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TECHNOLOGICAL TRANSFER, EMPLOYMENT AND DEVELOPMENT

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While there is controversy on its definition and size, few people dispute that unemployment is a quantitatively significant phenomenon in most underdeveloped countries. Unemployment, disguised or open, represents not only output lost and opportunities missed in terms of involving more people in creative activity; it also represents a most important inequity in income distribution and, as such, a major contributing cause to political instability. For these reasons, unemployment is generally acknowledged as a serious social problem by both academicians and the practitioners of development planning. In spite of the attention paid to the problem, however, a positive theory of unemployment for the underdeveloped world has not as yet been developed.[1/] This, we believe, is mainly due to the fact that unemployment in the underdeveloped world is a very complicated phenomenon but centrally related to economic growth in general and technological change in particular. At the present time, what we do know of the causes of unemployment is certain intuitive ideas neither integrated, from the theoretical standpoint, nor tested from the statistical standpoint. A brief (and by no means, complete) review of the various facets of the problem which are customarily cited would include the following:

(1) Technology and Factor Endowment. Eckaus[2/] refers to unemployment as "technical unemployment" where "technical" means non-substitutability

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[1/] This contrasts sharply with the highly developed theory of unemployment for the mature economy in the Keynesian tradition.

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

between capital and labor in the production process. In diagram (1a), let labor (capital) be measured on the horizontal (vertical) axis. Suppose the production contour is the L-shaped C_2-curve (with a corner point at E_2) and suppose the factor endowment point is at the point F_2. Then capital constitutes a bottleneck factor and technical unemployment in the amount of E_2F_2 units results. Thus, the unemployment problem is essentially a technological phenomenon and can be defined only relative to the well known characteristic of relative capital scarcity in the typical underdeveloped country.

(2) Economic Growth. The above characterization of the unemployment problem immediately leads to the logical conclusion that rapid capital accumulation (at a rate faster than population growth) is the only way in which technical unemployment can be eliminated in the long run. It is then obvious that the unemployment problem can only be understood in the context of economic growth in which saving, investment and capital accumulation play key roles. This is, implicitly at least, the position of the practitioners of development planning who usually regard the "employment effect" and the "output effect" as the two most important criteria against which to assess the success and failure of a given economic growth effort.3/

(3) Education and Skill Formation. For those who believe (e.g., Schultz4/) that the development of human resources lies at the heart of

3/ See virtually any five-year plan or government policy statement of recent vintage.

4/ T.W. Schultz, "Investment in Human Capital", American Economic Review, March, 1961.

economic development and modernization, it is the lack of education and labor skills which prevents labor from being fully employed in the course of the industrialization effort. Thus, it is only through improvements in the quality of labor, through education and/or learning by doing, that unemployment can be reduced and output raised. It would seem, after all, that skilled labor is scarce in most underdeveloped countries while it is usually the unskilled labor force which is unemployed.

(4) Innovation. One of the most important facts of life in the development of the contemporary underdeveloped system is the availability of "importable technology" which, once imported, constitutes technological change from the viewpoint of the underdeveloped society. Since these imported technologies originate in industrially mature economies which are characterized by affluence in capital and scarcity in labor, their transplantation to the underdeveloped system will have relatively small "employment effects" and possibly adverse "output raising" effects. The famous success story of Japanese industralization bears testimony to the fact that it is the ability to implant domestic innovations on top of imported technology which can be of the greatest importance.[5/] Thus, it would appear that from both the employment and output standpoints a wise technology-importation process may be described as technological assimilation which is the compounding of the effects of the importation of a foreign technology with its adaptation to make it more suitable to the indigenous factor endowment.

5/ See Fei & Ranis (Development of the Labor Surplus Economy, Theory and Policy, Irwin, 1964) for a fuller exposition of this issue.

The above review leads us to the conclusion that while we recognize that unemployment has a multiple causation, all the inter-relationships have not been satisfactorily explored. What we shall attempt to do in this paper is to integrate these facets into one theoretical framework in the hope that this may take us a step closer to a general theory of unemployment for the underdeveloped economy.

In Section I, we shall construct a general system for the explanation of employment and output growth. This general system is broadly constructed so as to be useful for an analysis of the four main facets of the problem identified above. Section II deals with the problem under the assumption of technological stagnation. Sections III and IV deal with the same problem when the importation of technology is an essential part of the picture. (Section III deals with "importation" without local "adaptation" and Section IV with "importation" with "adaptation".) Section V is devoted to a more careful examination of the available shelf of technology importable from abroad. Finally, in Section VI the theoretical framework of this paper will be examined and verified in a preliminary fashion in the light of the experience of historical Japan.

Section I. General Framework

It is the purpose of this section to introduce the main conceptual tools as well as the general theoretical framework of this paper.

The Technology of Production

Let K be the capital stock and L the total labor force in an economy in which N is the employed labor force. Let a production function:

1.1) $Q = f(K,N,t)$

be formally postulated where, for each time index "t", the production function is assumed to satisfy the condition of constant returns to scale. Under this assumption the unit production contour (i.e., the production contour $1=f(K,N,t_o)$ which produces one unit of output at time t_o,)can be represented by the curve $\alpha\alpha'$ in diagram 1a. This curve completely describes the art of production (1.1). We shall refer to the points A_o, A_1, A_2 ..... on the unit contour as the unit activities (i.e., unit production processes), for which the labor and capital coefficients are (u_o,k_o), (u_1,k_1), (u_2, k_2)... . Each unit activity determines a capital-labor ratio:

1.2) $T=K/N$ (i.e., $T_o = k_o/u_o$; $T_1 = k_1/u_1$; $T_2 = k_2/u_2$ .....)

which will be referred to as the technology ratio, and which differs from the factor endowment ratio:

1.3) $K^*=K/L$

since the employed labor force "N" is generally different from the total labor force "L". (In this paper x* will be used consistently to denote "x per unit L" -- i.e., x per unit of total labor.) In diagram 1a, the technology ratios are represented by the slopes of the technology lines Ot_o, Ot_1, Ot_2 .....

The unit activity concept is used to facilitate our introduction of certain unconventional notions of production. For each unit activity (A_i) we wish to associate a non-substitutable (i.e., strictly complementary) production process, as depicted by the L-shaped production contours c_i (i = o, 1, 2, 3, ...) in diagram 1a. As we have pointed out earlier, technical unemployment in the sense of Eckaus can be defined with the aid of these contour lines. For example, when the prevailing unit activity is A_2 and when the factor endowment point is F_2, technical unemployment is E_2F_2 units. This is due to the fact that the point F_2 lies on the L-shaped contour C_2 which represents the operation of the unit contour c_2 on a larger scale.[6/]

As long as the factor endowment ratio is lower than the technology ratio (i.e., $K^* < T$), there is technical unemployment of labor. Development with this characteristic will be referred to as unemployment or full capacity (of capital) growth. Conversely, $K^* > T$ is the defining property of full employment growth in which a part of capital capacity will not be utilized. Thus:

1.4a) $K^* < T$ (unemployment growth)

b) $K^* > T$ (full employment growth)

In the case of an underdeveloped society characterized by an abundance of unskilled labor the unemployment growth case is clearly more relevant.

Innovations are defined in this paper as any change of the unit activity through time. Thus, innovations may be depicted either by a shift of the position (generally toward the origin) of the entire unit contour[7/], or by a shift of the unit activity along the same unit contour, such as a shift from A_0 to A_1. In short, any deviation from the current (non-substitutable) production practice will be viewed as an innovation. As an illustration

6/ Under the assumption of constant returns to scale, the scale of operation is OE_2/OA_2.

7/ This is the conventional definition of innovation as used, for example by Fei and Ranis. (op.cit.)

of this rather unconventional concept, let A_o (diagram 1a) represent the current technology of an underdeveloped country. In comparison, the technologies of the industrially advanced countries are characterized, in varying degree, by higher technology ratios, i.e., unit activities which are more "capital using" and "labor saving". Thus, we may describe the spectrum of technologies for all advanced countries by the unit contour which, from the viewpoint of the underdeveloped countries, depicts the availability of new, potentially importable, technologies. This contour summarizes the twin forces of technological change and capital deepening in the developed world. We intend to explore its significance more fully in Section V. Let us accept for now that, for the less developed economy, the actual innovation process due to the importation of technology can be described by a movement through time upward along the contour line A_o, A_1, A_2, ...

Improvement in Labor Efficiency

Let the unit contour $\alpha\alpha'$ of diagram 1a be given. For each unit activity A_i contained in $\alpha\alpha'$, the inverse of the labor coefficient:

1.5) $p = Q/N \quad (= 1/u)$

is the (average) productivity of employed labor. The productivity of labor for each unit activity, i.e., $p_i = 1/u_i$ (i=1,2.....) is represented by the rectangular hyperbola in diagram 1b lined up with the contour map. The conventional interpretation of labor productivity (p_i) is that as "homogeneous labor" is equipped with more capital goods in the course of the capital deepening process (i.e., as the unit activity shifts upward along the unit contour $A_0, A_1, A_2, \ldots\ldots$) the productive efficiency of labor increases automatically. While such a formulation may be suitable for an industrially mature economy, it is inadequate for the underdeveloped economy. This is because of the much greater importance of the real learning effort (through formal education or "learning by doing") generally required if the efficiency of labor is to be improved at all.

In keeping with our interpretation of the unit contour above, we shall interpret the magnitude p_i as the demand for labor skill of a particular quality. Moving to the left in diagram 1b simply means that there is a demand for labor of a higher average skill (i.e., p_i is "higher") as the typical worker is required to become acquainted with and operate a larger volume of real capital goods. With increasing technological complexity, in other words, the average worker needs to be of a higher quality which is indicated by the proxy variable p_i.

In diagram 1c let time be measured on the horizontal axis (to the left) and let the productive efficiency (i.e., the quality) of labor, as measured by its average productivity (p), be represented by the labor improvement function. Conceptually, labor efficiency through time is determined by such factors as education, training, learning by doing, etc. To simplify our analysis, let us assume that this labor improvement function is given exogenously. In case labor efficiency is improving at a constant rate, the labor improvement function can then be written as:

1.6) $p=p_o e^{it}$ or $\eta_p = i$

where "i" is the rate of labor improvement. (In this paper the notation η_x stands for the rate of increase of x.) Given the labor improvement function and the unit contour we can determine the unit activity which will actually be achieved through time. Thus, at any time t_i, the unit activity which can be achieved is A_i as labor productivity reaches the level p_i (i=1,2,3, ...). Thus, in our view, the improvement of labor efficiency causally determines the prevailing technology when a "technology matrix" (i.e., a set of unit activities) is given.

Growth of Capital and Labor

In addition to the above innovational aspect of the problem, growth promoting forces in less developed societies, of course, include growth of the labor force and of the capital stock. To simplify the analysis of the growth of these material resources we shall assume the constancy of the population growth rate (r) and of the average propensity to save (s):

1.7a) $L = L_o e^{rt}$ or $\eta_L = r$

b) $S = I = sQ$

c) $I = dK/dt$

Equation 1.7a) is represented by the population growth curve in diagram 1d. The time axis (pointed downward) is aligned with that of diagram 1c (pointed to the left) through the 45^o line oo'.

The deterministic aspect of our model consists of the interaction of the forces of innovation and material resources accumulation. We assume knowledge of available technological choice along the unit contour, of the labor improvement function and of the population growth curve. Thus, in diagram 1, at $t = o$, given initial labor productivity at p_o and factor endowment at F_o, we can determine, from p_o, the unit technology A_o, and the technology ratio (radial line Ot_o) as well as the employment and output point (E_o) and the amount of unemployment E_oF_o. With the aid of the labor improvement function of (1.6), the savings function of (1.7b) and the population function of (1.7a), we can then determine the labor productivity p, and the endowment point F, in the next period. In this way, the growth process is dynamically determined as summarized in the employment path $E_oE_1E_2$ ..... and the endowment path $F_oF_1F_2$ .... .

In the general framework just outlined the determination of the growth process implies the determination of per capita income (Q^*) and of the degree of employment (N^*), or the degree of unemployment through time. These essential indicators of economic welfare on which our analysis centers will be denoted by:

1.8a) $Q^* = Q/L$ (per capita income)

b) $N^* = N/L$ (degree of employment)

c) $U^* = U/L$ (degree of unemployment) where

d) $L = U + N$

To facilitate our later work, the following formulae will be seen to be helpful:

1.9a) $N^* = K^*/T$ .... (by 1.8b, 1.3 and 1.2)

b) $Q^* = pN^* = pK^*/T$ .... (by 1.8a, 1.5, 1.8b and 1.9a)

Notice from diagram 1a that when the endowment path and the employment path do not intersect, unemployment can never be eliminated through time (as is seen by the existence of a horizontal gap between the two curves). In our earlier terminology (1.4a), the economy then finds itself in a permanent unemployment growth regime. Conversely, when the two paths do intersect at some future date, the economy shifts from an unemployment to a full employment growth regime. (In such a regime, the vertical gap between the two curves represents unutilized capital capacity.) The point of intersection will be known as the <u>terminal point</u> which marks off two stages of growth. Whether or not an economy is successful in reaching such a point is an important aspect of our analysis.

For easy reference, the general framework of this section may now be summarized as follows:

1.10a) $Q = f(K,N,t)$ .... (1.1)

b) $p = Q/N;\ T=K/N$ .... (1.2; 1.5)

c) $K^* = K/L;\ Q^* = Q/L;\ N^* = N/L$ .... (1.3; 1.8ab)

d) $\eta_p = i$ .... (1.6)

e) $\eta_L = r$ .... (1.7a)

f) $I = sQ$ .... (1.7b)

g) $dK/dt = I$ .... (1.7c)

The model presented here may be viewed as a general framework for analyzing the unemployment problem in the course of growth, taking into account both technological change and the augmentation of human and capital resources over time. In the sections which follow we shall, by postulating some special conditions relating to this general framework, explore a number of typical real world situations.

Section II. Development with Stagnant Technology

One real world situation which may occur in a less developed society is complete concentration on capital accumulation and neglect of the improvement of labor efficiency, leading to technological stagnation. This unhappy case is typified by the constancy of labor productivity, p, which leads, in turn, to the constancy of the capital-output ratio, k_o. Hence the general framework of 1.10) in the last section reduces to[8/]

2.1a) $Q = K/k_o$

b) $p = Q/N$

c) $p = p_o$

d) $dK/dt = sQ$

e) $L = L_o e^{rt}$

which is, in fact, an extension of the familiar Harrod-Domar model.

To understand the rules of growth of this model completely, we should note that the technology ratio (1.2) becomes:

2.2) $T = K/N = k_o\, p_o$ .... (by 2.1abc)

which is constant. This means that the technology line coincides with the employment path, i.e., the radial line OT_o in diagram 2 describes both. As long as the factor endowment ratio is below (above) this line, the

8/ More exactly (1.10d) reduces to (2.1c) when i=o. The constancy of labor productivity (p) in turn leads to the constancy of k_o in (1.10a) under the assumption of constant returns to scale.

economy is in the unemployment (full employment) growth regime. In the more typical unemployment growth regime the constancy of k_o immediately leads to the following familiar Harrod-Domar growth rates:

2.3a) $\eta_K = \eta_Q = s/k_o$ .... (by 2.1ac)

b) $\eta_{K*} = \eta_{Q*} = s/k_o - r \equiv h$ .... (by 2.3a; 2.1e)

The fact that the country is in the full capacity growth regime initially (i.e., in diagram 2 the point E_o lies below OT_o) is given by the condition

2.4) $K_o^* = K_o/L_o < T = k_o p_o$

As is well known, with the Harrod-Domar model we may have the case of success, with per capita income increasing, or of failure, where it decreases. These two cases are given by:

2.5a) $s/k_o > r$ (success, i.e., low population pressure case)

b) $s/k_o < r$ (failure, i.e., high population pressure case)

In the case of "failure" (i.e., the high population pressure case), there will be continuous decreases of per capita income and of the endowment ratio (2.3b). The latter condition implies that the endowment path (i.e., the curve E_oF in diagram 2) moves away from the employment path and hence the country will never be able to solve its unemployment problem. Conversely, the "success" case (2.5a) implies that per capita income increases through time and that technical unemployment can be eliminated at some point in time which is given by[9]

2.6a) $t_m = \dfrac{1}{s/k_o - r} \ln (T_o/K_o^*)$ or

b) $t_m = (1/h) \ln (1/N_o^*)$ .... (by 2.6a; 1.9a)

9/ Notice that the value of time (t_m) is completely determined by "h" (2.3b) and the initial degree of employment N_o^*. This equation is easily derived by equating T_o and $K_o^* e^{ht}$ (2.3b) and solving for t.

In diagram 2, the success case is given by the endowment path E_oH which crosses the employment path at H at the terminal point. At this point the country moves into the full employment regime of growth. Capital is no longer the scarce factor and the economy can be considered to have reached economic maturity.

In the full employment growth regime, the constancy of labor productivity (2.1c) and of the population growth rate (2.1e) imply that output continues to grow at the same rate as population, i.e., $\eta_Q = r$. The constancy of the average propensity to save (2.1d) then implies that investment also must be growing at the same rate (i.e., $\eta_I = r$). We can then easily calculate the time path of capital (K) and of the factor endowment ratio ($\dot{K}^*$)

2.7a) $I = dK/dt = I_o\ e^{rt}$

b) $K = A+Be^{rt}$ where $A=K_o-B$; $B=I_o/r > o$ ....(by 2.7a)

c) $K^*= K/L = A/L_oe^{rt} + \bar{K}^*$ where $\bar{K}^* = sp_o/r = B/L_o$
(proof: $\bar{K}^*=B/L_o = I_o/rL_o = sQ_o/rL_o = sp_o/r$)

The last equation (2.7c) shows that K* approaches a long run stationary value $\bar{K}^* = sp_o/r$. Furthermore, K* monotonically increases if, and only if, A (in 2.7) is negative, i.e., if and only if

$K_o < B$ or $K_o < L_o\ \bar{K}^*$ or $\underline{K_o^* < \bar{K}^*}$ or $k_op_o < sp_o/r$ (by 2.2)[10] or
$r < s/k_o$

Notice that the last inequality is the condition for success in (2.5a) while the underlined inequality states that the stationary value of $\bar{K}^*$

10/ In the second regime the initial value of K_o^* is equal to the technology ratio.

is greater than the initial value K_0^* when the condition of success is satisfied. Based on these results the case of success is depicted in diagram 2 by the endowment path E_0HF_2 which approaches the (dotted) radial line in the long run.[11/] This dotted line will be recognized as defining a "Von Neumann state" characterized by the long run constancy of the capital-labor ratio.

The above is a brief but rigorous summary of all the essential rules of growth of the Harrod-Domar model. There are two distinct cases depicted by the two endowment paths in diagram 2. In the case of failure the country stays forever in the unemployment growth regime and unemployment continues to worsen. In the case of success the country reaches a terminal point where unemployment disappears and whence it tends toward the Von Neumann regime in the long run. The arrival of this terminal point characterizes reaching economic maturity.

Let us now examine the quantitative aspects of our analysis. Using (2.6b), we can easily calculate, for the success case, the "multiple" by which the following economic variables must increase at the terminal date over their respective initial values:

2.8a) $Q^*/Q_0^* = 1/N_0^*$ (Q*-multiple at terminal point)

b) $Q/Q_0 = \frac{1}{N_0^{*s/kh}}$ (Q-multiple at terminal point)

c) $L/L_0 = \frac{1}{N_0^{*r/h}}$ (L-multiple at terminal point)

11/ In this full employment growth regime, the unutilized capital capacity at F_2 is E_2F_2 units.

We can next investigate the time paths of the degree of employment (N^*) and of the magnitude of unemployment (L-N) in the unemployment growth regime. The constancy of the technology ratio (2.2) implies that the amount of employment (N) is growing at the same rate as capital. Hence the degree of employment is growing at the same rate as per capita income (i.e., $\eta_{N^*}(=s/k_o-r)$) and hence, in the case of success (failure), the degree of employment gradually increases (decreases). The magnitude of unemployment and its direction of change are given by

$$2.9a)\quad U=L-N=L_o e^{rt} \quad - \quad N_o e^{(s/k_o)t}$$

$$b)\quad dU/dt \gtreqless o \text{ if and only if } r/(N_o^* \, s/k_o) \gtreqless e^{ht}$$

Condition (2.9b) in combination with our previous analysis of the case of failure (2.5b) immediately enables us to differentiate the following cases in terms of the relationship between the strength of the population pressure and the magnitude of unemployment through time:12/

2.10a) high population pressure: $s/k_o < r$ (U monotonically increases)

b) moderate " " : $N_o^* \, s/k_o < r < s/k_o$ (U first increases then decreases)

c) low " " : $r < N_o^* \, s/k_o$ (U monotonically decreases)

Notice that 2.10a is the same case of "failure" due to high population pressure as in (2.5b). We see that for this case, not unexpectedly, the absolute magnitude of unemployment increases all the time. Cases (2.10b) and (2.10c), on the other hand, constitute two sub-cases of the case of "success" in

12/ From 2.9b, we see that the analysis of the direction of change of U obviously depends upon the comparative magnitude of "r" and "$N_o^* \, s/k_o$". Since $N_o^* \, s/k_o$ is less than s/k_o, these two numbers mark off three regions on a positive population growth (r) axis. These three regions constitute the three cases of 2.10.

Table 1

TERMINAL AND SWITCHING POINT CHARACTERISTICS - MODEL OF STAGNANT TECHNOLOGY

$1-N^*(o)$	r	s/k_o	$(s/k_o)-r$	At Terminal Point			At Switching Point		
				Duration t_m	Q^*/Q^*_o	L/L_o	Duration t_n	Q^*/Q^*_o	N^*
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
20%	0.025	(1) .02	-0.005 F	---	---	---	---	---	---
		(2) .04	0.015 M	14.876	1.250	1.450	---	---	---
		(3) .06	0.035 M	6.375	1.250	1.173	---	---	---
	0.030	(4) .02	-0.01 F	---	---	---	---	---	---
		(5) .04	0.01 M	22.314	1.250	1.953	---	---	---
		(6) .06	0.03 M	7.438	1.250	1.250	---	---	---
40%	0.025	(7) .02	-0.005 F	---	---	---	---	---	---
		(8) .04	0.015 T	34.068	1.667	2.344	2.740	1.042	0.625
		(9) .06	0.035 M	14.601	1.667	1.440	---	---	---
	0.030	(10) .02	-0.01 F	---	---	---	---	---	---
		(11) .04	0.01 T	51.102	1.667	1.705	22.314	1.250	0.750
		(12) .06	0.03 M	17.034	1.667	1.667	---	---	---

F - Failure T - Success with switching point M - Success without switching point

(2.5a). Specifically, in the low population pressure case (2.10c), the magnitude of unemployment decreases monotonically until the terminal point is reached. In the moderate population pressure case, the magnitude of unemployment will first increase and then decrease before the terminal point is reached. Thus we can identify a switching point in the magnitude of unemployment as the economy moves toward the terminal point. The length of time it takes to reach this switching point is given by:

2.11) $t_n = (1/h) \ln (r/N^*_o \; s/k_o)$ .... (by equality in 2.9b)

It may be noted that the moderate population pressure case (2.10b) is, in fact, very likely to occur in the real world (see Table 1 below) and hence such a country should not expect its unemployment problem to be solved immediately. With the aid of (2.11), we can easily deduce the following indicators which the economy exhibits at the "switching point":

2.12a) $N^*_o = r/(s/k_o)$ (degree of employment at switching point)

b) $Q^*/Q^*_o = r/N^*_o \; s/k_o$ (Q*-multiple at switching point)

c) $L/L_o = (r/N^*_o \; s/k_o)^{r/h}$ (L-multiple " " ")

d) $Q/Q_o = (r/N^*_o \; s/k_o)^{s/k_o h}$ (Q-multiple " " ")

As an application of the various formulae derived above, we present Table 1 in which certain terminal and switching point characteristics are calculated. Let us investigate cases with a high (40%) or a low (20%) initial degree of unemployment (Column 1), a high (3%) or low (2.5%) degree of population pressure (Column 2), and rates of capital and income growth which vary between high (6%), medium (4%) and low (2%) (Column 3).

The rate of growth of per capita income ("h" in 2.3b) can then be calculated in (Column 4). Here we also indicate whether the case is one of "failure", or "success" (with or without a switching point) according to (2.10). For the terminal date, we calculate the duration of time (using 2.6b in Column 5), the Q*-multiple (using 2.8a, in Column 6) and the L-multiple (using 2.8c, in Column 7). For the switching point where applicable (i.e., the point at which unemployment begins to decline absolutely), in the case of modest population pressure we calculate the duration (using 2.11, in Column 8), the Q*-multiple (using 2.12b, in Column 9) and N* (using 2.12a, in Column 10).

The results of Table 1 permit us to recognize that for the realistic ranges of parameters postulated in Columns 1-3, all the theoretically possible cases are, in fact, likely to occur. While a low rate of growth of output or capital (2%) points to failure (and the impossibility of ever solving the employment problem) higher capital growth rates (4% and 6%) point to success. Within these "success" cases, if the initial degree of unemployment is low (20%), the country can count on continuous decreases in the amount of unemployment over time; on the other hand when the initial degree of unemployment is high (e.g., 40%), the country is more likely to experience an increase in unemployment before unemployment finally declines. Moreover, a slight variation of the population growth rate (from 2.5% to 3%) can bring about a large change in the "waiting time" required for the switching point to be reached (from 3 years to 22 years in Column 8).

As far as the length of time required to eliminate unemployment completely (i.e., t_m) is concerned (Column 5), in the case of a high rate of capital growth (6%), the country can count on eliminating unemployment in a foreseeable future (from 6 to 17 years). However, when the growth rate of capital is low, (4%), t_m becomes so large (14 to 51 years) that the social and political problems are likely to be difficult to deal with.

On the whole, we cannot avoid the feeling that development under a situation of stagnant technology basically leads to pessimistic conclusions. For example, when the initial degree of unemployment is low (20%), the country can obtain a very modest increase in per capita income, e.g., of 25% in 14 years, by the terminal date. If the initial degree of unemployment is high, the country may have to wait for 50 years to raise per capita income by two-thirds.

Fortunately, these somber conclusions rest largely on the assumption of a static technology which must be viewed as a special case. In exploring the significance of these findings for the real world, however, we must be quick to admit that in all too many cases such static technology assumptions underlie the work of development planners. There exists a general tendency to concentrate on the real resources side of the growth process while neglecting the dynamics of technological change, especially of the indigenous variety.

Our analysis above amply demonstrates the inadequacy of such a Harrod-Domar world. Per capita income growth can take place only in the first (unemployment growth) regime and at relatively modest multiples. In the second (full employment growth) regime per capita income is constant and equal to labor productivity, p. Hence the maximum per capita income multiple <u>for all time</u> in this world is that which is experienced during the first regime in accordance with (2.8), i.e., $Q^*/Q_o^* = 1/N_o^*$. This tells us that the greater the degree of initial unemployment the greater the potential per capita income multiple. This underlines the notion that unemployment and underemployment constitute the main element of "slack" in the less developed economy and that their elimination represents the primary source of potential income gain in a technologically stagnant society. But even more importantly it tells us that this modest multiple is all the society can <u>ever</u> expect. It is this latter conclusion, in particular, which emphasizes the inadequacy of the "resources augmentation only" approach of Harrod-Domar. A realistic conceptual framework from both the theoretical and policy points of view must take into account the possibilities of a non-stagnant technology.

Section III. Big Push for Modernization

To many a planner in the contemporary less developed world the most popular type of technological change is what may be called the "big push for modernization". This means the introduction, in a virtually unmodified form, of imported technology of the latest and most advanced variety. This type of innovation process results mainly from the influence of the "demonstration effect", i.e., the desire by entrepreneurs, usually encouraged by a variety of government policies, to emulate production functions proved feasible elsewhere though usually under radically different endowment conditions.

As was explained in Section I, the availability of imported technology will be denoted by the unit contour $\alpha\alpha'$ in diagram 1a. Here the process of introducing the imported technology is depicted by the sequence A_o, A_1, A_2 ... representing progress toward more "capital using" and "labor saving" technology. If the rapidity of the importation of technology is controlled by the rapidity of labor productivity increase, we can determine the prevailing unit activity through time. Using a Cobb-Douglas function to approximate the unit contour $\alpha\alpha'$, the model applicable to the big push for modernization follows readily from the general framework of (1.10). By using (3.1a) in place of (1.10a), we have:

(3.1a) $Q = K^{\alpha} N^{1-\alpha}$ $o < \alpha < 1$ implying

b) $T = p^{1/\alpha}$ . . . $(T = K/N)$

c) $k = T^{1-\alpha}$ . . . $(k = K/Q)$

d) $k = p^{(1/\alpha)-1}$ . . (by 3.1bc)

We can then readily derive the following growth rates:

3.2a) $\eta_T = i/\alpha$ . . (by 3.1b and 1.10d)

b) $\eta_k = i(1-\alpha)/\alpha \equiv D > o$ . . (by 3.1c and 3.2a)

c) $\eta_{\eta_K} = -\eta_k \equiv -D < o$ . . (by 3.2b; $\eta_K = s/k$)

d) $\eta_K = \eta_o e^{-Dt}$ ($\eta_o \equiv \frac{s}{k_o}$ is η_K at $t = o$)

e) $K = \bar{K} (K/\bar{K})^{e^{-Dt}}$ where $\bar{K}/K_o = e^{\eta_o/D} > 1$ . . . (by 3.2d)

To investigate the dynamics of the "big push for modernization" growth process we see that since labor productivity is assumed to increase at the constant rate ($\eta_p = i$) the technology ratio $T=K/N$ (3.2a) and the capital-output ratio $k=K/Q$ (3.2b) are both increasing at positive constant rates -- as we would expect. Since the average propensity to save (s) is assumed to be constant, (3.2c) indicates that the rate of growth of capital is decreasing at a constant rate (-D). We can then easily compute the time paths of the rate of growth of capital (3.2d) and of the capital stock itself (3.2e). We readily see that the rate of growth of capital (η_K) monotonically decreases to zero (from its initial value η_o) and that, in the long run, the capital stock gradually increases to a maximum value ($\overline{K}$) from its initial value (K_o). 13/ Thus, the endowment path of diagram 1a would approach a horizontal line asymptotically.

We have thus demonstrated the futility of development via the big push for modernization approach. The conclusion is that a country which blindly imitates capital intensive techniques developed abroad as fast as its labor efficiency level permits cannot escape the dismal prospect that capital accumulation will sooner or later cease. Notice that this futility thesis is valid regardless of the magnitude of the savings rate ($o < s < 1$), the rate of labor improvement ($i > o$), the population growth rate ($r > o$), or the nature of the available technological shelf, as measured by α. Thus, in case a country is determined to embark on a big push policy, a national effort directed

13/ The solution of this differential equation will be investigated later on (see 4.9 and 4.12 below).

at austerity (raising s), birth control (lowering r) education (raising i) or the availability of importable technology will not be sufficient to allow the country to escape from economic stagnation.[14/]

Let us reexamine what is wrong with the "big push" from the "innovation" standpoint. Let the unit contour $\alpha\,\alpha'$ be reproduced in diagram 3 where point A is the initial unit activity, with initial capital and labor coefficients at (u_o, k_o). Since innovation must reduce at least one of these input coefficients, movement from A to points within quadrants II, III, IV of the "circle" about point A indicates which factor of production is "saved" (i.e., reduced) or "used" (i.e., increased) because of the innovation.

As we have seen in Section I, if E is the factor endowment point, the initial technical unemployment is aE units. It is apparent that an innovation will

i) increase technical unemployment if the technology ratio is raised.

ii) decrease output if the capital-output ratio (k) is raised - as long as technical unemployment conditions prevail.

It is thus apparent that of all the possibilities of innovations (quadrants II, III and IV), the "big push for modernization" possibility is the worst since, when the movement is in the northwestern direction along $\alpha\,\alpha'$ (quadrant II), it creates more unemployment <u>and</u> depresses output.

14/ This pessimistic conclusion can easily be strengthened by an investigation of what happens to the rate of growth of output (Q), employment (N), per capita income (Q/L) or the degree of employment (N/L). One can easily verify the fact that, in the long run, the rate of growth of all these magnitudes will approach zero (see equation 4.8 below).

The difficulty with the "big push for modernization" is the well-recognized fact that the heavy capital using nature of most modern techniques makes them unsuitable for a capital scarce country. This was shown rigorously in 3.2c above where the capital deceleration phenomenon testified to the inherent impossibility of sustaining a reasonable rate of capital accumulation. Differently put, the high labor productivity of modern technology is achieved in the capital scarce underdeveloped country only at a considerable cost, i.e., only a limited number of workers can be employed through time. Thus, development through the big push for modernization route is comparable to development of economic enclaves under a colonial system, i.e., a small portion of the labor force is engaged in very capital intensive projects while the overall level of unemployment continues to rise. Neither technological stagnation nor the blind use of imported technology can thus be considered a viable alternative for the underdeveloped society. Other, more imaginative, alternatives must clearly be examined.

While there is considerable consensus among economists and practitioners alike on the unfavorable employment effects of imported technology, much controversy surrounds the question of the output effects. It is, in fact, a major purpose of this paper to present a more rigorous formulation of this problem by examining the nature of both the process of technological assimilation and the nature of the available technological shelf. The above controversy can be settled only via an investigation of the relationship between these two important phenomena.

Section IV. Technological Assimilation

The fact that imported technology is available to an underdeveloped society is probably the most important single "fact of life" affecting its growth performance. We have just seen, however, that this shelf of technical knowledge must be used wisely if economic development is to really benefit. It is essential for the underdeveloped country to achieve a blending of imported and indigenous technology so as to breed a new technological mix more suitable to the typical factor endowment of the contemporary underdeveloped economy. We refer to such an innovation process as technological assimilation.

Technological assimilation connotes two related ideas: the importation of technology (as formulated in the last section) and the "blending" of this technology with indigenous innovations. It is the second aspect which now needs to be more rigorously formulated and quantified. Our analysis of the futility of the big push for modernization suggests that if the desired or beneficial results are to be achieved by such "blending", the net effect of this new innovational activity must be in a capital-saving or labor-using direction in order to counteract the opposite effects caused by the importation.

Referring to diagram 3 in which the initial unit technology is at A, the importation of technology is represented (as before) by a change in the unit technology from A to B. The "blending" of technology may now be depicted by a downward shift of the unit technology from B to D representing a decline in the capital-output ratio. Such innovational blending activity may be equally well described as capital stretching which means essentially that the underdeveloped economy, by stretching the use of its scarce resource (i.e., capital) can make fuller use of its abundant resource (i.e., labor). The beneficial nature of capital stretching can be seen directly from both its employment-raising effects and its output-raising effects as a consequence of the decline in the capital-output ratio.15/

For a quantitative measurement of the degree of capital stretching, let k and k' denote the capital-output ratios at B and D, respectively. We define

4.1a) $m = k/k' > 1$

b) $k' = K/Q$

where "m" may be referred to as the degree of capital stretching and "k" is the effective capital-output ratio after capital stretching. A quantitative treatment of this phenomenon obviously necessitates an investigation of the forces which behavioristically determine the magnitude of "m".

Basically, the strength of any such innovation must be determined by the quality of the human resources within a society. This includes such factors as labor skills, entrepreneurial ability as well as government efficiency and the wisdom of the system's economic policies. This may

15/ In diagram 3 if the endowment point is fixed at E as a result of capital stretching, employment is increased by bd units. Output at point b (=Ob/OB) is less than output at point d (=Od/OD).

be summarized by the quality of the society's human resources as a product of education and "learning by doing" at any point in time. We may thus reasonably postulate that m is positively related to the level of labor productivity reached. Such a behavioristic relation may be approximated by the following capital stretching function:

4.2) $m = (p/p_o)^c \qquad c > o$

where p/p_o is the degree of increase of labor productivity summarizing a society's cumulative experience with changing technology, and where "c" is the elasticity of "m" with respect to "p/p_o". The shapes of the capital stretching functions for alternative values of "c" are given in diagram 4. For c=1, (c < 1 and c > 1), the capital stretching functions are represented by WX (WY and WZ). In our formulation the value of "c" is obviously a most important parameter as it is only when the value of "c" is sufficiently large that the model of technological assimilation is sufficiently different from the big push for modernization case. (When c=o, m=1 and the capital stretching function is WW', i.e., we are back to the big push case).

As in the last section, the Cobb-Douglas function (3.1a) is again taken to describe the availability of imported technology. Thus we obtain

4.3a) $k' = k/m = ap^b$ where

b) $a = p_o^c$; $b = 1/e - 1 - c$ (by 4.2 and 3.1d)

Making use of (4.1b) and $p = Q/N$, we can readily calculate the effective (i.e., post-assimilation) relationship between capital, labor and output as:

4.4a) $Q = Q_o K^B \quad N^{1-B}$ where

b) $B = \alpha/(1-c\,\alpha) = 1/(1+b)$ (by 4.3b)

c) $Q = p_o^{(1/(1-c/\alpha))}$......................(by 4.3, 4.1b and p=Q/N)

Equation (4.4a) formally resembles a Cobb-Douglas function where the Cobb-Douglas coefficient B (in 4.4b), as a function of "c", is represented by the two branches of the curves in diagram 5. There are three critical regions of values (Cases, I, II and III) for "c" as marked off by the critical values indicated on the horizontal axis. The three cases in ascending magnitudes of "c", the capital-stretching coefficient 16/ are:

4.5a) Case one: $o < B < 1$ for $o < c < (1-\alpha)/\alpha$

b) Case two: $B > 1$ for $(1-\alpha)/\alpha < c < 1/\alpha$

c) Case three: $B < o$ for $1/\alpha < c$

It is only in case one that (4.4a) resembles a genuine Cobb-Douglas production function. In case two (three), the unit production contour ($1=Q_oK^BN^{1-B}$) is positively sloped and convex (concave) as represented by the curve ADO (AHO) in diagram 3. In the case of ADO, for example, the imported capital output ratio is at point "B" in diagram 3 and the amount of decline of the capital-output ratio due to capital stretching is BD. The effective capital output ratio (k') is at point "D".

A formal model of "development with capital assimilation" can be constructed by replacing the general production function in (1.10a)

16/ In diagram 4, the capital stretching functions corresponding to the two critical values $c = 1/\alpha$ and $c = (1-\alpha)/\alpha$ are indicated.

by (4.4a). In summary, there are five parameters (α, c, i, s, r) in the model summarizing the availability of importable technology (α), the indigenous capital stretching effort (c), population pressure (r), savings behavior (s), and the improvement of labor efficiency (i).

For case one in (4.5), the "assimilation model" is virtually identical to the "big push" model (i.e., 4.4a is effectively the same as 3.1a). Hence we immediately come to the conclusion that to avoid stagnation there must be a minimum level of domestic ingenuity or assimilation as manifested in the magnitude of capital stretching.

To formulate this idea more rigorously, we define:

4.6a) $R \equiv (1 - \alpha)/\alpha$ (technology barrier)

b) $\gamma \equiv c - R$ (assimilation lever)

c) $\gamma > 0$ (i.e., $c > R$, or $c > (1-\alpha)/\alpha$) (minimum assimilation criterion (MAC))

We shall define R as the technology barrier dependent entirely on the nature of the foreign technology shelf (to be examined more fully in Section V); and the assimilation lever γ as the amount of "spread" between the domestic assimilation effort and the foreign technology barrier, which spread can be parlayed into additional domestic growth. Moreover, the fact that the assimilation lever must be positive can then be interpreted as the minimum assimilation criterion (MAC). For unless it is satisfied, i.e., the indigenous innovative effort in response to the stimulation of imported technology is strong enough to just overcome the technology barrier, growth cannot take place in the long run. In this fashion we have shown that satisfying the MAC is <u>necessary</u> for long term economic progress. It remains to be shown that it is also a <u>sufficient</u> condition.

Turning now to the two other cases (i.e., 4.5 b and c), for which the minimum assimilation criteria is satisfied, we see, from diagram 3, that development can be characterized either by raising the capital-labor ratio (Case two, ADO) or by lowering the capital-labor ratio (Case three, AEO). As we would intuitively expect, the capital shallowing case represents a relatively larger indigenous capital stretching effort ($c > 1/\alpha$) and leads to a higher level of output and employment.

Applying the same type of arguments as in the "big push" model, we obtain

4.7a) $\eta_T = i/B$

b) $\eta_{K'} = i\,(1-B)/B \equiv -\theta < 0$

c) $\eta_{\eta_K} = \theta > 0$

d) $\eta_K = \eta_0 \, e^{\theta t}$ $\quad (\eta_0 \equiv \frac{s}{K_0}$ is η_K at $t = 0)$

e) $K = K_0 \, J^{e^{\theta t}-1}$ where $J = e^{\eta_0/\theta} > 0$

comparable to (3.2) in the last section.[17] Equation (4.7a) indicates that in the case of a relatively high (low) capital stretching coefficient in case three (case two) of (4.5), the development process is characterized by capital shallowing (deepening) as T decreases (increases) through time. However, it is important to note from (4.7b) that, regardless of the fine distinction between the two cases, the

17/ Since (4.4a) replaces (3.1a) the growth rates in (4.7) are obtained from those in (3.2) by replacing "a" by "B". The relation between θ, the rate of capital acceleration in 4.7c and v, the assimilation lever, in 4.6 will be investigated in the next section.

capital output ratio decreases in both -- as long as the minimum domestic ingenuity test (4.6) is satisfied. It follows from this fact that in both instances there will be capital acceleration (4.7c), with the rate of growth of capital increasing at a constant rate (4.7d). The time path for the capital stock is monotonically increasing toward infinity as given by (4.7e).

In order to investigate the rate of increase of output (Q), employment (N), per capita income ($Q^* = Q/L$) and the degree of employment ($N^* = N/L$), we have

4.8a) $\eta_Q = \eta_o \; e^{\Theta t} + \Theta$ ..... (by 4.7bd)

b) $\eta_N = \eta_o \; e^{\Theta t} + \Theta - i$...... (by 4.8a and $\eta_p = i$)

c) $\eta_{Q^*} = \eta_o \; e^{\Theta t} + \Theta - r$...... (by 4.8a and $\eta_L = r$)

d) $\eta_{N^*} = \eta_o \; e^{\Theta t} + \Theta - i - r$... (by 4.8b and $\eta_L = r$)

We can readily see that all the growth rates in 4.8 are in the form of

4.9) $\eta_x = \eta_o \; e^{\Theta t} + g$ for $\eta_o > o$ and $\Theta > o$

Hence the behavior of all these rates of growth depends upon the fulfillment of the condition

4.10) $\eta_o + g > o$ or $\eta_o > -g$ (for $\eta_x > o$)

When condition (4.10) is fulfilled, η_x is positive and hence x monotonically increases. Conversely, when (4.10) is not fulfilled, there exists a "switching point" with duration

4.11) $t = (1/\Theta) \; \ln \; (-g/\eta_o)$ ..... (by setting $\eta_x = o$ in 4.9)

at which the sign η_x changes from negative to positive -- and hence the time path of x itself is U-shaped. We can easily deduce the time path for "x"[18/] as

4.12) $x = x_o \; e^u \; / \; e^{\eta_o/\theta}$ where $u = (\eta_o/\theta) \; e^{\theta t} + gt$

With respect to the terminal point phenomenon, i.e., the elimination of technical unemployment, we see that while the technology ratio (T=K/N) is growing at a constant rate (4.7a), the endowment ratio K* = K/L is growing at an increasing rate ($\eta_o e^{\theta t} - r$ by 4.7d). Thus sooner or later K* will catch up with T at the terminal point where the economy moves from the unemployment phase of growth into the full employment phase of growth. Thus, when the MAC test of (4.6c) is satisfied, the "maturity" of the economy (in respect to the loss of its labor surplus characteristic) is also ensured. The duration of time before the system reaches the terminal point can be obtained by solving for "t" in

4.13) 1 = N* where N* satisfies 4.8d

In this paper we shall not be concerned with the prospects of development <u>after</u> the terminal point. Equations (4.7) and (4.8) are valid only before that point is reached.

The above analysis demonstrates that the minimum assimilation criteria is indeed a most crucial condition for economic development as measured by the four welfare indicators in (4.8) as well as, and more importantly, whether or not the society will ever reach economic maturity. When this condition is not satisfied,

18/ The differential equation (4.9) can be readily solved by a separation of variables as $\int \frac{dx}{x} = \eta_o \int e^{\theta t} dx + g \int dt$ which leads to (4.12) capital accumulation and growth will cease; when it is satisfied, growth will succeed in the sense that all four indicators will continue to increase in the long run until the terminal point is reached.[19]

Since only the technological parameter "α" which measures the availability of imported technology, and "c" which measures the domestic effort in capital stretching, are involved in the minimum assimilation criterion of (4.6), our conclusion strongly supports the thesis that successful economic development is essentially a process of technological revolution brought about by a sufficiently large adaptive domestic response to the stimulation of imported technology. It is for this reason that we need to examine more carefully the meaning of the parameter α which summarizes the availability of importable technology.

Section V.. Nature of the Technological Shelf

A crucial assumption of our analysis is that the availability of imported technology can be described by a unit contour in the form of a Cobb-Douglas function (3.1a). In order to fully understand what lies behind this contour we must, first of all, realize that it is determined by past experiences of production and technology in the advanced and technology-exporting countries.

19/ In the short run the values of some of these indicators may decrease. Comparing the four growth rates of (4.8) and making use of (4.10), we see that the expansion of output ($\eta_o* > 0$) is most readily achievable in the short run while the expansion of the degree of employment ($\eta_W * > 0$) is the most difficult to achieve. This explains why, in the development process, it is easier to meet the "output criterion" than the "employment criterion".

It is well known that the production structure in these industrially advanced countries is characterized through time by (i) continuous innovation and (ii) continuous capital deepening. This is depicted in diagram 6 in which the sequence of unit contours aa', bb', cc', dd' ..... represents innovations (as they move toward the origin) and in which the sequence of factor endowment ratios OA, OB, OC, OD, ... represents capital deepening (i.e., increasing capital per head) through time. The locus of points A, B, C, D ... thus traces out a dotted curve $\alpha\alpha'$. It is this curve, combining the effects of innovation and capital deepening in the industrially advanced countries over time, which provides a summary of the borrowing possibilities for the underdeveloped country. In other words, the technology which can be visualized and borrowed by the underdeveloped society represents the export of historically realized technology while the unrealized portions of contours aa', bb', cc' . . . are irrelevant. Thus, the (dotted) $\alpha\alpha'$ curve of diagram 3 is really the (dotted) "ex post" curve $\alpha\alpha'$ of diagram 6.

For a rigorous analysis of the determination of the unit contour, let $d = Q/L$ denote the average productivity of labor and let $k = K/Q$ denote the capital-output ratio in the technology-exporting country. If we assume that the long run growth rates of k and d, (η_k and η_d) are constant, we can easily derive

5.1 a) $k^{\eta_d} = d^{\eta_k}$ [20]

b) $Q = K^{\alpha} L^{1-\alpha}$ where

c) $\alpha = \dfrac{\eta_d}{\eta_k + \eta_d}$ (by 5.1a, $k = K/Q$, $d = Q/L$)

20/ This is obtained by eliminating t from $k = k_o e^{\eta_k t}$ and $d = d_o e^{\eta_d t}$ and by a proper choice of unit of measurement so that $k_o = d_o = 1$.

Notice that 5.1b is precisely the same "production function" which we originally postulated in 3.1a (i.e., by letting Q = 1 in 5.1b we obtain the equation of the unit contour). This is the logical foundation for our postulation of a Cobb-Douglas function to depict the unit contour in the first place. Furthermore, the coefficient α is now seen to be a function of the rates of growth of k and d in the technology-exporting country. The previously defined concept of the technology barrier R, the assimilation lever γ, and the minimum assimilation criterion of 4.6 may now be expressed in terms of these growth rates:

5.2a) $R = \frac{1-\alpha}{\alpha} = \eta_k/\eta_d$ (by 4.6a, 5.1c)

b) $\gamma = c - R = c - \eta_k/\eta_d$ (by 4.6b, 5.1c)

c) $\gamma > o$ or $c > \eta_k/\eta_d$ (by 4.6c, 5.1c)

Furthermore, we recall from 4.7 and 4.8 that the rate of capital acceleration θ in the less developed country is an important parameter in determining the behavior of all the crucial economic variables in the system, e.g., K, Q, N, Q*, and N*. We can now express θ as a function of η_d and η_k

5.3) $\theta = i\,(B-1)/B = i\gamma = i\,(c-\eta_k/\eta_d)$ (by 4.7b, 4.4b, 5.2b)

The rate of capital acceleration θ is seen to be proportional to both the rate of increase of labor productivity i and the assimilation lever γ. Thus what contributes favorably to the rapidity of the growth process in the technology receiving country is a high rate of labor progress and a high innovation leverage effect. Clearly the leverage effect will be greater, the greater the domestic capital-stretching capacity, c. Moreover, the leverage effect, given c, is greater when the assimilation barrier is lower, i.e., when there is a higher rate of increase of labor and/or capital productivity in the advanced country. Thus, we see a mechanism through which economic progress in the advanced countries can be transmitted to the underdeveloped countries through the borrowing of technology.

Let us return now to the famous controversy of the output effect vis-a-vis the employment effect in a less developed country attempting to modernize via a "big push" policy (defined rigorously as technological borrowing without capital stretching). Contrary to our earlier conclusion one could legitimately argue that a high enough rate of progress in the advanced country can eliminate the need for capital-stretching in the underdeveloped country. Many a planning commission or foreign aid official certainly is of that view. The fact that this argument is not entirely without merit can readily be seen with the aid of diagram 6. With the indicated rate of capital deepening in the developed country (i.e., OA, OB, OC, OD...) the unit technology contour could, in fact, follow the path AB'C' ... <u>if</u> innovational intensity occurs at a high enough rate. The shape of this curve, it should be noted, is now comparable to the positively sloped post-capital-stretching curve in diagram 3. Thus the argument for the big push cannot, in fact, be rejected on <u>a priori</u> theoretical grounds and is deserving of further attention.

In view of the fact that the shape of the unit contour in 5.1b is completely determined by α we can, by a procedure entirely analogous to that followed in 4.5 deduce the following possible cases:

5.4a) $0 < \alpha < 1$ (unit contour negatively sloped)

b) $1 < \alpha$ (" " positively sloped and convex)

c) $\alpha < 0$ (" " " " " concave)

The three possible cases are thus represented by the three dotted unit contour lines in diagram 6. Furthermore, we see from 5.1c that α is determined by the magnitude of the rates of improvement of labor and capital productivity η_d and η_k in the advanced country.

The magnitudes of both η_d and η_k, in turn, can be traced directly to the forces of innovation, capital accumulation and population growth in the advanced country. We can, for example, postulate a production function in the conventional form and define the innovation intensity J, and the capital and labor elasticity of output:

5.5a) $Q = f(K,L,t)$ (constant returns to scale)

b) $J = \left(\frac{\partial Q}{\partial t}\right)/Q$ (innovation intensity)

c) $\phi_K = \left(\frac{\partial Q}{\partial K}\right)(K/Q)$; $\phi_L = \left(\frac{\partial Q}{\partial L}\right)(L/Q)$; (with $\phi_K + \phi_L = 1$)

and deduce the following growth equations:

5.6a) $\eta_d = J + \phi_K \eta_{K*}$

b) $\eta_k = -J + \phi_L \eta_{K*}$

which show that the magnitude of η_d and η_k are determined by the twin growth promoting forces of J (the intensity of innovation) and η_{K*} (the rate of capital deepening).[21] We can then derive the expression for α in terms of these underlying forces.

21/ For a fuller exposition see the authors' Development of the Labor Surplus Economy (op. cit. Chapter 3)

5.7) $\alpha = \frac{\eta_d}{\eta_k + \eta_d} = \frac{J}{\eta_{K*}} + \phi_K$ (by 5.1c and 5.6)

This then enables us to investigate the real causal factors which determine the demarcation between the three possible cases of 5.4. For this purpose we assume, as before, that the growth path in the mature economy is characterized by continuous capital deepening ($\eta_{K*} > o$).

5.8a) $o < \alpha < 1$ iff $\eta_d > o$ and $\eta_k > o$

b) $1 < \alpha$ iff $\eta_d > o$ and $\eta_k < o$

c) $\alpha < o$ iff $\eta_d < o$

We know that one of the stylized features of the mature economy is that it is characterized by continuous increases in labor productivity or per capita income. Thus, for all practical purposes, the positively sloped and concave unit contour possibility in diagram 6, (i.e., 5.8c, with $\eta_d < o$) can be ruled out.

This leaves us with the consideration of the two other cases characterized by rising labor productivity. The central question now becomes one of determining what happens to the capital-output ratio over time in the mature economy. This problem of the time trend of the capital-output ratio in the mature economy has been the subject of exhaustive study in the recent past.[22/] Most of these studies seem to indicate long term secular stability in the capital-output ratio but with some up and down swing phases. We must now recognize that these trends also have considerable significance for the less developed world anxious to borrow technology from abroad.

22/ 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.

First of all, let us note that the case of constancy in the capital-output ratio, i.e., $\eta_K = o$, is, in fact, the borderline case, i.e., $\alpha = 1$, between the two cases still under discussion, i.e., 5.8a and 5.8b. The assimilation barrier R of 5.2a for the two cases can be seen to be

5.9a) $o < \alpha < 1$ or $R > o$

b) $1 < \alpha$ or $R < o$

Thus we see that, in the first case, there exists a positive innovation barrier. In this case modernization through a big push policy does not work since we require a positive domestic capital stretching effort, i.e., $c > o$, to satisfy the minimum assimilation criterion (MAC) of 5.2. Conversely, in the second case, we see that the innovation barrier does not exist; hence even if no domestic ingenuity is expended in the capital-stretching direction the MAC is satisfied and the big push can succeed. This does not, of course, imply that capital-stretching does not help even if the capital-output ratio is falling in the advanced country (5.8b) because the rate of capital acceleration in the recipient country $\bar{\theta}$ (see 5.3) can be raised as the assimilation lever γ is increased by a larger $\bar{c}$.

It should be noted that the existence and the magnitude of the innovation barrier depends on the nature of the growth process in the developed world, i.e., the innovation barrier R can be written as

5.10) $$R = \frac{-J + \phi_L \eta_K^*}{\eta_d}$$ (by 5.2a and 5.6b)

As (5.6a) indicates, a given rate of growth of per capita income or labor productivity η_d in the mature economy can be brought about by different combinations of J, human ingenuity, and η_{K*}, the augmentation of material resources.

Equation 5.10 then shows that a given rate of progress in the technology-exporting country benefits the recipient country more if it is brought about by relatively larger doses of J and relatively smaller doses of η_{K*} through a relative lowering of the innovation barrier. This is a logical result since, after all, what is being transmitted in the international borrowing of technology should as much as possible constitute human ingenuity rather than the consequence of superior material resources. The broad brush implications for foreign assistance strategy are interesting. In the early days of Point IV the advanced countries conceived their main task to be one of making the international stockpile of knowledge and techniques available to the less developed world; in terms of our model this is equivalent to unveiling θ. In the years that followed we have experienced increasing concentration as well on the transfer of capital to augment the narrowly circumscribed savings capacity of the recipient countries; in our terms, this is equivalent to raising s. And finally, in the yet more recent period, the realization has grown that the importation of capital alone cannot do the job, but that it is really the release of domestic energies and ingenuity which lies at the heart of successful development and must therefore play a larger role in the foreign assistance strategies of the capital exporting countries; in terms of our model this means more attention must be paid to raising c and i to ensure that the maximum assimilation criterion (MAC) is satisfied.

Section VI. Verification

In this paper, we have constructed a model of employment and output expansion by integrating the following growth-related factors into one explanatory framework: population growth, savings behavior, changes in labor productivity, innovational borrowing, and the assimilation of technology. As a contribution to the theory of growth, the model can be used to attempt to explain historical experience. To decide what less developed country experience is, in fact, relevant, let us briefly reexamine the essential "causal structure" of the model.

In the causal order chart of diagram 7, the five key behavioristic assumptions are indicated by the five rectangles, while the direction of the arrows indicates the causal order of determination. The growth of labor efficiency is shown to be significant from three points of view: technical, capital-output and employment. The technical aspect determines, on the one hand, the imported capital-output ratio (through the "availability of imported technology") and, on the other, the degree of capital stretching (through the "domestic capital stretching function"). These together determine the technical aspect, i.e., the innovation process characterized by "assimilation". With respect to the capital-output aspect of things, the rate of increase of labor productivity determines the rate of change in the capital-output ratio ($\eta_{k'} < 0$) which, together with the savings function, determines the rates of growth of capital (η_K) and of output (η_Q) in the underdeveloped country.

Finally, the growth of labor efficiency determines the rate of growth of employment (η_N) when the rate of growth of output is known. We see that the population growth assumption lies at the "closed end" of the model and serves to determine both per capita income and the degree of employment.23/

From the above analysis we see that our model depicts a type of growth in which the increase of labor efficiency -- through education and learning by doing -- represents the primary growth promoting force. Furthermore, the significance of this labor productivity increase is manifested, in the first place, as a technological phenomenon via the assimilation

23/ Notice that the analysis of the nature of the available technological shelf, i.e., α, finds its place in a fuller understanding of the imported technology "box" (3.1a). In the statistical verification, we shall restrict ourselves to data of the technology-receiving country.

process, i.e., in the imitation and adaptation of foreign technology. There is ample evidence provided by economic historians that post-Meiji Japanese growth was characterized precisely by these conditions, i.e., rapid expansion of education and "imitative" growth. Thus, in the remainder of this section, the historical experience of Japan will be analyzed in the framework of our model.

In order to implement the model of the last section, we have to estimate the values of the five parameters (α, c, i, r, s). The following equations can be used for this purpose:

6.1a) $p = \hat{p}_o \, e^{\hat{i} t}$ .... (by 1.10d)

b) $k' = \hat{a} \, p^{\hat{b}}$ .... (by 4.3a)

c) $c = \ln \hat{a}/\ln \hat{p}_o$ .... (by 4.3b)

d) $\alpha = \dfrac{1}{1 + \hat{b} + c}$ .... (by 4.3b)

e) $L = \hat{L}_o \, e^{\hat{r} t}$ .... (by 1.10e)

f) $S = \hat{s} \, Q$ .... (by 1.10f)

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 6.1aef -- for which time series of output (Q), savings (S) population (L) and labor productivity p (=Q/N) are required. If we have, in addition, the time series of capital stock (K), we can estimate "a" and "b" in (6.1b) with the aid of the time series of k' (observed capital-output ratio) and p. We can then use equation (6.1cd) to estimate "c" and "α". This 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 the period 1888-1930, are presented in columns 1-4 of table two (i.e., for Q, K, and N).[24/] We can then derive the time series of $p=Q/N$ (Column 5), $k' = K/Q$ (Column 6) and $s=dK/dt/Q$ (Column 9).

The time series of p and k' are indicated in diagrams 8 and 9 in which the fitted curves (by the least square method) are also shown. The estimated values for p and k are recorded in columns (7) and (8) of Table two.

The relationship between p and k' is shown in the scatter diagram (diagram 10) in which the curve (6.1b) is shown. The regression curves of diagrams 8, 9, and 10 may be summarized as:

6.2 a) $p = p_o e^{\hat{i} t}$ where $\hat{p}_o = 89.33$ and $\hat{i} = .033$

b) $k' = \hat{k}'_o e^{\hat{\theta} t}$ where $\hat{k}'_o = 9.50$ and $\hat{\theta} = -.022$

c) $k' = \hat{a}\, p^{\hat{b}}$ where $\hat{a} = 168.6$ and $\hat{b} = -.642$

We can then estimate the parameters (α, c) by (6.1cd) since

6.3a) $c = \ln \hat{a} / \ln \hat{p}_o = 1.128$ ... (by 6.2ac)

b) $\alpha = 1/(1+\hat{b}+c) = 0.67$ ... (by 6.3a, 6.2c)

which are the two major "innovation parameters" of our model. For it is only in terms of these two parameters that the minimum assimilation criterion for success (4.6c) is defined. To see the economic implications of the above numerical results, we observe that:

24/ See Appendix for explanation of the data sources.

Table 2
BASIC JAPANESE DATA*

Year (1)	Output = Q (2)	Capital = K (3)	Employment = N (4)	Q/N = p (5)	K/Q = k' (6)	p (7)	k (8)	s = $\frac{dK}{dt}/Q$ (9)
1888	2,077	21,331.8	39,362	94	10.27	89.33	9.50	.0569
1889	1,953	21,449.9	39,795	88	10.98	92.28	9.29	.0670
1890	2,308	21,580.7	40,164	102	9.35	95.49	9.09	.0682
1891	2,202	21,738.1	40,444	96	9.87	98.71	8.90	.0722
1892	2,311	21,897.0	40,772	100	9.48	102.01	8.70	.0677
1893	2,586	22,053.4	41,127	111	8.53	105.50	8.55	.0631
1894	3,045	22,216.5	41,453	129	7.30	109.07	8.33	.0660
1895	2,981	22,417.5	41,883	125	7.52	112.73	8.15	.0778
1896	2,781	22,649.5	42,298	116	8.14	116.58	7.98	.0848
1897	3,040	22,885.4	42,765	126	7.53	120.60	7.81	.0878
1898	4,018	23,152.2	43,275	165	5.76	124.70	7.63	.0714
1899	3,408	23,439.2	43,736	139	6.88	128.90	7.48	.0759
1900	3,640	23,697.7	44,231	147	6.51	133.28	7.33	.0727
1901	3,985	23,962.6	44,748	160	5.95	137.75	7.15	.0703
1902	3,580	24,242.5	45,401	143	6.77	142.39	7.00	.0775
1903	3,975	24,520.0	45,988	157	6.17	147.31	6.85	.0759
1904	3,920	24,821.9	46,499	154	6.33	152.31	6.71	.0787
1905	3,433	25,130.4	46,934	134	7.32	157.40	6.56	.1021
1906	4,066	25,480.8	47,322	158	6.27	162.76	6.42	.0890
1907	4,345	25,842.7	47,828	168	5.95	168.39	6.28	.0927
1908	4,554	26,245.4	48,407	175	5.76	173.93	6.15	.1065
1909	4,623	26,730.4	49,027	177	5.78	179.91	6.01	.1117
1910	4,427	27,246.9	49,685	169	6.15	186.07	5.89	.1233
1911	5,197	27,792.9	50,396	198	5.35	192.24	5.74	.1055
1912	5,682	28,341.4	51,123	216	5.27	198.85	5.63	.0979
1913	5,807	28,897.4	51,856	220	4.98	205.64	5.51	.0912
1914	5,665	29,427.0	52,574	214	5.19	212.52	5.39	.1014
1915	5,498	30,001.4	53,310	207	5.46	219.75	5.27	.0831
1916	5,528	30,458.1	53,975	208	5.51	227.26	5.16	.1323
1917	5,773	31,189.5	54,588	217	5.40	234.85	5.06	.1277
1918	6,505	31,926.5	54,960	244	4.91	242.80	4.94	.1148
1919	7,889	32,673.3	55,363	296	4.14	251.20	4.84	.0989
1920	6,316	33,453.7	55,944	232	5.30	259.59	4.71	.1699
1921	7,538	34,527.1	56,624	274	4.58	268.35	4.64	.1463
1922	7,815	35,630.1	57,357	282	4.56	277.55	4.53	.1307
1923	8,144	36,651.3	58,331	291	4.50	286.84	4.43	.1260
1924	8,607	37,677.5	58,864	305	4.38	296.58	4.33	.1283
1925	9,268	38,781.6	59,757	326	4.18	306.67	4.24	.1358

BASIC JAPANESE DATA*(Cont'd)

Year	Output = Q	Capital = K	Employment = N	Q/N = p	K/Q = k'	p	k	$s = \frac{dK}{dt}/Q$
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
1926	10,095	40,067.3	60,522	352	3.97	317.03	4.16	.1343
1927	10,554	41,423.9	61,317	365	3.92	327.84	4.07	.1289
1928	10,696	42,783.9	62,122	367	4.00	339.19	3.98	.1225
1929	10,962	44,093.9	62,938	373	4.02	350.35	3.89	.1475
1930	12,715	45,710.9	64,450	429	3.60	362.59	3.81	

*See Appendix for explanation of data sources and methods.

6.4) $(1-\alpha)/\alpha < c < 1/\alpha$ i.e., $.5 < 1.128 < 1.5$

and hence (4.5b) is satisfied. Thus the value of the technology barrier R (4.6a) is .5 and the value of the assimilation lever γ (4.6b) is .628. We can immediately conclude that: 1) The development experience of Japan represents a case of "success" in the sense that the minimum assimilation criterion (4.6c) is satisfied. This means that the domestic effort in the direction of capital stretching was sufficiently strong to compensate for the unfavorable effect of the highly capital using nature of the imported technology. We can thus explain why output (Q) employment (N), per capita income (Q*) and the degree of employment (N*) did increase in the long run. (Whether or not these four welfare indicators may turn down in the "short run" is investigated below.) 2) The domestic capital stretching effort, however, was not quite strong enough to satisfy condition (4.5c). This means that for the 40 years taken as a whole, Japan developed under conditions of some capital deepening. This evidence, of course, does not contradict the fact that for the early years capital stretching could have played a much more important role. In fact, it is possible that Japan could even have shown a capital shallowing characteristic in the earlier stages (i.e., with a higher capital stretching coefficient).[25]

3) The Japanese data, moreover, reveal that α in 6.3b lies between 0 and 1. This depicts the use of the negatively sloping unit contour (5.9a) which

[25] 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.

means that Japan was borrowing technology when the exporting world was exhibiting some tendency for increasing capital-output ratios.[26] It also means that Japan would not have been able to grow successfully without a major domestic capital-stretching effort for which it is, in fact, justifiably famous.

Once we have determined the numerical magnitude of the three "innovation parameters" ($c = 1.128$, $\alpha = .67$ and $i = .033$), we can proceed to investigate the predicted values for the rates of growth of k', K, Q, N, Q* and N* (see causal order chart, diagram 7) based on these "innovation parameters", and then compare these with the directly observed values. In this way, the reasonableness of our model can be verified.

To begin with, we can calculate the rate of growth of the capital-output ratio by the formula

6.5) $\eta_{k'} = -\theta = i\ (1-B)/B = -i\ (c-(1-\alpha)/\alpha)$ ... (by 5.3)

$= -.0216$ ... (by 6.3 and 6.2a)

which shows that the predicted value for $\eta_{k'}$, i.e. $-.0216$, is approximately identical to its directly observed value in (6.2b), i.e., $\theta = -.022$.

As a second step, the numerical value of $\eta_{k'}$, the predicted rate of capital acceleration, is

6.6) $\eta_{\eta_K} = -\eta_{k'} = \hat{\theta} = .0216$ (by 4.7bc)

26/ Thus, an examination of purely Japanese date permits us to conclude that the capital output ratio of the advanced countries must have been increasing during the period 1888-1930. This phenomenon can of course be verified by independent evidence (see footnote 22).

However, the directly observed value of capital acceleration can also be calculated from column 3 (Table 2). Using columns 3 and 9, we can estimate the parameters in the following equations:

6.7a) $\eta_K = \hat{\eta}_o e^{\hat{\hat{\theta}} t}$ where $\hat{\hat{\theta}} = .043$ (η_K is the rate of growth of capital)

b) $s = \hat{s}_o \; e^{\hat{n}t}$ where $\hat{n} = .00898$ (s is the average propensity to save)

Thus, the observed value ($\hat{\hat{\theta}} = .043$) is about twice as large as the predicted value $\hat{\theta} = .0216$). This discrepancy is partly explained by the fact that the average propensity to save is not constant (as we have assumed in 1.10f) but is in fact growing at the rate of about 1% a year (6.7b). For we have

6.8) $\eta_{\eta_K} = \eta_{s/k'} = \eta_s - \eta_{k'}$

so that the observed rate of capital acceleration must be greater than $-\eta_{k'}$ by the amount of η_s, which is approximately the case. It is evident from the causal order chart (diagram 7) that the more realistic savings-behavioristic assumption (6.7b) -- or, for that matter, other savings-behavioristic assumptions -- could be used in place of (1.10f) near the "closed end" of our model.

For the remainder of this paper, we shall assume that the rate of capital acceleration is given in (6.7a), i.e., $\eta_{\eta_k} = \theta = .043$. Based on this assumption and the other parameters already estimated, we can next "predict" the numerical values of the rates of growth of output (Q), employment (N), per capita income (Q*) and the degree of employment (N*) according to (4.8). We obtain

$$6.9a)\quad \eta_Q = .0064\, e^{.043t} + .043 \qquad \text{(by 4.8a, 6.7a, 6.2a)}$$

$$b)\quad \eta_N = .0064\, e^{.043t} + .010 \qquad \text{(by 4.8b, 6.7a, 6.2a)}$$

$$c)\quad \eta_{Q*} = .0064\, e^{.043t} + .032 \qquad \text{(by 4.8c, 6.6a)}^{27/}$$

$$d)\quad \eta_{N*} = .0064\, e^{.043t} - .001 \qquad \text{(by 4.8d, 6.7a)}^{27/}$$

Based on these growth rates we could have calculated the "estimated" growth paths for Q, N, Q*, and N* (making use of 4.12) and compared these "estimated" growth paths with the observed growth paths. However, instead of this difficult comparison of two time series, let us concentrate on the analysis of the direction of change in the rates of growth in (6.9) making use of condition (4.10). For this purpose, it is sufficient to make the observation that condition (4.10) is satisfied for all four cases of (6.9), and hence that these four growth rates have been consistently positive through time. The conclusion is that the Japanese experience not only satisfies the minimum assimilation criterion of (4.6c) but, in fact, that the innovation effort has been so successful that employment and per capita output have been increasing from the very beginning of the growth process (i.e., the switching point phenomenon, as described by 4.11 never occurred for any of these welfare indicators).

Since the degree of employment (N* = N/L) is monotonically increasing without bound, full employment will be reached when N* = 1. Thus our

27/ For the estimation of η_{Q*} and η_{N*}, the population growth rate is assumed to be r = .0116 which is the growth rate of employment estimated from column (4) of Table 2.

model structure in the last section implies a "stages of growth thesis" composed of an unemployment growth regime, to be followed by a regime of full employment.[28] At "the terminal point" (i.e., when $N^* = 1$), the economy loses its labor surplus characteristic as it graduates into the family of mature economies. Previous work by the present authors suggested that such a turning point, in the case of Japan, occurred around 1917.[29] We may now calculate the time required to reach the "terminal point" by first computing the growth path of N^* (by 4.12) as

6.10a) $N^* = N_c^* e^u / e^{\eta_o/\theta}$ where

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

c) $\theta = .043$, $\eta_o = .0064$, $i = .033$, $r = .0116$

As indicated in 4.13, by setting $N^* = 1$ in (6.10) and by making use of the convenient fact that in our model $\theta - i - r$ ($= .001$) is approximately zero,[30] we can solve explicitly for the duration of the process before the terminal point is reached:

6.11a) $t = (1/\theta) \ln \ln (e^{\eta_o/\theta} / N_o^*)^{\theta/\eta_o}$ (when N^* increases to 1) for

b) $\theta = .043$, $\eta_o = .0064$, $i = .033$, $r = .0116$

Thus, we can calculate the time period till terminal point if we know the initial degree of employment (N^*_c) around 1888. Unfortunately, we

28/ Rigorously, all of our analysis in the last section is valid only in the first stage of growth in which unemployment exists.

29/ See Fei and Ranis Chapter 4. The result was obtained from the statistically observed fact that when the labor surplus condition ceased to exist, capital shallowing gave way to capital deepening in the industrial sector of the dualistic economy. We did not in our previous work explain <u>why</u> the termination point should occur in 1917 and not at any other date. Our work in this paper supplies a positive theory which provides a possible answer.

30/ If this were not conveniently true, everything would still hold but the calculation would be more complicated.

do not know of any data on unemployment (disguised or open) for these early years. Consequently, the hypothetical values of $N_0^* = .6, .7, .8$ and $.9$ (i.e., 10% to 40% of the total labor force openly or disguisedly unemployed in 1888) are assumed. Applying (6.10) we obtain the following results:

Initial degree of employment: (N_0^* in 1888)	.9	.8	.7	.6
Duration of unemployment phase t: (years)	12	21	27	34
Calendar Year (1888 + t)	1900	1909	1916	1922

In the early stage of Japanese economic development, it is quite unthinkable that there should have been no slack in the form of disguised unemployed labor force. We may reasonably assume that the initial unemployment is upward of 20%, which gives the terminal point for Japan somewhere after 1910. These results, though undoubtedly based on as yet inadequate data, are supported by independent earlier work on Japan.[31]

Conclusion

This paper has sought to demonstrate that a comprehensive theory of growth for less developed countries not only relates employment and unemployment with 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,

31/ See K. Ohkawa and H. Rosovsky "The Role of Agriculture in Modern Japanese Economic Development", Economic Development and Cultural Change, October 1960, for example, as well as the authors' Development of the Labor Surplus Economy (op. cit.). We hope that later information now becoming available from the Hitotsubashi University will make it possible to improve our estimates.

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 encouragement for 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 a technological gap and Veblen's advantage to the late-comer nation; c) the relationship between different internal patterns of growth in the developed world on the development process in the less developed world.

Appendix

Sources for the basic time series data used for the analysis of the growth experience of Japan:

1) Output data (Column 2) are taken from Ohkawa, The Growth Rate of the Japanese Economy Since 1878 page 248, Table 4, "Total Real National Income Produced". The data are measured in millions of Yen and in 1928-32 prices.

2) Capital stock estimates (Column 3) are from Fei and Ranis, Development of the Labor Surplus Economy pages 126-128. Figures are in millions of Yen and have been deflated by Ohkawa's (op. cit.) non-farm price index, page 130, 1930=100. The "Capital Stock" figures produced in this way are for the industrial sector which have been taken as approximations of the capital stock for the economy as a whole. Once more recent precise capital stock data become available these series should be revised.

3) Employment data (Column 4) are from Fei and Ranis (op. cit.), pages 126-128 Column 1. Numbers are in 1000's of persons. We have taken "total population" as an approximation of "total employment". From these data, the population growth rate is estimated to be r=1.158% (geometric average for the entire period) which is used in (5.8cd) in the text at the "closed end" of the model. (See the causal order chart in diagram 7).

4) The capital-output ratio, k' in Column (6) is Column (3)/Column (2). However, the figure for average productivity of labor (p) in Column (5) is not A/N as defined in Columns (2)/Column (4). Instead,

the Ohkawa (op. cit), page 250, "Total Real National Income per Gainfully Occupied Population". Figures are in 1928-1932 Yen. This is because we have taken "total population" as an approximation of "total employment". (Thus the data in Column 4 is used in the text only for the estimation of the total population growth rate r=1.158%.)

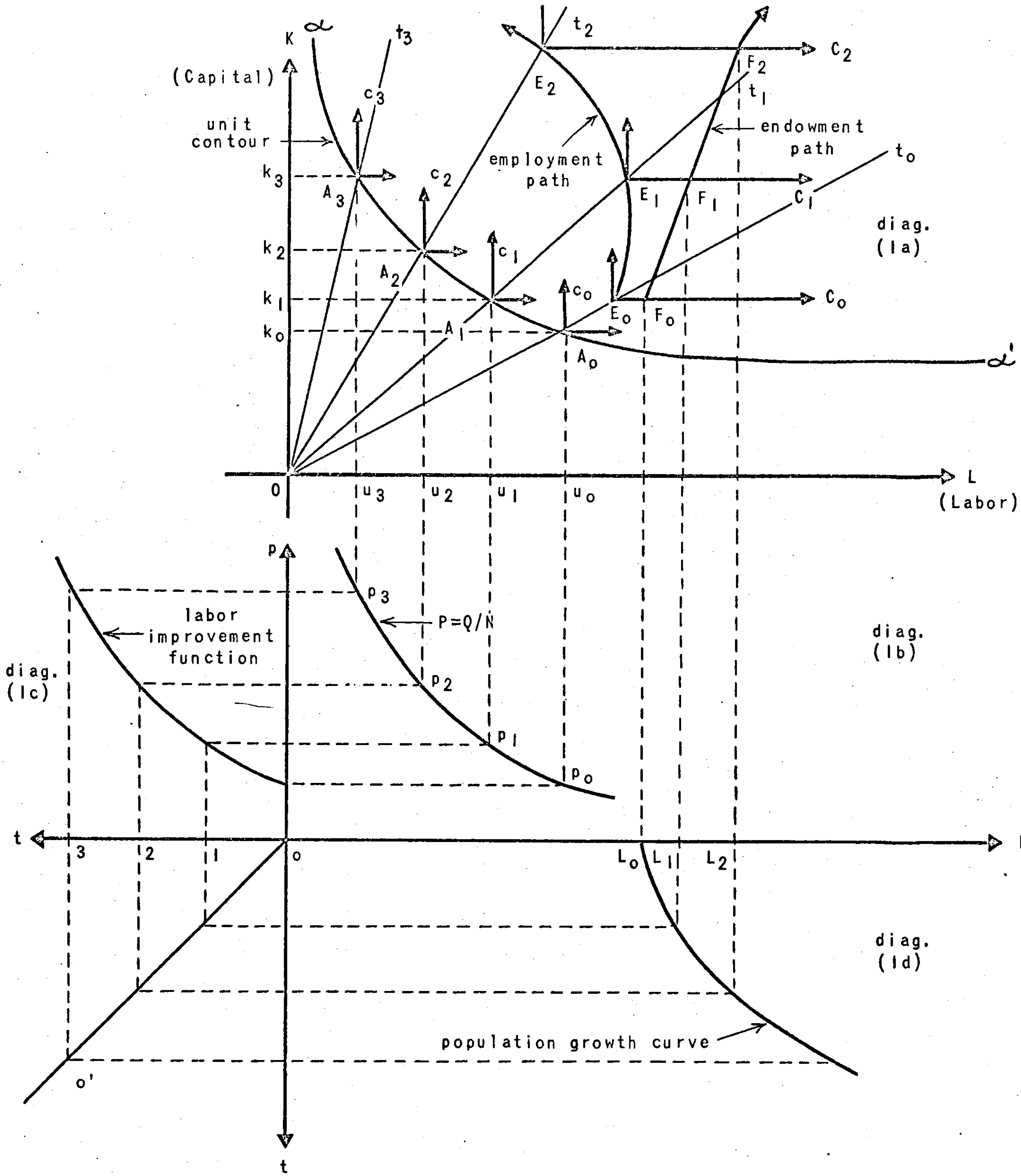
K
(Capital)
unit contour
employment path
endowment path
diag. (1a)
L
(Labor)
P=Q/N
labor improvement function
diag. (1b)
diag. (1c)
diag. (1d)
population growth curve
t
p
L

Diagram 1

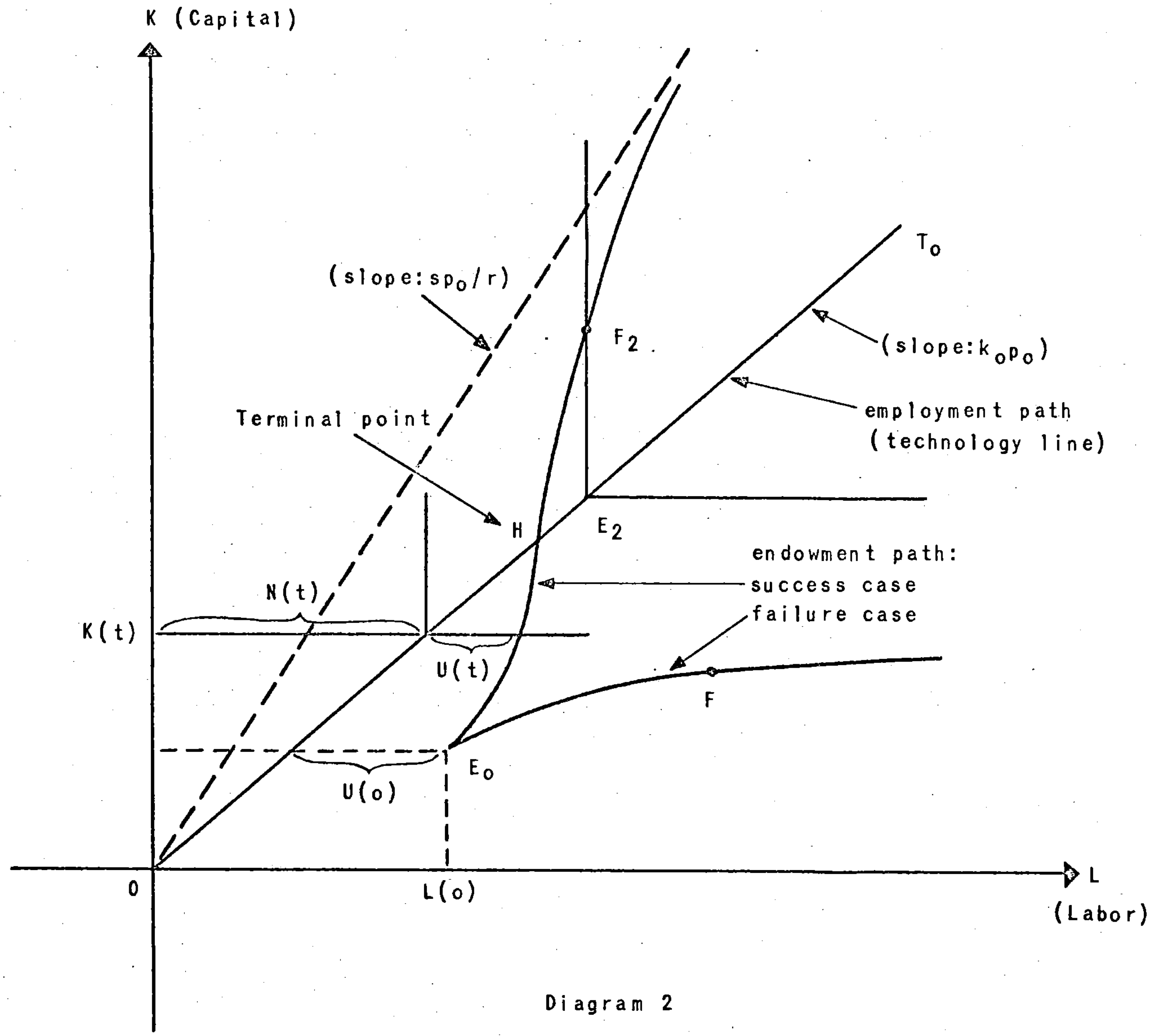
K (Capital)
(slope: sp_o/r)
T_o
F_2
(slope: $k_o p_o$)
employment path
(technology line)
Terminal point
H
E_2
endowment path:
success case
failure case
N(t)
K(t)
U(t)
F
E_o
U(o)
0
L(o)
L
(Labor)

Diagram 2

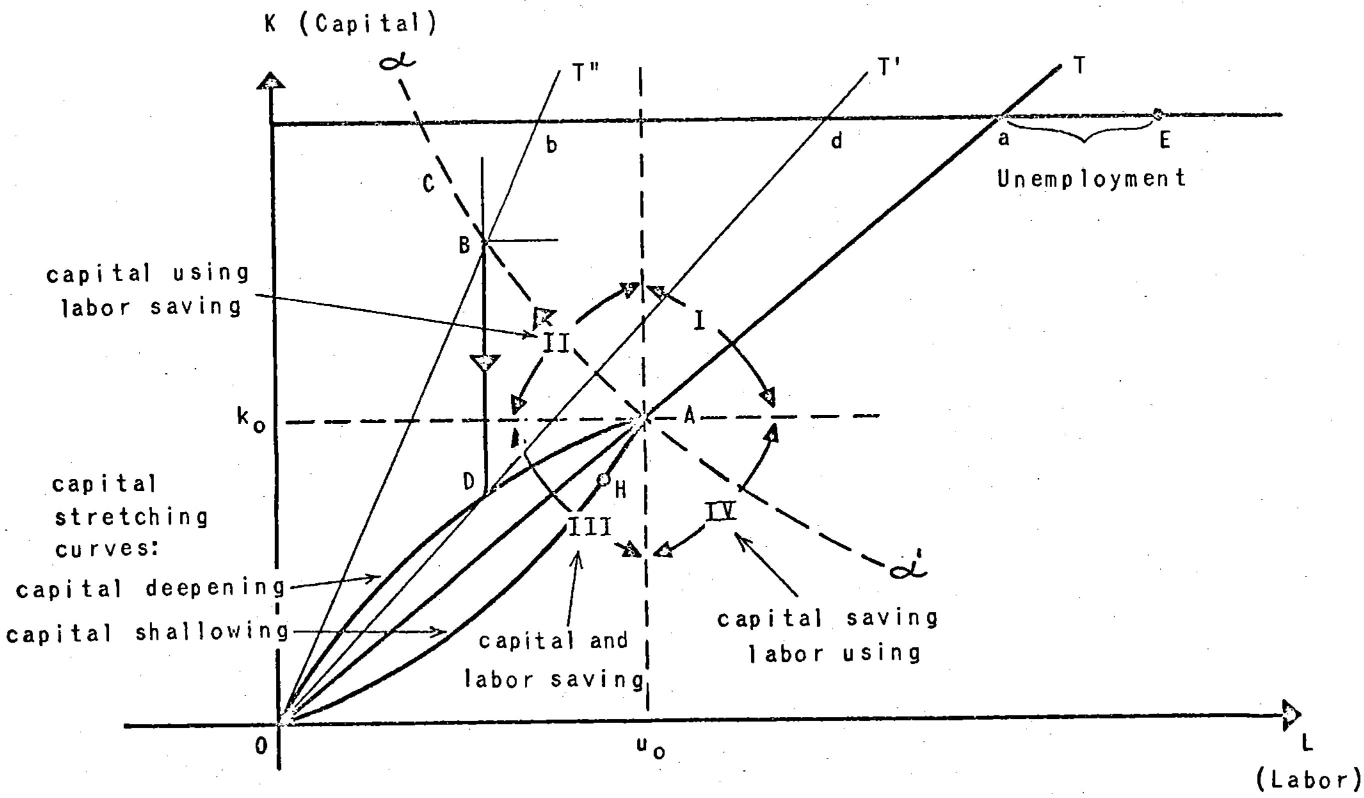

Diagram 3

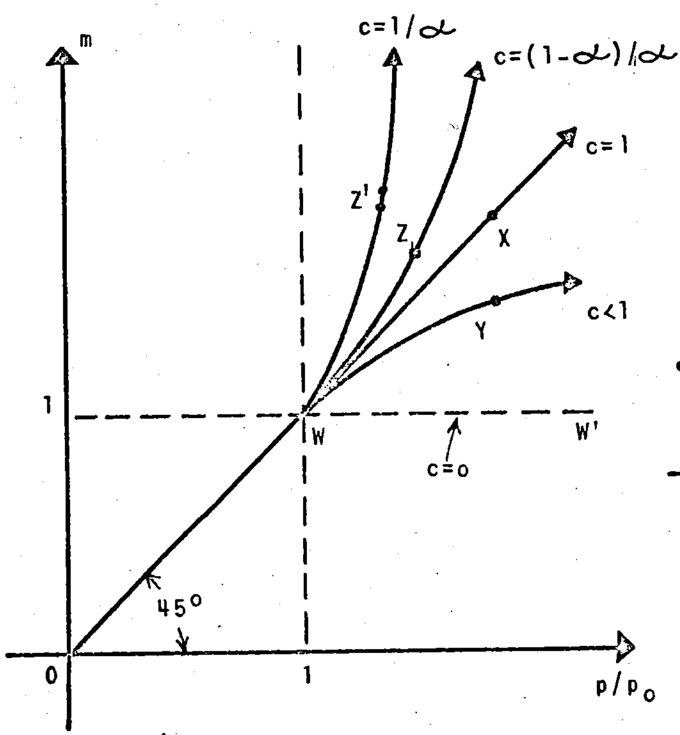

Diagram 4

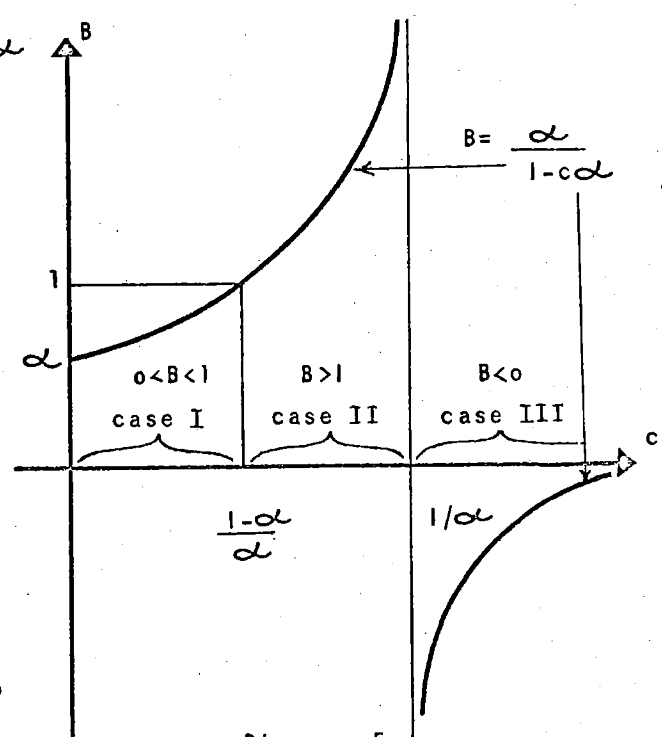

Diagram 5

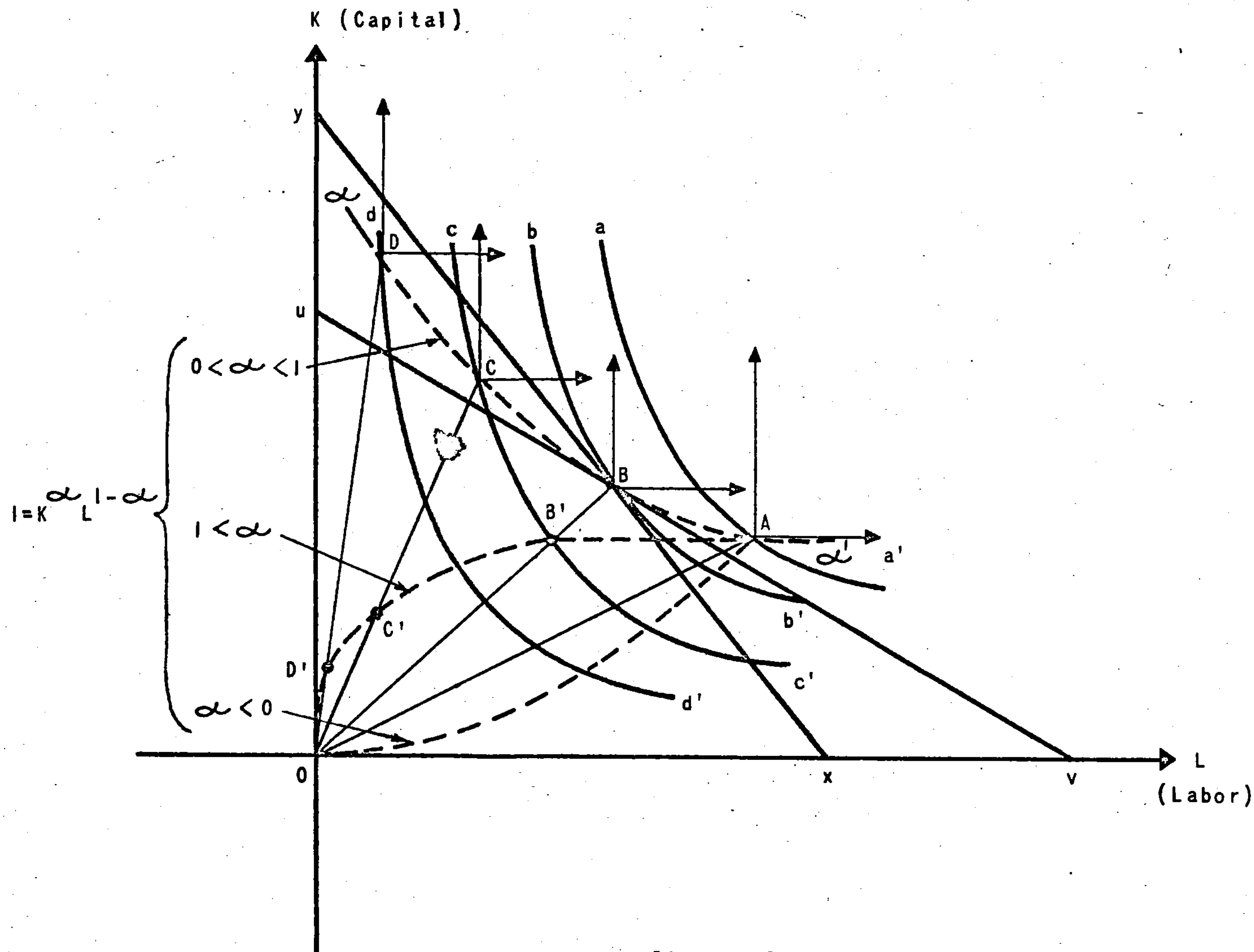
K (Capital)
L (Labor)
y
u
0
x
v
d
c
b
a
D
C
B
A
B'
C'
D'
a'
b'
c'
d'
α
α'
$0<\alpha<1$
$1<\alpha$
$\alpha<0$
$1=K^{\alpha}L^{1-\alpha}$

Diagram 6

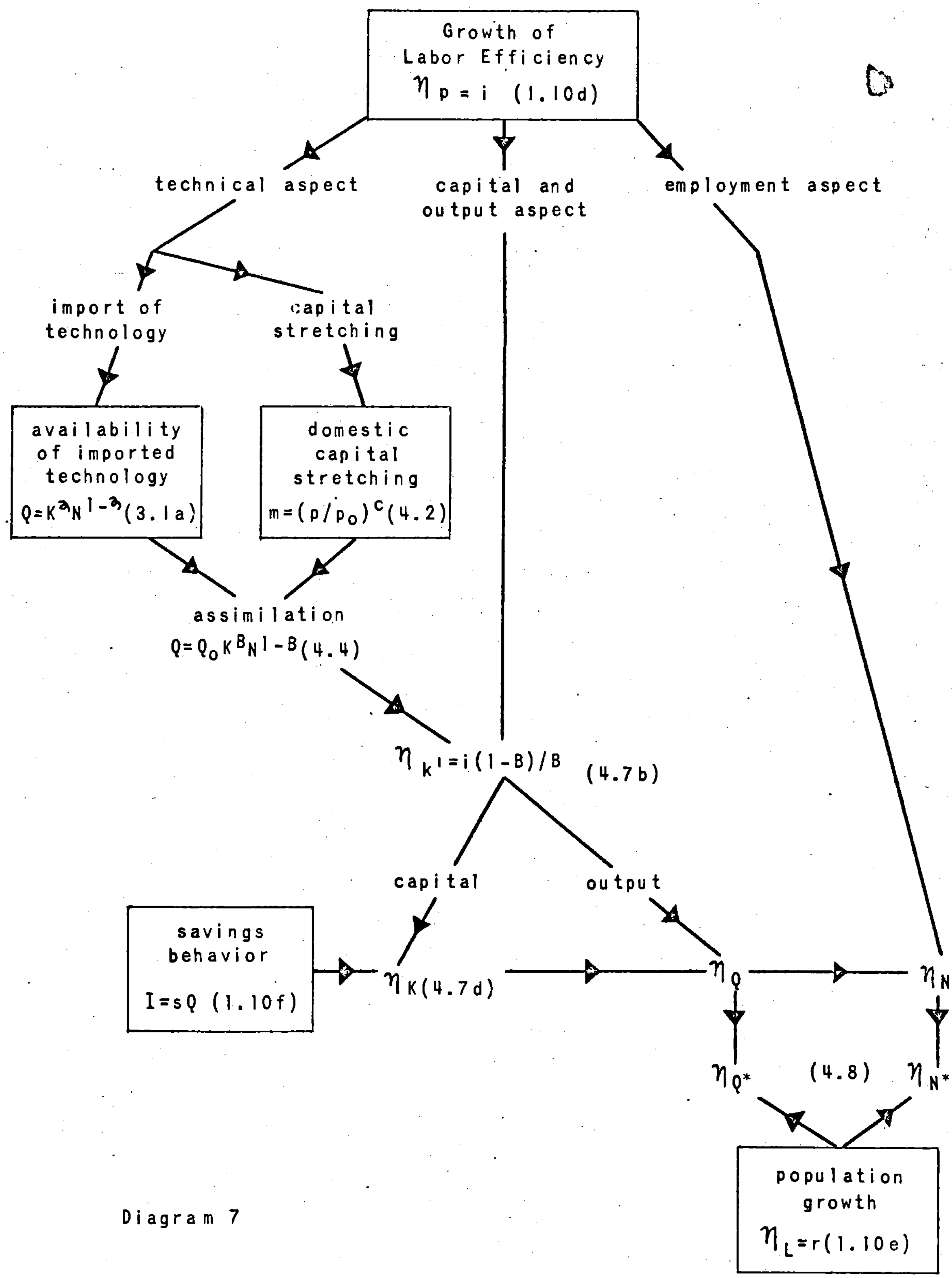
Growth of
Labor Efficiency
η p = i (1.10d)
technical aspect
capital and
output aspect
employment aspect
import of
technology
capital
stretching
availability
of imported
technology
Q=K^a N^1-a (3.1a)
domestic
capital
stretching
m=(p/p_o)^c (4.2)
assimilation
Q=Q_o K^B N^1-B (4.4)
η k'=i(1-B)/B (4.7b)
capital
output
savings
behavior
I=sQ (1.10f)
η K(4.7d)
η Q
η N
η Q*
(4.8)
η N*
population
growth
η L=r(1.10e)

Diagram 7

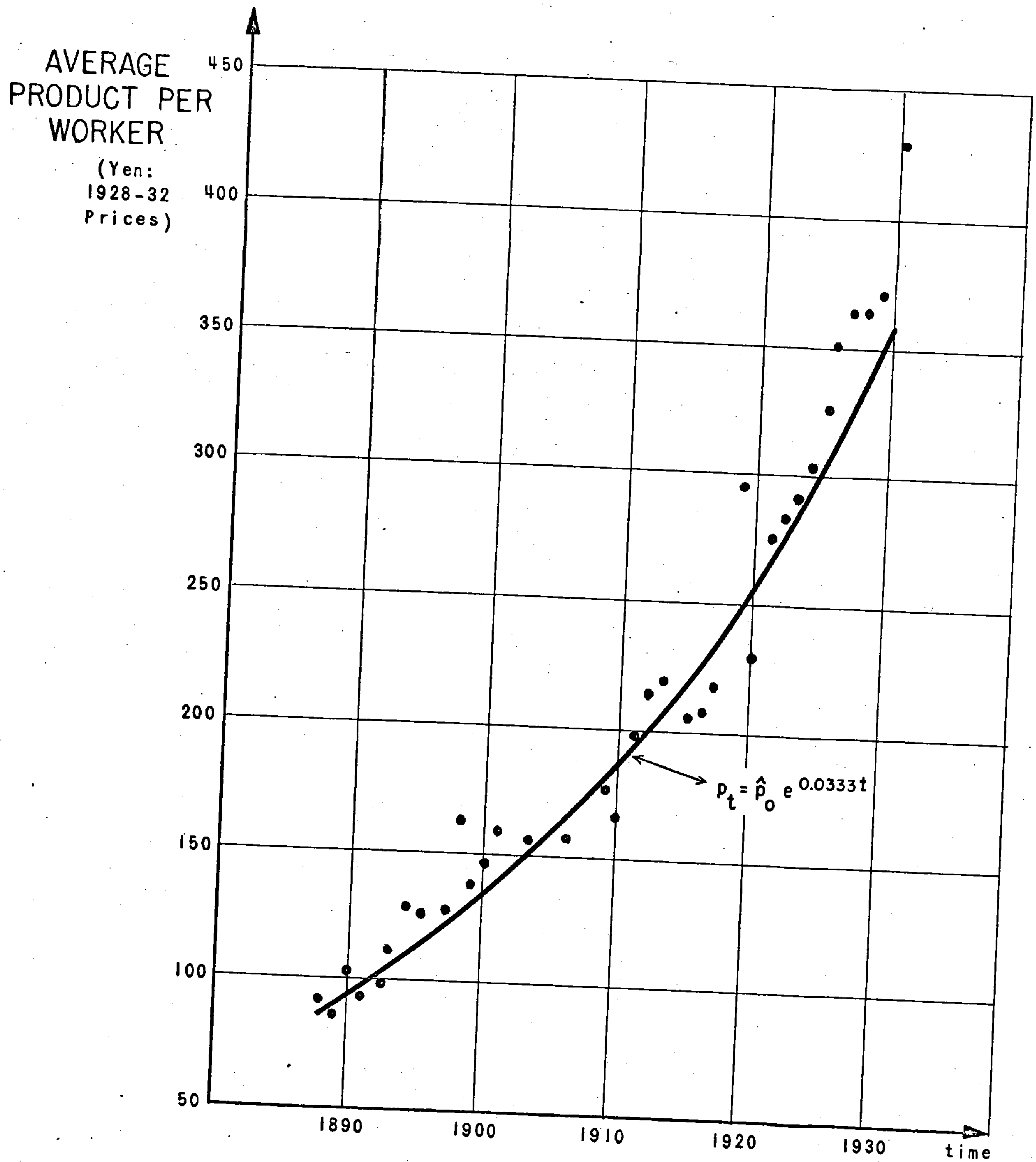
AVERAGE
PRODUCT PER
WORKER
(Yen:
1928-32
Prices)
450
400
350
300
250
200
150
100
50
1890
1900
1910
1920
1930
time
$p_t = \hat{p}_o e^{0.0333t}$

Diagram 8

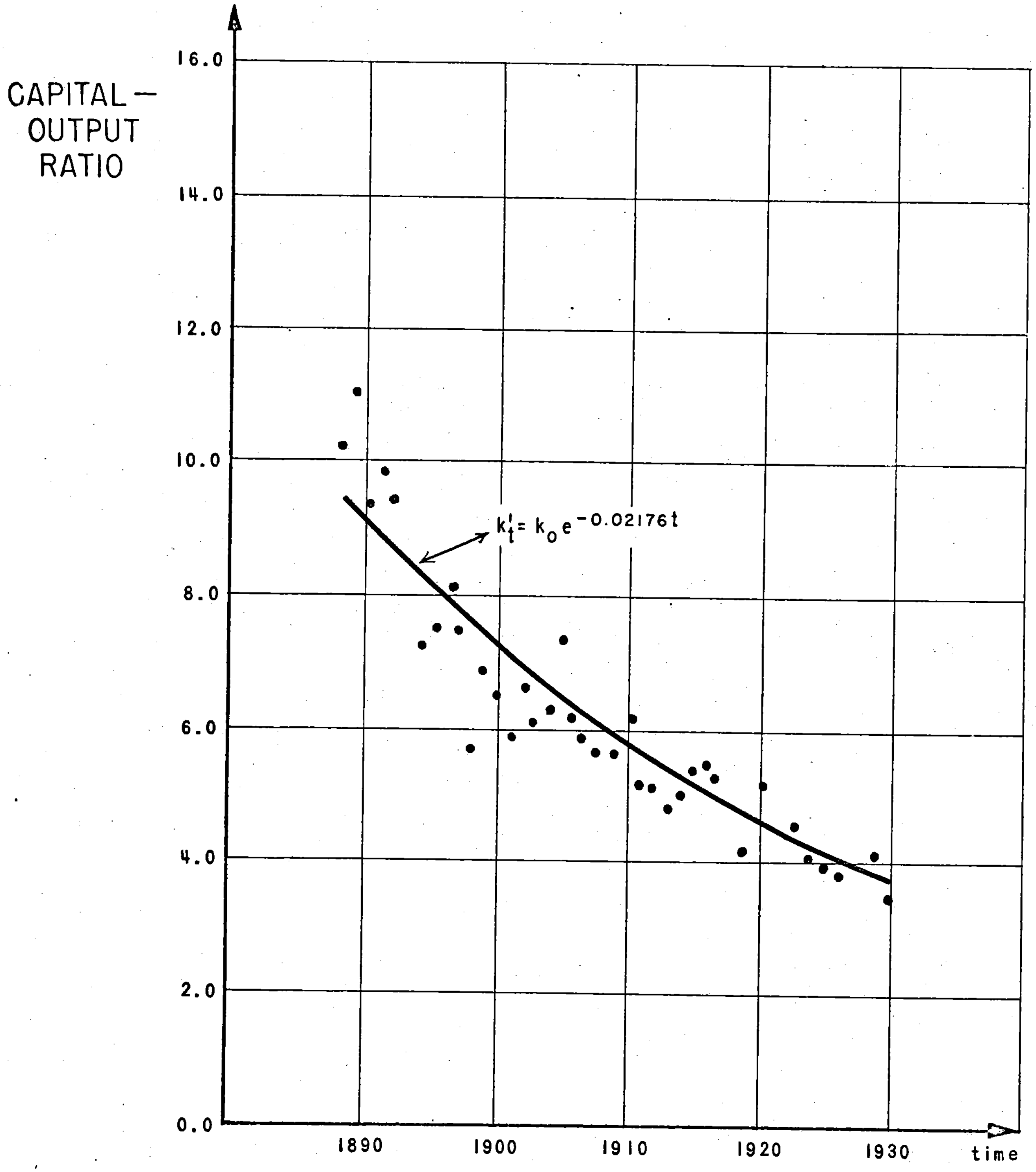
CAPITAL — OUTPUT RATIO
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0
$k_t' = k_0 e^{-0.02176t}$
1890
1900
1910
1920
1930
time

Diagram 9

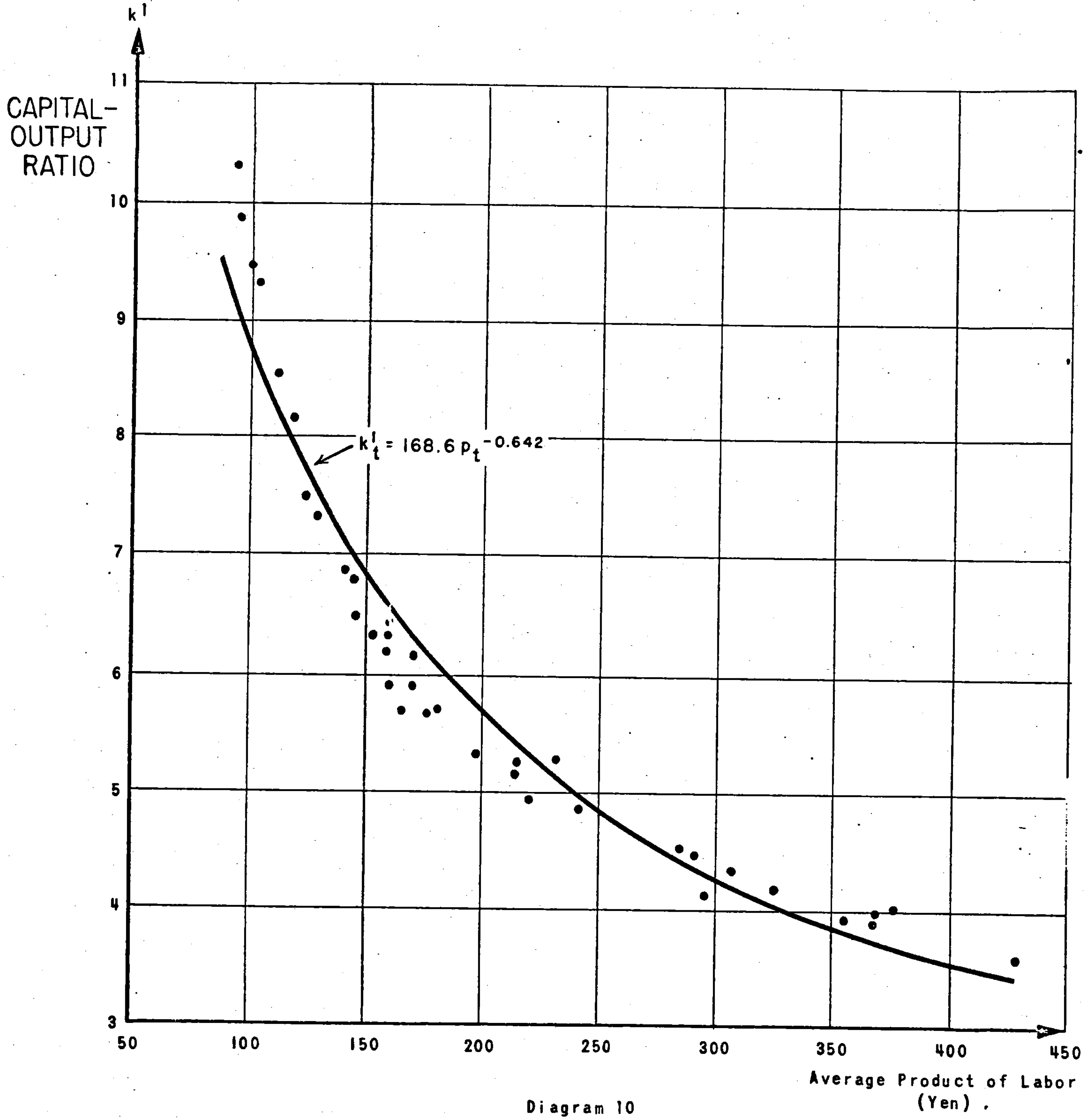
k'
CAPITAL-
OUTPUT
RATIO
11
10
9
8
7
6
5
4
3
$k'_t = 168.6\, p_t^{-0.642}$
50
100
150
200
250
300
350
400
450
Average Product of Labor
(Yen)

Diagram 10