WHAT REMAINS OF THE GROWTH CONTROVERSY?

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Working Paper No. 33

December 1989

Submitted to
The Jerome Levy Economics Institute
Bard College

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The author acknowledges the comments of K. Hoover, J.L.S. McCombie, D. Harris, R.E. Rowthorn, T. Mayer, A.P. Thirlwall and I.H. Rima.

I. INTRODUCTION

Until recently, the conventional wisdom dictated that international economic growth rates tended to converge.[1] Now, some major economists consider that the tendency toward convergence may be a product of selective sampling.[2] Until recently, many economists reckoned that a rapid rate of investment in capital, which embodied technical progress, was a sufficient condition for rapid economic growth.[3] This view too has come into doubt after the last decade when productivity growth fell steeply despite reasonably high levels of investment in capital and research and development.[4] No wonder, then, that economists have been focusing on growth and suggesting unconventional ideas. Perhaps slow economic growth, Griliches pondered, follows from the slow growth of aggregate demand.[5] Is the key to growth, Romer asked, endogenous technical change which results in increasing returns?[6] The divergence of growth rates, say Lucas, belongs on the research agenda.[7] Such research interests promise a substantial modification of the neoclassical model of economic growth, which to date has been based on the aggregate production function with constant returns to scale.

At this juncture, it is timely to consider how well the conventional aggregate production function has performed against the Keynesian, demand-side model in explaining economic growth. This essay contrasts the production function approach to Kaldor's model of increasing returns which are demand-determined. In particular, the essay analyzes Kaldor's three major empirical "laws", which were adopted by later economists, and the criticisms of these three "laws" by economists who used the Cobb-Douglas production function as a basis of analysis. In conclusion, the essay finds that econometrics has provided an inadequate basis upon which to choose between this aggregate production function and Kaldor's model of growth.

II. THE TWO GROWTH MODELS

This section compares the Cobb-Douglas production function with Kaldor's theoretical model.

The Cobb-Douglas production function states that

(1.) $Y = X^{\alpha}K^{1-\alpha}e^{rt}$,

where Y is output, X labor input, K the input of capital, and e^{rt} the time trend of neutral technical progress. The function commonly is defined to be homogeneous of degree one ($0<\alpha<1$). It follows that the marginal product of labor and capital diminish as

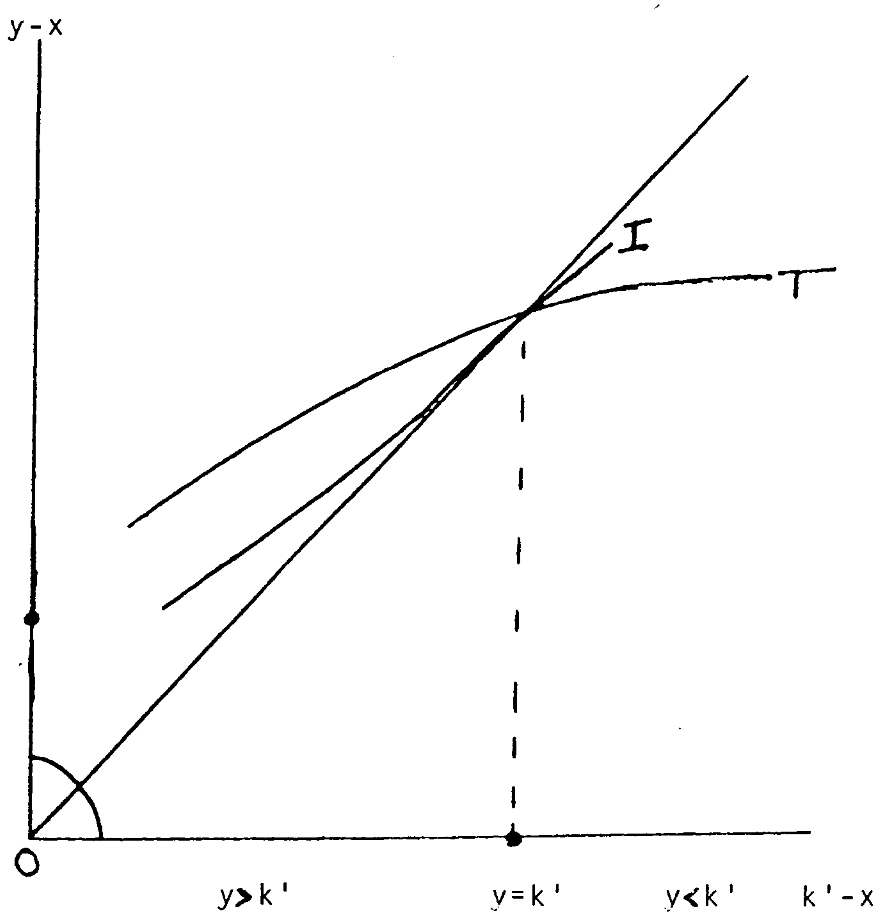

Figure 1. The Interaction of the Technical Progress Function (T) and the Inducement to Invest Function (I).

labor and capital increase. In a perfectly competitive economy, where factor prices equal the values of the marginal products, the share of wages and profits in output together account for all output, a distributional outcome that follows from Euler's theorem of linear homogeneous functions. Taking logarithms and differentiating with respect to time yields the production function (equation (1)) in the rate of growth form

(2.) $y = \alpha x + (1-\alpha)k + r$

where the lower case letters refer to rates of growth. Because the sum of the output elasticities (α, $1-\alpha$) equals one, equal proportionate increases in the supply of labor (x) and capital (k) cause an equal proportionate increase of output (y). There are, in other words, constant returns to scale. Any residual growth is due to productivity growth which depends on the rate of autonomous technical progress r.

In contrast, in the Kaldor model, economic growth depends on endogenous technical progress, which is embodied in capital accumulated by profit-seeking, oligopolistic firms. Technical innovation, which raises productivity, requires the use of more capital per worker, because of the use of more elaborate equipment or more mechanical power. This capital is heterogeneous, composed as it is of machines of different vintages.[8]

The technical progress function (T) shown in Figure 1 expresses the production relation

(3.) $y-x = f(k'-x) \qquad f'>0,$

where y-x is the growth of labor productivity and k'-x, the growth of vintage-capital per worker.[9] At any given stage of invention, capital accumulation eventually brings diminishing returns to productivity growth.

Investment (I), which makes capital per worker grow, is described by an accelerator type function

(4.) $I = g(y-x)$.

This implies that investment is sufficient to keep the economy at any point along the T curve. The position of the investment curve depends on the rate of profit on investment, defined as $\Delta Y/\Delta K'$, which tends to rise (fall) when output (capital) growth exceeds capital (output) growth. As Figure 1 shows, in long run equilibrium, the rate of investment occurs at the level at which the capital-output ratio and the rate of profit are constant, and output per worker is growing at the maximum feasible rate.

Owing to the problems of measuring capital over time, Kaldor modified the technical progress function to remove capital as an explicit term.[10] The derivation went like this[11]: The technical progress function (3) can be written in the convenient linear form as[12]

(5.) $p = r' + n(k'-x)$,

where r' stands for disembodied technical progress and p stands for the growth of labor productivity,

(6.) $p \equiv y-x$.

Disembodied technical progress (r') includes autonomous technical progress (Θ_1) and "learning by doing", which is partly induced ($\tau_1 y$),

(7.) $r' = \Theta_1 + \tau_1 y$.

Technical progress which is embodied in capital and makes the capital-labor ratio grow is partly autonomous (θ_2) and partly induced ($\tau 2$),

(8.) $k'-x = \theta_2 + \tau_2 y$

Substituting (6-8) into (5) and gives equation 9

(9.) $p = a + by$, $a= \theta_1 + n\theta_2$, $b = \tau_1 + n\tau_2$,

which is the formal counterpart of the "Verdoorn growth 'law'".

Kaldor intended this model as an extension of the "capital controversy" launched by Joan Robinson (1953-54) into growth economics. The assumptions behind the Kaldor growth model deliberately conflicted with those of the production function in growth form. In the neoclassical model, technical progress is exogenous (equation 2), in Kaldor's model it is demand-determined and embodied in capital (equations 3-4). This means that in Kaldor's model returns are increasing, in the sense that every increase in capital along the production function involves a shift of the production function. While technical progress in the neoclassical model is neutral between sectors, in Kaldor's model technical progress does not occur uniformly between sectors. Since technical progress typically involves labor reallocation, the distribution of labor between sectors at any time is not optimal. Even at "full employment" the economy is not resource-constrained.[13] In other words, the long run aggregate supply curve is horizontal.

III. KALDOR'S REGRESSIONS

The Verdoorn "law" stated that manufacturing productivity growth depended on the growth of manufacturing output. Kaldor learned this idea from Allyn Young, his tutor at the London School of Economics in the late 1920s. At this time economists were arguing over the scope of secular increasing returns. Inspired by Smith's dictum that "the division of labor is limited by the extent of the market", Young (1928) thought that the division of labor (which made returns and thus productivity increase) occurred mainly in manufacturing. It was in manufacturing that capital formation embodying technical progress required ever more division and specialisation of labor. The major productivity gains occurred as growing market demand led to new industries within the manufacturing sector.

Young's idea was taken up by his pupil G. T. Jones (1933) and his former research assistant C. Clark (1940). It prompted empirical investigations by Professor I. Svennilson in Stockholm (1945, 1954) and P. J. Verdoorn (1949) of the Dutch Central Planning Bureau. After the war, Verdoorn worked under Kaldor when Kaldor was Director of Research and Planning at the United Nations Economic Commission for Europe.[14] At this time, Verdoorn published a study of the relation between productivity growth and output growth in manufacturing. He used cross-sectional data for fourteen developed countries 1924-1938.[15] The regression yielded a constant of one and a regression coefficient of 0.6, roughly the same as Beckerman's (1964) estimates for postwar British industry.[16] (The existence of a dependency of productivity growth on output growth was familiar to Keynesian applied economists in the US. The Council of Economic Advisers under Kennedy argued that productivity increased fastest when the economy ran at high capacity utilization, an argument confirmed by a regression of productivity growth on real GNP growth, 1947-1960.[17])

Kaldor with Champernowne (1957, 1958) developed the technical progress function that provided the rationale for the relation between productivity growth and output growth.[18] Champernowne estimated the Mirrless-Kaldor (1962) model of a nonlinear technical progress function which related productivity growth to the growth of investment per worker.[19] Kaldor's own econometric work on the Verdoorn model was presented in his inaugural address (1966) shortly after he, as part-time adviser to the Labour Chancellor under Wilson's first Labour Government (1964-1970), devised the controversial selective employment taxation scheme. The SET (1966) placed a positive payroll tax on the service sector and a small negative tax on the manufacturing sector. Officially, the tax was intended partly to reduce Britain's relatively high rate of growth of service employment and raise her relatively low rate of economic growth (as shown in Figure 2).[20] Kaldor's theoretical position supported the tax scheme as a "Pigovian" fiscal device: The SET tended to redistribute labor from the service sector, which contributed a negligible "marginal product", to the manufacturing sector where the "marginal product" exceeded the "average product", as it does under conditions of increasing returns.[21]

Kaldor, who knew little econometrics, used a naive econometric procedure. To some extent, this lack of sophistication was a product of his time and place.

The Cowles Commission established econometrics in the United States in the 1940s. Yet, one could find virtually no econometrics course taught in British universities in the 1950s. Students who wanted econometrics would spend time at an American university or try to teach themselves. Still, notable applied econometrics work was being done at the Department of Applied Economics (DAE) at Cambridge. Under R. S. Stone's direction, the DAE developed the single errors-in-equation model. The simple criteria for an acceptable model were correctly signed coefficients, a high R^2, statistically significant coefficients, and Durbin-Watson statistics within the appropriate bounds.[22]

By the early 1960s, the errors-in-equation model had become the standard method of estimation. Meanwhile the DAE shifted its interest to economic planning and the center of time series analysis moved to the London School of Economics. The LSE offered its first econometrics course in 1962 and introduced the M.Sc. program in econometrics in 1967.[23] At this time, econometrics came into vogue in business and government.[24] The Economist, upon hearing the inaugural address (1966) in which Kaldor coined the term Verdoorn "law", remarked upon the "present Treasury shibboleth(), ... the language of regression equations".[25]

Regression analysis served mainly to estimate linear stochastic models based on formal theory. Little attention was paid to testing alternative hypotheses. Kaldor himself, not unlike other policy-oriented economists, was prone to treat his least-squares estimates as measures of a true model. He reported the R^2, the standard error of the regression coefficient and the standard error of the regression as a proportion of the mean value of the dependent variable, but did not lend these a statistical interpretation. Rather, he treated the estimates of the slope coefficients of the bivariate regressions as if these were to all intents and purposes the precise values of the elasticities.[26]

Kaldor's sample covered twelve of the twenty-two OECD countries for the period 1953/54-1963/64. His data came from the recently developed data banks of the OECD and the UN. The data were cross-sectional, one exponential growth rate for each variable for each country over the sample period.

Like many economists, Kaldor ignored the issue of the quality of the data. The industrial data tended to be reliable, though the aggregate output and employment series were not always comparable.[27] The grave drawback concerned the service sector, for which the real output indicators of many (though not the majority) of activities were based on the employment series.[28] Like many international studies, the Kaldor study neglected to explain its sample, which included some but not all of the industrialized OECD countries. Nevertheless, Kaldor's study possessed a simplicity and a directness, which drew attention to it.

In order to report all the relevant statistical "tests" and permit consistency throughout the essay, I reestimated the Kaldor regressions. The results presented in this essay of the growth "laws" are very close to Kaldor's estimates.

A. The First "Law"

According to the postwar maxim, "manufacturing growth is the engine of growth". Manufacturing growth induced productivity growth within the manufacturing sector itself and raised productivity growth in the non-manufacturing sector by supplying inventions to and reducing under-employment in that sector (see the third "law"). Kaldor's first "law", which related output growth (y) to manufacturing output growth (y_m) was estimated as:[29]

$$(10.) \qquad \hat{y} = 1.1082 + 0.613y_m \qquad R^2=0.95$$

standard error: (0.293) (0.045) F-stat=88.7

significance level: (0.020) (0.000). $ser/\bar{y}=0.09$

Kaldor saw that this relation might be spurious because manufacturing output composed a large part of total output. He replaced the regressor y_m by $(y_m\text{-}y_{nm})$, the difference between the growth rates of manufacturing (y_m) and nonmanufacturing output (y_{nm}). His estimates showed that rates of economic growth rate only exceeded 3.3 percent when y_m exceeded y_{nm}.

B. The Second "Law"

Kaldor expressed the second "law" by two alternative specifications, either the Verdoorn relation between manufacturing productivity growth (p_m) and manufacturing output growth (y_m) (equations 9, 13) or the relation between manufacturing employment growth (x_m) and manufacturing output growth (y_m) (equation 14). If Kaldor's data were consistent, only one of these specifications needed to be estimated since, by definition,

(11.) $y_m \equiv x_m + p_m$.

Using Kaldor's data, ordinary least-squares give the estimates:

(12.) $\hat{y}_m = 1.0005x_m + 1.0037p_m$ $R^2=0.99$ standard error: (.0098) (.0060) F-stat.=56061.

The tiny discrepancy between the estimated and the true coefficient is mainly due to measurement "error" in respect to France and West Germany, as shown in Figure 3.

Productivity was computed in base year prices as the ratio of the index of net output to the index of labor input at the industry level, with sizeable statistical adjustments made at the aggregate level.[30] The availability of the data on productivity can explain Kaldor's choice of countries. Continuous OECD series usually were limited to annual figures for 10-year periods and the OECD published a productivity index only for twelve countries.[31] Kaldor's sample covered eleven of these countries, but excluded Ireland, which was not industrialized, and included Japan.

Kaldor's estimates of the second "law" given the Verdoorn specification were:

(13.) $\hat{p}_m = 1.048 + 0.480y_m$ $R^2=.823$

standard error: (0.462) (0.070) F-stat=46

significance level: (0.047) (0.000) ser/$\bar{y}_{mt}$=.17

DW =2.63,

estimates which depended negligibly on the presence of West Germany and France in the sample. Since productivity growth (p_m) was itself computed from the output data (y_m), Kaldor preferred to estimate the second "law" in the alternative form:

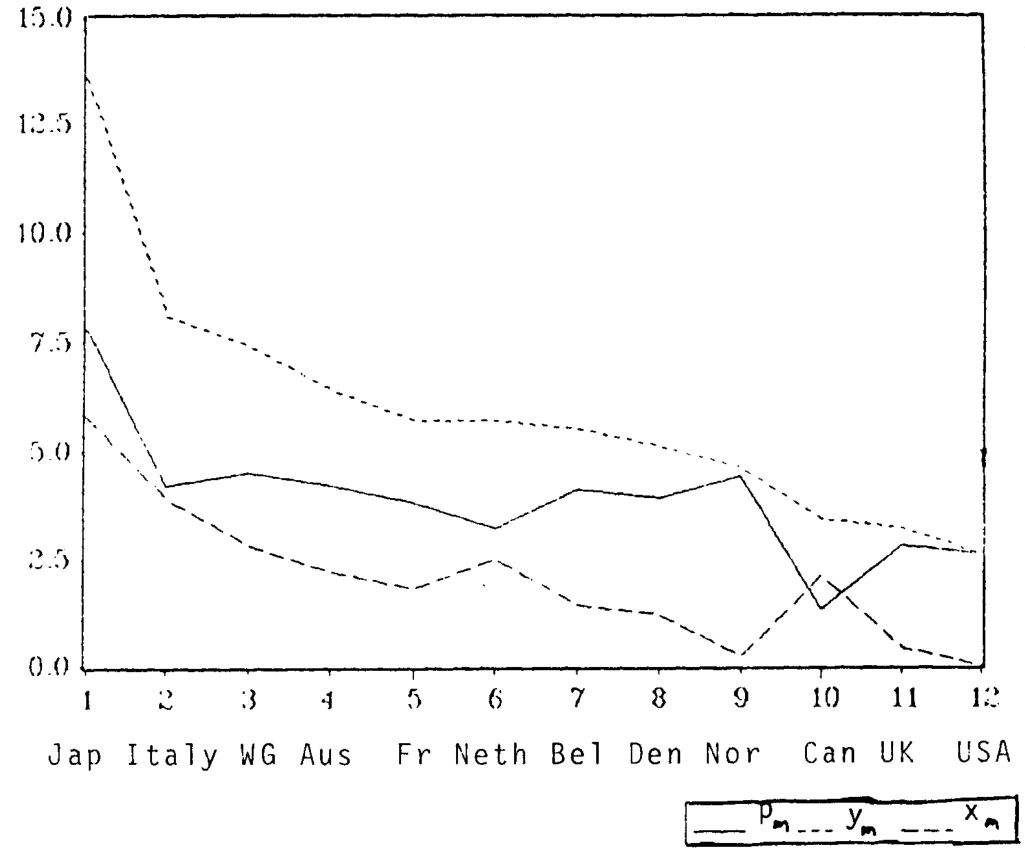
15.0
12.5
10.0
7.5
5.0
2.5
0.0
1 2 3 4 5 6 7 8 9 10 11 12
Jap Italy WG Aus Fr Neth Bel Den Nor Can UK USA
p_m y_m x_m

Figure 2:

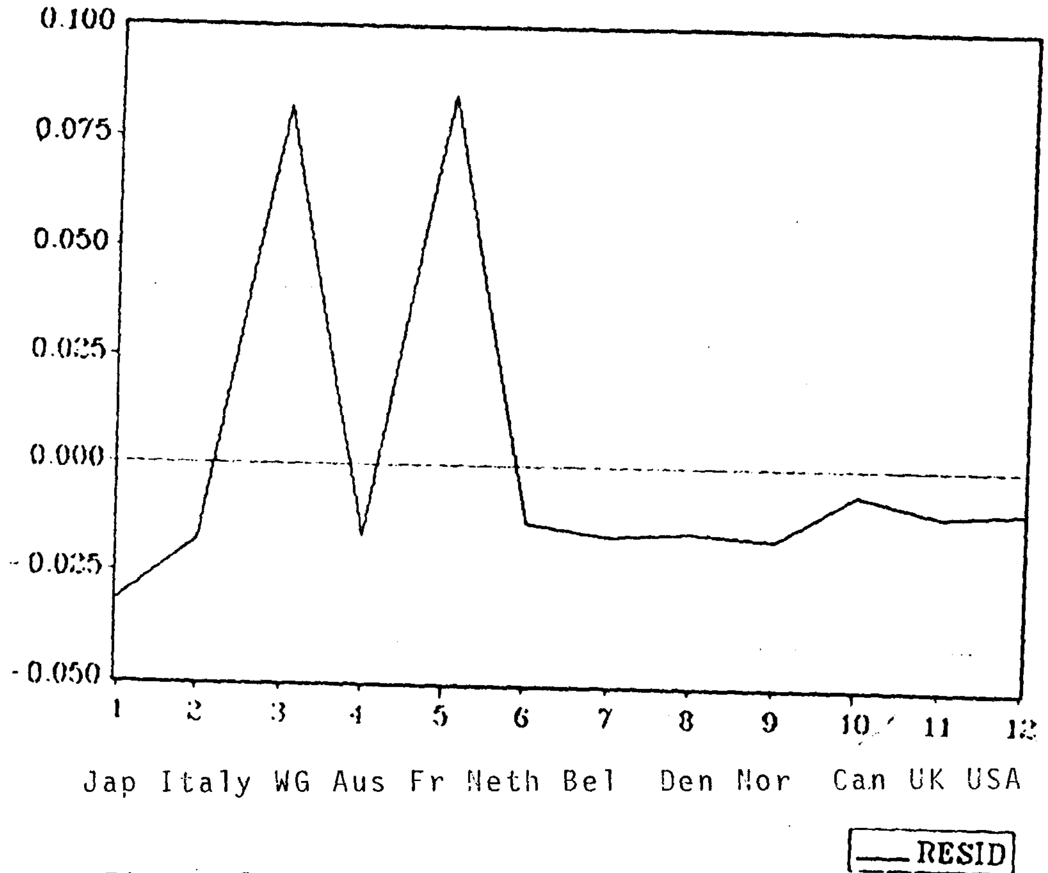
0.100
0.075
0.050
0.025
0.000
- 0.025
- 0.050
1 2 3 4 5 6 7 8 9 10 11 12
Jap Italy WG Aus Fr Neth Bel Den Nor Can UK USA
RESID

Figure 3:

(14.) $\hat{x}_m = -1.057 + 0.519y$ $R^2=0.84$

standard error: (0.462) (0.070) F-stat=54

significance level: (0.045) (0.000) $ser/\overline{y}_{mt}=0.3$

DW=2.68.

Since the data shown in Figure 2 were ordered in terms of economic growth rates, the Durbin-Watson statistic can interpreted as a test of heteroskedasticity. The values of this statistic in equations (13-14) border on the indeterminate range, but suggest negative serial correlation at the 5 percent significance level. The null of homoskedasticity could not be rejected by the Park-Glejser test at the 10 percent level.[32]

The Kaldor regressions were similar to those cross-sectional studies done in the 1940s of the simple Keynesian consumption and savings functions.[33] The consumption function $C = a + bY_d$ is of course the "inverse" of the savings function $S = -a + (1-b)Y_d$, given the identity $C + S \equiv Y_d$ (Y_d, real disposable income); similarly, the two statements of the Verdoorn "law" (equations 13, 14) were "mirror images" of each other. Because regressing consumption on real disposable income regressed consumption on itself, economists often preferred to estimate the relation between savings and real disposable income; similarly, Kaldor preferred to the estimate the relation between employment and output, instead of productivity and output.[34] The consumption and savings equations had only two variables, since economists assumed that any omitted explanatory variables were trivial and constant, an assumption confirmed by the estimates of the R^2 near unity.[35] Similarly, Kaldor assumed that manufacturing output growth totally explained productivity growth and employment growth, an assumption confirmed by the high R^2s. From such a deterministic stance, the existence of competing specifications also yielding strong statistical results was not foreseen to be a problem.

C. The Third "Law"

Kaldor's third "law" originated from A. W. Lewis' (1954) ecletic theory of the dual economy. According to Lewis, the economy of an undeveloped country was divided into a capitalist sector and a traditional sector. The traditional sector contained disguised unemployment in the sense that the marginal product of labor was zero. The real wage in the capitalist sector exceeded the subsistence wage in the traditional sector, which implied that employment was demand-constrained.

According to Kaldor (1968), the typical developed country also had a dual economy, with a manufacturing and a nonmanufacturing sector.[36] The third "law" took the general form

(15.) $p = c + dx_m - d'x_{nm}$,

where p stood for productivity growth in the economy as a whole. The positive (negative) coefficient on x_m (x_{nm}) implied that the "marginal product of labor" in the manufacturing (nonmanufacturing) sector was positive (negative). Therefore, overall productivity (p) would rise as labor was reallocated from the nonmanufacturing to the manufacturing sector. In contrast with neoclassical tenets, the third "law" apparently showed that (i.) the allocation of labor was not optimal and (ii.) manufacturing growth lacked a labor supply constraint.[37]

Under Kaldor's direction, the researchers Cripps and Tarling (1973) at the Department of Applied Economics tested the three growth laws with pooled data over a larger sample and a longer period. To test the Verdoorn "law", Cripps and Tarling regressed manufacturing productivity growth p_m on manufacturing employment growth x_m, given the specification

(16.) $p_m = c'/(1-b') + (b'/1-b')x_{m,}$

which followed mathematically from Kaldor's the original "law" (as in equations 9, 13-14). For the 1951-64 period, the R^2 was positive and the regression coefficient was statistically significant. For the 1965-70 period, the regression coefficient was statistically insignificant and the R^2 equalled zero, which led the researchers to admit that "the Verdoorn law has apparently ceased to be effective" (p.25.).[38] They next tested the third "law" (equation 15). Given the failure of the second "law", they ad hoc replaced x_m by y_m, which was related to p by definition. Cripps and Tarling found that the estimates confirmed the third "law" for the whole period and when increasing returns no longer pertained the estimates strengthened. On this basis, the DAE project cavalierly concluded that their "correlations provide[d] a striking indication of the significance and stability of Kaldor's generalisations" (p.30).

IV. THE NEOCLASSICAL ECONOMETRIC ARGUMENT

The strongest critics of the Keynesian growth "laws" were R. E. Rowthorn, a former student of W. B. Reddaway, who was reputed to have disliked Kaldor, and J. L. S. McCombie, himself a student of Rowthorn.[39] Neither of these two critics were strict neoclassical economists. Rowthorn often worked in the Marxist tradition, J.L.S. McCombie in the postKeynesian tradition. Nevertheless, their criticisms of the Keynesian growth "laws" were made from a neoclassical perspective.

A. The Critique of the First "Law" (Equation (15))

An empirical relationship can be explained by any number of theories. Indeed neoclassicists explained the first "law" in their own terms. In neoclassical theory, growth of factor supplies and autonomous technical progress made output, or real income grow, which in turn induced growth of demand for goods and services. It was recognised widely that countries with low per capita income had a high (low) income-growth elasticity of demand for manufactures (services) and conversely for countries with high per capita incomes. In this case, relatively fast growth of low income countries would generate a correlation between y_m and y, but the exogenous variable was y, meaning the growth of the <u>supply</u> of output.[40] The choice between the neoclassical specification, estimated as

(17.) $$\hat{y}_m = -1.418 + 1.550y \qquad R^2=0.95$$

standard error: (0.571) (0.113) F-stat=189

significance level: (0.032) (0.000),

and Kaldor's specification (equation (10)) required evidence of whether y or y_m was the "true" causal variable.

B. The Neoclassical Criticism of the Second "Law" (Equations 13-14)

Neoclassicists showed that the Verdoorn "law" could be derived from the Cobb-Douglas production function, identified the flaws in the Keynesian regression model that led the estimates to conflict with those expected on the basis of the Cobb-Douglas function, and specified a model that yielded estimates consistent with constant returns to scale.

1.The Cobb-Douglas Derivation of the Verdoorn "Law"

Verdoorn himself (1949) derived his elasticity from a function that looked like Cobb-Douglas. However, the sum of the output elasticities exceeded one and technical progress was "integrated" into the production function. As Verdoorn stated, the only reason he used the Cobb-Douglas form

> "to represent the relation between production, capital and labor [was] because it has been used for a long time as a theoretical device. However, it can be proved that also using a more general formulation of the production function [as in equations 5-9

above] the same formula can be obtained as those described below" ((1949) p.8).

Verdoorn started with the basic Cobb-Douglas form

(18.) $Y_m = X_m^{\alpha} K_m^{\beta}$ $(\alpha + \beta) > 1.$

Taking logs and differentiating with respect to time gave

(19.) $y_m = \alpha x_m + \beta k_m,$

the rate of growth form. Verdoorn divided equation (19) by $x_m,$

(20.) $y_m/x_m = \alpha + \beta(k_m/x_m).$

Next he defined the elasticity of productivity with respect to output (V)

(21.) $V = p_m/y_m$

or, given the definition of productivity growth (equation (11))

(22.) $V = 1 - (x_m/y_m).$

Substituting equation (22) into (20) resulted in the Verdoorn elasticity

(23.) $V = 1 - (1/(\alpha + \beta(k_m/x_m))).$

This elasticity depended on the ratio of the growth of capital to the growth of employment and <u>both</u> output elasticities, implying that the Verdoorn relation (equation (13)) pertained to the growth of <u>total</u> labor productivity.[41] Clearly, the stability of the Verdoorn relation rested on the constancy of α, β and k_m/x_m, a condition unlikely to be met except in a steady-state equilibrium.[42]

Rowthorn's (1979) neoclassical derivation of Verdoorn's elasticity began with the assumptions of substitutable factors and marginal productivity implicit in the constant returns Cobb-Douglas function. The derivation started with equations 18, 19. Substituting the identity, (24.) $x_m \equiv y_m - p_m$

into equation 19 yielded

(25.) $p_m = (\beta/\alpha)k_m + ((\alpha-1)/\alpha)y_m$

as the neoclassical model underlying the Verdoorn "law" (equation 13).[43] Since the Verdoorn elasticity,

(26.) $V = (\alpha-1)/\alpha$

depended solely on labor's output elasticity (α), it could not measure (as Keynesians interpreted) returns to scale or the effects of technical progress. In the case of diminishing returns, the Verdoorn regression coefficient would be negative.

Only the neoclassical specification of the Verdoorn relation gave capital growth as a variable explaining productivity growth (compare equation 9 to 25). Kaldor omitted capital growth as an explicit explanatory variable because he took the capital-output ratio to be constant, both as a steady-state condition and a "stylized fact". Capital growth in this case would be correlated perfectly with output growth, with the Verdoorn coefficient picking up the full effect of induced capital formation on productivity growth.[44] Because of measurement problems, findings on the capital-output ratio vary.[45] Evidence has suggested a constant ratio as a rough approximation for the developed countries.[46] But, to the extent that the trend rates of growth of capital and output diverged, the omission of capital growth in the Verdoorn model (equation (13)) would create an upwards bias in the estimated regression coefficient.[47] In response to this problem, Kaldor (1967), McCombie (1983) and Michl (1985) specified the Verdoorn "law" with the investment ratio or capital growth as an explanatory variable and arrived at estimates of the Verdoorn coefficient that still implied increasing returns (in equation 25, $\alpha>1$).[48] The Verdoorn definition of the elasticity (equation 23), given reasonable estimates of k/x and ß, also implied increasing returns to labor ($\alpha>1$) and to scale ($(\alpha+\beta)>1$).[49] None of these estimates, however, gave a basis for deciding whether the underlying model was a Keynesian or a neoclassical model.

2. The Neoclassical Estimates of the Verdoorn Law

McCombie (1982) related the logarithms of manufacturing employment and manufacturing output.[50] On a sample of OECD countries, the data for most of the period 1951-1973 showed a regression coefficient that was not statistically significant from unity at the 10 percent level:

(27.) $$\log X_m = C + \log Y_m.$$

According to McCombie, if the capital-output ratio was constant, the coefficient of one implied the existence of <u>constant</u> returns to scale. The rationale for this argument goes as follows: The Cobb-Douglas production function (equation 1) in logarithmic terms is

(28.) $$\log Y_m = \alpha \log X_m + \beta \log K_m$$

or

(29.) $$\log X_m = (-\beta/\alpha)\log K_m + (1/\alpha)\log Y_m.$$

Assuming a constant capital-output ratio gives

(30.) $\log X_m = (-\beta/\alpha)\log U + ((1-\beta)/\alpha)\log Y$, $K=UY$,

$((-\beta/\alpha)\log U)=C$

U, scaling factor

where $((1-\beta)/\alpha)=1$ implies constant returns to scale. To the extent that the assumption of a constant capital-output is a poor approximation, then a regression coefficient near unity (in equation 27) would imply static economies of scale ($(1/a)\approx 1$, $\beta>0$), which is consistent with the Verdoorn growth "law".

3. Causation

(i.) The technical diffusion hypothesis

Most growth economics of the early postwar period made technical progress the major cause of growth. Abramowitz's (1956), Solow's (1957), Massell's (1960) and Denison's (1962, 1967) estimates of the Cobb-Douglas function attributed a large proportion of output growth to the residual, technical progress (r). To account for apparent differences in rates of technical progress, Gomulka (1971) explained that technical progress diffused from high-tech to low-tech countries. The greater the technology gap, the difference between the level of technology of the most advanced country (say, the US) and a country's (say, Japan's) own level of technology, the higher the latter country's (Japan's) rate of economic growth. This implied that levels of technology and rates of economic growth tended to converge. Since technolgy is not readily measurable, tests of this hypothesis have used a proxy for the technology gap, the per capita income gap.[51]

Estimates showed a positive relation between economic growth and the per capita income gap for developed countries during 1951-1970.[52] However, a wide sample of countries during 1950-1981 showed no relation between growth and income, once exchange rates were corrected for departures from purchasing power parity.[53]

McCombie (1983) applied the technological diffusion hypothesis to explain the Verdoorn correlation for the twelve OECD developed countries, 1953/54-1963/64.:[54] Given a relatively large technology gap, relatively rapid technical progress would incur a relatively rapid growth of productivity. This in turn would lead to falling relative costs and prices that would cause a shift in demand towards the goods of the country in question and an increase in its rate of economic growth. The process would occur <u>mutatis mutandis</u> in the case of a small technology gap. In this light, productivity growth (p_m) rather than manufacturing output growth (y_m) should be the causal variable in the Verdoorn equation. The estimates of the Verdoorn model then are:

(31.) $$\hat{y}_m = -0.745 + 1.715p_m \qquad R^2=.82$$

standard error: (1.048) (0.251) F-stat=46.5

significance level: (0.493) (0.000).

The regression coefficient well over unity implies a higher degree of responsiveness to productivity growth than we may expect to be explained by international price flexibility alone.[55] On economic grounds, this equation appears to omit important explanatory variables. Whether p_m (as in equation (31)) or y_m (as in equation (13)) is the "true" causal variable remains an open question.

Kaldor acknowledged that output growth depended on productivity growth.[56] The crux of the Kaldor theory was that the neoclassical growth model based on a static equilibrium could not handle the interdependency between the two variables, which made country's economic growth rates diverge.[57] Kaldor and his exponent Thirlwall, who believed with some fervour in this cumulative causation model, defended the use of the single equation regression analysis. They rationalized that because the responsiveness of prices to productivity changes and demand to price changes were small, the differences between countries' growth rates remained roughly constant and the estimates of the single equation model sufficiently approximated the relations in question.[58] This argument serving to rationalize the specification of a single equation model was of a standard sort. Economists rarely demonstrated the absence of the simultaneous equation bias that would arise in the event of the presence of significant feedback.

(ii.) The case of Japan

Rowthorn (1975b) specified the Verdoorn "law" in terms of a direct relation between p_m and x_m, on the grounds that the increasing returns argument depended crucially on the existence of a positive relation between these two variables.[59] From this perspective, Rowthorn stated that Kaldor

> followed an inappropriate statistical procedure ... (by) adopting a roundabout procedure instead of the conventional method of relating productivity growth p_m directly to

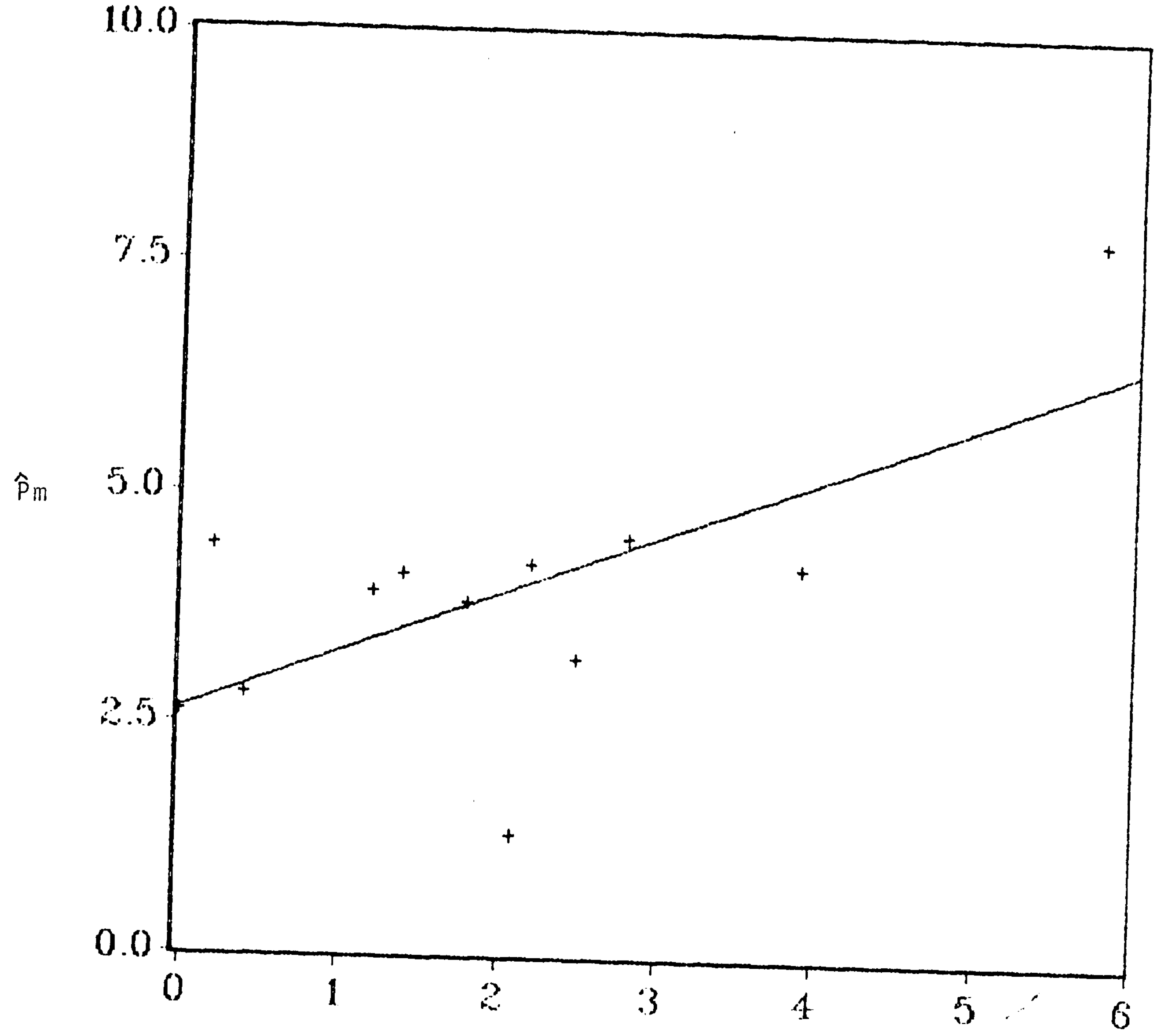

Figure 4:

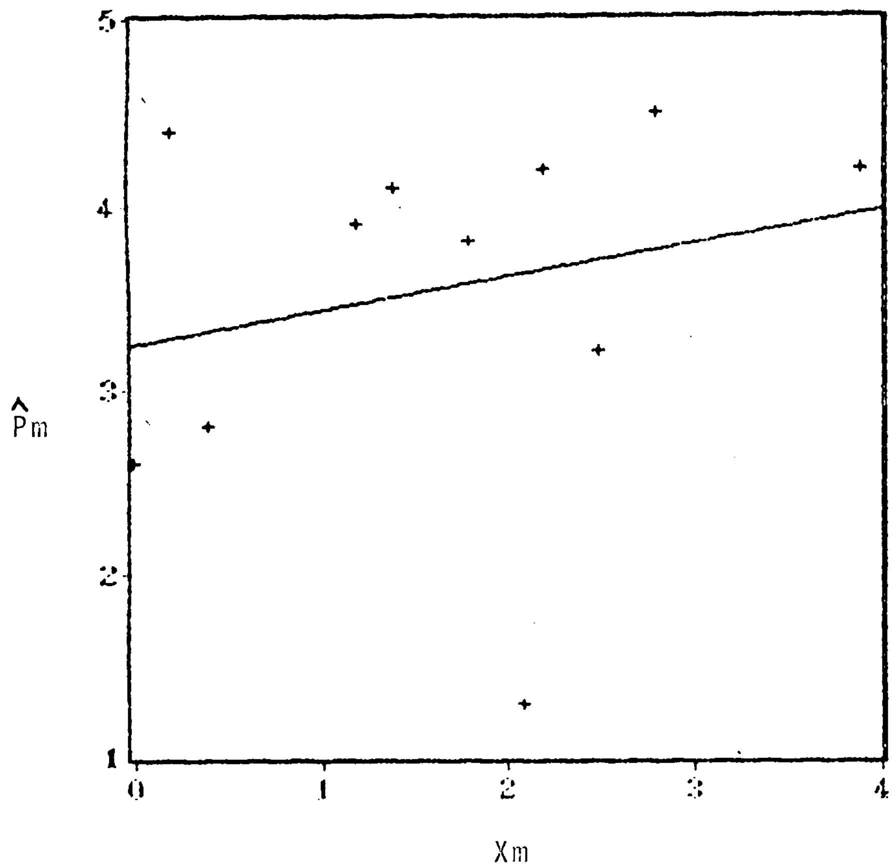

Figure 5:

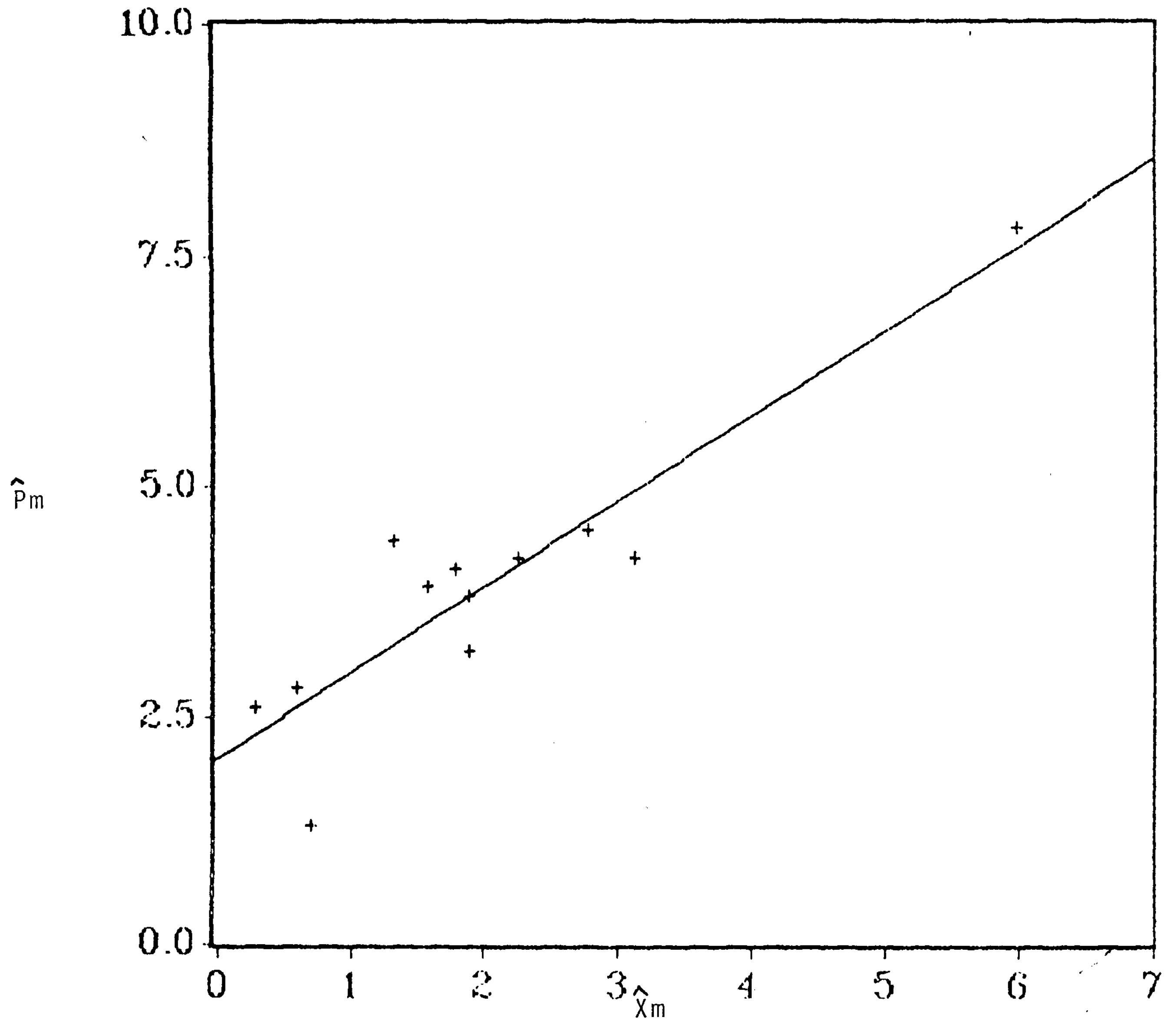

Figure 6:

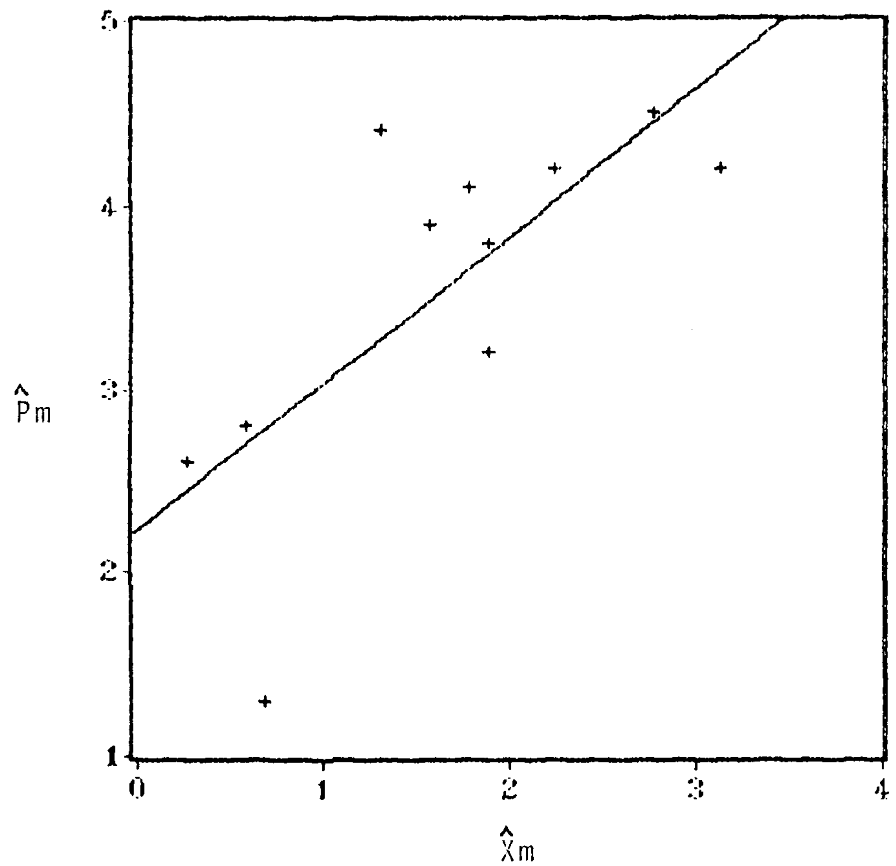

Figure 7:

> employment growth x_m. The advantages of estimating ß [the regression coefficient] by OLS regression of p_m on x_m are well known ...
> **Even if the errors are not independent of x_m, the OLS estimator may provice a sound basis for predicting the effect of a change in xm** on p_m (Rowthorn (1975a) pp.15, 17).

The emphasized portion of this statement is clearly wrong.

Rowthorn's OLS estimates of Kaldor's complete sample were:

(32.) $$\hat{p}_m = 2.631 + 0.626x \qquad R^2=0.45$$

standard error: (.566) (.220) F-stat=8.

significance level: (.001) (.018)

as shown in Figure 4. But without Japan in the sample, the results:

(33.) $$\hat{p}_m = 3.237 + 0.183x_m \qquad R^2=0.05$$

standard error: (0.541) (0.267) F-stat=0.5,

significance level: (0.000) (0.509)

as Figure 5 shows, indicated that the appearance of the Verdoorn regularity solely depended on an outlier.

Kaldor (1975b) responded that Rowthorn incorrectly specified the regressor. The supply of output was perfectly elastic in response to demand at the going price, which depended on costs.[60] Effective demand, or output growth was an exogenous variable, employment growth the endogenous variable correlated with the error term, which accounted for a downward bias in Rowthorn's estimates of the regression coefficient in equations 32-33.[61]

Let us allow, for argument's sake, that y_m really is an exogenous variable, while x_m is correlated with the error term.

Then, if we want to regress p_m on x_m, the single equation least squares estimator is undoubtedly inappropriate. The appropriate procedure is two-stage least squares, where p_m is regressed on x_m with y_m as the instrumental variable.[62]

The TSLS estimates for the complete sample as shown in Figure 6 are

(34.) $\hat{p}_m = 2.03 + 0.925\hat{x}_m$

standard error: (.605) (.261)

significance level: (.011) (.005)

which are mathematically consistent with the estimates of equations 13-14. Without Japan in the sample (Figure 7) the estimates are:

(35.) $\hat{p}_m = 2.33 + 0.725\hat{x}_m$

standard error: (0.750) (0.389)

significance level: (0.018) (0.095).

Thus, using the TSLS estimator, the statistical relation between p_m and x_m does not break down completely without Japan. Japan's contribution to the statistical relation instead appears to be only a marginal one. Moreover, the estimate of the Verdoorn coefficient is significant at the borderline, 90% confidence level. So, assuming that productivity growth p_m and employment growth x_m occur simultaneously given the growth of effective demand y_m - which is the Keynesian view - it transpires that the Verdoorn "law" does not appear to depend on the presence of Japan in Kaldor's sample.

Beckerman (1964)[63], Stoneman (1979)[64], McCombie and Ridder (1983)[65] and McCombie (1984)[66] also found that the economic significance of the growth "laws" were sensitive to the specification of the regressor. Estimates of p_m conditional on y_m

implied increasing returns to scale, yet estimates of p_m conditional on x_m implied constant returns to scale. Neither instrumental variables nor a simultaneous equation model resolved the problem.

The most successful causality test is Granger-Sims, a test for one-way temporal ordering in time-series, which obviously is inapplicable to inference about growth on cross-sectional data.[67] In any event, the presence of Granger-Sims causality cannot elucidate whether or not (1.) output is statistically exogenous or (2.) control over output makes productivity controllable, the two questions that have arisen in the growth controversy.[68] Growth like monetary economics would profit from the further development of a causality test that answered such questions (Hoover (1988a)).

C. The Critique of the Third "Law" (equation 15)

The third "law" comes down to tautology.[69] The definition of productivity growth is

(36a.) $p \equiv y - x$

or in respect to a dual economy

(36b.) $p \equiv a y_m + (1-a) y_{nm} - b x_m - (1-b) x_{nm}$

where a and b are shares of manufacturing output and employment, and (1-a) and (1-b) are shares of nonmanufacturing output and employment. Obviously, Kaldor's specification of the third "law" (equation 15) is an incomplete identity.[70]

V. The Current State of the Growth Debate

Tests of the first "law" using different specifications with data which were variously processed (in time series or cross-sections) and pertained to different regions and periods have met with mixed results. McCombie and Ridder (1983) and Gomulka (1983) confirmed the first "law"; Stoneman's (1979) estimates of this "law" were inconclusive; McCombie (1982) using Kaldor's preferred specification showed the "law" depended on the inclusion of two outliers, Japan and the U.K.

Recent estimates of the Verdoorn elasticity using postwar U.S. state data,[71] British postwar regional data,[72] British time series data 1800-1969,[73] and international postwar data,[74] confirmed the Verdoorn "law", though for the period after 1965 the international data definitely showed a weakened relationship. Keynesians generally have given short shrift of the apparent weakening of the Verdoorn relation. They believe that the "law" still holds while the pre-conditions of the statistical relation have changed. The capital-labor ratio, assumed to be constant, may have altered.[75] Perhaps full employment was a pre-condition of the "law" and the 1970s was a period of falling capacity usage.[76]

Thirlwall (1979) and others have developed an open-economy model in which growth of demand for exports, which is exogenous to the domestic economic system, is viewed as the <u>causa causans</u> of economic growth.[77] In the international context, neoclassicists and Keynesians continue to argue over whether supply or demand factors cause economic growth.[78]

VI. CONCLUSION

Growth theory once again is high on the economic research agenda (Barro (1989) pp.5-6). Unexpectedly, mainstream economists are investigating increasing returns, endogenous growth, public policy -- notions which have not fit into the orthodox framework. Romer (1986, 1989) has recognized Kaldor, the postwar exponent of increasing returns and the critic of orthodox economics, as an early source of the new growth theory. This essay sketches the econometric development of Kaldor's growth theory, which implied that economies should be run at a high rate of growth of aggregate demand. Kaldor's econometrics belonged to the "old-fashioned" sort, in which "estimates" served only to measure the free parameters of "laws" thought to be true *a priori*. In light of his reputation in Britain as a controversial theorist, the bald simplicity of Kaldor's regressions attracted attention and debate. Out-of-sample tests of the "laws" have shown mixed results, but generally have confirmed the "laws". This debate remains unresolved, pending a demonstration of whether factors of demand or supply control growth.

Notes

1. Baumol (1986) p.1073; Maddison (1987) p.669.

2. de Long (1987) p.1145; Lucas (1988) p.4; Baumol and Wolff (1988) pp.1155, 1159.

3. Solow (1988) p.315.

4. Griliches (1988) p.15; Jorgensen (1988)

5. Griliches (1988) p.19

6. Romer (1986) p.1003.

7. Lucas (1988) p.40.

8. Kaldor (1957) pp.265-293; Kaldor (1958) pp.206-215.

9. The Cobb-Douglas production function implies that the growth of labor productivity depends on the growth of the capital-labor ratio. This statement is similar, but not identical to the technical progress function (equation 3). In addition, integrating a linear equation based on the technical progress function may not imply a production function like Cobb-Douglas because of the constant of integration (McCombie (1982) p.289-290). With the technical progress function expressed in nonlinear form (as in Figure 1), there is no corresponding production function of any form (Black (1962).

10. Kaldor went from equation (5) -- in the 1958 paper --to equation (9) -- in the 1966 paper. Thirlwall and Dixon filled in equations (6-8) ((1975) p.209).

11. Thirlwall and Dixon (1975) p.209.

12. Kaldor (1958) p.215.

13. Kaldor (1958) pp. 204-206; (1975a) p.355; Thirlwall (1983a).

14. Thirlwall (1987) p.105.
I am grateful to R. E. Rowthorn for the information about Svennilson (letter to the author dated 11 August 1987).

15. Verdoorn carried out his regression in terms of the logarithmic differences of P_m, Y_m. No test statistics were reported. I re-estimated Verdoorn's regression using his published cross-sectional data in respect to growth rates p_m, y_m. The constant was statistically insignificant.

16. Beckerman (1964) p.227.

17. Council of Economic Advisers (1961), pp.374-375.

18. Champernowne mainly helped Kaldor with the mathematical model (Kaldor (1957) p.591.

19. Kaldor and Mirrless (1962) p.186 n.1.

20. Selective Employment Tax (1966) Cmnd.2986.

21. Letter to the author from N. Kaldor dated 12 October 1983; Kaldor (1966) p.31; (1980).

22. Gilbert (1988).

23. Gilbert (1989), p.7.

24. Johnston (1967), p.3.

25. Economist, 5 November 1966, p.547.

26. Kaldor (1966) p.11.

27. Hill and McGibbon (1966) p.47; Lomax (1964) p.10.

28. Hill and McGibbon (1966) pp. 40, 45.

29. In re-estimating Kaldor's equations, I see that the data Kaldor (1966) listed on page 5 for y in respect to my equation (10) were not the data that he used. He apparently estimated (my) equation (10) on the y data presented on page 12. The discrepancy between the two data series is minor.

ser/$\overline{y}$ stands for the standard error of the regression given the mean value of the dependent variable, in this case y.

30. National Research Council (1979) p.188; OECD (1966) p.18; Lomax (1965), pp.7-11.

31. National Research Countil (1979) p.190; OECD (1966) p.19.

32. Pindyck and Rubinfeld (1981) p.150.

33. Mosak (1945); Bean (1946); Bennion (1946); Woytinsky (1946).

34. Bean (1946) p.201.

35. Bean (1946) p.201; Bennion (1945) p.222.

36. Social factors in agriculture and imperfect competition in distribution led to excess supplies of labor in these sectors.

37. Kaldor (1966, 1968) thought that Britain was facing a labor supply constraint, in the sense that the service sector had absorbed the excess supply of labor in the primary sector, as shown by evidence of uniform real wages across all sectors. Kaldor (1975b) stated that this evidence was mistaken. The fact that Kaldor thought that the labor supply in the nonmanufacturing sector imposed a constraint on economic growth may explain why he specified employment growth the regressor.

38. Cornwall, using the Cripps-Tarling data and Kaldor's specification of the second "law", found that the estimates for 1951-1970 were statistically significant ((1977) p.149). Kaldor (1975b) admitted that with his specification of the second "law" (equation 18) the Cripps-Tarling data 1965-1970 did not yield a statistically significant relation.

39. Oral communication from A. P. Thirlwall at Canterbury, 20 October, 1989.

40. McCombie (1982).

41. Thirlwall (1980) p.387.

42. Verdoorn (1980) p.383; de Vries (1980) p.275; Turner (1983) pp.142-143; Boulier (1984) p.264.

43. Rowthorn (1979) pp.131-132; Thirlwall (1980) p.386.

44. Thirlwall (1980) p.386n.3.

45. Haache (1979) found little evidence of a constant capital-output ratio (p.280).

46. Romer (1989) pp.59-62.

47. Wolfe (1968) p.119; Rowthorn (1979) p.132n.1; Chatterji and Wickens (1981) p.416.

48. Kaldor (1967) p.81; McCombie (1983) p.418; Michl (1985) p.485.

49. McCombie (1983) p.411; Thirlwall (1980) p.387. For example, $\alpha>1$ if $k/x=4$ and $\beta\geq 0.25$ or if $\beta=.35$ and $k/x\geq 1.5$.

50. McCombie (1986) pp.282-288.

51. Cornwall (1977) p.119, n.47.

52. Cornwall (1976) pp.311, 313.

53. Romer (1989) pp.63-66.

54. p.419.

55. Stafford (1988) p.35.

56. Kaldor (1975b) p.895.

57. Kaldor (1972); Kaldor (1975a) pp.354-357.

58. Kaldor (1975b), p.895n1; Thirlwall and Dixon (1975) p.208; Thirlwall (1983b) p.357.

59.p.897.

60. Kaldor (1975a) pp.353-354.

61. Kaldor (1975b) pp.892, 895.

62. The first stage of TSLS gives the OLS estimates

(i.) $\hat{x}_m = \hat{a} + \hat{b}ym + u_1$

and the next stage

(ii.) $\hat{p} = \hat{c} + \hat{d}xm + u_2$

where the error terms u_1, u_2 are assumed to be independent of y_m and x_m.

63. p.531

64. pp.315-316.

65. p.382.

66.

67. Sims (1972), pp.540-543.

Parikh (1978) used the statistical test of significance as the criterion of correct causal specification. Statistical insignificance means that an estimate is a fluke. It does not say why.

68. Hoover (1988b) pp.168-176; Engle, Hendry and Richard (1983).

69. McCombie (1981).

Readers will recall the long series of economists who, following Mendershausen (1938), have argued that the Cobb-Douglas production function reflects an accounting identity. The output elasticities measure income shares, rather than the contribution of L and K to production (Kaldor (1968) p.389; Wallis (1979) pp.48-49; McCombie (1987)).

McCombie (1980) using Kaldor's sample of countries for 1950-1975 compared the contribution to productivity growth of (i.) the productivity growth that would have occurred given uniform employment growth and (ii.) the productivity growth due to the transfer of employment from agriculture to manufacturing. The former (i.) was more important but the contribution of the latter (ii.) in many cases was substantial.

70. Making what I could of Kaldor's (1967) data to construct the series y_{nmt}, I obtained the estimates
(i.) $y_{nm} = 2.8 + 0.7x_m$.
Also
(ii.) $y_m = 2.6 + 1.6x_m$.
Kaldor's estimates of the third "law" were
(iii.) $p = 2.9 + 0.8x_m - 1.2x_{nm}$.
The true value of the constant is 0 and the true value of the regression coefficient on x_m and x_{nm} are about -0.38 and -0.62 respectively.

The bias of the constant in (iii.) comes from
$0 + 0.38(2.6) + 0.62(2.8) \approx 2.9$.

The bias of the regression coefficient in (iii.) roughly comes from
$-0.38 + 0.38(1.6) + 0.62(0.7) = 0.67$
which is not significantly different from 0.8.

71. McCombie and Ridder (1984) p.274; Casetti (1985) pp.318-319.

72. Hildreth (1988-89) pp.287-290.

73. Stoneman (1979) pp.314-315.

74. Vagiago (1975) pp.236-238 ; Turner (1983) p.146; Gomulka (1983), p.390; McCombie (1983) p.418; Chatterji and Wickens (1983) pp.410-411; Michl (1985) pp.483, 485; McCombie (1986) p.1224 confirmed the "law". McCombie and Ridder (1983) p.381 and McCombie (1986) p.1223 showed that the law broke down after 1965.

75. Kaldor (1980) p.229; Thirlwall (1980) p.388.

76. McCombie (1980) p.110; Michl (1985) p.483.

77. Romer (1989) too endorsed this argument (pp.66-67).

78. Thirlwall (1981); McGregor and Swale (1985).

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