Lowe AND THE MARX-FELDMAN-OEBS MODELS: STRUCTURAL ANALYSIS OF A GROWING ECONOMY  

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1. Adolph Lowe - Six Decades of Structural Analysis of Real Capital Formation  

Adolph Lowe's contributions to the theory of the trade cycle were widely discussed among German economists during the period of the Weimar Republic (Cohn 1981). The members of the department for research on trade cycles of the Kiel Institute for World Economics (1926-1933) were internationally recognized as among the most important precursors of the modern theory of employment (Sarrey, 1975) and in the development of modern non-neoclassical capital and growth theory. Besides Lowe, who served as Chairman, such distinguished scholars as Fritz Borchardt, Gerhard Colin, Hans Nieser and, for a period of time, Wassily Leontief and Jacob Marschak were also members of this scientific community.  

After emigrating to the United States Lowe developed his ideas and ultimately produced a theory of cyclical growth, which centered on the structural analysis of real capital formation. Investment holds the key role in economic development because real capital is the central channel through which all other determinants, be they technical progress, changes in labor supply or the exploitation of natural resources, influence the secular process of an industrial system. His prescient role in the construction of models with a strong classical flavor has been widely recognized (see e.g. Clark 1974, 1983, and Walsh and Gram 1980, p. 4) though it has, surprisingly, been neglected by Ching (1980).  

Starting with an article entitled "How is Business Cycle Theory Possible at All?", which was published in German in 1956, Lowe pointed out the necessity for modifying Marx's schema of reproduction, which he later viewed as "the only comprehensive macro-economic model of the industrial process of production established before Keynes" (Lowe 1992, p. 141). This modified version rests on the premise that not all sub-divisions of the productive structure are equally important for the study of particular dynamic processes. Lowe considered Marx's schema also be especially suited for the study of real capital formation - provided that some defects are corrected (Lowe 1995, p. 586). Specifically, Lowe considered it necessary to extend the two-sector (labor goods) model to a three-sector schema, through the splitting up of the equipment goods sector. Thus, one capital goods sector produced the equipment for producing consumer goods and the other produced the equipment for the replacement and expansion of both equipment goods sectors (Lowe, 1928 p. 190).  

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This sub-division of the equipment-goods sectors is relevant for investigating the structural conditions for steady growth and, even more, to address questions of 'traverse analysis' in the two analyses of transition processes there is, in contrast to the traditional steady-state or 'golden age' analysis, no assumption of the proportionate growth of all sectors, so that the problem of structural change is moved to the center of the stage. The decisive problem that the economy confronts upon departing from a steady growth path is the inadequacy of the old capital stock. The necessary adjustment process both requires time and costs, and faces difficulties which arise from dis-proportionates between sectors. During the Soviet industrialization debate in the late 1920s, Feinman formulated the notion that investment-priority for the capital-goods sector was a pre-condition for attaining a high rate of growth. In Lowee's growth analysis the 'machine-tools sector' also plays a key role and altering the proportion of total investment allocated to this sector has great direct and indirect consequences for growth.

The main lesson to be learned from the Lowee-Feinman models is that the speed of the machine tools sector is the decisive constraint which limits the rate of growth in a closed economy. In an economy with a very small machine tools sector it is impossible to move from a lower to a higher rate of investment by heroic sacrifices of current consumption. Structural incapacity to supply enough capital goods will prevent an rise in the saving ratio from being fully transformed into the desired level of investment. The strategic role of the machine tools sector was also confronted by development planners in the fifties and sixties. Countries like India which lack a self-sufficient machine tools sector, face a problem which neither Feinman nor Lowee discusses. Marshalev (1969) has called attention to the problem of technological dependence in cases of structural inability to supply the required capital goods, which must then be imported from other countries. Examination of the structural conditions for steady growth and the adjustments required by dynamic disturbances, must therefore extend to the economy's external balance.

Despite the fact that Lowee's intentions are in many respects the same as Feinman's who wanted to include all activities that increase the capacity of an economy to produce output in one sector there is one important difference. No new post-constituent of machines between the two departments possible in the Feinman model: there is complete rigidity as in most other two-sector models with a fixed coefficient techniques. On the other hand, an essential characteristic of the three-sectoral Lowee model is that it combines transferability with specificity. Occurs an ex post transfer of machines between the two sectors of the equipment-goods group during the traverse. Dott (1963, pp. 40-107) made extensive use of Lowee's 1955 version of the three department scheme not to analyze the process of traverse but to discuss the question of the choice of techniques under planned development.

Our present concern is to make the essential characteristics of a three-sector model explicit with the help of techniques developed by Hicks (1965), Spawetns (1968, 1970) and Harris (1971) for their analysis of the two-sector fixed-coefficient models. We focus on the comparative statics of semi-stationary growth. Detailed comparison of various economies growing on a steady-state path with different allocations of resources prudence for the analysis of the traverse path that corrects two dynamic equilibria defined by different rates of change. This will become clear at the end of our comparative analysis shows us the terminal equilibrium conditions from a structural point of view.
resulting from changes in distribution. For purposes of intersectoral comparisons we have to recognize the dimension of these technologically given machine-labor ratios. Since we compare \(q_1\) and \(q_2\) directly, problems arise with \(q_3\), because a direct comparison with \(q_3\) makes no sense. But, contrary to Nell’s assertion that “the ratios cannot be compared dimensionally unless they are expressed in value terms” (Nell 1975, p. 303) there is a way out of the physical dimension dilemma which results from different types of equipment goods being applied in the production of consumer goods. We only have to reformulate the third machine-labor ratio. Multiplication of \(q_3\) by \(l_2/l_3\) yields \(q_2\) and \(l_2\), i.e., primary equipment goods per unit of labor. As an example, \(q_4\) means that the industry in sector \(n\) must have \(q_4\) units of equipment goods per unit of labor. Thus reformulation of the machine-labor ratio of sector \(n\) offers great advantage when dealing with the quantity system and the price system because machine-labor ratios play a crucial role in the price and quantity equations.

III. Growth Equilibrium: The Quantity System

We go on now to introduce the relations governing output, employment, and accumulation in the Leu model. In competitive equilibrium with continuous, full, and efficient utilization of the available inputs, the total stocks of primary and secondary equipment goods \(F_1\) and \(F_2\) and the total stock of labor \(L\) are adjusted to the technique in use and to the level of output of the three commodities, \(q_1\), \(q_2\), and \(q_3\). The output of the equipment goods provides for growth investment consisting of depreciation. Thus we get the following quantity equations:

\[
\begin{align*}
11(\Delta q_1) + \Delta q_2 &= F_1 \\
22(\Delta q_1) + \Delta q_2 &= F_2 \\
11(\Delta q_1) + 22(\Delta q_2) + L_0 &= L
\end{align*}
\]

Let us normalize the system by considering the ratios of all quantities to total labor employed in the economy:

\[
\begin{align*}
\frac{\Delta q_1}{L} &= \beta_1 \\
\frac{\Delta q_2}{L} &= \beta_2 \\
\frac{\Delta q_1}{L} + 2\frac{\Delta q_2}{L} + L_0 &= \alpha_1 + \alpha_2 + 1
\end{align*}
\]

Note that the seven technical parameters, the machine input coefficients \(a_{11}, a_{12}, a_{22}\), the labor input coefficients \(l_1, l_2\), and the depreciation rate \(\delta\) are given, and the system provides us with three equations in the four unknown variables \(\beta_1, \beta_2, l_1, l_2\), where \(\beta_1\) denotes the output of commodity per unit of labor, \(\beta_2\) the rate of depreciation per unit of labor, \(l_1\) denotes the inflow of fixed capital of type \(1\) per unit of labor. This means that the system of equilibrium relations possesses one degree of freedom and remains open unless one variable is given a predetermined value. To put it another way, once we know either of the four variables then the other three are fully determined. In order to show the possible equilibrium configurations of the system, we take the growth rate as exogenously given and solve for the rest in terms of it.
(4) \( L_{12} \frac{dF_{12}(g)}{dg} = \frac{a_{12}c_{12}h_{12}(d)(g) - a_{12}c_{12}h_{12}(g)}{d_{g}} \)

with \( \frac{d(F_{12}/L)}{dg} = a_{12}c_{12}h_{12}(d)(g) - a_{12}c_{12}h_{12}(g) \)

(5) \( \frac{F_{2}(g)}{\gamma_{2}} = a_{2}c_{2}(d)(g) \) with \( \frac{dF_{2}(g)}{dg} = a_{2}c_{2}(d)(g) \)

(6) \( \frac{F_{1}(g)}{\gamma_{1}} = \frac{a_{1}c_{1}(d)(g)}{\gamma_{1}} \) with \( \frac{dF_{1}(g)}{dg} = a_{1}c_{1}(d)(g) \)

Allocation of Resources

(7) \( \frac{F_{11}(g)}{F_{1}} = a_{1}(d)(g) \) with \( \frac{d(F_{11}/F_{1})}{dg} = a_{1}(d)(g) \)

(8) \( \frac{F_{12}(g)}{F_{1}} = 1 - a_{1}(d)(g) \) with \( \frac{d(F_{12}/F_{1})}{dg} = 1 - a_{1}(d)(g) \)

(9) \( \frac{F_{11}(g)}{F_{12}} = a_{11}(d)(g) \) with \( \frac{d(F_{11}/F_{12})}{dg} = a_{11}(d)(g) \)

(10) \( \frac{F_{11}(g)}{F_{12}} = 1 \)

(11) \( \frac{L_{1}(g)}{L} = \frac{a_{12}c_{12}h_{12}(d)(g)^{2}}{b_{g}} \) with \( \frac{d(L_{1}/L)}{dg} = \frac{a_{12}c_{12}h_{12}(d)(g)^{2}}{b_{g}} \)

(12) \( \frac{L_{2}(g)}{L} = \frac{a_{12}c_{12}h_{12}(d)(g)^{2}}{b_{g}} \) with \( \frac{d(L_{2}/L)}{dg} = \frac{a_{12}c_{12}h_{12}(d)(g)^{2}}{b_{g}} \)

Composition of Production

(13) \( \frac{L_{1}(g)}{L} = a_{12}c_{12}h_{12}(d)(g) \) with \( \frac{d(L_{1}/L)}{dg} = a_{12}c_{12}h_{12}(d)(g) \)

(14) \( \frac{L_{2}(g)}{L} = a_{12}c_{12}h_{12}(d)(g) \) with \( \frac{d(L_{2}/L)}{dg} < 0 \)

Curves (1)-(17) represent comparisons of economies using the same technique but operating under a different growth rate. To each exogenously given rate of growth belongs a special equilibrium structure of the economy. The dynamic progress between one growth equilibrium and another necessarily would involve a change in the whole quantity structure and - as Lloyd (1976) shows - surely would not be carried out in terms of the equilibrium relations (1)-(17), which represent curves on which one cannot move in historical time.

*To move, to change outputs, means investing, because the system cannot change output unless it first changes inputs. Yet to change inputs is to change the input-producing sectors. The system itself determines its own capacity for changes the capital-goods sector must provide the goods necessary to change the inputs to produce the new pattern of output. In turn, it is implied that the capital-goods sector must produce different goods, or deliver them to different investors, than it did previously. Moreover, this change will necessarily entail shortages and/or surplus capacity in some parts of the economy, relative to their previous full capacity utilizations."* (Lloyd, 1976, p. 308)

Obviously, the size of the output-maximizing ratio in sector 1 places an important upper limit upon the rate of growth achievable. The maximum rate of growth is given by

\[ g_{\text{max}} = \frac{1}{a_{12}} \]
which is a technological datum given by the technique, i.e., independent not only on relative prices but also of the output-machine ratios of the other two sectors. Of course, \( v_{0,11} \) is a theoretical ceiling which is economically irrelevant, because the whole system would only produce primary equipment goods, i.e., the relative shares of sectors 2 and 3 would be zero.

Equation (1) exhibits the well-known, monotonically inverse consumption-growth relationship providing an essential framework for Lavoie's analysis, for it shows the various possible 'dynamic' equilibria between which a country may take place. The identity of equations (17) and (6) reflects the fact that with steady growth the composition of investment is the same as the composition of the capital stock. Furthermore, one can see that the economy with the higher growth rate

a) has a greater outfit per capita with primary equipment goods or machine tools which are used in sector 1 (eq. 5)

b) has a smaller outfit with secondary equipment goods (5), and a greater relation between stocks of primary and secondary equipment goods (5),

c) uses a higher percentage of its primary equipment goods in the key sector 1 than in sector 2 (eq. 9), and

d) uses a higher percentage of its labor force in the production of primary equipment goods (13), also in relation to the production of secondary equipment goods (13), and uses a lower percentage of its labor force in the production of consumer goods (14).

e) The composition of production is such that the economy with the higher growth rate produces relatively more equipment goods than consumer goods (15, 16) and relatively more equipment goods of the primary type (17). Equations (6), (9), (13) and (17) are reflecting the fact that the contradiction between consumption and accumulation manifests itself in the proportion between the two sectors producing means of production.

But some open questions remain, which all have to do with the specific Lavoie-sector 2. The indeterminateness of equations (6) and (12) reflects the characteristic position of sector 2 as the bridge between the basic sector 1 and the consumer goods sector 3. The reason for this indeterminateness is evident. Sector 2 participates with lower percentages (8 and 13) in a bigger cake (2a and 14). The higher the growth rate the higher is the weight of sector 1 and the lower the weight of sector 3-no doubt about that, but the weight of sector 2, using inputs produced in sector 1 and producing equipment goods used in sector 3, is influenced by both these factors with no unique result.

IV. Income Distribution and the Price System

We go on now to introduce the relations governing wages, profits, and relative prices in the Lavoie model. Competitive equilibrium in a capitalist economy implies that firms obtain the same rate of profit on the value of invested capital. In any period, the equilibrium conditions for the price system are such that the price of a unit of output

\[ \frac{d z}{d r} = \frac{A + B}{B} \]

exactly covers its cost of production, equal to wages which are paid at the end of the period plus gross profits consisting of depreciation and net profit. Thus we get

\[ \frac{d z}{d r} = \frac{A + B}{B} \]

on choosing the consumption good as the numeraire commodity the following price equations:

\[ a_{11}(d z/d r) p_1 + w_1 = p_1 \]

\[ a_{12}(d z/d r) p_2 + w_1 = p_2 \]

\[ a_{22}(d z/d r) p_2 + w_1 = 1 \]

Note that like the quantity system the price system gives us three equations in the four price variables \( w_1, r_1, \text{and} p_2 \), where the prices of primary and secondary equipment goods, \( p_1 \), and \( p_2 \), are relative prices and the wage rate \( w \) and the rate of profit \( r \) expressed in units of the consumption good. The price system may be closed through e.g., a substitution wage theory of a 'central' bank theory of the rate of profits' (see Saffa 1968, pp. 33). The equations yield the following unique relationships between the rate of profit, on the one hand, and the wage-rate and relative prices, on the other, all fully identified by the given coefficients of the technique.

\[ w = \frac{1 - 2a_11(d r)}{1 - 2a_11(d r) + 2a_12(d r) + 2a_21(d r) + 2a_22(d r)} \]

with \( \frac{dw}{dr} < 0 \)

\[ p_1 = \frac{1}{r} \]

with \( \frac{dp_1}{dr} = - \frac{1}{r^2} \left( a_{11} - a_{12} \right) \frac{d r}{d r} \]

\[ p_2 = \frac{1}{r} \left( a_{11} - a_{12} \right) \frac{d r}{d r} \]

with \( \frac{dp_2}{dr} = \frac{1}{r^2} \left( a_{11} - a_{12} \right) \frac{d r}{d r} \]
\[
(21) \quad \frac{dP_1}{dP_2} = \frac{1}{L^2 \Delta (a_1 - 1) \Delta (a_2 - 1) \Delta (a_3 - 1)}
\]

with
\[
d(P_1/P_2) = \frac{1}{L^2 \Delta (a_1 - 1) \Delta (a_2 - 1) \Delta (a_3 - 1)} \left( -\frac{1}{2} \right)^{- \frac{1}{2}}
\]

for \( a_1 < a_2 \).

Curves \((18)-(21)\) represent comparisons of economies using the same technique but operating under different distribution patterns. The prices of production are uniquely determined by technology and the given distribution of net output, and are independent of the level and composition of output. The wage-profit relationship \((18)\) turns out to have exactly the same parametric form as the consumption-growth relationship \((1)\), with the rate of profit in the place of the growth rate and the wage rate in the place of consumption per capita, so that the two corresponding curves are the exact replica of each other. But it is a characteristic feature of the Lowve model that in contrast to the common two-sectoral or multi-sectoral (see Raifon 1977, pp. 199-208) models duality ceases as soon as we compare the relationships between prices and the rate of profits, \(p_1/p_2\) and \(p_2/p_3\), with the relationships between quantities and the rate of growth, \(q_1/q_2\) and \(q_2/q_3\).

Now we must consider how prices vary with the rate of profit. Looking at system \(III\) we can see that there are two elements in the price of each commodity which vary in opposite directions with differences in the monotonically inverse w-r relationship. Since Sraffa we know that the key to the movement of relative prices lies in the inequality of the proportions in which labor and means of production are employed in the various industries. With different sectoral machine-labor ratios restoring a uniform rate of profit in the three sectors requires different relative prices. In the Lowve model the sectoral machine-labor ratios \(q_1, q_2,\) and \(q_3\) play the crucial role for fixing direction and extent of these price differences associated to different rates of profit.

Looking at Table 1 reminds us that there exists one exception of the general rule that prices depend on distribution. It is the famous Ricardo-Mills-Samuelson case of equal organic composition of capital which is the Lowve model takes the form \(q_1 = q_2 = q_3\).

In this case only all three prices are using directly (sector n) the same ratio of primary equipment goods per unit of labor. Prices reduce to
\[
P_1 = \frac{1}{1 + \alpha} \quad P_2 = \frac{1}{1 + \beta} \quad P_3 = \frac{1}{1 + \gamma}
\]

thus, the labor theory of value holds in this special case which marks a watershed between all other cases.

As long as primary equipment goods are produced with the highest (lowest) ratio of primary equipment goods per unit of labor machines are relatively more (less) expensive than tractors or corn when the rate of profit is higher. The first derivation of equation \((19)\) only becomes indeterminate when \(q_2\) is in the middle position between \(q_2\) and \(q_3\).

Table 1

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Table 1 reminds us that open questions in the quantity system only arise in connection with the specific Lowve-sector 2 in considering how \(p_2\) varies with the rate of profit we can now see that numerous open questions exist. They always appear when the corresponding machine-labor ratio \(q_2\) is the lowest (cases 2, 3, 4) or highest (cases 8, 9, 10) one. Clear results emerge as soon as the machine-labor ratio of this sector 2 operates as the bridge between sectors 1 and 3 is also in the middle position.

Whereas \(p_1\) and \(p_2\) depend on the technical coefficients of the consumer goods sector (only a consequence of our choosing the consumer good as the numerate commodity since good n is a non-basic) their relation does not. No open question arises concerning the sign of the first derivation of equation \((21)\). The price relation \(p_2/p_3\) moves directly with the rate of profit if \(q_1, q_2\) and inversely if \(q_3, q_2\), i.e. the relation of the sectoral machine-labor ratios is decisive.

V. Saving, Income Distribution, and Capital Accumulation

Up to now the two systems of price and quantity equations were considered as independent of each other, although only for didactic reasons. As is well known, the postulation of a savings function in connection with his Keynesian equilibrium condition of saving-investment equality constitutes a relationship between the rate of profit and the growth rate. There remains one degree of freedom in the whole systems given either the growth rate or the rate of profit, all price and quantity variables as well as the combined price - quantity variables like the capital-output or capital-labor ratios are then simultaneously determined.

Choosing a Kalidans savings function, not savings per unit of labor equal
\[
(22) \quad S/L = \alpha \omega \omega^2 \beta (p_1 p_2)^{p_1} p_2^{p_1} p_2^{p_2},
\]

where \(\omega_1\) and \(\omega_2\) denote the propensions to save from wages and profits.
with
\[ 1 \geq s_p > s_w \geq 0. \]

Net investment per unit of labor is

\[ I/L = g(p, t, r, s_p, s_w). \]

Thus we get the following r-s relationships

\[ r = \frac{g}{s_p} - \frac{s_w}{s_p} \]

Alternative assumptions concerning saving behavior provide a direct link between income distribution and capital accumulation. When there is a saving behavior for different categories of income, the r-s relationship depends on the behavior with \( s_w \geq 0 \). In the special case of "classical" saving behavior, \( s_w = 0 \).

The growth-profit relation is independent of the technology. Our formulation of equation (24a) reflects the fact that there exists a two-sided relationship between profits and investments. Therefore, with view of "classical" formula (24a) is more neutral than is determined by the natural rate of growth divided by the capitalists' propensity to save, to work with low special case of a "classical" savings function, i.e., \( s_w = 0 \).

6. Traverse Structural Analysis and Adjustment to a Higher Rate of Growth of Labor Supply

Lowry's structural analysis underlies the traverse from one natural rate of growth to another in which the capacity augmenting role of investment is at issue. Since Herrod investment must fit together. Lowry puts the whole strain of adjustment on the savings ratio.

In general, the natural rate of growth consists of two components, the rate of growth of labor supply and the rate of growth of productivity. We are dealing here only the growth of labor supply. The adjustment process of an economy which experiences an expected higher rate of growth means that in the new one compare economies which use the same techniques but operate under a different growth and profit rate. Thus we prepared for the traverse analysis in this section on the assumption that we know the different outflow with consumer and equipment goods, the allocations of resources, and compositions of production in the old and in the new steady state. Furthermore, we know that the ability of an economy which is reacting to a change in the exogenously given growth rate of labor is limited by the quality and structure of the existing capital stock which has now become partly inappropriate. It is obvious that the formation of a complementary addition to real capital is the essential precondition for reaching the final equilibrium in which absorbing the additional increment of labor is absorbed and all new workers are provided with consumption goods. Since the balanced capital stock composition differs between the final and the initial equilibriums the three sectors are growing at different rates on the adjustment path which can be subdivided into four phases.

1. The key to a higher growth rate lies in increasing the shares of sector 2. The same logic requiring that the system as a whole first has to change inputs before it can change output makes such an increase dependent on the prior expansion of capital stock of this sector. At this place a characteristic property of the Lowry model comes into play, i.e., that sectors 1 and 2 are using the same type of equipment goods so that an export transfer of machines between these two sectors is possible. In the case of a rising rate of growth the proportion of machines devoted to making primary equipment goods during the first phase of the adjustment process. Since this intersectoral shift leads to a reduction in the growth rate of output of secondary equipment goods, it is necessary. Obviously, the cost of increasing this growth rate of consumption in the long run through increasing \( s_2 \) are greater the higher is \( s_2 \).

2. Lowry's path criterion of maximum speed of adjustment requires that up to the point of maximum expansion from within all savings have to be invested in the key sector producing primary equipment goods to initiate the process of self-saturation. At the end of this second phase of the adjustment process the terminally required addition to capital stock \( s_2 \) is accomplished and the original level of employment is restored. Once the labor force operating in the initial dynamic equilibrium has been brought back into employment, aggregate output at the point of maximum expansion from within equals the original output in value terms. Lowry (1970, p. 130) "This does not have to hold for the relative size of the sectors and, thus, for the physical composition of production. The shares of sector 1 have increased."

3. The third phase of the traverse is characterized by the adjustment of the capital stock of sector 2 to the higher rate of growth. In the last phase consumption output adjusts. When the new steady state is reached all sectors will expand with the same rate, the new and higher growth rate of the labor force.

During the traverse there are not only sectoral corrections in quantities but also in prices. Disequilibrium manifests itself in price changes and in non-uniformity of the sectoral profit rates. This divergence of the sectoral profit rates is a strong incentive for the whole adjustment process, which is completed when the rate of profit has reached its new uniform level. From equations (19) to (21) we know that the system of relative prices in the new steady state differs from that in the old one according to the different rate of profit, except in the Lowry-Samuelson case where relative prices are independent of the rate of profit.

The range of Lowry's traverse analysis is limited by the fact that he works throughout with the assumption of identical machine-labor ratios. His statement that...
perfect substitutability of the capital stocks in the two equipment-goods sectors makes it possible to "shift" of factors between the two subsectors of the capital-goods industry (1976, p. 97) to be modified as soon as \( q_1 > q_4 \). Despite the fact that sectors 1 and 2 are using the same type of equipment goods; the transfer of resources between these two sectors a major problem poses which Lowe eliminates through his special assumption. This will become immediately clear from our simple example.

Since \( q_1 > q_3 \), a shift of machine tools from sector 2 to sector 1 unambiguously sets free greater amounts of labor relative to primary equipment goods in sector 2 than can be absorbed by using the same machines in sector 1. Thus, the employment problem is aggravated in this case. Working out Lowe's traverse analysis for the non-Samuelson case is thus clearly an important field for future research.

Lowe's instrumental analysis is considerably richer than our rather technocratic structure analysis, which is only preliminary to a more force analysis. In contrast to Feldman and Dobb, force analysis plays a central role in his work because his special interest is to analyze traverse processes in free market systems. His force analysis reveals the significance of a functioning price mechanism (which is in no sense a mechanical apparatus) for an efficient traverse and highlights that, in general, measures of public control become inevitable, especially with investment decisions. Lowe's political economy which conceives the attainment of full employment as inseparable planning in a mixed economy which has achieved economic maturity.

Estimates

Instead of an economy facing this "Feldman constraint" on the investment capacity side there can exist the reverse possibility of an economy facing the "Prestininsh constraint" posed by the consumption side. If, e.g., the initial capacity of the equipment goods industry is sufficient only to replace the depreciated machines growth can only reduce in the output of consumer goods. If this reduction is impossible because of subsistence reasons then a condition was newly fulfilled in early Soviet Russia.

Of course, there are some other differences like Feldman's Lewis type assumption of an unlimited supply of labor.


Our analysis therefore has some affinity to Nell's alternative presentation of Lowe's basic model (1976) although differing in the way of reasoning and in some results. The main point of departure from Nell's interpretation is that in our analysis only good 1 is a basic product whereas Nell's translation of hours of labor into amounts of the consumption good translates also the other two goods into basics. Both interpretations are compatible with Lowe's equilibrium analysis in Part I (especially pp. 37-40) where he points out that "we need not fall back upon the classical hypothesis that labor should be treated as if it were produced by the 'input' of consumer goods" (Lowe 1976, p. 35). However, Nell's interpretation is not compatible with Lowe's traverse analysis where Lowe makes pretty clear that there is a strong hierarchy of sectors in his model containing only one basic product, so that e.g., a pure labor-displacing innovation in the consumer-good sector creates no secondary effects for both equipment goods sectors (Lowe 1976, Chapter 24).

The assumption that the rates of depreciation of the fixed capital goods are given coefficients in the list of parameters of the system implies that the economic lifetime of each capital good is a constant determined independently of distribution. This assumption of 'depreciation by evaporation' or 'radioactive decay' is as essential to Samuelson's demonstration of the existence of a surplus production function as is the assumption of identical machine-labor ratios in each sector. This 'equal proportions' assumption suffices to make the value of a new machine independent of \( w \) and \( r \) but it does not suffice to make the wage-profit relationship linear and the price of an old machine being independent of \( w \) and \( r \) (see Sassman 1979). An adequate treatment of the economic lifetime of fixed capital goods with different efficiency profiles requires a von Neumann-Morois approach. See Hagemann and Kurz (1976) who also show that the return of the same length of the production process and reshifting of techniques are closely linked phenomena. Our analysis therefore has some affinity to Nell's alternative presentation of Lowe's basic model (1976) although differing in the way of reasoning and in some results.

Nell's deviation result that \( p_1/p_2 \) depends only on the machine-input coefficients and not on the labor-input coefficients of sectors 1 and 2 rests upon a mistake in the numerator of his formula (Nell 1976, p. 380) for the first derivation of our equation (31) which correctly must read \( B_1(p_1/p_2) = B_2(p_1/p_2) \) in the Nell notation so that the relation of \( a_{12}/a_{21} \) to \( a_{11}/a_{22} \) and not \( a_{11}/a_{22} \) decides on the sign of the first derivation of the price of the two equipment goods.

This traverse problem was first analyzed by Hicks in Chapter 16 of 'Capital and Growth' (1950) on the basis of a two-sectoral fixed coefficient model whereas in 'Capital and Time' (1977) Hicks analyses the problem of a traverse caused by a change in technology on the basis of a neo-Austrian model. To a detailed comparison of 'Hicks' more recent traverse analysis with Lowe's analysis of traverses caused by nonneutral innovations in Part IV of his 'Path of Economic Growth' see Hagemann (1985).

Since this process requires time the expansion of the capital stock has to be large enough to absorb not only the permanently increased period flow of labor but also the intermediate store of idle labor that accumulates during the construction of the additional machines.
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ECONOMIC PLANNING AND ADOLPH LOWE'S ECONOMIC PERSPECTIVE

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Introduction

Two pioneering articles written during the 1950s by Adolph Lowe (1952) refer to the need for the "practical purpose of planning" (1952, p. 581) for a medium-level of disaggregation between the macro-planning models of the Harrod-Domar-Kalecki type and the inter-industry analysis of Leontief. It is too difficult to trace out the growth path of a large number of variables when each is simultaneously exposed to several stimuli. He proposed a creative development of Marx's expanded reproduction analysis with a division into Department Ia (machines to produce machines), Department Ib (machinery to produce consumer goods, such as textile looms) and Department II (final consumer goods) (1952, pp. 133-55 and 1976, Part I). We will later illustrate the practical importance of this approach by showing how it helps us to understand some problems in the recent development of China.

Lowe held that the problems elucidated in his structural model of production would arise in both individualist and collectivist economic organizations (Lowe, 1955, p. 582), since the specificity of the technical structure of the given stock of real capital creates key planning problems for both systems because it affects the adjustment processes through which capital formation occurs - the links between successive stages of growth (1955, p. 585).

Planning must take into account the individualities of the capital stock itself since the approach emphasizes that key variables such as "investment" or "consumption" must not be looked at solely as value aggregates "to the exclusion of the technical-physical properties which attach to them in an industrial system" (1954, p. 139).

Lowe focused attention on the machine-tools sector, as an example of the category "capital goods for producing more capital goods", in contrast with capital goods intended directly for the consumer goods sector (like textile looms). The "machine tools" sector has the peculiar ability to initiate and sustain a circular production process of its own (1952, p. 138 also see Lenin 1953, p. 130; Dobb, 1956) and thus not to be determined by the previously existing structural relations (Lowe, 1952, p. 155 and Dobb, 1960, Ch. IV). However, Lowe reminds us (1952, p. 146-55, 1955, pp. 587-93) that this sector is dependent on inputs of intermediate goods which could slow its rates of growth over a period of time. Imports to supplement the domestic output of capital goods could, however, relieve such bottlenecks, at least for a time (1955, p. 592, Sachs and Lenin, 1971).

Besides these suggestions for a simple, but powerful, theory of the structural aspects of economic change, Lowe provides as a complementary part of his analysis, a systematic account of how economic agents behave (1949). Taken together these provide a picture of the structural economic interdependence of a growing economy, whether

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