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John C. H. Fei

Gustav Ranis

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# TECHNOLOGICAL TRANSFER, EMPLOYMENT AND DEVELOPMENT (REVISED)

J.C.H. Fei

Gustav Ranis

August 1, 1969

# Technological Transfer, Employment and Development*

It is generally agreed that one of the most important factors shaping the course of development in the typical less developed country (LDC) is its coexistence with developed countries (DC's) and the possibility of technological transfers from the latter to the former, induced by the presence of a so-called technology gap. In practical terms, such transfers result in a modification of the ways in which the developing economy's labor force is utilized in the course of development and are likely to induce major changes in the output and employment performance of the system. Our purpose in the present paper is to attempt an analysis of technological transfer, and LDC employment and output generation, in the context of a fairly general growth-theoretic framework.

The dimensions cited of course go to the heart of the so-called LDC unemployment problem. Whether open or disguised, unemployment is a quantitatively significant phenomenon in most contemporary LDC's, and is exacerbated and accentuated even in areas with a relatively less unfavorable initial resource endowment by continuing population pressures. It is an empirical fact that unemployment has been on the rise in the developing world, including in countries which have had a fairly satisfactory growth performance over the last two decades. For example, Arthur Lewis found that open unemployment rates in Jamaica during the 50's stayed up while real output doubled.[1] Professor Turner concluded that "in a group of 14 less developed countries for which there are

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*John C.H. Fei and Gustav Ranis. The authors are Professors of Economics, Yale University.

[1] W. A. Lewis, Development Planning, (New York: Harper & Row, 1966), p. 78.

usable unemployment series back to the late 1950's, the total of known unemployed has since been growing at an average of 8 1/2 per cent a year."[1] Moreover, even if we were successful in curbing LDC population growth as of today, the developing world would have to face the political and social, as well as the economic, consequences of a formidable labor force explosion well into the '80's. Small wonder that development economists and practitioners alike are becoming increasingly concerned with this problem.[2]

In spite of this concern, we've made relatively little progress towards a positive theory of unemployment for the developing world--mainly because it is a relatively complicated phenomenon, centrally related to both capital accumulation and technological change.[3] While capital accumulation can be traced to the conventional sources of saving and investment, the causation behind technological change includes not only the aforementioned transfer of technology from abroad, but also the even more complicated innovative response and learning processes within. In Section I we shall discuss the conventional capital accumulation dimensions of the problem and its relationship to unemployment. Sections II and III will be devoted respectively, to an analysis of the technological transfer and learning

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[1] H. A. Turner, Can Wages by Planned, paper prepared for the Conference on The Crisis in Planning, Sussex, June/July 1969, p. 7.

[2] See, for example, W. Arthur Lewis, Development Planning, op. cit.; W. Baer and M. Hervé, "Employment and Industrialization in Development Countries," Quarterly Journal of Economics, February 1966; "Employment in Less Developed Countries: A First Look at the Size of the Problem", OECD Development Center, preliminary, April, 1969; and recent work by the ILO, UNIDO and AID.

[3] This contrasts sharply with the highly developed theory of unemployment for the mature economy in the Keynesian tradition. The essence of the Keynesian theory is that unemployment results from an excess of productive capacity relative to aggregate demand; such a theory is clearly irrelevant to a developing country where, as we shall show, unemployment occurs because the productive capacity is too small relative to aggregate demand.

dimensions of the problem. An integration of these facets into a comprehensive deterministic model will be attempted in Section IV. The applications of the model are discussed in Section V and its relevance tested against Japanese historical data in Section VI.

## I. Capital Accumulation and Unemployment

It is intuitively obvious that unemployment in an LDC can occur simply because of the inadequacy of the capital stock to absorb the available labor force. A rigorous statement of this idea is due to Eckaus[1] who first formulated the concept of "technical unemployment." In Diagram 1a, let labor (capital) be plotted on the horizontal (vertical) axis and let the L-shaped production contours be shown with the "technology line" OT. Now suppose the factor endowment is at point $E_o$, below the technology line. Then technical unemployment a la Eckaus of $U_o$-units occurs. This is due to the assumed essentially complementary nature of K and L, i.e., technical unemployment occurs because the existing capital capacity of $K_o$ units can accommodate only $M_o$ units of labor. Hence unemployment is induced by a shortage of capital stock.

Introducing the time dimension, it follows rigorously from the above that technical unemployment can be eliminated through time only when K is growing at a faster rate than L. If we then let time (t) be plotted on the vertical axis (downward) and on the horizontal axis (to the left), we can denote the population growth path (in the 4th quadrant) and the capital growth path (in the 2nd quadrant). With the

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[1] Richard S. Eckaus, "The Factor Proportions Problem in Underdeveloped Areas," American Economic Review, September 1955.

aid of the 45-degree line in the third quadrant, we can then determine the endowment path $E_o$, $E_1$, $E_2$ ...in the contour map. It is obvious that the endowment path will bend toward the technology line if and only if K expands at a faster rate than L. In fact, if this continues over a long enough period of time, the endowment path will intersect the technology line at a turning point "T". At that point technical unemployment, having fallen from $U_o$ to $U_1$ to $U_2$..., will have been eliminated.

It is easy to provide an algebraic solution to the above. Let the population grow at a constant rate "r",[1] and let a Keynesian average propensity to save "s" be postulated. Let the capital and labor coefficients of the unit contour (i.e., that contour which produces one unit of output) be k and n, respectively, as shown in Diagram 1. Thus, letting $\eta_x = dx/dt/x$ stand for the rate of growth of "x", we have

1a) $\eta_L = r$ (constant population growth rate)

b) $I = sQ$ (saving function)

c) $dK/dt = I$ (investment as the increment to capital stock)

d) $Q = K/k$ (k is the capital-output ratio)

e) $N = Q/n$ (n is the labor coefficient and N the <u>employed</u> labor force)

f) $U = L - N$ (technical unemployment).

Now suppose we know that the initial endowment point is at $E_o$ (with $L_o$ units of labor and $K_o$ units of capital), below the technology line. Since capital is "the" bottleneck factor, the Harrod-Domar model applies.[2] We can then determine the time path of K, Q and N, and of K/L, the endowment path:

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[1] Exogenously determined; an endogenous population theory could be easily accommodated.

[2] Notice that (1b, c, d) make up the familiar Harrod-Domar framework.

$$\left.\begin{array}{lll} \text{2a)} & n_K=s/k & (\text{or } K=K_o e^{(s/k)t})\text{-----------from} \\ \text{b)} & n_Q=s/k & (\text{or } Q=Q_o e^{(s/k)t};\ Q_o=K_o/k)\text{------} \end{array}\right\} \text{1b)c)d}$$

$$\begin{array}{lll} \text{c)} & n_N=s/k & (N=N_o e^{(s/k)t};\ N_o=Q_o/n)\text{-----from (1e)} \\ \text{d)} & n_{K/L}=s/k-r; & (K/L=\frac{K_o}{L_o} e^{(s/k-r)t}\ \text{--------from (1a,2a)} \end{array}$$

Since the slope of the technology line OT is k/n, the turning point (at T) occurs when the K/L (in 2d) is equal to k/n, i.e., when

3) $$k/n=(K_o/L_o)e^{(s/k-r)t}$$

or the endowment path intersects the technology line. Solving for "t", the time it takes to eliminate the technical unemployment, we have:

4) $$t=\frac{1}{s/k-r}\ \ln(k/K_o/n/L_o) \quad (\text{for } k/n > K_o/L_o)$$

From this equation, we can see the logic of the determination of the extent of unemployment in the context of growth as well as other significant indicators of growth performance, e.g., whether or not a termination point will, in fact, ever be reached;[1] the nature of the per capita income growth path;[2] the time path of the "extent" of employment which we may define as N/L;[3] and the time path of U, the amount of unemployment.[4]

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[1] From (4) we see that a positive solution to "t" exists if and only if $s/k > r$, i.e., $n_K > n_L$.

[2] From 1a and 2b we see that the rate of growth of per capita income (Q/L) is s/k-r. Hence a country can achieve continuous increases in per capita income if and only if it is able to eliminate unemployment in a finite number of years (see footnote 1).

[3] The constancy of the slope of the technology line implies that the amount of employment N is growing at the same rate as capital K. Hence the extent of employment N/L is growing at the same rate as per capita income.

[4] Significant questions can be raised with respect to whether U declines monotonically or first increases before it declines toward zero at the turning point. By differentiating U (in 1f) with respect to t, it can be shown that the time path of U is inverse U-shaped if and only if $N^*_o(s/k) < r < s/k$ where $N^*_o$ is the initial extent of employment. On the other hand, if $r > s/k$ the absolute amount of unemployment increases monotonically, and if $r < N^*_o\, s/k$ it decreases monotonically.

The above Eckaus-related formulation of technical unemployment postulates a fairly rigid relationship between the aggregate capital stock and aggregate employment and thus undoubtedly exaggerates the extent of technological complementarity. However, it does serve to emphasize the technology and growth-relevant nature of the unemployment problem in the LDC's. Our own formulation below, will seek to soften this rigidity by emphasizing that the relationship between capital and labor is, in fact, continuously modified under the impact of technological change.[1]

## II. The Transmission of Technology

As we have just pointed out, a major shortcoming of the above view of the world is the assumption of the constancy of technology. Most development theorists and empirical workers will readily agree that modernization involves much more than physical resource augmentation a la Harrod-Domar but is deeply affected by qualitative changes, especially changes in technology.[2] The basic notion of technological transfer is based on the recognition that a major source of technological change in the developing world derives from the importation of technology from the advanced countries. This basically sound notion of long standing[3] is often paired with the idea, which we also accept, that the blessings

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[1] The sharp distinction between complementarity and substitutability along a static production function becomes muted when, as in our case, continuous technological change is admitted.

[2] S. Kuznets, Six Lectures on Economic Growth, (Glencoe, Ill.: Free Press, 1960) and R. M. Solow, "Technical Change and the Aggregate Production Function," RES, August 1957, for example.

[3] Thorstein Veblen, "The Opportunity of Japan" in Essays in our Changing Order (New York, 1934).

flowing from such technological transmission are not unmixed; for the so-called "modern" technology has been developed in the capital-rich, labor-scarce mature economy and is not necessarily appropriate to the factor endowment of the borrower. Instead of generating employment, it may, in fact, create additional unemployment. This problem lies at the crux of the controversy concerning the so-called output vs. employment effects of adopting alternative technologies.[1] Finally, once we accept the possible dangers of an indiscriminate transplantation of technology, we are driven to the recognition that the truly significant aspect of such a transfer may well lie in its catalytic effect in terms of domestic innovative processes. It is the adaptation of imported technology to the existing factor endowment, illustrated by the case of historical Japan[2] which lies at the heart of the matter. Let us now proceed with a more rigorous formulation of these intuitive ideas, building on the foundations of the simple growth model already presented.

First, we introduce the notion of a technology shelf, developed and perfected in the mature economies, from which the developing countries are free to borrow. We have earlier chosen to describe a particular technology by an L-shaped unit contour--defined rigorously by a pair of input coefficients $(k,n)$. A technology shelf may then be represented by a set of unit activities $(k_o, n_o)$, $(k_1, n_1)$, $(k_2, n_2)$...as represented

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[1] W. Galenson and H. Leibenstein, "Investment Criteria, Productivity, and Economic Development," LXIX (Aug. 1955), 69, 343-70; G. Ranis, "Investment Criteria, Productivity and Economic Development: An Empirical Comment," Quarterly Journal of Economics, Vol. LXXVI, May 1962; and J.C.H. Fei and G. Ranis, Development of the Labor Surplus Economy: Theory and Policy, Irwin, 1964.

[2] G. Ranis, "Factor Proportions in Japanese Economic Development," American Economic Review, September 1957.

by the points $A_o$, $A_1$, $A_2$,...forming a smooth envelope curve in Diagram 2. An LDC at any point in time is then in a position to borrow a particular unit activity from the shelf. This view of technological transfer immediately raises two questions: (1) how does the shelf come about? and (2) by what rules does an LDC borrow from it?

With respect to the first question, the technology shelf contains technologies which have been demonstrated to be feasible in the mature economies either at present or at some historical point in the past. We may thus view $A_o$, $A_1$, $A_2$,...as the actual technology of different historical vintages (e.g., $A_o$ in 1900, $A_1$ in 1920, and $A_2$ in 1930...) prevailing, say, in the U.S.[1] Thus as we move upward along the shelf, we run into more modern technology, i.e., that of more recent vintage. This is represented by an ever increasing capital per head (k/n) (i.e., steeper radial lines $OA_o$, $OA_1$, $OA_2$...) signifying that a typical worker has learned to cooperate with more units of capital goods in a society with increasing technological complexity.[2] As a result of the gain in proficiency in this sense labor productivity increases (i.e., n decreases). This is shown by the negatively sloped rectangular hyperbola (1/n) in Diagram 2b, the height of which indicates labor efficiency (approximated by labor

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[1] In the realistic world, there exist, of course, other technology exporting countries (e.g., Western Europe, Japan...) whose historical experience would also be summarized on the shelf. The same sequence may or may not occur in different historical time periods for each such country.

[2] Thus, to us, in a historical sense, a capital deepening process is much more complicated than "homogeneous labor being equipped with more units of homogeneous capital goods" and is virtually inseparable from increasing technological complexities being mastered by better labor in a learning process. This historical interpretation of our unit contour (i.e., the technology shelf) should be sharply distinguished from the unit contour of a static production function as ordinarily encountered in production theory.

productivity) for the corresponding unit technology vertically lined up in Diagram 2a. According to this historical view of the technology shelf, labor is not a homogeneous entity and the improvement of the quality of labor, through education or learning by doing, is essential for the society to master a more advanced state of technology.[1]

The historical experience of every mature economy, e.g., the U.S., Germany, etc. can be viewed in this way, as demonstrating the existence of a particular technological shelf available for borrowing. Statistically, such a shelf can be constructed from the time series of labor productivity p(t) and capital-output ratio k(t).[2] In case the capital-output ratio rises with increasing labor productivity--which is the "normal case"--the shelf is negatively sloped; otherwise it is positively sloped. Since there are many mature countries, the typical LDC is faced with a multiplicity of such shelves. However, since historically there has been continuous technological transfer among the mature countries it is not unreasonable to postulate the existence of a single technological shelf for the entire mature world, with both contemporary and past vintages represented. The much discussed technology gap between two mature economies at any point in time may then be interpreted as the gap between the currently in use technology of any such pair of countries. As far as the LDC's are concerned they simultaneously face a range of technology in contemporary use across the mature countries as well as all relevant historically experienced technologies.

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[1] Thus the change of quality of both K and N over time are, to us, essential facets of growth and hence rigorously, our model belongs to the family of vintage models. The technology shelf is thus _not_ a production function in the ordinary static sense.

[2] These problems have been studied fairly exhaustively, both on theoretical and empirical grounds by such people as Solow and Kuznets, _op. cit_.

The above notion of an increasing skill level of the labor force in historical perspective can be depicted in Diagram 2c, with time measured on the horizontal axis (to the left). Let the improvement of the quality of labor through time be depicted by the labor progress function, given exogenously as a historical reality in the mature economy. On the vertical axis we measure p=1/n, labor productivity as a proxy for the level of labor efficiency or labor quality. Diagram 2abc thus serves to show that the improvement of labor efficiency through time enables workers to cooperate with more and more capital goods per head, describing a society reaching ever higher levels of technological complexity.

In short, the technology shelf came about as a consequence of the historical growth experience of the industrially mature economy, involving changes in the quality of labor as well as in technological complexity. When an LDC tries to borrow from this shelf in an efficient fashion it must be respectful of the same basic discipline. In other words, a wise borrower is constrained by the education and skill attainment levels of its own economic agents. Consequently, the progress it is capable of making in improving indigenous skill and education levels really constitutes a basic constraint on its rate of progress. It is with this understanding that we approach the analysis of the rules of borrowing.

## III. Education and Technology

It is clear that the customary sharp contrast between an industrially mature and a developing country is due primarily to the existence of a wide technology gap between them, and that the typical LDC, and aid givers abroad, are busily trying to narrow this gap by means of technological transfers. When a technology shelf as defined above is postulated the phenomenon of continuous technological transfer may be depicted as the "climbing upward over time along the technology shelf" so that, through time, the unit technology representative of a more recent vintage $A_o$, $A_1$, $A_2$... (Diagram 2a) will be absorbed by the borrower. However, since, simultaneously, the industrially mature economy will presumably continue to move along its own historical trend of continuous technological change and capital deepening, the technology gap will be narrowed if and only if the LDC can effectively absorb newer (i.e., more capital using) technology at a sufficiently fast rate. It follows that the rules governing effective technological transfer must be closely scrutinized.

The historical experience of the mature economy--as analyzed in the last section--strongly suggests that what determines the rapidity of technological borrowing by the LDC is the skill level necessary for the mastery of an increasingly modern technology. This may be broadly interpreted to relate to the level of labor efficiency, and of public and private entrepreneurial skills which are themselves gradually enhanced in the course of development. Consequently, using Diagram 2 now for a somewhat different purpose, the exogenously given labor progress function of Diagram 2c may now be interpreted as that pertaining to the typical LDC. A country with a more favorable cultural inheritance and/or successful education policy over time can be represented by a more steeply rising labor progress function. It is, in fact, a basic hypothesis of this paper that the rapidity of the development of the human resources in this sense is causally crucial in at least two important respects to the technological transfer problem, i.e., to the rapidity with which foreign technology can be borrowed and, second, once borrowed, to the extent to which it can be assimilated via the exercise of domestic innovative ingenuity.

In this connection it will prove helpful to distinguish between the "pure transplantation case" in which foreign technology is imported without further modification, and the case of "technological assimilation" in which some domestic innovative effort is made "on top of" the imported technology. This notion of "assimilation" refers to that vital indigenous innovative effort through which the initially "capital using" character of imported technology is modified and adapted to make it more suitable to the labor rich and capital scarce factor endowment condition of the typical LDC.[1]

Using Diagram 2, let the developing country's labor progress function and the technology shelf available to the LDC be postulated. In the case of "pure transplantation" the skill level which has been attained at any point in time causally determines the "vintage" of the unit technology which can be borrowed. Thus at time $t_1$, $t_2$,...the imported (i.e., borrowed) technology can be represented by technology $A_1$, $A_2$,... This also repreeents the effective technology which prevails in the LDC at that historical point in time. The underlying justification for this "rule of borrowing" is that a unit technology of a more recent

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[1] Such "assimilation," taking the form of multiple shifting, machine speed-ups, changes in handling and other peripheral activities, variations in plant size, structure and organization has been documented for Japan (Ranis, "Factor Proportions in Japanese Economic Development," op. cit.) Mexico (Paul Strassman, Technological Change and Economic Development, (Ithaca, N.Y.: Cornell University Press, 1968) and the Soviet Union (David Granick, "Economic Development and Productivity Analysis: The Case of Soviet Metalworking," Quarterly Journal of Economics, May, 1957 among others.

vintage, or a vintage representing a higher technological complexity, can only be mastered when the pertinent domestic "skill level" has been achieved.

Turning next to the more general case, i.e., when borrowing is accompanied by technological assimilation, the effective unit technology at time $t_1$, $t_2$,...in fact turns out to be represented by points $B_1$, $B_2$,... as shown by the curve labeled "post-assimilation technologies." In this general case, the basic hypothesis is that the domestic ingenuity and skill level achieved at a particular point in time (e.g., $t_2$) enables the country not only to import the technology (e.g., $A_2$) of the "correct" vintage but also to "stretch" the use of that capital resulting in a reduction of the value of the capital coefficient (e.g., to the level indicated at point $B_2$). In this case, the ratio of the distance $A_2B_2/B_2n_2$ in Diagram 2a may be interpreted as the degree of capital stretching, which gives us a quantitative measure of the strength of the indigenous innovative effort aimed at modifying the imported technology. If that effort is weak, the degree of capital stretching may be zero, bringing us back to the special case of "pure transplantation."

Notice that the technology shelf, represented by a negatively sloped curve, implies that the importation of more modern technology via pure transplantation, while it leads to increased labor productivity, does so only at an increasing capital cost, i.e., an increase in the value of the capital-output ratio. In a developing country characterized by low saving, capital scarcity and unemployed labor, the transfer of technology from abroad may thus actually result in increased technical unemployment and hence a lower value of per capita income (Q/L)--in spite of the fact that labor productivity (Q/N) is raised. This unfavorable unemployment effect can, however, be considerably ameliorated by the domestic capital stretching effort, the effect of which is to enable more labor to be employed per unit of capital stock. The borrowing of technology which involves a maximum of domestic innovative effort is thus clearly superior to the pure transplantation case. The successful Japanese growth experience in the nineteenth century and the Korean, Taiwanese and Mexican experience in the twentieth have provided ample proof of the substantial advantages of the selective importation of technology coupled with a major domestic innovative effort.

The importance of this point is underscored when we recognize that the choice may not be simply between the pure transplantation case--at the skill level appropriate within the recipient economy--and borrowing with assimilation. It is a fact of life that many contemporary LDC's are not interested in borrowing anything but the latest vintage technology--quite irrespective of the domestic skill levels they have reached. Sometimes, encouraged by aid givers and by mistaken domestic policy packages--as well as misguided notions of prestige--they thus try to move upward along the technology shelf ahead of what is reasonable and efficient, given the skill levels they have reached. In such cases the aforementioned difficulties of the pure transplantation case are exacerbated and underlined.

In summary, the rules of technological borrowing as we have formulated them are based on a one-to-one correspondence between the "skill level" attained by a society and the vintage of the technology which can be borrowed from the international shelf. Such a one-to-one relationship is based on the belief that there exists a one-to-one relationship between the degree of technological complexity on the one hand and the degree of technological competence required to handle it effectively, on the other. The optimum and hence natural course to follow in the course of the development process is for the two to move in unison and harmony through time. There is no denying that, in the real world, many a contemporary LDC has, in fact, through unwarranted policy measures or otherwise, managed to distort this harmony. The attempt to import the latest technology ahead of an economy's human competence levels leads to the establishment of "technological dualism" characterized by the coexistence of an extremely modern sector side by side with traditional technology, with little interplay between them. The very size of the technological gap between these two domestic sectors causes a lack of spill-over characteristic of the so-called "big push" for modernization effort. The same achievement of an adequate domestic skill level commensurate with the technology borrowed also affects the strength of the assimilation effort, i.e., the degree of capital stretching. Economies which try to borrow ahead of their skill level also find it more difficult to assimilate that technology--and thus find themselves two steps removed from the optimal. As we shall see, the borrowing of technology without the accompanying domestic innovative effort toward capital stretching may be very costly in terms of both the employment and output objectives of the developing society.

## IV. Technological Transfer and Unemployment

Contemporary growth theory has had a pronounced material resources orientation and relied heavily on the accumulation of capital as in the Harrod-Domar model (see Section I). Increasingly, however, the importance of human resources is being recognized, and our arguments in the last section have placed considerable emphasis on education, and on technological change via the transmission from rich to poor. We are now ready to put these two strands of thought together in order to formulate a more deterministic growth model. This model builds on our earlier work in Sections I and II, but now includes not only the saving function and population growth among its behavioristic assumptions but also the labor progress function, the technology shelf and the rules of technological transfer of Section III. The purpose of the model is the projection of the time path of the growth of output (Q), employmend (N), unemployment (U), capital stock (K), as well as of the indicators of technological change, (e.g., p, k, and n).

The deterministic aspect of the model can be easily explained with the aid of Diagram 2. Initially at time $t=t_o$, it is the skill level ($p_o$) which determines the effective unit technology (i.e., the point $A_o$ and the technology line $OT_o$) in a way described in the last section. The initial supply of capital stock ($K_o$) then determines the scale of operation of the technology (at $F_o$) the amount of labor which can be accommodated ($N_o$) and the output ($Q_o$). The initial population ($L_o$) then serves to determine the volume of unemployment ($U_o$). The system is thus completely determined statistically. In the next period, ($t_1$) the skill level ($p_1$) determines the imported unit technology ($A_1$) which becomes the effective unit technology ($B_1$) after capital stretching (measured by the distance $A_1B_1$). With the aid of the average propensity to save (s) and output ($Q_o$) we can determine savings and investment $I_0=sQ_o$ in the second period and hence the new capital stock ($K_1$). The total population ($L_1$) is given by the population growth curve. In this way we can determine an <u>employment path</u> $F_o$, $F_1$, $F_2$,...as well as an <u>endowment path</u> $E_o$, $E_1$, $E_2$, ...through time, the horizontal gap between the two curves giving us the time path of technical unemployment $U_o$, $U_1$, $U_2$,... It is apparent that technical unemployment can be eliminated over time when, and only when, the endowment path bends upward fast enough to "catch up with" and finally intersect the employment path.[1]

The model which we have constructed is broad enough to include in its scope not only the impact of capital accumulation but also that of technological change resulting from the improvement of human resources and the availability of importable technologies--dimensions which are certainly crucial to the development process. For purposes of statistical implementation and in order to make it possible for us to deduce the full implications of the model, we will now proceed with the specification of more precise functional forms for our behavioristic assumptions. These include the six equations of Section I (1a-1f) which are accepted, with the only provision that k and n (the capital and labor coefficients) are no longer constants. Instead their value is determined with the aid of the following additional behavioristic equations:

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[1] The main difference between this model and the model of Section I is that instead of a fixed technology line OT (Diagram 1) the technology line now shifts continuously through time due to technological change (i.e., due to technological transfer and assimilation).

5a) $n_p=i$ or $p=p_o e^{it}$ where $p=1/n$ (labor progress function; i is the rate of labor progress)

b) $1=j^{\alpha} n^{1-\alpha}$ or $j=p^{\theta}$ for $\theta=(1/\alpha)/\alpha$ (technology shelf; j is the "imported" pre-assimilation capital-output ratio)

c) $m=j/k$ (m is the degree of capital stretching)

d) $m=(p/p_o)^c$ (capital stretching function; "c" is the capital stretching coefficient)

Taking these one at a time, labor productivity is specified to grow at a constant rate "i" as described by the labor progress function (5a). The technology shelf available is depicted by the unit contour of a Cobb-Douglas type (5b). Notice that in this functional form "j" is the initial "imported" capital-output ratio which must be differentiated from the "effective" post-assimilation capital-output ratio "k". In (5c) the degree of domestic capital stretching is measured by $m=j/k$; the higher the value of m, which corresponds to a lower value of k, the higher the degree of capital stretching. Finally, in (5d), we have postulated a capital stretching function which simply states that m is causally determined by the cumulative effect of labor progress $(p/p_o)$, i.e., the multiple by which the current skill level has increased over some initial level. The underlying idea here stresses the importance of education and learning by doing as causal factors determining the amount of capital stretching technological change which can be incorporated in the imported technology. Thus there are altogether ten equations (1a-f) plus (5a-d) containing five behavioristic parameters, $(r, s, i, \alpha, c)$, relevant to our model.

The three unfamiliar parameters (i, $\alpha$, c) are all related to the phenomenon of technological change in our model. The rate of labor progress "i" summarizes the cultural heritage and/or the effectiveness of a country's education policy as related to the increase of a nation's technological competence. The Cobb-Douglas coefficient "$\alpha$" in (5b) can be viewed as describing the "generosity" or amplitude of the existing technology shelf since the elasticity of the Cobb-Douglas function, measuring the percentage increase of the capital coefficient (dj/j) per unit percentage decrease in the labor coefficient (dn/n), may be defined as

6) $\theta = (1 - \alpha)/\alpha$ (pure transplantation cost)

$\theta$ may thus be viewed as a summary statement of the cost, in terms of capital use, of importing technology from abroad. The typical LDC will want $\theta$, which we may call the pure transplantation cost, to be as low as possible--for that would mean that a given percentage increase of labor productivity (or decrease in the labor coefficient) can be obtained at a smaller capital cost, i.e., a smaller percentage increase in the capital-output ratio. Finally,the capital stretching coefficient "c" (in 5d) appears to be a crucial behavioristic parameter since only when it is sufficiently large can domestic innovative effects be counted on to contribute significantly to alleviating the unemployment and capital shortage creating impact of the initial act of importation of new technology. This intuitive interpretation of the various parameters used in the model will be reinforced by further deductive reasoning below.

To solve the entire system, let us combine the various behavioral assumptions related to technology change. Starting with 5c, we have: ,

7a) $k=j/m=a\ p^{b}$ where

b) $a=p_{o}^{c}$ ; $b=\theta-c$; $\theta=(1-\alpha)/\alpha$ by (5b) and (5d).

c) $Q=Q_{o}K^{B}\ N^{1-B}$ where

d) $B=1/(1+b)=\alpha/(1-c\alpha)$; $Q_{o}=p_{o}^{(1/\ (1-1/c\alpha))}$...by (7a)

Notice that (7c) is deduced directly from (7a) and represents the effective production function which turns out to be in a Cobb-Douglas form.[1] However, from (7d) we see that the coefficient "B" of this Cobb-Douglas function is defined in terms of "$\alpha$" and "c", reminding us of the crucial fact that in a contemporary LDC, the production condition is intrinsically a product of importable technology ($\alpha$) as well as of domestic innovative ingenuity (c). Analogous to (6), the elasticity of (7c) i.e., the production elasticity is:

8) $b=(1-B)/B=\theta-c$ where $\theta=(1-\alpha)/\alpha$,

which is the difference between $\theta$, the pure transplantation cost, and c, the capital stretching coefficient. Since the LDC is better off the lower $\theta$ and the higher c, i.e., the lower b, we may think of $-b=c-\theta$ as the "excess" of the domestic capital-stretching effort over the pure transplantation costs attending the importation of technology. The larger

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[1] Notice also that (7c) now becomes a genuine (negatively sloped) Cobb-Douglas function if and only if $0<B<1$. In other cases (i.e., $0>B$ or $B>1$) the production contour becomes positively sloped; then the unit contour of (7c) is the equation of the effective technology locus in Diagram 2a.

this excess, the more favorable the anticipated growth performance of the country in question.

From (7a) and the labor progress function of (5a), we can easily deduce the growth path of a number of interesting variables including the effective capital-output ratio $\eta_k$, and--with the aid of the saving function of (1b)--the rate of capital acceleration ( $\eta_{\eta_K}$) the growth rate of capital ( $\eta_K$), and the growth rate of capital per head ($\eta_{K/N}$):[1]

9a) $\eta_k = b\,\eta_p = bi$ (by 7a; 5a)

b) $\eta_{\eta_K} = \eta_{(s/k)} = -\eta_k = -bi$ (by 2a; 9a)

c) $\eta_K = \eta_o e^{-bit}$ (by 9b)

d) $K = K_o J^{e^{-bit}-1}$ where $J = e^{-\eta_o/bi} > 0$

e) $\eta_{K/N} = \eta_{(Q/\theta)(N/Q)} = \eta_{kp} = bi + i = i(1+b) = i(1+\theta-c) = i(1/\alpha-c)$ (by 8)

From this it is then easy to deduce the rates of growth and the time paths governing all the significant economic variables in the system, including output (Q), employment (N), per capita income ($Q^* = Q/L$), the extent of employment ($N^* = N/L$):

10a) $\eta_Q = \eta_{K/k} = \eta_o e^{-bit} - bi$ (by 9ac)

b) $\eta_N = \eta_{Q/p} = \eta_o e^{-bit} - bi - i$ (by 10a, 5a)

c) $\eta_{Q^*} = \eta_{Q/L} = \eta_o e^{-bit} - bi - r$ (by 10a, 1a)

d) $\eta_{N^*} = \eta_{N/L} = \eta_o e^{-bit} - bi - i - r$ (by 10b, 1a) )

In this fashion the system is formally and fully determined. Let us now examine the conclusions which flow from an application of this model, before we turn, in the final section, to the matter of empirical verification.

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[1] This latter will later help us to distinguish between capital deepening and capital shallowing in the developing country.

## V. Application

The above formulation has hopefully served to convince the reader of the rather complicated nature of the LDC unemployment problem when compared with its traditional formulation in the context of the mature economy. In fact, our model has hopefully shown that the problem can only be understood as an integral part of the growth process as a whole, including as crucial components not only capital accumulation but also continuous technological change traced to human skill formation at home and technological transmission from abroad. Thus, our model provides the insight that the problem of unemployment in an LDC must ultimately be resolved in terms of the combined forces of an adequate level of austerity, the creation of the proper educational plant--in terms of both quality and quantity--, and sufficient ability and willingness to assimilate imported technology. These three forces are summarized by the three parameters (s, i, c). To the extent that these parameters can be affected by budgetary or other policy measures within the LDC they may be regarded as "instrumental variables" in the Tinbergen tradition and will be treated as such in the discussion which follows.[1]

Our model enables us to embark on the important analytical task of assessing which of these policy instruments (i.e., s, c, i) should be viewed at a higher level of causal order, and hence more crucial for development. To begin with, we may take the raising of per capita income ($Q^*=Q/L$) and the elimination of unemployment (or raising the extent of

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[1] The other variables, "$\alpha$" (a property of the technology shelf), and "r" (the population growth rate) may be regarded as beyond the control of the LDC and will be treated as such in our paper. A population theory endogenous to the system could easily be accommodated once again.

employment $N^* = N/L$) as the major twin social objectives. In this connection, the well-worn assumption of a necessary conflict between these two objectives, the output and the employment effect, often associated with technological transfer, can perhaps he laid to rest. Equations (10c) and (10d), it will be noted, indicate that the rate of growth of both $Q^*$ and $N^*$ are determined by the same terms "bi", in the sense that the condition

11) $bi < 0$ (criterion of success)

is both necessary and sufficient for both $\eta_{Q^*}$ and $\eta_{N^*}$ to increase monotonically and without limit in the long run. In other words, the employment effect is favorable (i.e., $\eta_{N^*} > 0$) if and only if the output effect is favorable (i.e., $\eta_{Q^*} > 0$)--so that these two crucial welfare criteria are actually never in conflict. For this reason (11) may be interpreted as "the" criterion of success, with "success" implying a simultaneous movement in both directions.[1]

A closer scrutiny of (11) indicates that since $i > 0$ (i.e., the rate of labor improvement is positive) the criterion of ultimate success reduces to $b < 0$ i.e.,

12) $c > \theta \equiv (1-\alpha)/\alpha$ (by (11), (8) and $i > o$).

This result represents a conclusion of some importance since it pinpoints the factors related to technological change which make for success in the development effort. In essence, our conclusion is that an LDC's growth performance both in terms of employment and output goals can be crowned with success in the long run if and only if the domestic innovative capital stretching effort (c) is sufficiently strong to compensate for the high capital cost ($\theta$) associated with the modern imported

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[1] On the other hand, when (11) is not satisfied, both $Q^*$ and $N^*$ will, in general, decline.

technology. What is surprising about this conclusion is that the question of success seems to depend on technological factors only. The extent of population pressure (r), saving capacity (s), and even educational performance in terms of labor progress (i) seem to be irrelevant to the question of long run success or failure.

To elaborate on this point, we must note that if (12) is satisfied, the rate of labor progress (i) does indeed affect the rapidity of the increase of Q* and N*, even if it has no impact on the question of whether or not these two welfare criteria will continue to increase without limit in the long run. Hence, a faster rate of labor progress (larger i) indeed contributes to a more rapid increase of per capita income and of the extent of employment (see 10c, d). Moreover, a lower population pressure (smaller r) and a higher average propensity to save, (larger s) also contribute favorably to the magnitude of both $\eta_{Q*}$ and $\eta_{N*}$, as we would expect.[1] Thus while (c, $\alpha$ ) determine the basic qualitative characteristics of the system (i.e., "success" or "failure") the other parameters (i, s, r) determine the rapidity of the process.

Finally, a word may be added with respect to the case of pure transplantation defined as the absence of indigenous innovative effort in a capital stretching direction "on top of" the imported technology.

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[1] A closer scrutiny of 10c shows that when $r > \eta_o - bi$ and when (11) is satisfied the value of Q* decreases at first and then increases monotonically after a finite time span. The same U-shaped characteristic can be established for N* when the population pressure is relatively high, i.e., when $r > \eta_o - bi - i$. Notice that the saving parameter "s" enters into (10) through the initial value of the rate of growth of capital $\eta_o = s/k_o$ where $k_o$ is the initial capital-output ratio. Thus a high saving rate also contributes favorably to the rapidity of the growth of Q* and N*.

This turns out to be a special case of (12) defined by c=o, in which case the criterion of success is reduced to

13) $\theta = (1-\alpha)/\alpha < 0$ (criterion of success for c=o)

In this special case "success" can occur if and only if the unit contour of Diagram 2a is positively sloped.[1] Specifically, this means that, as the process of development unfolds in the mature economy, increasing labor productivity (p) through time must have been accompanied by a sustained decrease of the capital-output ratio (k). Condition (13) permits us to conclude that when a particular LDC fails to develop the ability to engage in indigenous innovative effort, the only way in which it can still be successful is by being in a position to borrow from a mature economy shelf which itself benefitted from capital-saving innovations over time.[2] Empirical studies on this subject are by no means agreed, but they have shown that the capital-output ratio in the mature country seems to have undergone long swings in both upward and downward directions.[3]

In any case, the importance of relying on one's own indigenous innovative capacity has been illustrated. In fact, the most crucial element of a successful development strategy, both in terms of output and employment effects, is clearly the strength of this indigenous

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[1] From (5b) we see that $dj/dp = \theta p^{\theta-1}$ so that the shelf if positively sloped if and only if $\theta < 0$. See Section II above for a fuller discussion of what determines the slopes of the technology shelf.

[2] Here "capital-saving" is taken to mean only that the capital-output ratio has been declining through time.

[3] See W. Fellner, Trends and Cycles in Economic Activity, (New York: Henry Holt & Co., 1956).

innovative effort as induced by and responsive to the importation of technology. This involves, inter alia, the ability to resist the temptation to invariably import the "latest" available technology, as well as to refrain from sticking with outmoded handicraft production. It is essential, from the point of view of the spill-over effects achieved as a result of the initial importation, that pure transplantation take place at a point in keeping with the technological maturity and entrepreneurial ability of the recipient's human resources. Only in this fashion can the use of the. relatively abundant factor, labor, be sufficiently enhanced and that of the relatively scarce factor, capital, economized. While the more traditional, material resource-oriented development effort, impinging on saving and population growth behavior, must continue to be viewed as helpful, policy and budgetary planning to encourage the requisite domestic innovative effort is crucial. Assigning a priority role to the government's creation of the required overheads, including education, and to fashioning the proper policy mix vis-a-vis the private sector to foster the fullest possible development of domestic entrepreneurship, may be cited as among the key development issues. The prime historical example of a country which seems to have solved this problem admirably is the case of post-Restoration Japan. Let us now turn to an analysis of the growth experience of that country in the light of our model.

## VI. Empirical Analysis

It is, by now, a well accepted fact that the modernization of Japan since the Meiji Restoration was conspicuous for its emphasis on education and the assimilation of Western technologies.[1] In spite of the soundness of these notions, the relationship between education and the assimilation of technology, on the one hand, and economic development, on the other, have, up to now, resisted rigorous analysis within the framework of a comprehensive growth model. It is the purpose of this section to fill this gap by implementing our model with the help of historical data for Japan.

The essential task of statistical implementation is to estimate the numerical values of the five parameters (c, i, $\alpha$ , s, r) of our model. Succinctly, the equations which will be used for this purpose are

14a) $p=\hat{p}_o e^{\hat{i}t}$ (by 5a)

b) $k=\hat{a}\,p^{\hat{b}}$ (by 7a)

c) $c=\ln\hat{a}/\ln\hat{p}_o$ (by 7b)

d) $\alpha = \frac{1}{1+\hat{b}+c}$ (by 7b)

e) $L=L_o e^{\hat{r}t}$ (by 1a)

f) $I=\hat{s}Q$ (by 1b)

where a hat "$\wedge$" denotes a parameter estimated by the method of least squares. The estimation of (i, r, s) and $p_o$ is given by 14aef--for which the time series of output (Q), saving (S), population (L) and labor

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[1] Anthony Tang, "Research and Education in Japanese Agricultural Development: 1880-1938," Economic Studies Quarterly, XIII (Part I: Feb. 1963; Part II: May 1963). See also dissertation in progress at Yale University by Gary Saxonhouse, "Basic Determinants of Improvements in the Efficiency of Production in the Japanese Cotton Textile Industry, 1880-1940."

productivity p (=Q/N) for the whole economy are required. If we have, in addition, the time series of capital stock (K), we can estimate "a" and "b" in (14b) with the aid of the time series of k (the observed capital output ratio) and p. We can then use (14cd) to compute "c" and "$\alpha$". Thus, all the parameters can be estimated when the time series of Q, N, K, L, and S are available.

The basic data for Japan, for Q,K,L and N for the period 1878-1939, are presented in columns 1-5 of Table 1, from which the time series of $p=Q/N$ (column 6), $k=K/Q$ (column 7) and $s=(dK/dt)/Q$ (column 8) are derived. The time series of "p" and "k" and the scatter diagram between them are given in Diagrams 3, 4 and 5, in which the curves (fitted by the method of least squares) are also shown. The coefficients of the regression curves of these diagrams may be summarized as follows:

15a) $p=\hat{p}_o e^{\hat{i}t}$ where $\hat{p}_o = 66.86$; $\hat{i} = .035$

b) $k=\hat{k}_o e^{bit}$ where $\hat{k}_o = 2.57$; $bi = -.0065$

c) $K=\hat{a}\, p^{\hat{b}}$ where $\hat{a} = 6.006$; $\hat{b} = -.199$ [1]

We can then estimate parameters ($\alpha$, c) in (14c,d) as follows:

16a) $c=\ln\hat{a}/\ln\hat{p}_o = .427$ (by 15a, c)

b) $\alpha = \frac{1}{1+\hat{b}+c} = .814$ (by 15c, 16a)

These are the two parameters in terms of which the criterion of success of equation (12) is defined. To see the economic implications of these results, we observe:

17) $(1-\alpha)/\alpha < c < 1/\alpha$, i.e., $.229 < .427 < 1.229$,

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[1] (15b) follows from (9a). We can use (15a and b) to estimate $b=bi/i=-.0065/.035=-.19$ which is consistent with the estimate of b in (15c).

# TABLE I

## BASIC JAPANESE DATA

| Year (1) | Output=Q (2) | Capital=K (3) | Population =L (4) | Employment =N (5) | p=Q/N (6) | k=K/Q (7) | s=I/Q (8) |
|---|---|---|---|---|---|---|---|
| 1878 | 1152.00 | 4361 | 36166 | 18841 | 61.14 | 3.786 | .0391 |
| 1879 | 1519.00 | 4406 | 36464 | 19193 | 79.14 | 2.901 | .0362 |
| 1880 | 1664.00 | 4461 | 36649 | 19542 | 85.15 | 2.681 | .0325 |
| 1881 | 1533.00 | 4515 | 36965 | 19883 | 77.10 | 2.945 | .0274 |
| 1882 | 1473.00 | 4557 | 37259 | 20224 | 72.83 | 3.094 | .0597 |
| 1883 | 1520.00 | 4645 | 37569 | 20537 | 74.01 | 3.056 | .0368 |
| 1884 | 1561.00 | 4701 | 37962 | 20859 | 74.84 | 3.012 | .0442 |
| 1885 | 1877.00 | 4770 | 38313 | 21163 | 88.69 | 2.541 | .0378 |
| 1886 | 2245.00 | 4841 | 38541 | 21463 | 104.60 | 2.156 | .0272 |
| 1887 | 2116.00 | 4902 | 38703 | 21759 | 97.25 | 2.317 | .0766 |
| 1888 | 2140.82 | 5064 | 39029 | 22043 | 97.12 | 2.365 | .0411 |
| 1889 | 2012.23 | 5152 | 39473 | 22312 | 90.19 | 2.560 | .0462 |
| 1890 | 2379.38 | 5245 | 39902 | 22583 | 105.36 | 2.204 | .0416 |
| 1891 | 2270.75 | 5344 | 40251 | 22825 | 99.49 | 2.353 | .0484 |
| 1892 | 2381.71 | 5454 | 40508 | 23085 | 103.17 | 2.290 | .0714 |
| 1893 | 2665.91 | 5624 | 40860 | 23316 | 114.34 | 2.110 | .0476 |
| 1894 | 3139.00 | 5751 | 41142 | 23551 | 133.29 | 1.832 | .0484 |
| 1895 | 3072.67 | 5903 | 41557 | 23769 | 129.27 | 1.921 | .0778 |
| 1896 | 2867.12 | 6142 | 41992 | 23977 | 119.58 | 2.142 | .1071 |
| 1897 | 3134.86 | 6449 | 42400 | 24195 | 129.57 | 2.057 | .0683 |
| 1898 | 4141.86 | 6663 | 42886 | 24382 | 169.87 | 1.609 | .0311 |
| 1899 | 3512.12 | 6792 | 43404 | 24572 | 142.93 | 1.934 | .0661 |
| 1900 | 3753.01 | 7024 | 43847 | 24768 | 151.53 | 1.872 | .0397 |
| 1901 | 4108.15 | 7173 | 44359 | 24959 | 164.60 | 1.746 | .0343 |
| 1902 | 3689.79 | 7314 | 44964 | 25122 | 146.87 | 1.982 | .0458 |
| 1903 | 4098.57 | 7483 | 45546 | 25298 | 162.01 | 1.826 | .0468 |
| 1904 | 4041.31 | 7675 | 46135 | 25436 | 158.88 | 1.899 | .0626 |
| 1905 | 3539.43 | 7928 | 46620 | 25599 | 138.26 | 2.240 | .1054 |
| 1906 | 4190.94 | 8301 | 47038 | 25729 | 162.89 | 1.981 | .0888 |
| 1907 | 4478.78 | 8673 | 47416 | 25858 | 173.21 | 1.936 | .0853 |
| 1908 | 4693.88 | 9055 | 47965 | 25971 | 180.74 | 1.929 | .0954 |
| 1909 | 4766.62 | 9503 | 48554 | 26085 | 182.73 | 1.994 | .0822 |
| 1910 | 4564.51 | 9895 | 49184 | 26169 | 174.42 | 2.168 | .1133 |
| 1911 | 5358.37 | 10412 | 49852 | 26259 | 204.06 | 1.943 | .0972 |
| 1912 | 5857.93 | 10933 | 50577 | 26347 | 222.34 | 1.866 | .1026 |
| 1913 | 5986.46 | 11534 | 51305 | 26422 | 226.57 | 1.927 | .0702 |
| 1914 | 5839.37 | 11954 | 52039 | 26471 | 220.59 | 2.047 | .0524 |
| 1915 | 6418.65 | 12260 | 52752 | 26527 | 241.97 | 1.910 | .0657 |
| 1916 | 5699.78 | 12682 | 53496 | 26557 | 214.62 | 2.225 | .1316 |
| 1917 | 5951.24 | 13432 | 54134 | 26589 | 223.82 | 2.257 | .1781 |
| 1918 | 6705.74 | 14492 | 54739 | 26618 | 251.93 | 2.161 | .1869 |
| 1919 | 8133.19 | 15745 | 55033 | 26623 | 305.49 | 1.936 | .1448 |
| 1920 | 6510.99 | 16923 | 55391 | 27263 | 238.82 | 2.599 | .1305 |

## BASIC JAPANESE DATA (Cont'd)

| Year (1) | Output=Q (2) | Capital=K (3) | Population =L (4) | Employment =N (5) | p=Q/N (6) | k=K/Q (7) | s=I/Q (8) |
|---|---|---|---|---|---|---|---|
| 1921 | 7771.99 | 17773 | 56120 | 27498 | 282.64 | 2.287 | .0908 |
| 1922 | 8057.82 | 18479 | 56840 | 27733 | 290.55 | 2.293 | .0513 |
| 1923 | 8395.31 | 18892 | 57580 | 27969 | 300.16 | 2.250 | .0538 |
| 1924 | 8872.71 | 19344 | 58350 | 28206 | 314.57 | 2.180 | .0604 |
| 1925 | 9554.87 | 19880 | 59179 | 28442 | 335.94 | 2.081 | .0737 |
| 1926 | 10407.79 | 20584 | 60210 | 28676 | 362.94 | 1.978 | .0725 |
| 1927 | 10879.71 | 21339 | 61140 | 28913 | 376.29 | 1.961 | .0601 |
| 1928 | 11026.76 | 21993 | 62070 | 29148 | 378.30 | 1.995 | .0586 |
| 1929 | 11301.21 | 22639 | 62930 | 29384 | 384.60 | 2.003 | .0490 |
| 1930 | 13111.01 | 23193 | 63872 | 29619 | 442.66 | 1.769 | .0322 |
| 1931 | 14150.29 | 23615 | 64870 | 28990 | 488.11 | 1.669 | .0333 |
| 1932 | 14269.35 | 24086 | 65890 | 29176 | 489.08 | 1.688 | .0457 |
| 1933 | 14294.13 | 24738 | 66880 | 29777 | 480.04 | 1.731 | .0620 |
| 1934 | 14598.97 | 25624 | 67690 | 30794 | 474.08 | 1.755 | .0735 |
| 1935 | 15689.43 | 26697 | 68662 | 31400 | 499.66 | 1.702 | .0776 |
| 1936 | 16630.31 | 27914 | 69590 | 30855 | 538.98 | 1.679 | .0774 |
| 1937 | 16078.21 | 29201 | 70040 | 31162 | 515.96 | 1.816 | .0985 |
| 1938 | 18097.97 | 30784 | 70530 | 31473 | 575.03 | 1.701 | .1405 |
| 1939 | 20584.84 | 33327 | 70850 | 31780 | 647.73 | 1.619 | .1248 |

Sources: Output data, in millions of yen, (column 2) are from Ohkawa, The Growth Rate of the Japanese Economy Since 1878, p. 247, Table 3, and are deflated by Ohkawa's general price deflator, p. 130, converted to a 1934-36 base.

Capital stock estimates, in millions of yen, 1934-36 prices (column 3) are from Estimates of Long-Term Economic Statistics of Japan Since 1868, Vol. 3, pp. 149-151, Total Net Capital Stock excluding Residences.

Population data, in thousands of persons, (column 4) are from Hundred-Year Statistics of the Japanese Economy, published by the Statistics Department of the Bank of Japan.

Employment data, in thousands of persons, (column 5) are from Ohkawa, (op. cit.), p. 145 with "total gainfully occupied population" serving as an approximation to "total employment."

This permits us to conclude (1) that the historical experience of Japan represents a case of success. This means that the domestic effort in the direction of capital stretching was sufficiently strong to compensate for the unfavorable effects of the highly capital using nature of the imported technology. We can thus explain why the twin criteria Q* and N* increased continuously in the long run in the Japanese case. (2) From equation (9e) above, we can see that, if $i > o$, the development process is characterized by capital shallowing (i.e., declining capital per head) if and only if $c > 1/\alpha$. This means that the domestic capital stretching effort is so pronounced that it swamps the initial capital deepening effect of imported technologies leading to a net lower effective capital output ratio. Our results summarized in the second inequality in (17) however, indicate that the domestic capital stretching effort was not strong enough to guarantee capital shallowing. This means that for the sixty years as a whole Japan developed successfully under conditions of some capital deepening.[1]

The Japanese data moreover reveal that "$\alpha$" in (16b) lies between o and 1. This depicts the case of a negatively sloping technology shelf

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[1] From 15c we have $d(K/N)/dp=d(k\cdot p)/dp=d(ap^{i+b}$ $/dp=a(1+b)p^{b}$. Hence capital deepening occurs when $a > o$, and $b > -1$, which is our case. This evidence, of course, does not necessarily indicate that capital stretching could not have been sufficiently strong over a more limited period to result in capital shallowing. In Fei and Ranis (*op. cit.*) Chapter 4, we, in fact, presented some statistical evidence that, for the industrial sector, capital shallowing gave way to capital deepening around 1917. Since the possibility of "capital stretching" is greater, the greater the difference between the imported and the indigenous technology, it stands to reason that at the early stages of development (when presumably, the domestic production structure differs more from the foreign technology than at a later stage) the role of capital stretching is greater. This hypothesis can be verified by a more systematic statistical investigation than we have undertaken here, i.e., by placing shorter time periods under examination.

(5b), which in turn means that Japan was borrowing technology from a mature world which had shown some tendency for a secularly increasing capital output ratio.[1] This also means that Japan could not have been successful in its development effort without a major domestic capital stretching innovative effort. This conclusion follows rigorously from the success criterion of (13), i.e., when c=o.

As a second type of empirical verification of our theory, we can compute the "predicted" values of the growth path of Q* and N* based on (10c,d) using the above estimated parameter values. To begin with, we can compute the predicted rate of growth of the capital output ratio and of the rate of capital acceleration:

18a) $\eta_k = ib = i((1-\alpha)/\alpha - c) = -.00696$ (by 9a, 7b, 15a and 16a,b)[2]

b) $\eta_{\eta_K} = -ib = .00696$

While, in our model, the average propensity to save (s) was assumed to be constant, (see 1b), an investigation of the actual time path of "s" for Japan yields the following:

19) $s = s_o e^{gt}$ where $g = .0121$

so that the propensity to save in Japan actually shows an annual increase of about one per cent a year. Consequently, our model can be modified by computing the rate of capital acceleration as

20) $\eta_{\eta_K} = \eta_{s/k} = \eta_s - \eta_k = .0121 + .00696 = .019$ (by 19 and 18a).

---

[1] Thus, an examination of purely Japanese data permits us to conclude that the capital output ratio in the advanced countries must have been increasing during the period 1888-1930. This phenomenon can of course be verified by independent evidence. Fellner, for example, in Trends and Cycles in Economic Activity, (New York: 1956) sees the capital-output ratio for the U.S. rising slightly between 1870 and 1900, fairly constant between 1900 and 1930, and slightly falling thereafter.

[2] The directly observed value of "$\eta_k$" from (15b) is -.0065 which is seen to be very close to the predicted value.

On the other hand, using columns (3) and (8), of Table 1, we can calculate the "observed" rate of capital acceleration:

$$21)\qquad \eta_K = \eta_o e^{\hat{\hat{h}}t} \qquad \text{where } \hat{\hat{h}} = .019$$

which is precisely the same as the predicted value above when the more realistic propensity to save is assumed.

We can now, moreover, proceed to computing the time paths of $\eta_{Q*}$ and $\eta_{N*}$ in (10c, d):

$$22a)\qquad \eta_{Q*} = .0171^{e^{.019t}} + .0075 = \eta_o e^{ht} + h - r$$

$$b)\qquad \eta_{N*} = .0171^{e^{.019t}} - .0275 = \eta_o e^{ht} + h - i - r$$

From these equations we see not only that Japan can be predicted to be successful but that the values of the two above welfare indicators can be expected to monotonically increase throughout.[1] This shows that the innovative effort in Japan was sufficiently strong to overcome the relatively modest pressure of population growth. Thus our model coincides with actual Japanese historical experience, with both per capita income and the degree of employment monotonically increasing through time.

The above conclusion leads directly to the last empirical application of our paper, namely the computation of a numerical value for the "turning point" in Japanese development. Such a "turning point" is operationally defined as the time when Japan got rid of her technical unemployment, i.e., the employment path and the endowment path finally intersect (see Diagram 2 above). From the time path of N* in (22b) we have

$$23a)\qquad N^* = N^*_o e^u / e^{\eta_o/h} \qquad \text{where}$$

$$b)\qquad u = (\eta_o/h)\, e^{ht} + (h-i-r)t \qquad \text{for}$$

$$c)\qquad h = .019;\ \eta_o = .0171,\ i = .035,\ r = .0115$$

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[1] In other words, Q* and N*, for Japan, are increasing from the very beginning and do not exhibit the possible U-shaped characteristic referred to earlier.

The data when technical unemployment is eliminated can then be obtained by solving for "t" when $N^*=1$ in (23a). Unfortunately, we do not have much confidence in the estimates of the initial extent of technical unemployment in 1878, i.e., $N^*_o$--but we can safely assume that it varied between 10 per cent and 20 per cent of the total labor force. Applying (23a,b), we can then obtain the following results by approximation:

| | | |
|---|---|---|
| Initial degree of employment: ($N^*_o$ in 1878) | .9 | .8 |
| Duration of unemployment phase, t: (years) | 53 | 58 |
| Calendar Year (1878 + t) | 1931 | 1936 |

This gives us a "turning point in the 1930's which seems to be supported by other independent work on Japan.[1]

## Conclusion

This paper has sought to demonstrate that a comprehensive theory of growth for less developed countries not only relates employment and unemployment to all the other customary growth phenomena at the aggregative level, but must also tie up with the nature of the technology available for borrowing from abroad. Such a general explanatory framework, of course, should not only be capable of explaining historical experience but also have substantial implications for planning and policy-making. We have only scratched the surface in both respects. But the preliminary results presented here do seem to provide considerable encouragement for

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[1] See K. Ohkawa and H. Rosovsky, "The Role of Agriculture in Modern Japanese Economic Development," Economic Development and Cultural Change, October 1960 and R. Minami, "The Turning Point in the Japanese Economy," Quarterly Journal of Economics, August 1968.

further exploration, in particular into a) the nature of the relationship between technological borrowing and lending countries at different stages of development; b) the precise meaning of the technological gap and Veblen's advantage to the late-comer nation; and c) the impact of different internal patterns of historical growth in the rich countries on the development process in the less developed world.

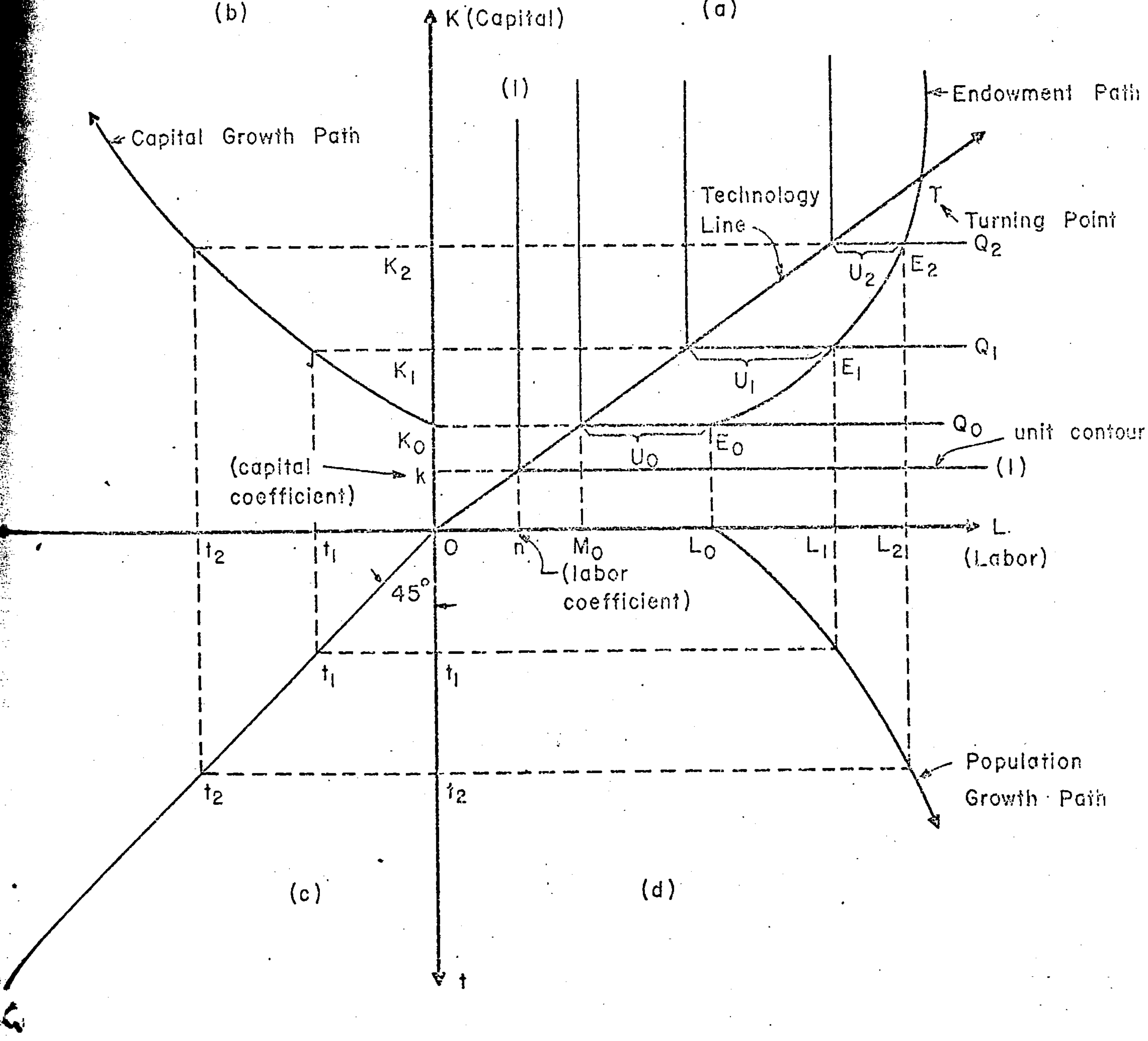

(b)
K (Capital)
(a)
(I)
Endowment Path
Capital Growth Path
Technology Line
T
Turning Point
Q2
K2
U2
E2
Q1
K1
U1
E1
Q0
K0
U0
E0
unit contour
(capital coefficient)
k
(I)
t2
t1
O
n
M0
L0
L1
L2
L
(Labor)
(labor coefficient)
45°
t1
t1
Population Growth Path
t2
t2
(c)
(d)
t

Diagram I

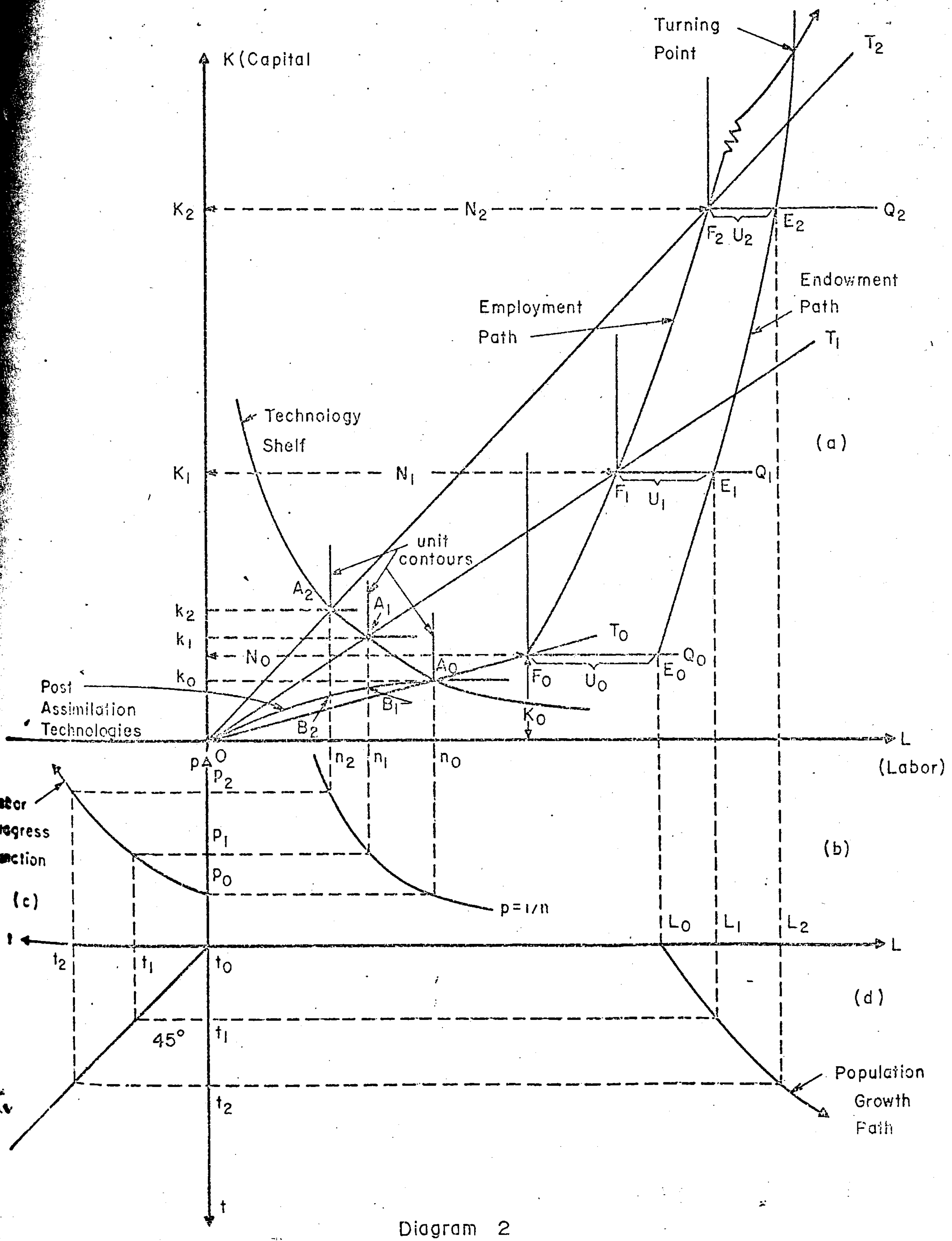
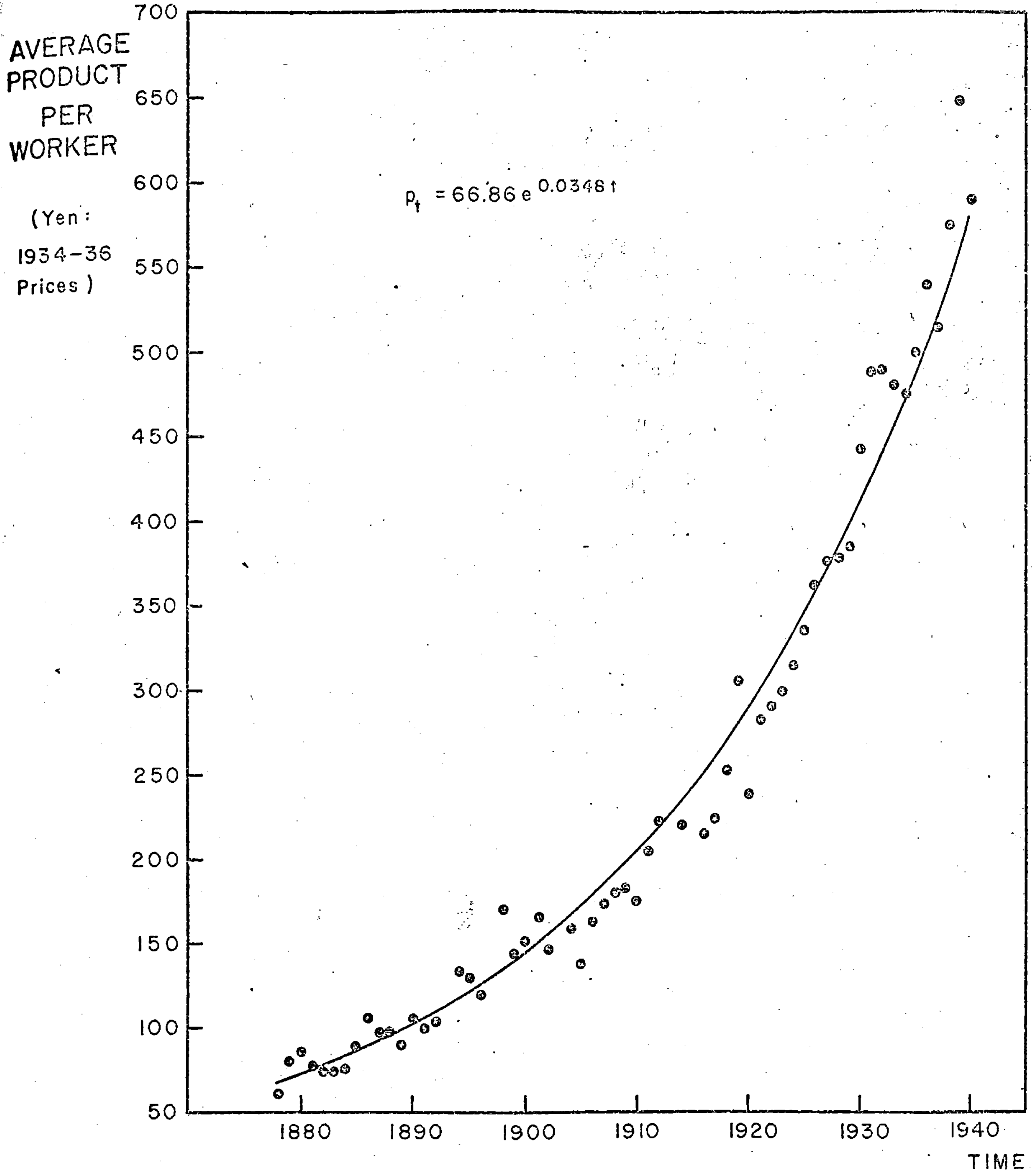

Turning Point
T2
K (Capital
K2
N2
Q2
F2
U2
E2
Endowment Path
Employment Path
T1
Technology Shelf
(a)
K1
N1
Q1
F1
U1
E1
unit contours
A2
A1
k2
k1
T0
N0
Q0
A0
F0
U0
E0
k0
Post Assimilation Technologies
B1
B2
K0
L
(Labor)
p
O
n2
n1
n0
p2
Labor Progress Function
p1
(b)
p0
(c)
p = 1/n
L0
L1
L2
t
L
t2
t1
t0
(d)
45°
t1
t2
Population Growth Path
t

Diagram 2



AVERAGE PRODUCT PER WORKER
(Yen: 1934-36 Prices)
700
650
600
550
500
450
400
350
300
250
200
150
100
50
$p_t = 66.86 e^{0.0348 t}$
1880
1890
1900
1910
1920
1930
1940
TIME

Diagram 3

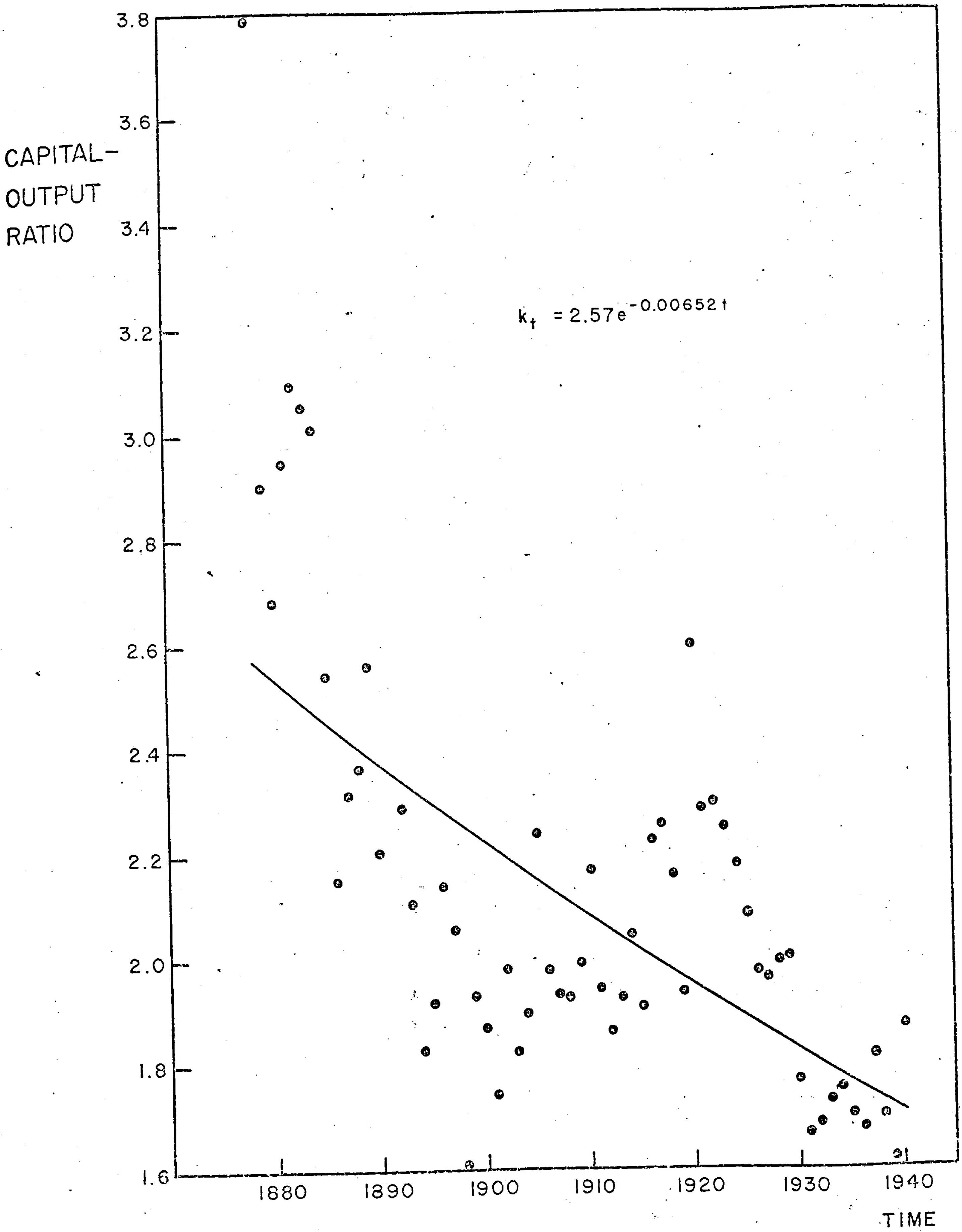

CAPITAL-
OUTPUT
RATIO
3.8
3.6
3.4
3.2
3.0
2.8
2.6
2.4
2.2
2.0
1.8
1.6
$k_t = 2.57e^{-0.00652t}$
1880
1890
1900
1910
1920
1930
1940
TIME

Diagram 4

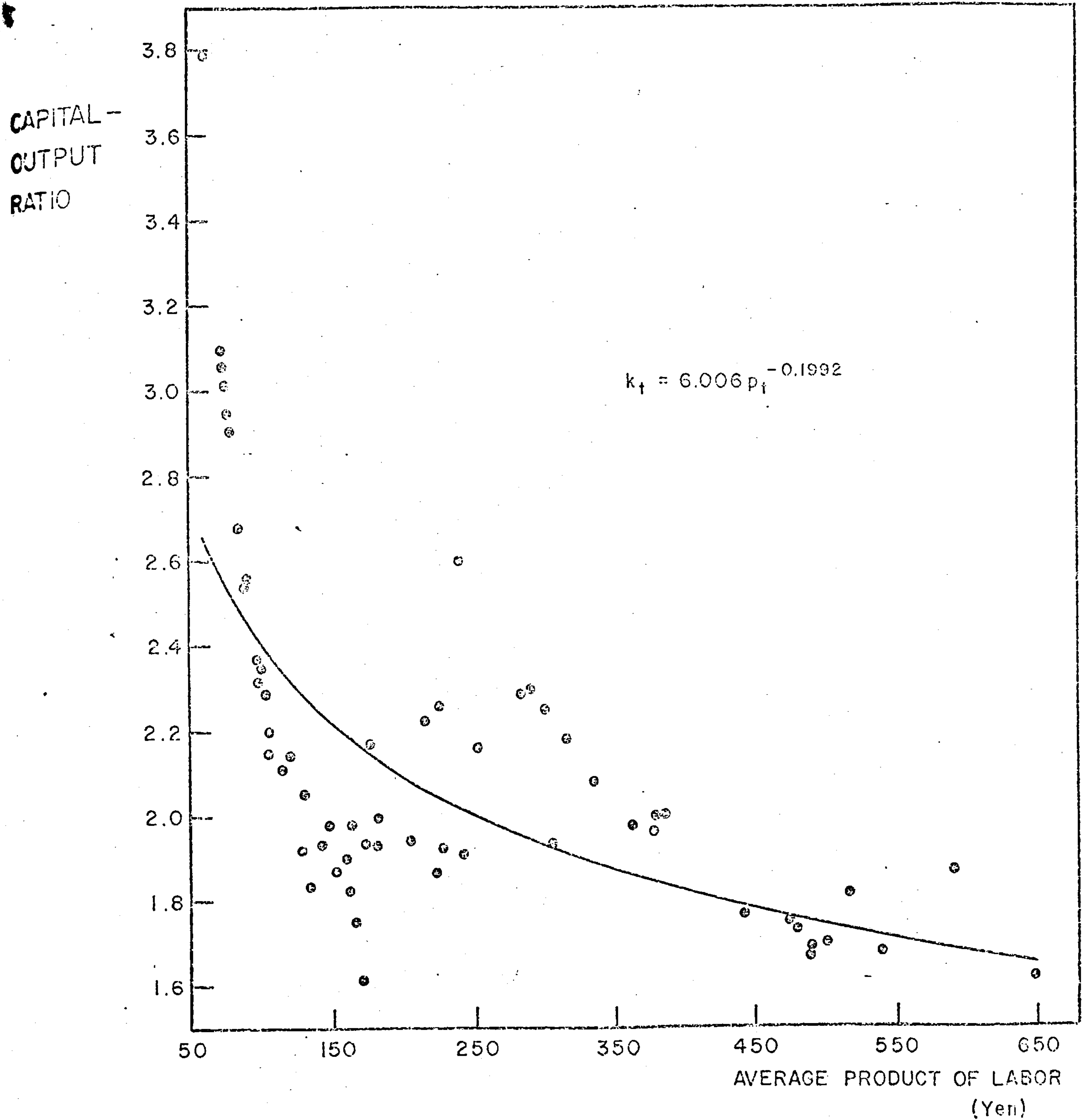

CAPITAL-
OUTPUT
RATIO
3.8
3.6
3.4
3.2
3.0
2.8
2.6
2.4
2.2
2.0
1.8
1.6
$k_t = 6.006 p_t^{-0.1992}$
50
150
250
350
450
550
650
AVERAGE PRODUCT OF LABOR
(Yen)

Diagram 5