will be called the crowding-out coefficient. The sign of the crowding-out coefficient can be either positive if a change in the growth rate of exports induces the production of local goods or negative if the production of export goods absorbs resources that would have been used in the production of local goods.

Equations (3.10), (3.11), and (3.12) constitute an export-base model of the regional economy since the growth rate of output has become attuned to the growth rate of the production of exports. No explicit role for imports is recognized. However, they are taken into account indirectly to the extent that imports of consumption goods and factors of production affect the growth rates of output, export goods, and local goods.

The efficiency wage is assumed to operate exclusively in the export sector and is adopted from Dixon and Thirlwall's (1975) model with the exception that the per unit mark-up on labor cost is assumed to be a constant; as a result, its growth rate is zero. The efficiency wage is given by

$$p_{dt} = w_t - r_t. \tag{3.13}$$

The Verdoorn effect is modified to take account of the impact of the rate of growth of capital on the growth of labor productivity. This is accomplished indirectly by allowing the growth rate of labor productivity to depend on the growth rate of the average product of capital as well as the growth rate of regional output. The specification can be derived from the neoclassical production function, given in equation (2.1) of Chapter II, by dropping the subscripts and letting T denote the index of technical progress.[3]

The production function for regional output is then given by

$$G = f(K,L,T).$$

Take the total derivative of G with respect to time,

$$\frac{dG}{dt} = f_K\frac{dK}{dt} + f_L\frac{dL}{dt} + f_T\frac{dT}{dt},$$

where f_K, f_L, and f_T are partial derivatives of f with respect to K, L, and T respectively. Divide the total derivative by G and rearrange terms to obtain

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[3]This derivation is similar to Casetti's (1981).

$$\frac{1}{G}\frac{dG}{dt} = \frac{Kf_K}{GK}\frac{dK}{dt} + \frac{Lf_L}{GL}\frac{dL}{dT} + \frac{f_T}{G}\frac{dT}{dt} .$$

Since constant returns to scale are not assumed, Euler's Theorem cannot be applied to arrive at equation (2.2) of Chapter II. Instead, let the partial output elasticity with respect to capital and labor be defined as

$$E_K = f_K(K/G) \qquad (E_K>0),$$
$$E_L = f_L(L/G) \qquad (E_L>0),$$

respectively, and let

$$r_a' = \frac{f_T}{G}\frac{dT}{dt}.$$

Substitution yields

$$\frac{1}{G}\frac{dG}{dt} = \frac{E_K}{K}\frac{dK}{dt} + \frac{E_L}{L}\frac{dL}{dt} + r_a,$$

or

$$g = E_K k + E_L l + r_a. \qquad (3.14)$$

Now, define, respectively, the average product of capital and labor as

$$V = G/K,$$
$$R = G/L.$$

The growth rates of the average product of capital and labor are then, respectively

$$v = g - k, \qquad (3.15)$$

$$r = g - l.$$

Thus, the respective growth rates of capital and labor are

$$k = g - v,$$

$$l = g - r.$$

Substituting these latter growth rates into equation (3.14) yields

$$g = E_K(g - v) + E_L(g - r) + r_a'. \qquad (3.16)$$

To arrive an expression for the average product of labor, r, solve equation (3.16) for r and simplify to obtain

$$r' = \frac{(E_K + E_L - 1)}{E_L} g - \frac{E_K}{E_L} v + \frac{r_a'}{E_L},$$

or

$$r' = r_a + \lambda_1 g + \lambda_2 v, \qquad (3.17)$$

where

$$\lambda_1 = (E_K + E_L - 1)/E_L,$$

$$\lambda_2 = -(E_K/E_L).$$

$$r_a = r_a'/E_L.$$

For the Verdoorn effect to be valid, there must be a positive relationship between the growth rates of output and labor productivity. Thus, $\lambda_1 > 0$ or, equivalently, $E_L + E_K >$ 1 which means that there must be increasing returns to scale in the production of output. The sign of λ_2 is negative if the partial elasticities of output with respect to capital and labor are positive. Regional output is, then, restricted to the economic feasible range of production, and in this range, the growth rates of the average products of labor and capital are inversely related for constant levels of output. The constant term, r_a, represents neutral-disembodied technical progess scaled by the partial elasticity of output with respect to labor.

To complete the system of equations, the growth rate of the average product of capital must be specified. This requires specifying the growth rate of capital. Since by assumption the capital stock does not depreciate, the change in the capital stock will equal the level of investment expenditures, I_t. As noted in Chapter II, a condition for export-led growth is that there be an acceleration type link between investments and exports. Generalizing this condition, there must be an accleration type link between investment expenditures and the growth rate of regional output. Thus, assume investment expenditures conform to a simple accelerator principle of investment so that the growth rate of the capital stock is proportional to the growth rate in regional output, i.e.

$$k_t = hg_t \quad (0<h<1), \qquad (3.18)$$

where h is the accelerator coefficient.

Equations (3.10)-(3.13), (3.15), (3.17), and (3.18) constitute a simultaneous system of equations representing an extended cumulative causation model of regional growth.

The model is also presented in Table I.

TABLE I

CUMULATIVE GROWTH MODEL OF REGIONAL OUTPUT

$$g_t = a_1 + a_2x_t + a_3d_t \quad (a_1>0,\ a_2>0,\ a_3>0) \tag{3.10}$$

$$x_t = e_1+e_2p_{dt}+e_3p_{ft}+e_4z_t \quad (e_1>0,\ e_2<0,\ e_3>0,\ e_4>0) \tag{3.11}$$

$$d_t = d_1 + d_2x_t + d_3n_t \quad (d_1>0,\ d_2\ 0,\ d_3>0) \tag{3.12}$$

$$p_{dt} = w_t - r_t \tag{3.13}$$

$$r_t = r_a + \lambda_1g_t + \lambda_2v_t \quad (r_a>0,\ \lambda_1>0, \lambda_2<0) \tag{3.17}$$

$$v_t = g_t - k_t \tag{3.15}$$

$$k_t = hg_t \tag{3.18}$$

The equilibrium growth rate of output derived in Appendix A equals

$$g_e = \frac{c_0 + c_1w_t + c_2p_{ft} + c_3z_t + c_4n_t}{1 + c_5}, \tag{3.19}$$

where

$c_0 = a_1 + a_2e_1 + a_3d_1 + a_3d_2e_1 + (a_2e_3 - a_3d_2e_2)r_a,$

$c_1 = e_2(a_2 + a_3d_2),$

$c_2 = e_3(a_2 + a_3d_2),$

$c_3 = e_4(a_2 + a_3d_2),$

$c_4 = a_3d_3,$

$$c_5 = e_2 \; {}_3(a_2 + a_3 d_2),$$
$$\lambda_3 = \lambda_1 + \lambda_2(1-h).$$

Unlike Dixon and Thirlwall's model, the impact on the equilibrium growth rate of output of changes in the exogenous variables (w_t, p_{ft}, z_t, n_t) depends upon the sign of the crowding-out coefficient. It will also be demonstrated below that the stability of the growth rate of regional output in a disequilibrium situation depends upon the crowding-out coefficient. The derivation of the comparative-static properties of the growth rate is postponed until the stability conditions are analyzed.

Adopting Dixon and Thirlwall's methodology, the stability conditions for the growth of output can be determined by assuming a one-period lag in the response of exports to its determinants. In which case equation (3.5') specifies the growth rate of exports. The growth path for output derived in Appendix A is

$$g_t = (g_o - g_e)\ (-c_5)^t + g_e \qquad (3.20)$$

where g_o is the initial growth rate. Its stability depends on whether $(-c_5)$ is greater than unity (instability) or less than unity (stable). That is whether

$$(-c_5) \lessgtr 1$$

or

$$-e_2 \lambda_3(a_2+a_3 d_2) \lessgtr 1 \qquad (-e_2 > 0).$$

Rearranging terms, yields

$$a_2 + a_3 d_2 \begin{smallmatrix} < \\ > \end{smallmatrix} \frac{-1}{e_2 \lambda_3}. \tag{3.21}$$

Like Dixon and Thirlwall's model, this model's stability condition depends on the product of the price elasticity of exports, the Verdoorn coefficient, and the elasticity of output with respect to exports. Note, however, that this latter term is adjusted by a term that contains the crowding-out coefficient $(a_2 + a_3 d_2)$. When there are no intersector relationships between the sectors growth rates $(d_2 = 0)$, this model stability condition is identical to Dixon and Thirlwall's model.

To interpret the stability conditions, consider the coefficient as partial derivatives so that[4]

$$a_2 = \frac{\partial g_t}{\partial x_t}, \quad a_3 = \frac{\partial g_t}{\partial d_t}, \quad e_2 = \frac{\partial x_t}{\partial p_{dt}},$$

$$\lambda_3 = \frac{\partial r_t}{\partial g_t}, \quad d_2 = \frac{\partial d_t}{\partial x_t}.$$

Substitution of these partial derivates into equation (3.21) yields

$$\frac{\partial g_t}{\partial x_t} + \frac{\partial g_t}{\partial d_t}\frac{\partial d_t}{\partial x_t} \begin{smallmatrix} < \\ > \end{smallmatrix} \frac{-1}{\dfrac{\partial x_t}{\partial p_{dt}}\dfrac{\partial r_t}{\partial g_t}}. \tag{3.22}$$

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[4]Note an expression for continuous change is being used to describe an essentially discontinuous process.

Equation (3.22) shows that the likelihood of instability is greater the larger the Verdoorn effect and the price elasticity of exports since this means a smaller denominator on the right. Also the larger the crowding-out effect the smaller the expression on the left, therefore, decreasing the likelihood of instability.

The stability condition enables the comparative-static properties of the model to be analyzed. These properties are derived in Appendix A and summarized in Table II. The comparative static properties depend on the stability of the growth path, the sign, and magnitude of the crowding-out coefficient. In general, a negative crowding-out coefficient, d_2, indicating the presence of crowding-out, implies the comparative-static properties depend on the stability condition and on whether the crowding-out coefficient working though the domestic-lead growth term, a_3d_2, dominates the export-lead-growth coefficient, a_2. For example, suppose there is a stable growth path and the wage declines so that there is an increase in the growth rate of exports. As the export sector expands its production, resources will flow out of the domestic sector reducing the production of local goods. The net impact on the growth rate of regional output of the expanding export sector and contracting domestic sector depends on the relative magnitudes of these changes. The growth rates of regional output and the wage rate will be directly related if the domestic sector contracts more than the export sector expands, i.e.

TABLE II

COMPARATIVE-STATIC QUALITATIVE PROPERTIES OF THE THE EQUILIBRIUM GROWTH RATE OF REGIONAL OUTPUT

VARIABLES	STABLE GROWTH PATH		GROWTH PATH NOT STABLE	
	PRESENCE OF CROWDING-OUT	ABSENCE OF CROWDING-OUT	PRESENCE OF CROWDING-OUT	ABSENCE OF CROWDING-OUT
$\frac{g_t}{w_t}$	− $\lvert a_2\rvert > \lvert a_3 d_2\rvert$ - - - - - - + $\lvert a_2\rvert < \lvert a_3 d_2\rvert$	−	− $\lvert a_2\rvert < \lvert a_3 d_2\rvert$ - - - - - - - + $\lvert a_2\rvert > \lvert a_3 d_2\rvert$	+
$\frac{g_t}{P_{ft}}$	+ $\lvert a_2\rvert > \lvert a_3 d_2\rvert$ - - - - - - − $\lvert a_2\rvert < \lvert a_3 d_2\rvert$	+	+ $\lvert a_2\rvert < \lvert a_3 d_2\rvert$ - - - - - - - - − $\lvert a_2\rvert > \lvert a_3 d_2\rvert$	−
$\frac{g_t}{z_t}$	+ $\lvert a_2\rvert > \lvert a_3 d_2\rvert$ - - - - - - − $a_2 < a_3 d_2$	+	+ $\lvert a_2\rvert < \lvert a_3 d_2\rvert$ - - - - - - - − $\lvert a_2\rvert > \lvert a_3 d_2\rvert$	−
$\frac{g_t}{n_t}$	+	+	−	−

$|a_2| < |a_3 d_2|$. On the other hand, they will be inversely related if the export sector expands more than the domestic sector contracts, i.e. $|a_2| > |a_3 d_2|$. When crowding-out is absence and the growth path is stable, both the export and the domestic sector will be expanding as a consequence of the decline in the growth rate of wages. The growth rate of regional output will be increasing and, thus, inversely related to the growth rate of wages. When the growth path of output is not stable, the qualitative properties of the growth rate of output with respect to changes in the growth rate of wages will have the opposite sign of their counterparts for a stable growth path.

A similar analysis can be applied to the comparative-static properties of a change in the growth rates of the foreign price and world income. The initial effect of a change in either of these variables is to cause a corresponding change in the production of exports. Thus, for example, given a stable growth path, an increase in the growth rate of world income would cause a increase in the growth rate of exports. In the presence of crowding-out, the growth rate of the domestic sector's output would decline as resources flowed to the expanding export sector. If this contraction in output offsets the expansion in the export sector, there would be an inverse relationship between the growth rates of regional output and world income. However, if the output of the domestic sector contracted less than the expansion in the export sector or if it expanded as in the case of no crowding-out, there would be a direct relationship between the growth rates of regional output and world income.

Turning to the influence of changing population growth rates on the growth rate of regional output, the comparative-static properties depend solely on the stability of the growth path of output. Since regional population growth does not affect the export sector and domestic production is directly related to these changes, there will be a positive relationship between the growth rates of regional output and population when the growth path is stable and an inverse relationship when it is not.

Notice that in the analysis of the stability condition it was found that the explosive growth of output was more likely when the crowding-out effect was absent. Thus, when the growth path of output is not stable and crowding-out is absent, the likelihood of cumulative growth is greatest. Examination of the comparative-static properties under these conditions shows nonintuitive results. The growth rate of regional output is directly related to the growth rate of wages and inversely related to the growth rates of foreign price, world income, and population. Because these results are not intuitive, it does not invalidate the idea of cumulative regional growth, but it does suggest its unlikeliness.

Hypotheses

The foregoing analysis has developed the conditions for cumulative growth. Embodied in the analysis has been the assumption that will enable the validity of the cumulative causation thesis to be determined.

Since cumulative growth is essentially an endogenous growth process, it needs a trigger mechanism to start the growth process. The model assumes that changes in the growth of exports triggers the cumulative growth process. Thus, the export-led growth coefficient must be positive to have cumulative growth. To substain and internalize the growth process, the Verdoorn effect and efficiency wage must be operating. For the Verdoorn effect to be valid, there must be a positive relationship between the growth rate of the average product of labor and the growth rate of output. To transmit the Verdoorn effect to the export sector, the efficiency wage must have a negative effect on price, and price must be inversely related to exports. Thus, the coefficient representing the own price elasticity of exports must be negative. The economy must diverge from its long-run equilibrium growth rate when there is an exogenous change in exports. This requires explosive instability in the disequilibrium adjustment.

Summary

The cumulative causation thesis asserts that the economic growth process is a disequilibrium process promoting divergent growth substained by endogenous factors. The chief endogenous mechanism is the Verdoorn effect. In regard to regional economic growth, the cumulative model has been presented as a modified export-base model where the Verdoorn effect translates the initial growth impluse into a sustained growth through the endogenous efficiency wage. The Verdoorn effect and efficiency wage combine to cause the volume of exports to become endogenous. A multiplier effect spreads this growth process originating in the export sector to the remaining sectors of the economy.

An extended two sector cumulative regional growth model incorporating the growth rate of capital according to the accelerator principle of investment and the possibility of crowding-out of production for local consumption by the export sector has been analyzed. The a priori restrictions on the coefficients of the model create a favorable environment for cumulative growth. Dynamic instability in the disequilibrium adjustment of the growth rate of regional output insures the economy will diverge from its equilibrium growth path as required by the cumulative causation thesis. Thus, it is necessary and sufficient for cumulative regional growth that the a priori restrictions be satisfied and that there be instability in the economy.

CHAPTER IV

THE CUMULATIVE CAUSATION THESIS: AN EMPIRICAL SPECIFICATION AND ANALYSIS

Introduction

This chapter undertakes an empirical analysis of the extended cumulative causation model. This entails an examination of its econometric properties in order to determine an appropriate estimator. The model is estimated with a two-stage least squares (2SLS) estimator using time series from five states and five urban areas. The estimated parameters of the model allow the hypotheses of the previous chapter to be tested to examine the validity of the cumulative causation thesis as a theory of regional growth.

The Empirical Properties of the Extended Model

The statistical preliminaries to the estimation of the extended model are developed in this section. The empirical structural equations are specified and solved for their reduced form. Since the extended cumulative causation model is a simultaneous system of equations, the condition of identification for each equation must be analyzed. These conditions imply that the 2SLS estimator is appropriate.

Specification

The extended model of cumulative regional growth can be converted into an econometric model by the addition of a stochastic disturbance term to all equations except those representing a definition. Following the standard specification for a system of equations the disturbance terms are assumed to be independent normally distributed random variables with zero means and a constant covariance matrix (Intriligator, 1978). Letting u_{it}, i = 1, 2, ..., 5 be the disturbance terms at time t, the empirical form of the extended cumulative causation model is

$$g_t = a_1 + a_2 x_t + a_3 d_t + u_{1t}, \quad (4.1)$$

$$x_t = e_1 + e_2 p_{dt} + e_2 p_{ft} + e_3 z_t + u_{2t}, \quad (4.2)$$

$$p_{dt} = w_t - r_t, \quad (4.3)$$

$$r_t = r_a + \lambda_1 g_t + \lambda_2 v_t + u_{3t}, \quad (4.4)$$

$$v_t = g_t - k_t, \quad (4.5)$$

$$k_t = h g_t + u_{4t}, \quad (4.6)$$

$$d_t = d_1 + d_2 x_t + d_3 n_t + u_{5t}. \quad (4.7)$$

The endogenous variables are g_t, x_t, p_{dt}, r_t, v_t, k_t, and d_t, while the predetermined variables, the exogeneous and the lagged endogenous variables, are p_{ft}, z_t, w_t, and n_t. Since the number of equations is the same as the number of endogenous variables, the system of equations is complete.

Equations (4.3) and (4.5) are deterministic and need not be estimated directly. Equation (4.6) can be eliminated by substitution. To eliminate these equations, substitute equation (4.3) into equation (4.2), equation (4.6) into equation (4.5), and equation (4.5) into equation (4.4). After simplification, the simultaneous system of equations becomes

$$g_t = a_1 + a_2 x_t + a_3 d_t + u_{1t}, \tag{4.8}$$

$$x_t = e_1 + e_2(w_t - r_t) + e_3 p_{ft} + e_4 z_t + u_{2t}, \tag{4.9}$$

$$r_t = r_a + \quad {}_3 g_t + u_{6t}, \tag{4.10}$$

$$d_t = d_1 + d_2 x_t + d_3 n_t + u_{5t}, \tag{4.11}$$

where

$$\lambda_3 = \lambda_1 + \lambda_2(1 - h),$$

$$u_{6t} = \quad {}_2 u_{4t} + u_{3t}.$$

In Appendix A the reduced form for the non-stochastic equations (4.8)-(4.11) has been derived. With the addition to that specification of stochastic disturbance terms, u'_{it}, $i = 1, 2, 3, 4$, that are assumed to be independent normally distributed random variables with zero means and a constant covariance martix, the reduced-form equations for (4.8)-(4.11) becomes in matrix notation

$$\begin{pmatrix} g_t \\ x_t \\ r_t \\ d_t \end{pmatrix} = \begin{pmatrix} b_{ij} \end{pmatrix} \begin{pmatrix} 1 \\ w_t \\ p_{ft} \\ z_t \\ n_t \end{pmatrix} + \begin{pmatrix} u'_{1t} \\ u'_{2t} \\ u'_{3t} \\ u'_{4t} \end{pmatrix}$$

where b_{ij}, $i = 1, 2, 3, 4$, $j = 1, 2, \ldots, 5$ is the matrix of reduced-form coefficients.

Identification

In a simultaneous system of equations, the identification problem concerns whether the estimates of an equation's structural parameters and the parameter's covariance matrix are deducible from the estimated parameters of the reduced-form equation (Intriligator, 1978). When a derivation is possible, the equation is said to be identified. An equation is just-identified when a unique set of structural parameters can be derived from the estimated reduced-form equation. The equation is overidentified when the derivation yields more than one set of structural pararameters. When a derivation is impossible, the equation is said to be underidentified in which case the structural parameters cannot be estimated.

One approach for determining the identification property of a particular equation is based upon zero restrictions on the structural parameters (Theil, 1971). This method assumes that a sufficient number of structural parameters vanish in each equation to enable its identification. The order condition of identification gives a necessary condition for identification in terms of the number of vanishing structural parameters. An equation is just-identified when the number of predetermined variables in the system of equations excluded from the equation equals the number of included endogenous variables less one (Theil, 1971). If the number of excluded predetermined variables exceeds the number of included endogenous variables less one, the equation is overidentified. When neither condition holds, the equation is underidentified.

In the extended cumulative causation model, given by equations (4.8)-(4.11), the predetermined variables are w_t, z_t, n_t, p_{ft}, and the constant term. For each equation in the system, the number of excluded predetermined variables exceeds the number of included endogenous variables less one. Thus, each equation is overidentified.

Since the order condition is a necessary condition, it is not sufficient to ensure identification. The rank condition of identification is necessary and sufficient for identification (Theil, 1971). Appendix B develops the rank conditions and tests the extended model in regards to these conditions. The results of these tests show that each equation is overidentified.

<u>Two-Stage Least Squares Estimator</u>

The 2SLS estimator can be used to estimate structural equations that are overidentified, and will be used to estimate the extended model of cumulative growth. It is a consistent estimator of overidentified and just-identified equations, but it is biased (Intriligator, 1978). The bias of the estimator is the result of the nature of a simultaneous system of equations where there is at least one explanatory variable in one equation that is an endogenous variable in another equation. In this case these variables are not independent of the disturbance term(s).

Two qualifications must be made about the 2SLS estimator. Since the estimates of the structural parameters are biased, the t-statistic used to test the significance of the estimates will also be biased (Cassidy, 1981). However, according to Cassidy, "Most researchers use the usual t-statistic computed from 2SLS estimates with the knowledge that they are usually approximately correct" (Cassidy, 1981, p. 230). The other qualification concerns the interpretation of the coefficient of determination, R^2. The R^2 for a 2SLS estimator is based upon two sets of regressions, the first and second stage, and thus does not have the normal interpretation as the proportion of the variance explained by the regression (Intriligator, 1978). Therefore, the F-test for the significance of the regression equation is not appropriate.

The estimation of the cumulative causation model requires using time series. There will, thus, be a likelihood of serial correlation of the disturbance terms. Serial correlation means the disturbance terms will not be independent of one another, which is a violation the classical assumptions of the least squares model (Intriligator, 1978). The presence of serial correlation implies a biased estimate of the variance of the estimated parameters and, therefore, invalid statistical test of significance (Intriligator, 1978). To test for the presence of serial correlation, the Durbin-Watson statistical test will be utilized (Theil, 1971).

Regression Strategy

The data requirements of the cumulative growth model given by equations (4.8)-(4.11) preclude its estimation. In particular, the model requires regional output data at both the aggregate level and by sector. Unfortunately, this data does not exist in sufficient quantity for the sample areas of this study; however, employment data are available and will be used to test the cumulative causation thesis. The use of this data requires respecifying the cumulative growth model to allow for the possibilty of cumulative growth in employment.

A Model of Cumulative Growth in Employment

The models that are developed, analyzed, and estimated in this section modify the extended model cumulative of growth so that the possibility of cumulative employment growth can be tested. Since there are differences in the availability of published data for state and urban areas of this study, state and urban models are specified.

State Model

A model of the cumulative growth in the spirit of the model developed previously has the specification

$$TOTEM_t = a_{11} + a_{12}MANU_t + a_{13}NOMANU_t + a_{14}MIN_t + a_{15}AGE_t + u_{1t}, \qquad (4.12)$$

$$MANU_t = a_{21} + a_{22}BMANU_t + a_{23}PIPC_{t-1} + u_{2t}, \qquad (4.13)$$

$$BMANU_t = a_{31} + a_{32}EW_t + a_{33}NDIPC_t + a_{34}DMANU_t + u_{3t}, \qquad (4.14)$$

$$VAMHR_t = a_{41} + a_{42}VA_t + a_{43}CMEPF_t + a_{44}CE_t + u_{3t}, \qquad (4.15)$$

$$VA_t = a_{51} + a_{52}MANU_t + a_{53}CE_t + u_{5t}, \qquad (4.16)$$

$$NOMAN_t = a_{61} + a_{62}MANU_t + a_{63}POP_t + a_{64}MANU_{t-1} + a_{65}TOTEM_{t-1} + u_{6t}, \qquad (4.17)$$

where the a_{ij}'s are the parameters to be estimated and u_{it}, $i = 1, 2, \ldots, 6$ are the independent normally distributed disturbance terms with zero means and a constant covariance matrix.

Equation (4.12) specifies the growth rate in total employment at time t. The equation simply states that the sum of the weighted growth rates of the various sectors of the state economy equals the total employment growth rate. These sectors are the manufacturing (MANU), nonmanufacturing (NOMAN), mining (MIN), and agricultural (AGE). Since the mining and agricultural sectors are natural resource based sectors, their employment levels are assumed to be exogenously determined. In other words, employment growth in these sectors is assumed to be independent of the employment growth in the manufacturing and nonmanufacturing sectors. The employment growth rates in the manufacturing and nonmanufacturing sectors are endogenous variables. The estimated constant term should be forced to zero by this specification because of the absence of autonomous employment growth.[1] The remaining parameters are the weights of the respective sectors' contribution to the employment growth. They are expected to be positive and sum to unity.

Equations (4.13)-(4.16) modify the cumulative growth model so that the manufacturing sector becomes the source of the cumulative growth. In equation (4.13) the growth rate of manufacturing employment depends upon the endogenously determined growth rate of basic employment in the manufacturing sector (BMANU) and on the state's growth rate of per capita personal income (PIPC) lagged one period. This specification presumes that BMANU represents export-related employment growth in manufacturing while lagged PIPC approximates employment growth associated with non-export activity. There is a theoretical and an empirical rationale for selecting this latter variable. At the theoretical level, personal income measures the sum of all factor payments received by the factors of production used in producing the states' output.[2] By converting this

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[1]In the estimation of this equation, employment in the government sector was excluded so that the constant term was not forced to zero.

[2]Strictly, "personal income is the sum of wage and salary disbursements, other labor income, proprietors income with inventory valuation and capital consumption allowances, rental income of persons with capital consumption adjustment, personal dividend income, personal interest income, and transfer payments less personal contribution for social insurance" (<u>Survey of Current</u>

measure into per capita terms, a measure of the level of economic activity at the individual level as well as individual purchasing power is obtained. If the state residents purchase their manufactured goods, then the growth rate of PIPC can be used to approximate the growth in manufacturing employment resulting from the growth in local consumption of manufactured goods. Given these considerations, the expected sign of lagged PIPC is positive because manufactured goods are expected to be normal goods. The expected sign of the coefficient for BMANU is positive because given the other determinants of MANU an increase in BMANU would cause a corresponding increase in MANU.

Equation (4.14) is from the previous model. It is the export demand equation for the determination of the growth rate in basic employment in manufacturing. The efficiency wage (EW) is, in effect, a measure of profitability. If it declines, one would expect export employment to increase. Therefore, its expected sign is negative. The exogenous variables are the growth rates of per capita national disposable income (NDIPC) and the manufacturing price index (DMANU). They control for conditions in the national market. Given a national market for export goods, one would expect that an increase in NDIPC would result in a corresponding increase in the purchase of manufactured

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Business. August, 1982, p. 49). Per capita personal income uses resident population as of July 1 (Survey of Current Business. August, 1982).

goods. Therefore, the expected sign of NDIPC is positive. The sign of DMANU is expected to be negative since, other things equal, there is an inverse relationship between the price and the quantity of manufacturing goods purchased so that as the growth rate of price changed purchases would change in the opposite direction and so would the growth of basic employment.

Equation (4.15) tests for the Verdoorn effect which is the expected positive relationship between the growth rates in labor productivity (VAMHR) and value-added (VA). The growth rate in the number of employees per establishment (GMEPF) is a proxy for internal economies of scale. The variable, in effect, controls for the advantages of specialization and the division of labor that result as the number of employees per establishment increase. One would expect a positive sign if internal economies are present.

Equation (4.16) is a neoclassical production function specifying the growth rate of manufacturing output (VA). It depends on the endogenous growth of manufacturing employment and the exogenous growth rate of the capital stock (CE). The exogenous treatment of the capital stock is an assumption which is made for its empirical simplicity and to maintain the labor-oriented spirit of the model.[3] The expected signs of the variable's coefficients are positive.

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[3]In Appendix D it is shown that the major qualitative results of this study are not affected by an endogenous treatment of capital.

Equation (4.17) adapts a reduced-form equation from Gerking and Isserman's (1981) export-base model. A major issue addressed by this equation is whether employment growth in the manufacturing sector spills over into the non-manufacturing sector creating conditions for the cumulative growth in total employment or whether it crowds out non-manufacturing employment preventing the cumulative growth of total employment. Thus, the endogenous variable MANU and the predetermined variable $MANU_{t-1}$ are included in the equation. Positive coefficients for either variable indicate the absence of crowding-out, while negative coefficients indicate its presence. The purpose of the growth rate of lagged total employment ($TOTEM_{t-1}$) is to determine whether a labor supply constraint retards the growth of non-manufacturing employment (NONMAN), increasing the likelihood of crowding-out. Interpreting the variable as an indicator of the tightness of the labor market, a negative sign indicates the presence of a labor supply constraint and a positive sign its absence. The population growth rate (POP) is included to control for the local market serviced by the nonmanufacturing sector. As population increases, so does the market for nonmanufacturing goods so that one would expect a positive sign for this variable.

The process of cumulative growth postulated by the model proceeds in the following manner. Assume that an increase in the demand for manufacturing exports triggers the cumulative growth process. To satisfy this new demand there are increases in the growth rates of export-related employment, manufacturing employment, and, therefore, manufacturing output. As the growth rate of manufacturing output increases, the Verdoorn effect causes a corresponding increase in the growth rate of labor productivity. Given a nationally determined wage rate, the increase in labor productivity causes exports to become more profitable and, therefore, causes further increases in exports and export-related employment. Thus, there is cumulative growth in employment and output. This process of cumulative growth in the manufacturing sector is a precondition for cumulative growth in total employment growth. For cumulative growth in total employment, another precondition is the absence of crowding-out of nonmanufacturing employment. To ensure the economy diverges from its equilibrium growth rate in total employment, the disequilibrium adjustments must be explosive.

Table III summarizes the expected signs of the model's variables. When the theoretical analysis suggests a particular sign, the appropriate t-test to determine the significance of the variable is a one-tailed test. A two-tailed test is appropriate when theory suggests the variable can have either a positive or a negative sign as in the case of crowding-out.

There are a total of eleven predetermined variables (the ten listed in table III and the wage rate) and seven

TABLE III

EXPECTED SIGNS OF THE VARIABLES IN THE MODEL OF CUMULATIVE EMPLOYMENT GROWTH

EQUATION	VARIABLE	SIGN	t-test
	PRECONDITIONS		
4.13	$BMANU_t$	+	one-tailed
4.14	EW_t	-	one-tailed
4.15	VA_t	+	one-tailed
4.16	$MANU_t$	+	one-tailed
	CROWDING-OUT		
4.17	$MANU_t$	$\pm$	two-tailed
4.17	$MANU_{t-1}$	$\pm$	two-tailed
	EXOGENOUS		
4.12	MIN_t	+	one-tailed
4.12	AGE_t	+	one-tailed
4.13	$PIPC_{t-1}$	+	two-tailed
4.14	$NDIPC_t$	+	two-tailed
4.15	$GMEPF_t$	+	two-tailed
4.16	CE_t	+	one-tailed
4.17	POP_t	+	two-tailed
4.17	$TOTEM_{t-1}$	$\pm$	two-tailed
	OTHER		
4.13	$MANU_t$	+	one-tailed
4.13	$NOMAN_t$	+	one-tailed

endogenous variables in this model.[4] Since in each equation the number of excluded predetermined variables exceeds the number of included endogenous variables less one, each equation in the model is overidentified. The equations also satisfy the rank-condition of identification. This property is analyzed in Appendix B.

The dynamic properties of the model can be analyzed by solving the structural equations for their reduced-form equations and then solving the resulting difference equations to determine the equilibrium growth paths of the endogenous variables. In particular, the reduced-form equation for the growth rate of total employment and its equilibrium growth rate must be derived to test the stability condition.

As in the other models of cumulative growth, repeated substitution of equation (4.13)-(4.17) into equation (4.12) yields the reduced-form equation for TOTEM. An alternative approach with greater computation simplicity is to write the system of equations in matrix form and use Cramer's rule to solve for the reduced-form equation for TOTEM (Chiang, 1976). Using this latter approach, the reduced-form equation for TOTEM written as a ratio of two determinants is

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[4]The seventh endogenous variable is the efficiency wage. Since the efficiency wage is an identity, its specification, given by equation (4.3), has been suppressed.

$$TOTEM_t = \frac{\begin{vmatrix} E_{4.12} & -a_{12} & -a_{13} & 0 & 0 & 0 \\ E_{4.13} & 1 & 0 & -a_{22} & 0 & 0 \\ E_{4.14} & 0 & 0 & 1 & a_{32} & 0 \\ E_{4.15} & 0 & 0 & 0 & 1 & -a_{42} \\ E_{4.16} & -a_{52} & 0 & 0 & 0 & 1 \\ E_{4.17} & -a_{62} & 1 & 0 & 0 & 0 \end{vmatrix}}{\begin{vmatrix} 1 & -a_{12} & -a_{13} & 0 & 0 & 0 \\ 0 & 1 & 0 & -a_{22} & 0 & 0 \\ 0 & 0 & 0 & 1 & a_{32} & 0 \\ 0 & 0 & 0 & 0 & 1 & -a_{42} \\ 0 & -a_{51} & 0 & 0 & 0 & 1 \\ 0 & -a_{62} & 1 & 0 & 0 & 0 \end{vmatrix}}, \quad (4.18)$$

where $E_{4.12}$, $E_{4.13}$, ..., $E_{4.17}$ are the sums of the respective equations constant and predetermined variables, i.e., equations (4.12)-4.17). Calculating the values of the two determinants in equation (4.18) and simplifying yields in matrix form the reduced-form equation for $TOTEM_t$,

$$TOTEM_t = \begin{bmatrix} B \end{bmatrix} \begin{bmatrix} 1 \\ MIN_t \\ AGE_t \\ PIPC_{t-1} \\ WM_t \\ NDIPC_t \\ DMANU_t \\ GMEPF_t \\ CE_t \\ POP_t \\ MANU_{t-1} \\ TOTEM_{t-1} \end{bmatrix} \begin{bmatrix} \frac{1}{1 + B_{12}} \end{bmatrix}, \quad (4.19)$$

where

$$\begin{bmatrix} B \end{bmatrix} = \begin{bmatrix} B_0, B_1, \ldots, B_{11} \end{bmatrix},$$

$$B_0 = a_{11}+a_{22}a_{32}a_{11}+a_{22}a_{32}a_{42}a_{52}a_{11}+a_{62}a_{13}a_{21}+a_{12}a_{21}$$
$$+a_{22}a_{13}a_{62}a_{31}+a_{22}a_{12}a_{31}-a_{22}a_{13}a_{62}a_{42}a_{41}$$
$$-a_{22}a_{13}a_{32}a_{62}a_{42}a_{51}-a_{22}a_{32}a_{42}a_{12}a_{44}$$
$$+a_{22}a_{13}a_{32}a_{52}\ a_{42}a_{61}+a_{13}a_{61},$$
$$B_1 = a_{14}+a_{22}a_{32}a_{14}+a_{22}a_{32}a_{42}a_{52}a_{14},$$
$$B_2 = a_{15}+a_{22}a_{32}a_{15}+a_{22}a_{32}a_{42}a_{52}a_{15},$$
$$B_3 = a_{62}a_{13}+a_{12}a_{32},$$
$$B_4 = a_{22}a_{13}a_{62}a_{32}+a_{22}a_{12}a_{32},$$
$$B_5 = a_{22}a_{13}a_{62}a_{33}+a_{22}a_{12}a_{33},$$
$$B_6 = a_{22}a_{13}a_{62}a_{44}+a_{22}a_{12}a_{34},$$
$$B_7 = -(a_{22}a_{13}a_{32}a_{62}a_{42}a_{43}+a_{22}a_{32}a_{42}a_{12}a_{43}),$$
$$B_8 = -(a_{22}a_{31}a_{32}a_{62}a_{42}a_{53}+a_{22}a_{32}a_{42}a_{15}a_{53}),$$
$$B_9 = a_{22}a_{13}a_{32}a_{52}a_{42}a_{63}+a_{13}a_{63},$$
$$B_{10} = a_{22}a_{13}a_{32}a_{52}a_{42}a_{64}+a_{13}a_{64},$$
$$B_{11} = a_{22}a_{13}a_{32}a_{52}a_{42}a_{65}+a_{13}a_{65},$$
$$B_{12} = a_{52}a_{22}a_{32}a_{42}.$$

Equation (4.19) is a first-order difference equation in terms of TOTEM. Following the procedure of Chapter III and Appendix A for solving this type of equation, the equilibrium growth path of TOTEM is given by

$$TOTEM_t = (TOTEM_0 - TOTEM_e)\left(\frac{B_{11}}{1 + B_{12}}\right)^t + TOTEM_e, \quad (4.20)$$

for $B_{12} \neq -1$, where $TOTEM_o$ is the initial value of TOTEM and $TOTEM_e$ is the equilibrium growth rate which is

$$TOTEM_e = \left(\frac{H_t}{1 + B_{12} - B_{11}}\right),$$

where

$$H_t = \begin{bmatrix} B_0, B_1, \ldots, B_{10} \end{bmatrix} \begin{bmatrix} 1 \\ MIN_t \\ AGE_t \\ PIPC_{t-1} \\ WM_t \\ NDIPC_t \\ DMANU_t \\ GMEPF_t \\ CE_t \\ POP_t \\ MANU_t \end{bmatrix} . \qquad (4.21)$$

The stability of the growth path depends on whether the absolute value of $B_{11}/(1 + B_{12})$ is less than unity. When the structure parameters are substituted into the stability conditions and after simplification, the condition becomes

$$\frac{B_{11}}{1 + B_{12}} = \frac{a_{22}a_{13}a_{32}a_{52}a_{42}a_{65} + a_{13}a_{65}}{1 + a_{52}a_{22}a_{32}a_{42}} = a_{13}a_{65}.$$

If the structure parameters are interpreted as partial derivatives, the stability condition becomes

$$a_{13}a_{65} = \frac{\partial TOTEM_t}{\partial NOMAN_t} \frac{\partial NOMAN_t}{\partial TOTEM_{t-1}} .$$

The stability of the growth path of TOTEM depends on the magnitudes of the induced nonmanufacturing growth from the previous period's total employment growth and on the induced total employment growth from current nonmanufacturing growth. This result shows that although the equilibrium growth rate in total employment is dependent on manufacturing employment growth and the cumulative growth process in the manufacturing sector, the stability of the equilibrium growth path is determined solely by the nonmanufacturing sector. Intuitively, this result is appealing. While cumulative growth in manufacturing employment is a distinct possibility, it does not guarantee cumulative growth of total employment due to the possibility of the crowding-out of nonmanufacturing employment. If, however, growth in manufacturing employment results in total employment growth and this in turn induces future nonmanufacturing employment which results in further total employment growth, then the cumulative growth process in the manufacturing sector spills over into the nonmanufacturing sector. Employment growth in the nonmanufacturing sector becomes cumulative. For such a process to occur, the growth path of total employment must be explosive.

Urban Model

As mentioned earlier, due to differences in the availability of data between the state and urban areas in this study, a different specification is needed to test for the cumulative growth in employment. The specification for the urban model of cumulative employment growth is

$$TOTEM_t = a_{11}+a_{12}MANU_t+a_{13}NOMAN_t+a_{14}MIN_t+u_{1t}, \quad (4.22)$$

$$MANU_t = a_{21}+a_{22}BMANU_t+u_{2t}, \quad (4.23)$$

$$BMANU_t = a_{31}+a_{32}EW_t+a_{33}DMANU_t+a_{34}NDIPC_t+u_{3t}, \quad (4.24)$$

$$VAMHR_t = a_{51}+a_{52}VA_t+a_{53}GMEPF_t+u_{4t}, \quad (4.25)$$

$$VA_t = a_{51}+a_{52}MANU_t+a_{53}CE_t+u_{5t}, \quad (4.26)$$

$$NOMAN_t = a_{61}+a_{62}MANU_t+a_{63}MANU_{t-1}$$
$$+a_{64}TOTEM_{t-1}+u_{6t}, \quad (4.28)$$

where as before the a_{ij}'s are the parameters to be estimated and the, u_{it}, i= 1, 2, ..., 6 are the independent normally distributed disturbance terms with zero means and a constant covariance matrix. The only exception to this specification is for Joplin. The mining sector is absent in the Joplin area so this variable is excluded from Joplin's specification. Except for Joplin, a comparison of the state and urban models shows that the only differences are the excluded predetermined variables AGE_t, $PIPC_{t-1}$, and POP_t in equations (4.22), (4.23), and (4.28), respectively. The exclusion of these variables does not affect the identification of the equations of the model or change the fundamentals of the dynamic analysis. To make the dynamic analysis of the state corresponding to the urban model, set B_2, B_3 and B_9 equal to zero in equations (4.19) and (4.21). For Joplin also set B_1 equal to zero in these equations. This will affect the equilibrium growth rate and growth path, but it does not change the model's stability condition. This latter property is relevant for testing for cumulative growth of employment.

Empirical Analysis and Findings

The empirical work is presented in two sections. First, the data used in the analysis are developed; and second, the results are presented.

Data

The sample space consists of five states (California, Michigan, Missouri, Oklahoma, Texas), four SMSA's (Detroit, Houston, Kansas City, Springfield, Missouri), and the urban area of Joplin, Mo. (Jasper and Newton Counties). Annual time series for each variable are constructed with the length of the time series varying over the sample space due to the lack of annual observation for several of the urban economies. The data are for the period 1958-1977 for the states, Kansas City, and Detroit. The time period for Joplin, Springfield, and Houston are 1963-1976, 1965-1976, 1965-1977, respectively.

The nonagriculture employment data were obtained from Employment and Earnings, States and Areas, 1938-1978 (Bureau of Labor Statistics, 1979) with the exception of the Joplin area where the data were obtained from Missouri Area Labor Trends (Missouri Department of Labor and Industrial Relations). The employment sector definitions used in these publications were maintained in this study. The sum of employment in the wholesale-retail trade, finance, insurance, real estate, construction, and the service sectors equals NOMAN employment. TOTEM equals the sum of nonagriculture and agriculture employment. Agriculture employment is from Agricultural Statistics (United States Department of Agriculture).

Export-related employment in manufacturing is calculated using the location quotient approach discussed in Chapter II. For the state economy the reference area is the national economy. With the exception of Kansas City, the reference economy for each urban area is the corresponding state economy. Since the Kansas City SMSA is located in both Kansas and Missouri, its reference economy is the average of the manufacturing employment in both states.

Table IV shows manufacturing employment, export-related employment and the percent of export-related employment in manufacturing for the beginning and terminal years of the study. In a number of cases, the calculated export-related employment is negative indicating that the ratio of manufacturing employment to total employment is less than the reference area's ratio. In export-base studies this means basic employment is zero, and the calculation is disregarded. Since this study concerns the growth of export-related employment, the calculations are not disregarded but used to calculate the annual percentage growth rate. Thus, for example, when the negative estimate increased over consecutive years indicating the area had become more concentrated in manufacturing relative to its reference area, a positive growth rate was assigned to the annual percentage growth rate of export-related employment

TABLE IV

MANUFACTURING AND EXPORT-RELATED EMPLOYMENT

	BEGINNING YEAR			TERMINAL YEAR		
	MANFACTURING EMPLOYMENT (Thousands)	EXPORT-RELATED EMPLOYMENT (Thousands)	PERCENTAGE[1]	MANUFACTURING EMPLOYMENT (Thousands)	EXPORT-RELATED EMPLOYMENT (Thousands)	PERCENTAGE[1]
CA.	1217.4	-180.1	14.8%	1728.1	-409.4	26.6%
MI.	887.3	202.6	22.8	1056.7	252.3	23.2
MO.	337.3	-67.5	20.2	439.6	-23.3	5.3
OK.	85.1	-87.3	102.6	163.0	-78.5	48.1
TX.	460.7	-302.7	65.7	893.5	-326.4	33.6
DE.	447.8	120.1	25.3	568.7	149.4	26.2
HO.	111.3	6.93	6.2	195.1	-18.6	9.5
JO.	7.0	.472	6.6	10.8	.469	4.3
KC.	99.3	-15.7	15.8	119.7	-28.3	23.6
SP.	11.8	.959	8.1	18.3	.721	3.9

[1]The percentage was calculated using the absolute vaule of the export-related employment.

(BMANU). The percentage of export-related employment is calculated to determine whether it is such a large fraction of employment that, in effect, equations (4.13) and (4.23) are identities. With the exception of Texas and Oklahoma, the percentages do not indicate this possibility since the highest percent is 33.6 percent for Detroit's terminal year. For Texas and Oklahoma the percentages decline over the period of the study while manufacturing employment increased. Therefore, there are other determinants of manufacturing employment besides export-related employment.

Value-added (VA), new plant and equipment expenditures (CE), hourly wage in manufacturing (WM), and production worker hours data were obtained from the _Census of Manufacturing_ (Bureau of Labor Statistic, 1977) and selected years of the _Annual Survey of Manufacturing_ (U.S. Bureau of the Census).[5] State per capita personal income data were obtained from the _Survey of Current Business_ (Bureau of Economic Analysis, 1982).

GMEPF was calculated as the annual percentage change in the ratio of the number of manufacturing employees to the number of establishments. The data were obtained from the _Annual Survey of Manufacturing_ (U.S. Bureau of the Census)

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[5]The growth rate of plant and equipment expenditures is a proxy for the growth rate of the capital stock. This variable was chosen because of the lack of an appropriate initial capital stock to use in the calculation of the growth rate.

and County Business Patterns (U.S. Bureau of the Census).

Annual national disposable income per capita (NDIPC) was used for the world income variable and the producers price index (DMANU) for all manufacturing goods was used as the foreign price variable. In addition, real value-added, real wages, and real labor productivity in manufacturing were calculated using this price series. NDIPC was converted into real terms using the implicit gross national product deflator. Real new plant and equipment expenditures were calculated using the fixed nonresidential investment deflator. The data source for the price series and NDIPC was the Economic Report to the President (U.S. Office of the President, 1982).

The variable's annual percentage growth rates were calculated and used in the regression analysis. Missing annual observations were interpolated using a linear interpolation method (Intriligator, 1978). Annual labor productivity (VAMHR) was calculated by dividing the annual value-added by the annual number of production worker hours and then calculating the annual percentage growth rate. The efficiency wage (EW) equals the difference between the annual percentage growth rates in WM and VAMHR.

Findings

The 2SLS estimator was used to estimate the structure equations of the model. When serial correlation of the disturbance terms was suspected, the Cochrane-Orcutt transformation was estimated by the 2SLS method suggested by Pindyck and Rubinfeld (1976) when there was a sufficient number of observations. Otherwise, the transformation was estimated by ordinary least squares (OLS). In a number of cases, the results of the 2SLS estimation of the transformation did not yield acceptable results. In these incidents the transformation was reestimated using OLS.

The analysis of the findings proceeds in the following manner. First, the preconditions for the cumulative growth of manufacturing employment and output are examined. This involves determining the statistical significance of the estimated coefficients of the variables EW, VA, BMANU, and MANU. Second, the magnitude of the crowding-out effect must also be analyzed. This entails an examination of the statistical significance and magnitudes of the estimated coefficients in the structural equation for NOMAN. When the possibility of crowding-out is indicated, it must then be determined if it offsets MANU's influence on TOTEM by examining the magnitudes of the coefficients in equations (4.12) or (4.22). Third, the stability coefficient is calculated to determine the nature of the growth path of TOTEM and to ascertain whether the model satisfies the sufficient condition for cumulative growth. Finally, the other variables of the model are examined to determine their statistical significance. The findings are presented in

Table V.[6] Appendix C exhibits the 2SLS estimates of the structural equations for which serial correlation was indicated.

California. The statistical findings satisfy the preconditions for cumulative growth of manufacturing employment and output. The Verdoorn coefficient in (C.4) proves to be positive as hypothesized and significant at the one percent level for a one-tailed test. For the same test but at the ten percent level of significance, the efficiency wage's coefficient in (C.3) is negative as expected. BMANU is an important explanatory variable of MANU in a one-tailed test of the level of significance.

The existence of crowding-out of nonmanufacturing employment by manufacturing is not indicated by (C.6). A complementary relationship between the growth of employment in these sectors is suggested by the highly significant coefficient of MANU. The remaining coefficients of the equations are insignificant, but the sign of lagged MANU suggest that it has a tendency to retard NOMANU.

Using the point estimates of the coefficients, the calculated stability coefficient is .0775. This indicates a stable growth path for TOTEM that converges to the equilibrium growth rate.

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[6]In the analysis of the findings, reference will be made to the equation numbers in Table V.

TABLE V

REGRESSION EQUATIONS FOR THE MODEL OF CUMULATIVE GROWTH OF EMPLOYMENT

CALIFORNIA

(C.1)

$TOTEM_t^* = .0012 + .246MANU_t + .655NOMAN_t + .0006MIN_t + .053AGE_t$
(1.06) (14.3) (17.3) (3.71) (6.07)
R^2_{OLS}= .99   s= .001   SSE= .00003   DW= 1.85
$F_{4,12}$= 6825   n= 18   TOTEM= .021   p= .314738

(C.2)

$MANU_t^* = .017 + .061BMANU_t + .0521PIPC_{t-1}$
(1.55) (3.75) (.111)
R^2_{2SLS}= .47   s= .034   SSE= .015   DW= 2.11
n= 17 $MANU^*$= .012   p= .30102

(C.3)

$BMANU_t = -.451 - 7.93EW_t + 1.78DMANU_t + 4.90NDIPC_t$
(1.99) (1.67) (1.01) (.706)
R^2_{2SLS}= .13   s= .169   SSE= .046   DW=1.90
n= 18   BMANU= -.113

(C.4)

$VAMHR_t = -.007 + .741VA_t - .600GMEPF_t$
(.521) (3.47) (1.65)
R^2_{2SLS}= .43   s= .148   SSE= .021   DW= 2.00
n = 18   VAMHR= .027

(C.5)

$VA_t^* = .016 + 1.72MANU_t - .222CE_t$
(1.27) (3.30) (1.41)
R^2_{2SLS}= .48   s= .053   SSE= .044   DW= 2.03
n= 17 VA^*= .027   p= .38612

(C.6)

$NOMAN_t = .026 + .229MANU_t + .252POP_t - .015MANU_{t-1} + .119TOTEM_{t-1}$
(1.86) (3.53) (.746) (.087) (.272)
R^2_{2SLS}= .55   s= .038   SSE= .001   DW= 2.08
n= 18   NOMAN= .039

TABLE V (Continued)

MICHIGAN

(M.1)

$$TOTEM_t^{*} = .0009 + .343MANU_t + .623NOMAN_t + .012MIN_t + .072AGE_t$$
$$(1.21)\quad(50.7)\quad(109.6)\quad(1.52)\quad(5.39)$$

R^2_{OLS}= .99 s=.000002 SSE= .00004 DW= 1.74
$F_{5,13}$ = 6056 n= 18 $TOTEM^{*}$= .022 p= .32096

(M.2)

$$MANU_t = -.007 + .323BMANU_t + .292PIPC_{t-1}$$
$$(.615)\quad(6.08)\quad(1.24)$$

R^2_{2SLS}= .69 s= .035 SSE= .019 DW= 1.85
n= 18 MANU= .010

(M.3)

$$BMANU_t^{*} = -.099 + 1.16EW_t - .123DMANU_t + 4.18NDIPC_t$$
$$(.612)\quad(.444)\quad(.444)\quad(1.62)$$

R^2_{2SLS}= .32 s= .151 SSE= .296 DW= 1.90
n= 17 $BMANU^{*}$= .021 p= -.350103

(M.4)

$$VAMHR_t = .043 + .583VA_t - .870GMEPF_t$$
$$(.612)\quad(6.37)\quad(4.18)$$

R^2_{2SLS}= .73 s= .027 SSE= .011 DW= 1.97
n= 17 VAMHR= .024

(M.5)

$$VA_t = .024 + 1.619MANU_t - .020CE_t$$
$$(1.27)\quad(4.88)\quad(.257)$$

R^2_{2SLS}= .63 s= .076 SSE= .093 DW= 2.35
n= 18 VA= .039

(M.6)

$$NOMAN_t^{*} = .051 - .155MANU_t - .591POP_t + 1.28MANU_{t-1} - 1.00TOTEM_{t-1}$$
$$(1.97)\quad(.456)\quad(.255)\quad(3.86)\quad(2.53)$$

R^2_{2SLS}= .60 s= .057 SSE= .627 DW= 1.60
n= 16 $NOMAN^{*}$= .034 p_1= .19704 p_2= -.180197

TABLE V (Continued)

MISSOURI

(Mo.1)

$$TOTEM_t = -.035 + .199MANU_t + .779NOMAN_t - .016MIN_t + .121AGE_t$$

(2.11)(8.44) (10.02) (1.59) (9.95)

R^2_{2SLS}= .99 s= .001 SSE= .00003 DW= 2.02
n= 18 TOTEM= .012

(MO.2)

$$MANU_t = -.007 - .0008BMANU_t + .610PIPC_{t-1}$$

(.958) (.570) (4.13)

R^2_{2SLS}= .51 s= .029 SSE= .014 DW= 2.47
n= 18 MANU= .007

(Mo.3)

$$BMANU_t^* = -2.199 - 1.869EW_t + 63.7DMANU_t + 1.621NDIPC_t$$

(.073) (1.42) (7.22) (.044)

R^2_{2SLS}= .78 s= 2.392 SSE= 97.2 DW= 1.80
n= 17 BMANU* = 1.269 p= -.218262

(MO.4)

$$VAMHR_t^* = .043 + .430VA_t - .255GMEPF_t$$

(.064) (3.72) (.345)

R^2_{2SLS}= .47 s= .042 SSE= .030 DW= 2.40
n= 17 VAMHR* = .041 p= -.388529

(MO.5)

$$VA_t = .021 + 1.207MANU_t + .111CE_t$$

(1.02) (2.36) (.631)

R^2_{2SLS}= .42 s= .083 SSE= .110 DW= 1.74
n= 18 VA= .036

(MO.6)

$$NOMAN_t^* = .0246 + .286MANU_t + .008POP_t + .398MANU_{t-1} - .468TOTEM_{t-1}$$

(6.07)(8.36) (3.30) (5.32) (1.70)

R^2_{2SLS}= .89 s= .002 SSE= .0004 DW= 1.65
n= 16 NOMAN* = .038 p_1= -.2778 p_2= -.2142

TABLE V (Continued)

OKLAHOMA

(O.1)

$TOTEM_t^* = -.003 + .225MANU_t + .722NOMAN_t + .147MIN_t + .287AGE_t$
(.384) (4.81) (2.97) (4.16) (9.22)

R^2_{2SLS} = .94 s= .003 SSE= .066 DW= 1.93
n= 16 $\overline{TOTEM}^*$= .024 p_1= .106076 p_2= -.218412

(O.2)

$MANU_t = .029 + .120BMANU_t + .252PIPC_{t-1}$
(2.25) (1.84) (.644)

R^2_{2SLS} = .33 s= .029 SSE= .013 DW= 2.43
n= 18 $\overline{MANU}$= .036

(O.3)

$BMANU_t = -.092 + .187EW_t + .951DMANU_t + 2.355NDIPC_t$
(1.17) (.156) (1.54) (.976)

R^2_{2SLS} = .18 s= .139 SSE= .290 DW= 2.03
n= 18 $\overline{BMANU}$= -.0004

(O.4)

$VAMHR_t = .006 + .540VA_t + .291GMEPF_t$
(.350) (2.95) (.453)

R^2_{2SLS} = .53 s= .001 SSE= .016 DW= 1.79
n= 18 $\overline{VAMHR}$= .030

(O.5)

$VA_t^* = .028 + .679MANU_t + .150CE_t$
(.805) (1.23) (1.35)

R^2_{2SLS} = .20 s= .064 SSE= .066 DW= 1.60
n= 16 $\overline{VA}^*$= .088 p_1= -.190478 p_2= -.121108

(O.6)

$NOMAN_t = .021 + .168MANU_t - 1.868POP_t + .018MANU_{t-1} + .226TOTEM_{t-1}$
(4.68) (2.42) (.478) (.252) (1.48)

R^2_{2SLS} = .49 s= .008 SSE= .001 DW= 1.92
n= 18 $\overline{NOMAN}$= .031

TABLE V (Continued)

TEXAS

(T.1)

$$TOTEM_t^* = -.00002 + .163MANU_t + .712NOMAN_t + .046MIN_t + .122AGE_t$$

(.038) (11.05) (114.0) (4.46) (8.01)

R^2_{2SLS}= .99 s= .001 SSE= .00005 DW= 2.19
n= 17 $TOTEM^*$= .027 p= .199653

(T.2)

$$MANU_t = .019 + .001BMANU_t + .546PIPC_{t-1}$$

(.042) (1.47) (1.47)

R^2_{2SLS}= .12 s= .033 SSE= .017 DW= 2.46
n= 18 MANU= .034

(T.3)

$$BMANU_t^* = .123 + .796EW_t - .505DMANU_t - 2.473NDIPC_t$$

(1.05) (.730) (.796) (1.22)

R^2_{2SLS}= .21 s= .153 SSE= .375 DW= 1.92
n= 16 $BMANU^*$= -.047 p_1= -.510292 p_2= -.191654

(T.4)

$$VAMHR_t = .017 + .249VA_t - .386GMEPF_t$$

(1.51) (1.48) (1.87)

R^2_{2SLS}= .30 s= .027 SSE= .012 DW= 1.91
n= 18 VAMHR= .029

(T.5)

$$VA_t = .035 + .766MANU_t - .015CE_t$$

(2.40) (2.44) (.330)

R^2_{2SLS}= .32 s= .040 SSE= .026 DW= 1.71
n= 18 VA= .060

(T.6)

$$NOMAN_t = .019 + .237MANU_t + .003POP_t + .997MANU_{t-1} - .705TOTEM_{t-1}$$

(.263) (.371) (1.43) (1.71) (2.06)

R^2_{2SLS}= .35 s= .063 SSE= .056 DW= 1.97
n= 18 NOMAN= .042

TABLE V (Continued)

DETROIT

(D.1)

$$TOTEM_t^* = .0003 + .219MANU_t + .813NOMAN_t - .011MIN_t$$
(.816) (2.08) (9.69) (.066)

R^2_{2SLS}= .92 s= .018 SSE= .004 DW= 2.13
n= 16 $TOTEM^*$= .023 p_1= .203812 p_2= .15787

(D.2)

$$MANU_t^* = .002 + .349BMANU_t$$
(.179) (1.64)

R^2_{2SLS}= .13 s= .006 SSE= .071 DW= 1.49
n= 17 $MANU^*$= .006 p= -.411354

(D.3)

$$BMANU_t = -.067 -1.052EW_t -.059DMANU_t + 3.26NDIPC_t$$
(2.27)(2.04) (.258) (3.65)

R^2_{2SLS}= .47 s= .054 SSE= .043 DW= 1.69
n= 18 BMANU= .008

(D.4)

$$VAMHR_t = .017 + .252VA_t - 1.21GMEPF_t$$
(2.02) (4.18) (2.18)

R^2_{2SLS}= .63 s= .001 SSE= .018 DW= 1.92
n= 18 VAMHR=.021

(D.5)

$$VA_t = .023 + 1.54MANU_t - .009CE_t$$
(.993) (4.55) (.125)

R^2_{2SLS}= .56 s= .093 SSE= .140 DW= 2.37
n= 18 VA= .035

(D.6)

$$NOMAN_t = .034 + .212MANU_t + .792MANU_{t-1} - .700TOTEM_{t-1}$$
(3.06) (1.27) (2.66) (3.97)

R^2_{2SLS}= .63 s= .040 SSE= .025 DW= 1.89
n= 18 NOMAN= .027

TABLE V (Continued)

HOUSTON

(H.1)

$TOTEM_t^* = -.002 + .199MANU_t + .826NOMAN_t + .015MIN_t$
(.978) (8.22) (24.03) (1.03)
R^2_{OLS}= .98 s= .016 SSE= .000002 DW= 1.77
$F_{3,6}$=1753 n= 10 $TOTEM^*$= .063 p_1= -.09940 p_2= .057270

(H.2)

$MANU_t$= .044 +.0008$BMANU_t$
(6.30)(.637)
R^2_{2SLS}= .048 s=.022 SSE= .005 DW= 1.64
n= 12 MANU= .042

(H.3)

$BMANU_t^* = 82.68 - 14.058EW_t - 65.4DMANU_t - 20.619NDIPC_t$
(1.85) (2.06) (2.24) (.256)
R^2_{OLS}= .20 s= 3.66 SSE= 134.6 DW= 2.11
$F_{3,6}$= 15.9 n= 10 $BMANU^*$= -4.687 p_1= -.27283 p_2=-.274918

(H.4)

$VAMHR_t^* = -.013 + .603 VA_t + .541GMEPF_t$
(.800) (2.99) (1.01)
R^2_{OLS}= .52 s= .030 SSE= .009 DW= 1.57
$F_{2.7}$=15.5 n= 10 $VAMHR^*$= .032 p_1= -.318301

(H.5)

$VA_t^* = .090 - .498 MANU_t + .0591CE_t$
(1.72) (.422) (.699)
R^2_{OLS}= .04 s= .066 SSE= .076 DW= 1.79
$F_{2,8}$= .708 n= 11 VA^*= .047 p= -.153077

(H.6)

$NOMAN_t = -.046 + .204MANU_t - .307MANU_{t-1} + .376TOTEM_{t-1}$
(2.60) (.849) (.878) (1.29)
R^2_{2SLS}= .25 s= .014 SSE= .001 DW= 2.05
n= 12 NOMAN= .063

TABLE V (Continued)

JOPLIN

(J.1)

$$TOTEM_t^* = -.0009 + .251MANU_t + .763NOMAN_t$$
$$(2.59) \quad (56.3) \quad (75.6)$$

R^2_{2OLS}= .99   s=.001   SSE= .00001   DW= 1.41
$F_{2,9}$= 17171   n= 13 $TOTEM^*$= .028   p= -.289241

(J.2)

$$MANU_t = .014 + .048BMANU_t$$
$$(1.08) \quad (3.61)$$

R^2_{2SLS}= .63   s= .044   SSE= .023   DW= 1.81
n= 13   MANU= .029

(J.3)

$$BMANU_t = .344 - .569EW_t - .463DMANU_t - 2.61NDIPC_t$$
$$(.693) \quad (.738) \quad (.099) \quad (.216)$$

R^2_{2SLS}= -.10   s= 1.09   SSE= 11.9   DW= 1.89
n= 13   BMANU= .306

(J.4)

$$VAMHR_t = -.025 + 1.90VA_t + .0596MEPF_t$$
$$(.923) \quad (15.9) \quad (.211)$$

R^2_{2SLS}= .96   s= .096   SSE= .102   DW= 2.29
n= 13   VAMHR= .052

(J.5)

$$VA_t = -.024 + 1.47MANU_t + .337CE_t$$
$$(.302) \quad (1.42) \quad (1.53)$$

R^2_{2SLS}= .01   s= .262   SSE= .758   DW= 2.23
n= 13   VA= .073

(J.6)

$$NOMAN_t = .020 + .087MANU_t - .309MANU_{t-1} - .473TOTEM_{t-1}$$
$$(1.90) \quad (.704) \quad (1.60) \quad (1.22)$$

R^2_{2SLS}= .28   s= .031   SSE= .009   DW= 1.88
n= 13   NOMAN = .020

TABLE V (Continued)

KANSAS CITY

(K.1)

$TOTEM_t$= .0[illegible]0006 + .234$MANU_t$ + .760$NOMAN_t$ + .003MIN_t
(.[illegible]9) (34.0) (36.4) (1.26)
R^2_{2SLS}= .99 s= .009 SSE= .00001 DW= 2.26
n= 17 TOTEM= .023

(K.2)

$MANU_t$= .00[illegible] − .005$BMANU_t$
(.7[illegible]) (.727)
R^2_{2SLS}= .[illegible]8 s= .043 SSE= .030 DW= 2.23
n= 17 MANU= .006

(K.3)

$BMANU_t^*$= .[illegible]95 + .588EW_t − .581$DMANU_t$ − .467$NDIPC_t$
([illegible].87) (1.07) (.479) (2.63)
R^2_{2SLS}= .32 s= .065 SSE= .068 DW= 2.06
n= 16 $BMANU^*$ = .029 p= −.448710

(K.4)

$VAMHR_t$= −.[illegible]61 + .669VA_t + .0003$GMEPF_t$
(.716) (3.92) (.861)
R^2_{2SLS}= .54 s= .053 SSE= .043 DW= 2.06
n= 17 VAMHR= .032

(K.5)

VA_t= .024 − 1.58$MANU_t$ + .012CE_t
(1.09) (3.25) (.077)
R^2_{2SLS}= .19 s= .087 SSE= .114 DW= 2.26
n= 17 VA= .035

(K.6)

$NOMAN_t$= .019 + .214$MANU_t$ − .024$MANU_{t-1}$ − .067$TOTEM_{t-1}$
(3.57) (3.14) (.158) (.188)
R^2_{2SLS}= .39 s= .012 SSE= .002 DW= 2.25
n= 17 NOMAN= .029

TABLE V (Continued)

SPRINGFIELD

(S.1)

$$TOTEM_t^* = .0002 + .275MANU_t + .715NOMANU_t$$
(.444) (138.2) (103.7)

R^2_{OLS}= .99 s= .0001 SSE= .000002 DW=1.58
$F_{3,7}$= 56326 n= 10 $TOTEM^*$= .062 p= -.342095

(S.2)

$$MANU_t^* = .010 + .0918MANU_t$$
(.609) (4.30)

R^2_{OLS}= .60 s= .046 SSE= .021 DW= 1.44
$F_{1,8}$= 14.7 n= 10 $MANU^*$= .053 p= -.344258

(S.3)

$$BMANU_t^* = 2.21 - 2.05EW_t - 8.05DMANU_t - 34.95NDIPC_t$$
(2.70) (.652) (3.52) (1.50)

R^2_{OLS}= .46 s= .420 SSE= 1.77 DW= 1.23
$F_{3,6}$=32.8 n= 10 $BMANU^*$= .520 p= -.479646

(S.4)

$$VAMHR_t = -.025 + .777VA_t + .040GMEPF_t$$
(1.20) (4.63) (1.74)

R^2_{2SLS}= .73 s= .059 SSE= .028 DW= 1.60
n= 10 VAMHR= .016

(S.5)

$$VA_t = .993 + .0002MANU_t + .068CE_t$$
(.008) (2.63) (2.07)

R^2_{2SLS}= .58 s= .085 SSE= .058 DW= 1.60
n= 10 VA= .054

(S.6)

$$NOMAN_t^* = -.0005 - .388MANU_t + .006MANU_{t-1} + 1.40TOTEM_{t-1}$$
(1.01) (65.8) (2.16) (91.9)

R^2_{OLS}= .99 s= .0006 SSE= .000003 DW= .674
$F_{3,5}$= 16318 n= 10 $NOMAN^*$= .048 p= -.479646

* Correction for autocorrelation.

TABLE V (Continued)

t-values: Absolute value of estimated t-statistic are given below their respective coefficients.

R^2_{2SLS}: Coefficient of determination for 2SLS estimator.

R^2_{OLS}: Coefficient of determination adjusted for degrees of freedom for OLS estimator.

s: Standard error of the estimate.

SSE: Residual sum squared.

DW: Durbin-Watson statistic.

$F_{n,k}$: F-statistic with n,k degrees of freedom.

n: Number of observations.

TOTEM, MANU,...: average value of dependent variable.

p: Coefficient(s) of autocorrelation.

The coefficients of the remaining variables of the model have mixed results. Only the coefficients of MANU, NONMAN, MIN and, AGE in (C.1) are significant and positive as expected; the remaining variables are insignificant.

To understand the quantitative properties of the model, consider a one percentage point increase in the growth rate of export-related employment, other things equal. From (C.2) this results in a 6.1 (1 x .061 x 100) percentage point increase in the growth rate of manufacturing employment. From (C.1) this causes a 1.5 (.246 x .061 x 100) percentage point increase in the growth rate of total employment, and from (C.5) a 10.4 (.061 x 1.72 x100) percentage point increase in the growth rate of value-added. The increase growth of value-added leads to a 7.7 (.104 x .741 x 100) percentage point increase in the growth rate of labor productivity in (C.4). From (C.3) a 6.1 (.077 x 7.93 x 100) percentage point further increase in the growth of export-related employment. This completes the first round of the cumulative growth process in the manufacturing sector. The affect on the growth rate of nonmanufacturing employment can be calculated by substituting into (C.6) the values for $MANU_t$ (.061 x .610), $MANU_{t-1}$ (.061), and $TOTEM_{t-1}$ (.015) to obtain a 0.29 percentage point increase in its growth rate. The stable growth path for TOTEM ensures that eventually this process stops. Since the one percentage point change in BMANU resulted in a 1.5 percentage point change in TOTEM, this is equivalent to an export-base multiplier of 1.5.

Michigan. The results for Michigan do not satisfy the preconditions for cumulative growth in the manufacturing sector. The coefficient of EW does not have its hypothesized sign. Its insignificant coefficient indicates that the efficiency wage fails to operate as hypothesized by the cumulative causation thesis. The Verdoorn coefficient in (M.4) has the hypothesized sign which is significant at the one percent level. BMANU's coefficient in (M.2) also has the hypothesized sign and it is significant at the one percent level. The coefficient of MANU in equation (M.5) is positive at the one percent level as expected.

In (M.6) the results concerning crowding-out are mixed. Although the coefficient of MANU is insignificant, its negative value does give some indication of the crowding-out effect. To the extent this occurs, it will be short-lived, since the coefficient of lagged MANU is positive, significant at the one percent level, and of greater magnitude. Its magnitude also exceeds the negative and significant coefficient of lagged TOTEM suggesting that lagged MANU growth can offset the retarding effects of lagged TOTEM on NOMAN.

The stability condition for the cumulative growth of TOTEM is not satisfied. The calculated coefficient (-.733) indicates a nonexplosive oscillating growth path for TOTEM.

In addition to these findings, the coefficients of MANU, NOMAN, and AGE are significantly positive in equation (M.1). The coefficient of GMEP, in (M.4), is also significant at the one percent level.

<u>Missouri</u>. The conditions for cumulative growth in the manufacturing sector and in total employment do not hold for Missouri. The failure is due to the poor performance of export-base theory. BMANU's coefficient in (M.2) is negative contrary to its hypothesized sign, but it is insignificant. The Verdoorn and efficiency wage coefficients in (M.4) and (M.3), respectively, are both significant at least at the ten percent level and have their hypothesized signs. One possible explanation for the insignificance of BMANU as an explanatory variable is the downward bias introduced by the location quotient.

Crowding-out of nonmanufacturing employment by the growth of manufacturing is not indicated by (Mo.6). The estimated coefficients of MANU and lagged MANU are both significant and positive. It appears that the lagged TOTEM retards NOMAN, but it is not significant for a two-tailed test.

The stability coefficient (-.3649) implies a nonexplosive but oscillating growth path of TOTEM. Thus, the stability condition is not satisfied.

In (Mo.1) MANU, NOMAN, and AGE are significant and have the expected signs. However, MIN is significant at the ten percent level and as a negative sign contrary to expectations. The positive coefficient for lagged PIPC in (Mo.2) indicates that Missouri's manufacturing goods are normal goods with respect to lagged PIPC. DMANU in (Mo.3) is a significant explanatory variable of BMANU. Its positive coefficient could be due to a smaller rate of price increase relative to the national average for Missouri's manufacturing exports, resulting in an increase in the exports of these goods. Finally, population growth rates are a significant explanatory variable for NOMAN in (Mo.6).

Oklahoma. The statistical findings for Oklahoma do not support the cumulative growth process because the efficiency wage is not a meaningful explanatory variable. In (O.3) the coefficient of EW is insignificant and its sign contradicts the hypothesized sign. The remaining endogenous variables of the cumulative growth process in the manufacturing sector perform acceptably. The Verdoorn coefficient in (O.4) is significant at the one percent level. As expected, the coefficient of MANU is significant in equation (O.5).

Turning to the nonmanufacturing sector, (O.6) indicates a complementary relationship between employment growth in the nonmanufacturing and manufacturing sectors. The coefficients of MANU and lagged MANU are both positive; the former is significant and the latter is insignificant. Lagged TOTEM is not a significant explanatory variable, nor does its sign indicate crowding-out.

The stability coefficient (.1735) indicates a stable growth path of TOTEM. Oklahoma's model does not satisfy the stability conditions for cumulative growth.

Of the remaining variables, only those of (O.1) prove to be significant. The coefficients of MANU, NOMAN, MIN, and AGE are both positive and significant at the one percent level as expected.

Texas. The results for Texas resemble Oklahoma's with regards to the preconditions for the cumulative growth because the efficiency wage is positive in (T.3). The Verdoorn effect is significant, so is BMANU in (T.2), and MANU in (T.5). These three variables have the hypothesized sign that satisfy the preconditions for cumulative growth.

The coefficients in (T.6) do not indicate the crowding-out of nonmanufacturing employment by manufacturing employment. The positive signs of MANU and lagged MANU suggest a complementary relationship, but neither variable is significant. The negative coefficient of lagged TOTEM is significant at the ten percent level indicating it retards nonmanufacturing employment.

The stability condition for cumulative growth does not hold for Texas. The calculated stability coefficient (-.499) indicates an nonexplosive oscillating growth path for TOTEM.

The OLS estimate of (T.1) has all its explanatory variables significant. GMEPF in (T.4) is the only other remaining significant variable. Its negative coefficient does not indicate significant internal economies of scale.

Detroit. The findings for Detroit support the preconditions for cumulative growth in the manufacturing sector. The efficiency wage and Verdoorn coefficients have the hypothesized signs at the five percent level in (D.3) and (D.4), respectively. BMANU is significant at the ten percent level in (D.2), and it has the hypothesized sign. In (D.5) the coefficient of MANU has the expected positive sign at the one percent level.

A complementary relationship rather than crowding-out is indicated by (D.6). The coefficients of MANU and lagged MANU are both positive with the latter coefficient significant and the former coefficient insignificant. However, lagged TOTEM is significant at the one percent level indicating that it retards NOMAN. This can be offset by lagged MANU because the magnitude of its coefficient exceeds lagged TOTEM's coefficient.

The stability coefficient (-.057) indicates nonexplosive oscillating growth for TOTEM. The stability condition is not satisfied for cumulative growth.

In (D.1) the coefficients of MANU and NOMAN are both significant and positive as expected. Of the remaining predetermined variables, the coefficients of NDIPC in (D.3) and GMEPF in (D.4) prove to be significant. The positive sign for NDIPC's suggests that Detroit's manufacturing goods are normal goods. The negative coefficient for GMEPF does not give evidence of internal scale economies.

Houston. An examination of the coefficient for Houston shows that the cumulative growth endogenous mechanisms are present, but the preconditions for cumulative growth are not satisfied. The Verdoorn effect and efficiency wage are significant at the five percent level in (H.4) and (H.3), respectively. The coefficient of BMANU is not statistically significant in equation (H.2); although, it has the correct sign. MANU in (H.5) is insignificant and does not have the hypothesized sign. In fact (H.5) performs poorly as shown by the low value of the F-statistic. Thus, in a statistical sense, changes in the growth rate of export-related employment does not change the growth rate of manufacturing employment, and, thus, the growth rate of output in manufacturing does not change.

In (H.6) none of the explanatory variables are significant so the equation yields no statistical evidence of crowding-out. The poor performance of (H.6) may be due to multicollinearity between its explanatory variables.

Explosive growth is not indicated by the findings. The stability coefficent (.310) indicates a convergent growth path for TOTEM.

The variables NOMAN and MANU are significant in (H.1). Of the remaining variables only DMANU is significant at the ten percent level. In general this model of cumulative growth does not explain the growth of employment in Houston.

Joplin. There are indications of the cumulative growth process for Joplin, but they are not statistically significant. The efficiency wage is not a significant explanatory variable of BMANU in (J.3), although its coefficient has the expected sign. The Verdoorn coefficient proves to be positive and significant in (J.4). MANU performs adequately in (J.5) since it has the hypothesized sign and is significant at the one percent level. As hypothesized, BAMU is positive and significant in (J.2) indicating that it explains some of the growth in manufacturing employment.

In (J.6) none of the variables are significant. The equation does not provide any information about crowding-out.

The stability condition does not indicate cumulative growth. The stability coefficient is -.360 indicating nonexplosive oscillating disequilibrium adjustments for TOTEM.

All variables of (J.1) are significant and positive. Of the remaining predetermined variables only the coefficient of CE in (J.5) is significant at the five percent level, and its positive sign is expected.

Kansas City. The preconditions for cumulative growth are not satisfied for Kansas City because the efficiency wage in (K.3) and BMANU in (K.2) have signs contrary to their hypothesized signs. They are, however, insignificant explanatory variables. The Verdoorn effect in (K.4) is significant. MANU is a significant explanatory variable in (K.5).

The positive and significant coefficient of MANU in (K.6) indicates a complementary relationship between MANU and

NOMANU. The remaining variables of this equation are insignificant, but their signs suggest they have a tendency to retard NOMAN.

The findings do not satisfy the stability condition for cumulative growth. The stability coefficient is -.051 indicating a nonexplosive oscillating growth path for TOTEM.

The positive and significant coefficients of MANU, NOMAN, and MIN in (K.1) are expected. The model's remaining predetermined variables are not significant.

Springfield. An examination of the preconditions for cumulative growth in the manufacturing sector once again reveals the failure of BMANU to respond to changes in the efficiency wage in (S.3). Except for this finding, the model of cumulative growth in TOTEM performs satisfactorily. The estimated Verdoorn coefficient is significant in (S.4). In (S.2) export-base theory is supported by the positive and significant coefficient of BMANU. The simple production function specification of (S.5) proves to be statistically acceptable with both explanatory variables being significant at the five percent level.

Regarding crowding-out, MANU's coefficient in (S.6) indicates its presence. However, it will be short-lived since the coefficient of lagged MANU is significant and positive. Furthermore, the significant and positive coefficient of lagged TOTEM implies that it also offsets and dominates the crowding-out effect. The Durbin-Watson statistic indicates the presence of positive serial-correlation even after the correction for autocorrelation so these findings must be interpreted cautiously.

The calculated stability coefficient is 1.003 indicating an explosive growth path for TOTEM. Thus, the findings satisfy the stability condition for the cumulative growth of TOTEM.

The explanatory variables of (S.1) are significant. DMANU is also significant with expected sign in (S.3). The remaining predetermined variables are not significant.

Summary of Findings

Table VI summarizes the signs and the statistical significance of the relevant variables of this analysis. In six of the regressions (California, Missouri, Detroit, Houston, Joplin, and Springfield), the efficiency wage and the Verdoorn effect had the signs predicted by the preconditions that imply the existence of the endogenous cumulative growth mechanisms in the manufacturing sector. For four of these estimates (California, Missouri, Detroit, and Houston), the coefficients were significant. In the remaining regressions the export-related employment did not respond to the efficiency wage as hypothesized. The trigger mechanism failed to operate as postulated in two cases (Missouri and Kansas City). No coefficients had significant signs that contradicted the hypothesized signs of the preconditions. The growth rate of manufacturing employment was found to be a positive explanatory variable

TABLE VI

SUMMARY OF SIGNS AND STATISTICAL SIGNIFICANCE OF THE RELEVANT COEFFICIENT IN THE MODEL OF CUMULATIVE GROWTH IN EMPLOYMENT

	EXPLANATORY VARIABLE									
	MANU	BMANU	EW	VA	MANU	$MANU_{t-1}$	$TOTEM_{t-1}$	GMEPF	CE	SC
	EQUATION NUMBER IN TABLE V									
	5	2	3	4	6	6	6	4	5	
	EXPECTED SIGN									
	+	+	−	+	±	±	±	+	+	
CA.	+	+	−	+	+	$-^{+}$	$+^{+}$	$-^{+}$	−	.077
MI.	+	+	$+^{+}$	+	$-^{+}$	+	−	−	$-^{+}$	−.773
MO.	+	$-^{+}$	−	+	+	+	$-^{+}$	$-^{+}$	$+^{+}$	−.364
OK.	$+^{+}$	+	$+^{+}$	+	+	$+^{+}$	$+^{+}$	$+^{+}$	$+^{+}$	.173
TX.	+	+	$+^{+}$	+	$+^{+}$	+	−	$-^{+}$	$-^{+}$	−.499
DE.	+	+	−	+	$+^{+}$	+	−	−	$-^{+}$	−.057
HO.	$-^{+}$	$+^{+}$	−	+	$+^{+}$	$-^{+}$	$+^{+}$	$+^{+}$	$+^{+}$	.310
JO.	$+^{+}$	+	$-^{+}$	+	$+^{+}$	$-^{+}$	$-^{+}$	$+^{+}$	+	−.360
KC.	+	$-^{+}$	$+^{+}$	+	+	$-^{+}$	$-^{+}$	$+^{+}$	$+^{+}$	−.051
SP.	+	+	$-^{+}$	+	−	$+^{+}$	+	$-^{+}$	+	1.003

+: Coefficient positive and significant at the 10 percent level.

−: Coefficient negative and significant at the 10 percent level.

$+^{+}$: Coefficient positive and insignificant at the 10 percent level.

$-^{+}$: Coefficient negative and insignificant at the 10 percent level.

SC: Stability coefficient.

of the growth rate of value-added in all estimates except Houston. Therefore, cumulative growth in the manufacturing sector is a possibility, but in general the cumulative growth process does not appear to be significant.

The failure of a general realization of the cumulative growth process in manufacturing was due to the poor performance of the trigger mechanism and the efficiency wage. The Verdoorn effect was positive and significant in every estimate.

The crowding-out of nonmanufacturing employment by the growth of manufacturing employment was not evident. Only in two estimates (Michigan and Springfield) were there any indication of crowding-out by the growth of contemporary manufacturing employment, and this effect was significant in just one case (Springfield). In the remaining eight estimates the growth of contemporary manufacturing and nonmanufacturing employment had a complementary relationship. In four cases (California, Missouri, Oklahoma, and Kansas City) this relationship proved to be significant. Lagged manufacturing employment growth had a complementary relationship with the growth rate of nonmanufacturing in six regressions (Michigan, Missouri, Oklahoma, Texas, Detroit, and Springfield), and four of these relationships (Michigan, Missouri, Texas, and Detroit) were significant. Crowding-out of nonmanufacturing employment by lagged manufacturing employment growth was not found to be significant.

Although crowding-out from the manufacturing sector does not appear important, lagged total employment growth did in a number of regressions retard nonmanufacturing employment growth. A significent inverse relationship was found in three regressions (Michigan, Texas, and Detroit), and in three other regressions (Missouri, Joplin, and Kansas City) the inverse relationship was insignificant. A positive and significant relationship was found in one estimates (Springfield). If lagged total employment is interpreted as a measure of the tightness of the labor market, i.e., increasing growth rates in lagged TOTEM indicating a tighter labor market, other things equal, then the predominance of the inverse relationship supports Kaldor's (1966, 1970) contention that a labor supply constraint prevents the realization of the cumulative growth.

The stability condition for cumulative growth held in one regression (Springfield). The remaining calculated stability coefficients indicated a convergent or nonexplosive but oscillating growth path for the growth rate of total employment. The fact that the estimated coefficient of lagged TOTEM proved to be negative a majority of the time while the estimated coefficient of NOMAN proved to always be positive accounts for the nonexplosive oscillating growth path.

The performance of the variable GMEPF was not satisfactory. It was significant in two regressions (Michigan and Detroit), and in both cases the negative sign did not give any indication of internal economies of scale. Perhaps the

Verdoorn effect picked up the internal economies of scale, since value-added is also a measure of size.

The performance of the explanatory variables in the neoclassical production function were mixed. MANU was an acceptable explanatory variable. The capital input variable (CE) was significantly postive in only two regressions (Joplin and Springfield). As a consequence of this variable's poor performance, the production function results are not satisfactory. This does not suggest that in general the production function specification was a misspecification of the determinants of the growth rate of output, but it does indicate that the growth rate of new plant and equipment expenditures is not a desirable measure of the growth rate of the capital input. This could be due to the inability of the variable to account for the rate of utilization for the existing capital stock and differences in the vintage of the capital stock. What is important for this study, however, is the relationship between the growth rates in manufacturing employment and value-added. In regards to this relationship, the production function specification was adequate.

Summary and Conclusion

This chapter was concerned with the empirical analysis of the cumulative causation thesis and its validity as a theory of regional growth. A model was developed to test for the cumulative growth process in the manufacturing sector and cumulative growth in total employment. Two-stage least squares regressions were performed on the model using time series from a sample of five states and five urban areas. When deemed necessary, Cochrane-Orcutt transformations of the model's equations were estimated with either a 2SLS or an OLS estimator.

The findings of the regressions do not simultaneously satisfy the necessary or sufficient conditions for cumulative growth. The preconditions for cumulative growth held at the ten percent level of significance in two of the ten models. The basic reasons for the models not satisfying the preconditions were the failures of the trigger and efficiency wage mechanisms to operate as hypothesized. The Verdoorn effect proved to be significant at the ten percent level in every estimate.

The stability condition for cumulative growth was satisfied in one of the ten models. This latter finding, however, is subject to a bias due to the presence of serial-correlation.

Springfield's findings gave the strongest indication of the cumulative growth process. These findings satisfy the conditions for cumulative growth, but the preconditions were not statistically significant. The acceptance of Springfield as indicating the validity of the cumulative causation thesis requires accepting a probability of a Type II error equal to 53 percent. This is the probability of accepting this cumulative causation model as a valid theory of regional growth, when in fact it is not. Deeming this an excessive risk, the cumulative causation thesis as postulated by the model of this study cannot be accepted as a statistically valid explanation of the regional growth for the sample areas of this study.

The different point estimates of the structural parameters of the model means the economies of the sample space have different equilibrium growth rates. Therefore, the model of cumulative employment growth had the capability to explain interregional variation in economic activity.

CHAPTER V

SUMMARY, CONCLUSIONS, AND FURTHER RESEARCH

Summary

This study tested whether the cumulative causation thesis suggested by Myrdal (1957), extended by Kaldor (1970), and Dixon and Thirlwall (1975) constituted a meaningful theory of regional growth. The thesis is in contrast to the traditional equilibrium models of regional growth since it emphasizes dynamic forces which cause cumulative change leading to a disequilibrium growth process. However, the theoretical foundations of the thesis are general because they synthesize a number alternative theoretical explanations of regional growth. As such, it provides an explanation for periods of divergent growth in income and factor returns across regional economies.

The regional growth process postulated by the thesis is an endogenous growth process maintained by internal dynamic forces in the processing sector. These forces are the Verdoorn effect and efficiency wage mechanism. The Verdoorn effect is a positive correlation between the scale of the activity and the growth rate of productivity so that as the scale of the activity increases so does the growth rate of productivity. The efficiency wage is the ratio of an index of money wages to an index of productivity. Given an exogenous wage, the growth rate of the efficiency wage will vary inversely with respect to changes in the growth rate of productivity that are directly related through the Verdoorn effect to the changes in the scale of the activity.

For the cumulative causation model of regional growth to be valid, the Verdoorn effect and efficiency wage must operate as postulated by the model. They are not sufficient for cumulative growth, however, since they are not linked to the remaining sectors of the economy nor are there mechanisms to initiate the cumulative growth process. The thesis relies upon exogenous changes in the level of exports of the processing sector to trigger the cumulative growth process and an income-expenditure multiplier to spread the growth process throughout the regional economy. These represent the preconditions for cumulative growth.

Taken together, the preconditions are not sufficient for cumulative growth because they do not ensure a disequilib brium growth process. There must be dynamic instability in the economies' disequilibrium adjustments so that the economy will diverge from its equilibrium growth path.

The preconditions and the stability condition are necessary and sufficient for cumulative growth. When they hold, the cumulative causation thesis is a meaningful theory of regional growth.

In order to test the validity of the cumulative causation of regional growth, the study proceeded to determine whether the necessary and sufficient conditions held in a sample of regional and urban economies. Data limitations, however, prevented the direct testing of the model using output data. Instead, alternative cumulative growth variables were used in the construction, estimation, and testing of a model in the spirit of the cumulative regional growth model.

The model was essentially an export-base model incorporating a cumulative growth process. The cumulative growth variable was total employment. In the model the growth of export-related employment in manufacturing determined the growth of manufacturing employment which then influenced the growth rates of value-added in manufacturing and total employment. The major determinants of export-related employment were the growth rates of the efficiency wage and the Verdoorn effect.

A major issue in this model was the role of intersector employment flows. Since in the model's initial phase the cumulative growth process relied upon export-led growth, an inflow of resources to sustain the growth process was necessary so that the full employment constraint could be circumvented. If the inflow did not materialize, the growth in the export sector would be at the expense of the other sectors of the economy. In effect, the growth of the export sector would be crowding-out the growth in the other sectors. The model allowed for the possibility of the crowding-out of nonmanufacturing employment by current and the previous periods' manufacturing employment while controlling for population growth and total employment growth. The absence of crowding-out was an additional pre-condition for the cumulative growth process.

The model was estimated using time series from a sample of five states and five urban areas with a two-stage least squares estimator. When deemed necessary, the Cochrane-Orcutt transformation of the equation was estimated by a two-stage least squares or an ordinary least squares estimator.

Conclusions

The primary conclusion of this study was that the cumulative causation model of regional growth did not represent a valid theory of regional growth with regards to sample space. The necessary and sufficient conditions for cumulative growth in employment were not satisfied in the regression study.

The regression findings indicated differences in the values of the parameters determining the equilibrium growth rate total employment. There was variation in the growth rate of economic activity in the sample space of this study. Therefore, the cumulative growth model had the capability to explain differences in equilibrium growth rates even though the cumulative growth process was not statistically significant.

Preconditions

The preconditions held statistically in two of the ten estimates, and in two other estimates the coefficients had the signs which satisfied the preconditions. When the preconditions did not hold, it was generally due to the failure of the efficiency wage or the trigger mechanism. One explanation for the performance of the trigger mechanism was due to the bias introduced into the calculation of export-related employment using the location quotient. The location quotient estimates net rather than gross exports so that it underestimates the true level of exports. The failure of the efficiency wage to be a significant explanatory variable indicates that export-related employment did respond to its changes as hypothesized by the model. In all estimates the Verdoorn effect was statistically significant. The growth rate of manufacturing employment was found to be a positive explanatory variable of the growth rate of value-added in all estimates.

Stability Condition

The stability condition for cumulative growth held in only one estimate. The equilibrium growth path for the growth rate of total employment in Springfield, Missouri, was explosive. In the remaining estimations the disequilibrium adjustments converged to the equilibrium growth rate of total employment. The explosive growth postulated by the model was not present.

Crowding-out

In general the findings indicated a complementary rather than a crowding-out relationship between the growth of nonmanufacturing employment and the growth of current and lagged manufacturing employment. Lagged total employment growth did retard the growth of nonmanufacturing employment in a number of estimates. This finding gives support to the contention that a labor supply constraint prevents the realization of the cumulative growth process.

Qualifications

Why are the findings of this study not supportive of the general realization of the cumulative growth process? A number of reasons can be cited:

1. It should be recognized that the conditions for cumulative growth are restrictive. When the Verdoorn effect and efficiency wage are considered in isolation, the signs of the coefficient are correct in six regressions so that rising growth rates of output induce higher labor productivity which reduces the efficiency wage.

2. Fiscal redistribution and equalization policy during the period of the study may have offset the divergent tendencies of the cumulative growth process.

3. The use of value-added as a cumulative growth variable limited the analysis to the manufacturing sector. Cumulative growth in output of the other sectors of the economy could be present even though it was not indicated in

the manufacturing sector.

Further Research

There is adequate evidence of the cumulative growth process, in particular the endogenous mechanisms, to warrant further research on this topic. The model and data used in this study can be refined and modified in a number of directions for futher research. This includes:

1. Construction of a time series of regional output data by sector so that it can be used as a substitute for the employment variables in the model of cumulative growth of total employment.

2. A study of the determinants of the Verdoorn effect. This can include investigating the impacts of capital formation and technological progress on the magnitude of the Verdoorn effect.

3. A study of why the efficiency wage and export-related employment failed to operate as hypothesized. This research can include the specifying of an endogenous wage variable and a regional labor market. The labor demand can be derived from a neoclassical production function. The labor supply specifications can include the determinants of the natural increases in the labor force as well as net migration.

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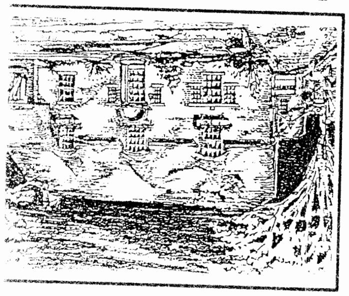

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APPENDIXES

APPENDIX A

THE DYNAMIC COMPARATIVE STATIC PROPERTIES OF THE EQUILIBRIUM GROWTH RATE OF OUTPUT

The model of cumulative growth to be analyzed has the structural equations

$$g_t = a_1 + a_2x_t + a_3d_t \quad (a_1>0,\ a_2>0,\ a_3>0), \tag{A.1}$$

$$x_t = e_1+e_2p_{dt}+e_3p_{ft}+e_4z_t \quad (e_1>0,\ e_2<0,\ e_3>0,\ e_4>0), \tag{A.2}$$

$$p_{dt} = w_t - r_t, \tag{A.3}$$

$$r_t = r_a + \lambda_1 g_t + \lambda_2 v_t \quad (r_a>0, \lambda_1>0, \lambda_2<0), \tag{A.4}$$

$$v_t = g_t - k_t, \tag{A.5}$$

$$k_t = hg_t, \tag{A.6}$$

$$d_t = d_1 + d_2x_t + d_3n_t \quad (d_1>0,\ d_2\ 0,\ d_3>0). \tag{A.7}$$

The derivation of the reduced-form equation for the growth rate of output, g_t, requires a number of substitutions. First, substitute equations (A.6), (A.5), and (A.5) into (A.4). The substitution yields

$$\begin{aligned} r_t &= r_a + \lambda_1 g_t + \lambda_2(g_t - k_t), \\ &= r_a + \lambda_1 g_t + \lambda_2(g_t - I_t), \\ &= r_a + (\lambda_1 + \lambda_2(1 - h))g_t, \end{aligned}$$

$$r_t = r_a + \lambda_3 g_t, \tag{A.8}$$

where

$$\lambda_3 = \lambda_1 + \lambda_2(1 - h).$$

Next, substitute equations (A.8) and (A.3) into (A.2) to obtain

$$x_t = e_1 + e_2(w_t - r_t) + e_3p_{ft} + e_4z_t,$$
$$= e_1 + e_2(w_t - (r_a + \lambda_3g_t)) + e_3p_{ft} + e_4z_t,$$

or

$$x_t = e_1 + e_2w_t - e_2r_a - e_2\lambda_3g_t + e_3p_{ft} + e_4z_t. \quad \text{(A.9)}$$

Now, substituting (A.9) into (A.7) yields

$$d_t = d_1 + d_2(e_1 + e_2w_t - e_2r_a - e_2\lambda_3g_t + e_3p_{ft} + $$
$$+ e_4z_t) + d_3n_t,$$

or

$$d_t = d_1 + d_2e_1 + d_2e_2w_t - d_2e_2r_a - d_2e_2\lambda_3g_t + d_2e_3p_{ft} + $$
$$+ d_2e_4z_t + d_3n_t. \quad \text{(A.10)}$$

Finally, the reduced-form equation for the growth rate of output is found by substituting (A.9) and (A.10) into (A.1). Thus,

$$g_t = a_1 + a_2(e_1 + e_2r_a + e_2w_t - e_2\lambda_3g_t + e_3p_{ft} + e_4z_t) + $$
$$+ a_3(d_1 + d_2e_1 + d_2e_2wt - d_2e_2r_a - d_2e_2\lambda_3g_t + $$
$$d_2e_3p_{ft} + d_2e_4z_t + d_3n_t),$$

and after simplification

$$g_t = \frac{c_0 + c_1w_t + c_2p_{ft} + c_3z_t + c_4n_t}{1 + c_5}, \quad \text{(A.11)}$$

where

$$c_0 = a_1 + a_2e_1 + a_3d_1 + a_3d_2e_1 + (a_2e_2 - a_3d_2e_2)r_a,$$

$$c_1 = e_2(a_2 + a_3d_2),$$

$$c_2 = e_3(a_2 + a_3d_2),$$

$$c_3 = e_4(a_2 + a_3d_2),$$

$$c_4 = a_3d_3,$$

$$c_5 = e_2\lambda_3(a_2 + a_3d_2).$$

The equilibrium growth rate, g_e, is given by

$$g_e = \frac{c_0 + c_1w_t + c_2p_{ft} + c_3z_t + c_4n_t}{1 + c_5}, \qquad \text{(A.12)}$$

for $c_5 \neq -1$.

The reduced-form equations of the structural equations are derived by substituting (A.11) into (A.8)- (A.10) and simplifying. This yields a system of equations, which in principle, can be represented in matrix form as

$$\begin{bmatrix} g_t \\ x_t \\ r_t \\ d_t \end{bmatrix} = [b_{ij}] \begin{bmatrix} 1 \\ w_t \\ p_{ft} \\ z_t \\ n_t \end{bmatrix},$$

where $[b_{ij}]$ is a 4x5 matrix of reduced-form coefficients.

The Dynamic Properties

By assuming a one-period lag in the response of exports to its determinants, a dynamic analysis of the model is possible. This assumption allows equation (A.11) to be written as

$$g_t = c_0 + c_1 w_{t-1} + c_2 p_{ft-1} + c_3 z_{t-1} + c_4 n_{t-1} - c_5 g_{t-1},$$

or

$$g_t + c_5 g_{t-1} = c_0 + c_1 w_{t-1} + c_2 p_{ft} + \\ + c_3 z_{t-1} + c_4 n_{t-1}. \qquad \text{(A.13)}$$

Equation (A.13) is a first-order differences equation in terms of the growth rate of output. A particular solution, g_p, is found by letting $g_p = g_t = g_{t-1}$ and solving for g_p. The solution is given by

$$g_p = \frac{c_0 + c_1 w_{t-1} + c_2 p_{ft-1} + c_3 z_{t-1} + c_4 n_{t-1}}{1 + c_5} \qquad (c_5 = -1).$$

This is nothing more than the equilibrium growth rate lagged one-period. The complementary solution, g_c, is found by letting $g_t = mb^t$ and $g_{t-1} = mb^{t-1}$, then setting equation (A.13) equal to zero, and solving for m and b. Thus,

$$mb^t + c_5 mb^{t-1} = 0,$$

or

$$b = -c_5,$$

and the complementary solution is

$$g_c = m(-c_5)^t.$$

The general solution to equation (A.13) is the sum of the particular and complementary solutions, so

$$g_t = g_p + g_c, \\ = g_e + m(-c_5)^t.$$

The determination of the arbitary constant, m, requires the initial condition that $g_t = g_0$ when $t = 0$. Thus, for $t = 0$

$$g_0 = g_e + m,$$

or

$$m = g_0 - g_e.$$

Consequently, the growth path of output is given by

$$g_t = g_e + (g_0 - g_e)(-c_5)^t \tag{A.14}$$

Comparative Static Properties of the Equilibrium Growth Rate

The comparative static properties of the equilibrium growth rate of output given by equation (A.14) depend upon the magnitudes of the stability condition and the crowding-out coefficient. The first step in the analysis is to determine the partial derivates of the equilibrium growth path with respect to changes in the exogenous variables. The partial differentiations yield

$$\frac{\partial g_t}{\partial w_t} = \frac{c_1}{1 + c_5} = \frac{e_2(a_2 + a_3 d_2)}{1 + e_2\ 3(a_2 + a_3 d_2)}, \tag{A.15}$$

$$\frac{\partial g_t}{\partial p_{ft}} = \frac{c_2}{1 + c_5} = \frac{e_3(a_2 + a_3 d_2)}{1 + e_2\ 3(a_2 + a_3 d_2)}, \tag{A.16}$$

$$\frac{\partial g_t}{\partial z_t} = \frac{c3}{1 + c_5} = \frac{e_4(a_2 + a_3 d_2)}{1 + e_2\ 3(a_2 + a_3 d_2)}, \tag{A.17}$$

$$\frac{\partial g_t}{\partial n_t} = \frac{c4}{1 + c_5} = \frac{a_3 d_3}{1 + e_2\ 3(a_2 + a_3 d_2)}. \tag{A.18}$$

The a priori restrictions of the parameters of the model imply that the qualitative properties of equations (A.15)-(A.18) are determined by the signs of c_5 and d_2. Ruling out oscillating explosive growth paths as economically infeasible implies the additional a priori restriction $(-c_5) > -1$. A stable growth path implies, $-1 < -c_5 < 1$, instability in the growth path implies $-c_5 > 1$. Therefore, restricting the analysis to a stable growth path means the denominators of equations (A.15)-(A.18) will be positive, i.e. at least $-c_5 < 1$ or $1 - c_5 > 0$; thus, $1 + c_5 > 0$. Instability in the growth path means the denominators of equations (A.15)-(A.18) are negative, i.e., $-c_5 > 1$ or $1 + c_5 > 0$. The presence of crowding-out means $d_2 < 0$, and its absence means $d_2 > 0$.

The qualitative property of equation (A.18) depends only on the stability of the growth path since the a priori restrictions imply a positive numerator. Thus, the growth rate of output will vary directly with changes in the growth of rate population, when the growth path is stable, and indirectly for an unstable growth path. By assuming a stable growth path and a negative crowding-out coefficient the qualitative properties of (A.15) - (A.17) depend on the sign of their respective numerators. Since $e_2 < 0$, the numerator of (A.15) will be positive when $|a_2| < |a_2 d_3|$. In equations (A.16) and (A.17), the numerator will be positive when $|a_2| > |a_2 d_3|$ since $e_3 > 0$ and $e_4 > 0$. Therefore, when there is a stable growth path and a negative crowding-out coefficient,

$$\frac{\partial g_t}{\partial w_t} = \begin{cases} > 0 & \text{as } |a_2| < |a_3 d_2| \\ < 0 & \text{as } |a_2| > |a_3 d_2| \end{cases},$$

$$\frac{\partial g_t}{\partial p_{ft}} = \begin{cases} > 0 & \text{as } |a_2| > |a_3 d_2| \\ < 0 & \text{as } |a_2| < |a_3 d3| \end{cases},$$

$$\frac{\partial g_t}{\partial z_t} = \begin{cases} > 0 & \text{as } |a_2| > |a_3 d_2| \\ > 0 & \text{as } |a_2| > |a_3 d_2| \end{cases}.$$

A positive crowding-out coefficient and a stable growth path implies the numerator of (A.15) will always be negative while the numerators of (A.16) and (A.17) will be positive. Therefore, the growth rate of output will vary directly with changes in the the rates of growth in national income and foreign prices. The rate of growth of output will vary indirectly with respect to changes in the growth rate of the exogenous wage.

When the growth path is not stable, the denominators of (A.15)-(A.17) will be negative. This means the qualitative properties of the growth rate of output with respect to exogenous changes will have the opposite signs of their counterparts under a stable growth path for various values of the crowding-out coefficient.

APPENDIX B

Identification

The rank condition of identification is a necessary and sufficient condition for the identification of a simultanous system of equations. This Appendix develops, informally, the identification problem and the rank condition of identification. The rank condition is then used to determine the identity of the equations in the extended model of cumulative growth and the model of cumulative growth of employment.

The Identification Problem and the Rank Condition of Identification

Consider a general econometric specification of a simultaneous system of equations given by

$$YA + XB = E, \qquad \text{(B.1)}$$

where

Y: n x L matrix of dependent variables,

X: n x K matrix of predetermined variables,

A, B: L x L and K x L matrices of unknown structural parameters respectively,

E: n x L matrix of disturbance terms,

n: number of observations,

L: number of dependent variables,

K: number of predetermined variables.

Futhermore, assume the disturbance terms are normally distributed random variables with zero means and constant covariance matrix, V. If A is a nonsingular matrix, the reduced-form equations are obtained by post multiplying the structural equations by the inverse of A, A^{-1}. Thus,

$$YAA^{-1} + XBA^{-1} = EA^{-1},$$

or

$$Y = -XBA^{-1} + EA^{-1}. \tag{B.2}$$

The identification problem concerns the conditions under which the estimated reduced-form parameters, BA^{-1}, and their covariance matrix $(A')^{-1}VA^{-1}$, where A' is the transpose matrix of A, can be used to obtain estimates of the structural parameters and their covariance matrix. The problem results from the simple fact that there are more unknowns than knowns. Counting the variables shows that there are $\frac{1}{2}L(2K + 3L + 1)$ unknown parameters and $\frac{1}{2}L(2K + 2L + 1)$ known parameters (Theil, 1972). There is, thus, an excess of L^2 unknown parameters. Unless additional information is obtained about the L^2 unknown parameters, the structural parameters cannot be derived from the reduced-form parameters. However, when an equation excludes some of the structural parameters included in the other equations of the system, the number of unknown parameters is reduced, and identification becomes possible if the rank condition of identification holds.

The rank condition gives necessary and sufficient conditions for the identification of an equation in terms of the number of structural parameters that are excluded from the equation but included in the system of equations. According to the rank condition of identification, an equation is identified when the submatrix formed from the coefficients of the excluded endogenous and predetermined variables has a rank equal to one less than the number of endogenous variables in the system of equations.[1]

Identification In The Extended Model Of Cumulative Regional Growth

The extended model of cumulative growth, given by equations (4.8)-(4.11), written in the econometric form of a simultanous system of equations, given by (B.1), is

$$\begin{bmatrix} g_t \\ x_t \\ r_t \\ d_t \end{bmatrix}' \begin{bmatrix} 1 & 0 & -\lambda_3 & 0 \\ -a_2 & 1 & 0 & -d_2 \\ 0 & e_2 & 1 & 0 \\ a_3 & 0 & 0 & 0 \end{bmatrix} + \begin{bmatrix} 1 \\ w_t \\ p_{ft} \\ z_t \\ n_t \end{bmatrix}' \begin{bmatrix} -a_1 & -e_1 & -r_a & -d_1 \\ 0 & -e_1 & 0 & 0 \\ 0 & -e_3 & 0 & 0 \\ 0 & 0 & 0 & -d_3 \end{bmatrix}$$

$$= [u_{1t} \; u_{2t} \; u_{6t} \; u_{5t}]$$

where, from left to right, the first matrix is Y, the second matrix is A, the third matrix is X, the fourth matrix is B,

---

[1]For a formal proof of the rank condition of identificaton, see Theil, H., Principles of Econometrics, (1972), pp. 490-493. For an informal discussion of the rank condition, see Murphy, J., Introductory Econometrics, (1973), pp. 427-435.

and the fifth matrix is E. Since there are four endogenous variables in this system, the rank condition of identification implies that, for each equation of the model to be identified, the submatrices formed from the coefficients of the excluded endogenous and predetermined variable must have a rank of three.

A simple method of constructing these submatrices is shown for equation (4.8). The first columns of A and B are the matrix specification of equation (4.8). A zero in either of these columns indicates that an endogenous or predetermined variable has been excluded from the equation. Thus, strike out the first column in A and B; then, for every zero entry in these columns, the remaining row indicates the excluded variable's coefficients and can be used as a row of the submatrix. The submatrix for the equation is

$$\begin{bmatrix} e2 & 1 & 0 \\ -e2 & 0 & 0 \\ -e3 & 0 & 0 \\ -e4 & 0 & 0 \\ 0 & 0 & -d3 \end{bmatrix} = S_1.$$

The rank of S_1 must equal three for identification of equation (4.9), i.e. $r(S_1) = 3$. One way of determining the rank of a matrix is by transforming the matrix into its echelon form by column and row reductions. In the echelon form, the number of unit elements on the diagonal corresponds to the number of linearly independent columns and, therefore, the rank of the matrix. The echelon form for

S_1 is

$$\begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \\ 0 & 0 & 0 \\ 0 & 0 & 0 \end{bmatrix},$$

so that

$$r(S_1) = 3.$$

Therefore, the rank condition of identification for equation (4.9) is satisfied.

For equations (4.9)-(4.11), the submatrices of excluded variable's coefficients are respectively

$$\begin{bmatrix} 1 & -\lambda_3 & 0 \\ -a_3 & 0 & 0 \\ 0 & 0 & -d_3 \end{bmatrix}, \quad \begin{bmatrix} -a_2 & 1 & -d_2 \\ -a_3 & 0 & 0 \\ 0 & -e_2 & 0 \\ 0 & -e_3 & 0 \\ 0 & -e_4 & 0 \\ 0 & 0 & -d_3 \end{bmatrix}, \quad \begin{bmatrix} 1 & 0 & -\lambda_3 \\ 0 & e_2 & 1 \\ -a_3 & 0 & 0 \\ 0 & -e_2 & 0 \\ 0 & e_3 & 0 \\ 0 & -e_4 & 0 \end{bmatrix},$$

and their respective echelon forms are

$$\begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix}, \quad \begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & 0 \end{bmatrix}, \quad \begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \\ 0 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & 0 \end{bmatrix}.$$

Thus, the rank of each of these submatrices is three; therefore, each equation satisfies the rank condition of identification.

Identification of The Model of Cumulative Growth of Employment

Equation (4.18)-(4.23) written in the form given by

(B.1) are

$$\begin{bmatrix} TOTEM_t \\ MANU_t \\ BMANU_t \\ VAMHR_t \\ VA_t \\ NOMAN_t \end{bmatrix}' \begin{bmatrix} 1 & 0 & 0 & 0 & 0 & 0 \\ -a_{12} & 1 & 0 & 0 & -a_{52} & -a_{62} \\ 0 & -a_{22} & 1 & 0 & 0 & 0 \\ 0 & 0 & a_{32} & 1 & 0 & 0 \\ 0 & 0 & 0 & -a_{42} & 1 & 0 \\ -a_{13} & 0 & 0 & 0 & 0 & 0 \end{bmatrix} +$$

$$\begin{bmatrix} 1 \\ MIN_t \\ AGE_t \\ PIPC_t \\ NDIPC_t \\ DMANU_t \\ GMEPF_t \\ CE_t \\ WM_t \\ POP_t \\ MANU_{t-1} \\ TOTEM_{t-1} \end{bmatrix}' \begin{bmatrix} -a_{11} & -a_{12} & -a_{13} & -a_{41} & -a_{51} & -a_{61} \\ -a_{14} & 0 & 0 & 0 & 0 & 0 \\ -a_{15} & 0 & 0 & 0 & 0 & 0 \\ 0 & -a_{23} & 0 & 0 & 0 & 0 \\ 0 & 0 & -a_{33} & 0 & 0 & 0 \\ 0 & 0 & -a_{34} & 0 & 0 & 0 \\ 0 & 0 & 0 & -a_{43} & 0 & 0 \\ 0 & 0 & 0 & 0 & -a_{53} & 0 \\ 0 & 0 & -a_{32} & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & -a_{63} \\ 0 & 0 & 0 & 0 & 0 & -a_{64} \\ 0 & 0 & 0 & 0 & 0 & -a_{65} \end{bmatrix} =$$

$$[\ u_{1t},\ u_{2t},\ u_{3t},\ u_{4t},\ u_{5t},\ u_{6t}\ ].$$

For the rank condition to hold, the rank of the submatrices of the excluded endogenous and predetermined variable's coefficients must be five. If one examines the submatrices of the coefficients of excluded endogenous and predetermined variables of the equations and transforms these matrices into their echelon form, then one can verify that the rank of all submatrices are five. Therefore, all equations of the system are identified.

APPENDIX C

TWO-STAGE LEAST SQUARES ESTIMATES OF THE MODEL OF CUMULATIVE GROWTH OF EMPLOYMENT

The regression findings reported in this Appendix are the two-stage least squares estimates of the cumulative growth model for which the Durbin-Watson statistic indicated serial correlation. The corresponding equations reported in Table V have been reestimated to eliminate this problem.

CALIFORNIA

$$TOTEM_t = .001 + .245MANU_t + .651NOMAN_t + .005MIN_t + .057AGE_t$$
$$(.910)\quad (15.0)\quad (11.3)\quad (2.84)\quad (5.75)$$

$R^2{}_{2SLS}$ = .99 s = .006 SSE = .00004 DW = 2.39
n = 18 TOTEM = .030

$$MANU_t = .025 + .0687BMANU_t - .0532PIPC_{t-1}$$
$$(1.60)\quad (3.07)\quad (.088)$$

$R^2{}_{2SLS}$ = .39 s = .137 SSE = .018 DW = 2.60
n = 18 MANU = .016

$$VA_t = .026 + 1.56MANU_t - .190CE_t$$
$$(1.90)\quad (2.87)\quad (1.03)$$

R22SLS = .49 s = .215 SSE = .046 DW = 2.74
n = 18 VA = .042

MICHIGAN

$$TOTEM_t = -.0005 + .346MANU_t + .623NOMANU_t + .003MIN_t + .086AGE_t$$
$$(.541)\quad (36.8)\quad (79.2)\quad (.332)\quad (5.42)$$

$R^2{}_{2SLS}$ = .99 s = .002 SSE = .000006 DW = 1.56
n = 18 TOTEM = .019

$$BMANU_t = -.0346 + 3.05EW_t - .391DMANU_t + 3.58NDIPC_t$$
(.421) (1.23) (.643) (1.46)

$R^2{}_{2SLS} = .35$ $s = .150$ $SSE = .340$ $DW = 1.31$

$n = 18$ $\overline{BMANU} = .027$

$$NOMAN_t = .040 + .155MANU_t - .759POP_{t-1} + 1.04MANU_{t-1} - .706TOTEM_{t-1}$$
(1.68) (.494) (.339) (3.28) (1.77)

$R^2{}_{2SLS} = .50$ $s = .058$ $SSE = .047$ $DW = 1.60$

$n = 17$ $\overline{NOMAN} = .033$

MISSOURI

$$BMANU_t = -1.23 + 23.7EW_t + 69.5DMANU_t - 13.9NDIPC_t$$
(8.68) (.603) (6.16) (.336)

$R^2{}_{2SLS} = .75$ $s = 2.69$ $SSE = 109.1$ $DW = 1.56$

$n = 18$ $\overline{BMANU} = 1.01$

$$VAMHR_t = .011 + .558VA_t - .461GMEPF_t$$
(1.00) (3.09) (1.24)

$R^2{}_{2SLS} = .33$ $s = .043$ $SSE = .030$ $DW = 1.22$

$n = 18$ $\overline{VAMHR} = .030$

$$NOMAN_t = .014 + .296MANU_t + .229POP_t - .094MANU_{t-1} + .527TOTEM_{t-1}$$
(5.03) (8.41) (.792) (2.57) (4.35)

$R^2{}_{2SLS} = .87$ $s = .005$ $SSE = .0004$ $DW = 1.44$

$n = 17$ $\overline{NOMAN}$ .023

OKLAHOMA

$$TOTEM_t = -.003 + .143MANU_t + .767NOMAN_t + .105MIN_t + .197AGE_t$$
(.880) (5.14) (6.62) (6.13) (10.2)

$R^2{}_{2SLS} = .98$ $s = .002$ $SSE = .00007$ $DW = 2.19$

$n = 18$ $\overline{TOTEM} = .020$

$$VA_t = .042 + .366MANU_t + .111CE_t$$
(1.73) (.638) (1.18)

$R^2{}_{2SLS} = .15$ $s = .068$ $SSE = .074$ $DW = 1.30$

$n = 18$ $\overline{VA} = .064$

TEXAS

$$TOTEM_t = -.0002 + .173MANU_t + .708NOMAN_t + .051MIN_t + .124AGE_t$$
(.306) (10.2) (79.5) (4.97) (7.38)

$R^2_{2SLS} = .99$ $s = .002$ $SSE = .00006$ $DW = 2.38$
$n = 18$ $\overline{TOTEM} = .032$

$$BMANU_t = .094 - .998EW_t - .687DMANU_t - 4.47NDIPC_t$$
(.824) (.558) (.545) (1.27)

$R^2_{2SLS} = .06$ $s = .225$ $SSE = .764$ $DW = .971$
$n = 18$ $\overline{BMANU} = -.025$

DETROIT

$$TOTEM_t = -.0003 + .202MANU_t + .800NOMAN_t + .027MIN_t$$
(1.85) (4.68) (136.4) (2.46)

$R^2_{2SLS} = .99$ $s = .0007$ $SSE = .000008$ $DW = 2.44$
$n = 18$ $\overline{TOTEM} = .023$

$$MANU_t = .023 + .492BMANU_t$$
(1.74) (2.50)

$R^2_{2SLS} = .20$ $s = .056$ $SSE = .055$ $DW = 1.17$
$n = 18$ $\overline{MANU} = .027$

HOUSTON

$$TOTEM_t = -.001 + .202MANU_t + .809NOMAN_t + .018MIN_t$$
(.555) (8.23) (21.3) (1.31)

$R^2_{2SLS} = .98$ $s = .001$ $SSE = .00002$ $DW = 1.33$
$n = 12$ $\overline{TOTEM} = .060$

$$BMANU_t = -3.41 - 4.11EW_t + 14.3DMANU_t + .386GMEPF_t$$
(.823) (.136) (.398) (.119)

$R^2_{2SLS} = .04$ $s = 5.37$ $SSE = 259.7$ $DW = 1.47$
$n = 12$ $\overline{BMANU} = -2.17$

$$VAMHR_t = -.013 + .476VA_t + .383GMEPF_t$$
(.953) (3.44) (2.45)

$R^2_{2SLS} = .65$ $s = .030$ $SSE = .009$ $DW = 1.42$
$n = 12$ $\overline{VAMHR} = .026$

$$VA_t = .053 + .200MANU_t + .039CE_t$$
(1.12) (.175) (.438)

$R^2{}_{2SLS}$ = .01 s = .071 SSE = .051 DW = 1.49
n = 12 VA = .067

JOPLIN

$$TOTEM_t = -.0007 + .254MANU_t + .760NOMAN_t$$
(2.00) (52.4) (72.1)

$R^2{}_{2SLS}$ = .99 s = .001 SSE = .00001 DW = 1.41
n = 13 TOTEM = .022

KANSAS CITY

$$BMANU_t = -.012 - 7.70EW_t + 1.35DMANU_t + 6.63NDIPC_t$$
(1.41)(.941) (.204) (.260)

$R2{}_{2SLS}$ = .003 s = 1.62 SSE = 36.7 DW = 1.12
n = 17 BMANU = .313

SPRINGFIELD

$$TOTEM_t = .0003 + .276MANU_t + .708NOMAN_t$$
(.795) (102.9) (76.7)

$R^2{}_{2SLS}$ = .99 s = .0005 SSE = .000002 DW = 1.32
n = 10 TOTEM = .046

$$MANU_t = .010 + .082BMANU_t$$
(.618) (3.73)

$R^2{}_{2SLS}$ = .57 s = .049 SSE = .022 DW = 1.26
n = 10 TOTEM = .039

$$BMANU_t = 1.68 - 1.44EW_t - 8.81DMANU_t - 41.1NDPIC_t$$
(2.780 (.433) (2.63) (1.82)

$R^2{}_{2SLS}$ = .52 s = .586 SSE = 2.40 DW = 1.03
n = 10 BMANU = .349

$$NOMAN_t = .039 + .091MANU_t - .020MANU_{t-1} + .153TOTEM_{t-1}$$
(1.91) (.863) (.097) (.288)

$R^2{}_{2SLS}$ = .09 s = .023 SSE = .003 DW = 2.23
n = 10 NOMAN = .049

The symbols have the same meanings as in the text which are:

t-values: Absolute value of estimated t-statistic are given below their respective coefficients,

R^2_{2SLS}: Coefficient of determination for 2SLS estimator,

s: Standard error of the estimate,

SSE: Residual sum squared,

DW: Durbin-Watson statistic,

n: Number of observations,

TOTEM, MANU,...: average value of dependent variable.

APPENDIX D

ENDOGENOUS RATE OF CAPITAL FORMATION

This appendix explores the possibility that the model of cumulative growth in employment is a misspecification because of the assumption of an exogenous rate of capital formation. A misspecified model means that the regression results and conclusions are sensitive to an alternative specification. Thus, one way to determine if there is a misspecification due to the model's treatment of the rate of capital formation is to estimate the model using an endogenous growth rate of the capital stock. Major differences in the regression findings would then indicate a specification error. The findings for these regression are reported for California, Detroit, and Springfield.

When the growth rate of capital is treated as an endogenous variable, a structural equation is needed to specify its determinants. In the model of cumulative employment growth, the wage rate and cost of capital were assumed to be exogenous variables. The growth rates of labor and capital then depend on the same set of determinants. One specification of the growth rate of capital is then

$$CE_t = a + bBMANU_t + cPIPC_{t-1},$$

for California and for the urban areas

$$CE_t = a + bBMANU_t.$$

The importance of these specifications are not their explanatory powers but the affect on the structural parameters of the model, when treating the growth of capital as an endogenous variable. These equations were added to the respective state and urban models, and the models were estimated using the 2SLS estimator. The findings of these estimates are:

California

$$TOTEM_t = .001 + .243MANU_t + .668NOMAN_t + .0005MIN_t + .058AGE_t$$
$$(.567)\ (14.7)\quad (10.8)\quad (2.88)\quad (5.79)$$
$$R^2_{SLS} = .99 \quad s = .006 \quad SSE = .0004 \quad DW = 2.42$$

$$MANU_t = .025 + .071EMANU_t - .078PIPC_{t-1}$$
$$(1.63)\quad (3.02)\quad (.128)$$
$$R^2_{2SLS} = .38 \quad s = .137 \quad SSE = .018 \quad DW = 2.86$$

$$BMANU_t = -.448 - 7.55EW_t + 1.80DMANU_t + 5.03NDIPC_t$$
$$(1.98)\quad (1.59)\quad (1.02)\quad (.728)$$
$$R^2_{2SLS} = .13 \quad s = 1.68 \quad SSE = 2.84 \quad DW = 1.89$$

$$VAMHR_t = -.009 + .789VA_t - .664GMEPF_t$$
$$(.666)\quad (3.50)\quad (1.50)$$
$$R^2_{2SLS} = .42 \quad s = .053 \quad SSE = .026 \quad DW = 1.95$$

$$VA_t = .073 + 2.19MANU_t - .462CE_t$$
$$(2.05)\quad (3.06)\quad (1.75)$$
$$R^2_{2SLS} = .41 \quad s = .06 \quad SSE = .054 \quad DW = 2.59$$

$$NOMAN_t = .027 + .220MANU_t + .244POP_t - .007MANU_{t-1} + .102TOTEM_{t-1}$$
$$(1.90)\ (3.37)\quad (.723)\quad (.044)\quad (2.08)$$
$$R^2_{2SLS} = .53 \quad s = .038 \quad SSE = .001 \quad DW = 2.08$$

$CE_t = .073 + .187BANU_t + .111PICP_{t-1}$
(1.60) (2.75) (.062)
$R^2{}_{2SLS} = 04$ s= .163 SSE= .159 DW= 2.55

DETROIT

$TOTEM_t = -.0004 + .197MANU_t + .805NOMAN_t + .001MIN_t$
(2.01) (44.9) (135.5) (1.64)
$R^2{}_{2SLS} = .99$ s= .000006 SSE= .00009 DW= 2.23

$MANU_t = .023 + .509BMANU_t$
(1.73) (1.35)
$R^2{}_{2SLS} = .20$ s= .001 SSE= .025 DW= 1.92

$BMANU_t = -.064 -.831EW_t -.066DMANU_t + 3.19NDIPC_t$
(2.29)(1.68) (3.37) (1.65)
$R^2{}_{2SLS} = .60$ s= .002 SSE= .040 DW= 1.65

$VAMHR_t = .015 + .290VA_t - 1.15GMEPF_t$
(1.78) (4.67) (2.61)
$R^2{}_{2SLS} = .60$ s= .001 SSE= .019 DW= 1.94

$VA_t = .020 + 1.47MANU_t - 3.42CE_t$
(1.12) (4.32) (.429)
$R^2{}_{2SLS} = .56$ s= .008 SSE= .141 DW= 2.35

$NOMAN_t = .035 + .159MANU_t + .817MANU_{t-1} - .746TOTEM_{t-1}$
(3.17) (.959) (4.08) (2.82)
$R^2{}_{2SLS} = .63$ s= .001 SSE= .025 DW= 1.89

$CE_t = .095 + 1.19BMANU_t$
(1.39) (1.20)
$R^2{}_{2SLS} = .10$ s= .082 SSE= 1.40 DW= 1.30

SPRINGFIELD

$TOTEM_t = .001 + .278MANU_t + .692NOMANU_t$
(1.91) (86.4) (62.4)
$R^2{}_{2SLS} = .99$ s= .0007 SSE=.064 DW=2.23

$MANU_t = .008 + .088BMANU_t$
(.492) (3.96)
$R^2{}_{2SLS} = .56$ s= .024 SSE= .004 DW= 2.24

$$BMANU_t = 1.65 - 1.13EW_t - 8.67DMANU_t - 39.7NDIPC_t$$
$$(1.76)\ (1.24)\ (2.59)\ (1.76)$$
R^2_{2SLS}= .52 s= .584 SSE= 2.39 DW= 1.07

$$VAMHR_t = -.035 + .931VA_t + .111GMEPF_t$$
$$(1.52)\ (5.19)\ (.449)$$
R^2_{2SLS}= .69 s= .179 SSE= .032 DW= 1.87

$$VA_t = .003 + .938MANU_t + .061CE_t$$
$$(.121)\ (2.47)\ (1.85)$$
R^2_{2SLS}= .58 s= .086 SSE= .058 DW= 1.60

$$NOMAN_t = .036 - .134MANU_t - .035MANU_{t-1} + .186TOTEM_{t-1}$$
$$(1.76)\ (1.24)\ (.344)\ (.169)$$
R22SLS= .06 s= .024 SSE= .004 DW= 2.24

$$CE_t = .332 - .336BMANUt$$
$$(1.08)\ (.872)$$
R22SLS= .001 s= .869 SSE= 6.79 DW= 3.39

A comparison of these findings with the 2SLS estimates reported in Table V and Appendix C (the estimates not corrected for autocorrelation) shows differences quantitatively but very little difference qualitatively. The quantitative differences are due to the exclusion of CE from the first-stage regression. The similarity in the qualitative results indicates that the major findings and conclusions of the study are insensitive to the assumption concerning the nature of the capital stock.

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