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INNOVATION, EMPLOYMENT AND PRODUCTION IN THE DEVELOPMENT PROCESS

BY

John C. H. Fei
Cornell University

and

Gustav Ranis
Agency for International Development

Innovation, employment and production in the...

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Innovation, Employment and Production in the Development Process

While there is controversy on definition and size, few people dispute that unemployment is a quantitatively significant phenomenon in underdeveloped countries. Unemployment, disguised or open, represents not only output lost and missed opportunities to involve more people in creative activity; it also represents a most important inequity in income distribution and, as such, a major contributing cause in political instability. For this reason, unemployment is well recognized as a serious social problem by both the academicians and practitioners of development planning. In spite of the attention paid to this problem, 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 related to economic growth in general and technological change in particular. At the present time, what we do know on the causes of unemployment are certain intuitively 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 by either academicians or practitioners would include the following:

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

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."

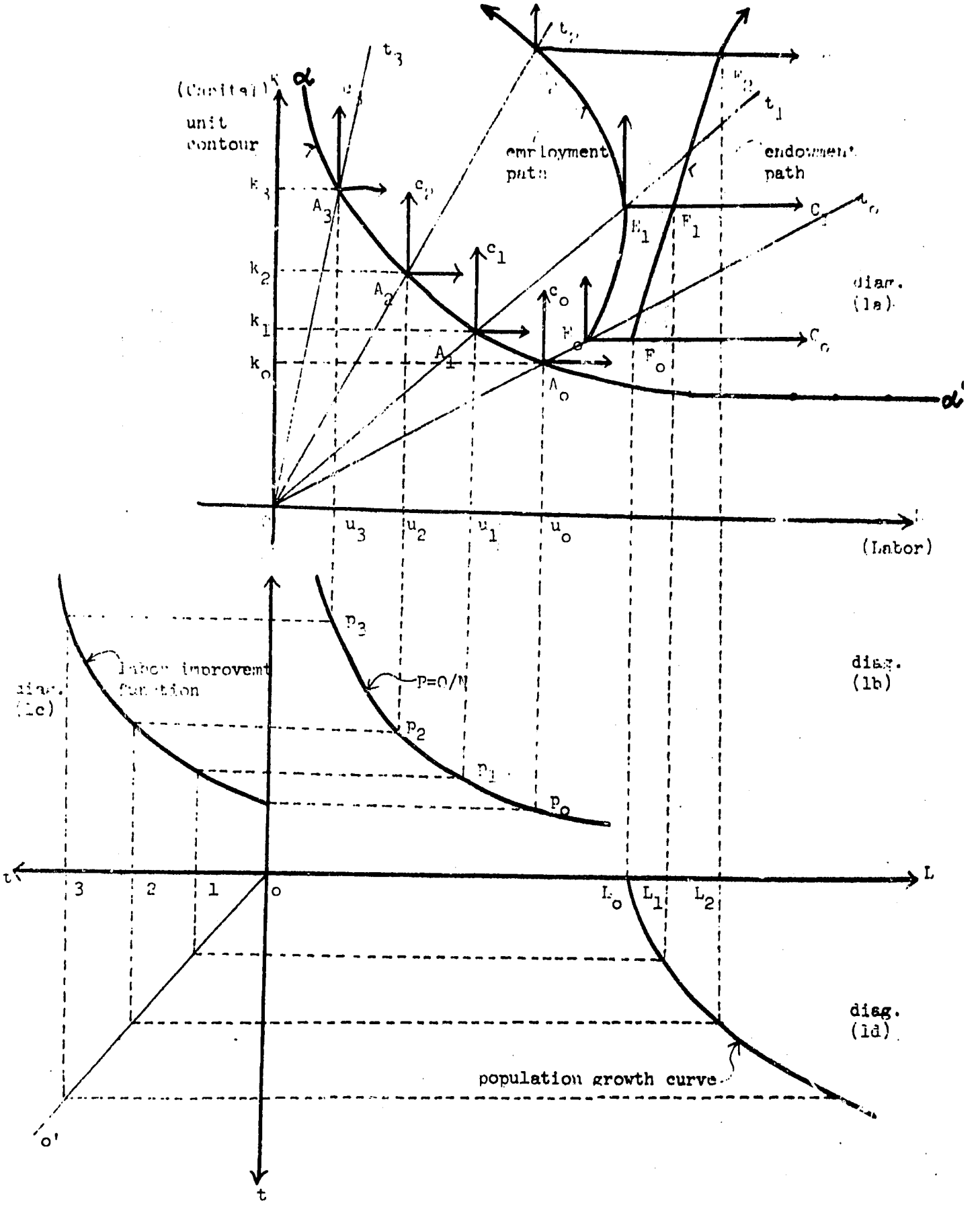
(Capital) K
unit contour
employment path
endowment path
diag. (1a)
(Labor)
diag. (1b)
labor improvement function
P=O/N
diag. (1c)
diag. (1d)
population growth curve
L
t
o'

Diagram 1

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 unit 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 to assess the success and failure of an economic growth effort.[3/]

(3) Education and Skill Formation. For those who believe (e.g., Schultz[4/]) that the development of human resources lies at the heart of economic development and modernization, it is the lack of education and labor skills education 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

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

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, when imported, constitutes technological change from the view point 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 bear 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 the adaptation of that technology to make it more suitable to the indigenous factor endowment conditions.

The above review leads us to the conclusion that while we recognize that LDC unemployment has a multiple causation, these relationships have not been satisfactorily explored, either singly or in combination. What we attempt to do in this paper, therefore, is to integrate some of these facets into a common theoretical framework.

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

In Section I, we shall construct a general system for the explanation of employment and output growth, to be used as a guide for the rest of the paper. This general system is broadly constructed so as to be useful for an analysis of the four 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 essential. (Section III deals with "importation" without local "adaptation" and Section IV with importation with such adaptation.) Finally, Section V the theory of Section IV will be examined and verified in the light of the experience of historical Japan.

Section I. General Framework

It is the purpose of this section to introduce the 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 $\lambda\lambda'$. In diagram 1a, which describes the art of production (1.1) completely, 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), $(u_2,\ k_2)$ ..... (see diagram 1a). 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 $(i = o, 1, 2, 3, \ldots)$ 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., $K^* < T$), technical unemployment of labor will appear. Development with this characteristic will be referred to as full capacity 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) $K^* < T$ (full capacity growth)

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

In the case of an underdeveloped society characterized by an abundance of unskilled labor the unemployment or full capacity growth case is 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 of this rather unconventional concept, let A_0 (diagram 1a) constitute the current technology of an underdeveloped country. In comparison, the technologies of the industrially advanced countries are characterized, in various degrees, by higher technology ratios, i.e., unit activities which are more "capital using" and "labor saving". Thus, we may describe the

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.)

spectrum of technologies for all countries by the unit contour which, from the view point of the underdeveloped country, depicts the availability of new, potentially importable, technologies. The actual innovation process due to the importation of technology can then be described by a movement upward along the contour line $A_0, A_1, A_2, \ldots$ 8/. If, at the same time, technological change takes place abroad, the position of the unit contour itself will shift toward the origin.

Improvement in Labor Efficiency

Let the unit contour $\lambda\lambda'$ of diagram 1a be given. For each unit activity A_i contained in $\lambda\lambda'$, 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., $p = 1/u_i$ $(i=1,2\ldots)$ is represented by the negatively sloped (rectangular hyperbola) in diagram 1b below the countour 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 $A_0, A_1, A_2, \ldots$) the productive efficiency of labor increases automatically. While such an interpretation may be suitable for an industrially mature economy, it is not suitable for the underdeveloped economy since it neglects the very real learning effort (through formal education or "learning by doing") which is generally required if the efficiency of labor is to be improved at all.

8/ This notion of the importation of technology will be used in Sections III, IV and V.

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 the demand for a higher skill of labor becomes higher (i.e., p_i is higher) as the average 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 the expression in the parentheses the notation η_x stands for the rate of increase of x -- a convention which will be used consistently throughout this paper.) Given the labor improvement function (diagram 1c) and the unit contour (diagram 1a), we can determine the unit activity which will actually be achieved through time. Thus, at any time t_1, the unit activity which

can be achieved is A_i as labor productivity reaches the level p_i ($i=1,2,3,\ldots$). 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 capital accumulation. To simplify the analysis of the growth of these material resources we shall assume the constancy of the population growth rate (r) and 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 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 the population growth rate. 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 improvem

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 $E_0E_1E_2$ ..... and the endowment path $F_0F_1F_2$ .... .

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 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)

d) $L = U + N$

which are the focal points of the investigation which follows. To facilitate our later work, the following formula will be seen to be helpful:

1.9a) $N^* = K^*/T$ ..... (by 1.3b, 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 inersect, 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 or full capacity growth regime. Conversely, when the two paths do intersect at some future date, the economy will shift from a full capacity to a full employment growth at that time. (In such a regime, the vertical

gap between the two curves represents unutilized capital capacity). Thus, the model which we shall investigate further also contains the germ of a stage thesis of growth.

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 the analysis of the unemployment problem in the growth process, taking into account both technological change and the augmentation of human and capital resources over time. As we pointed out earlier the observed phenomenon of unemployment may be traceable to a multiplicity of causes because of the relevance of all these factors. In the sections which follow we shall, by postulating some special conditions relating to this general framework, explore a number of typical real world unemployment situations.

Section II. Development with Stagnant Technology

One situation which may occur in a less developed society is complete concentration on capital accumulation and relative 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[9]

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 extended form of the familiar Harrod-Domar model. In the context of our general framework, the Harrod-Domar model is seen to be a very special case, namely, the case of development with stagnant technology.

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

9/ 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.

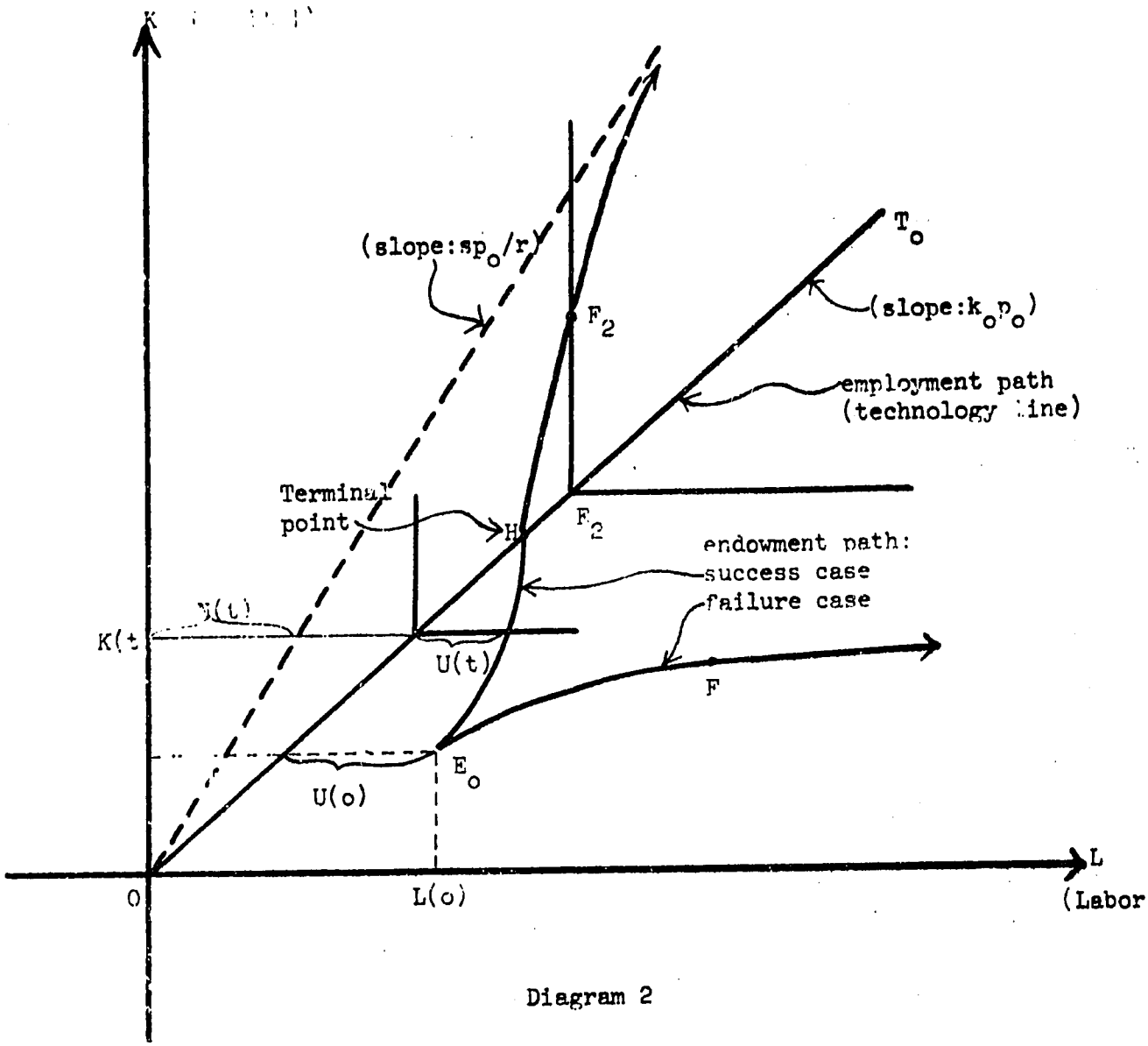
K
(slope: sp_o/r)
T_o
(slope: $k_o p_o$)
F_2
employment path
(technology line)
Terminal
point
H
F_2
endowment path:
success case
failure case
K(t)
U(t)
U(t)
F
E_o
U(o)
L
0
L(o)
(Labor)

Diagram 2

2.3a) $\eta K = \eta Q = s/k_o$ .....(by 2.1ac)

b) $\eta K^* = \eta Q^* = s/K_o - r = h$ .....(by 2.3a; a.1d)

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 know, with Harrod-Domar Model we may have the use of success, in which per capita income increases or failure, where it decreases, these two cases are given by

2.5a) $s/k_c > r$ (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 through time. 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[10/]

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)

In diagram 2, the success case is given by the endowment path E_oH which crosses the employment path at H at the termination date. At this point the country moves into the full employment regime of growth. Capital

10/ Notice that the value of time is completely determined by "h" (2.3b) and the initial degree of employment N_o^*. This equation is easily calculated by equating T_o and $K_o^* e^{rt}$ (2.3b).

is no longer the scarce factor and the economy can be considered to have reached economic maturity.

In the final full employment growth regime, the constancy of labor productivity (2.1c) and of the population growth rate (2.1e) imply that output is growing 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 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 (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) $K^* = K/L = A/L_o e^{rt} + \bar{K}^*$ 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 $K_o < I_o/\bar{K}^*$ or $\underline{K_o^* < \bar{K}^*}$ or $k_o p_o < sp_o/r$ (by 2.2)[11] 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 $\bar{K}^*$ is greater than the initial value K_o^* when the condition of success is satisfied. In diagram 2, the case of success is described by the

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

endowment path E_oHF_2 which approaches the (dotted) radical line in the long run.[12] 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 full capacity growth regime and unemployment continues to worsen. In the case of success the country reaches a terminal point where unemployment disappears and from which it tends toward the Von Neumann regime in the long run. The arrival of this terminal part thus 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) $Q^*/Q_o^* = 1/N_o^*$ (Q*-multiple at termination point)

b) $Q/Q_o = N_o^{*s/kh}$ (Q-multiple at termination point)

c) $L/Lo = N_o^{*r/h}$ (L-multiple at termination point)

We can next investigate the time paths of the <u>degree</u> of employment (N*) and of the <u>magnitude</u> of unemployment (L-N) under the full capacity growth regime. The constancy of the technology ratio (2.2) implies that the

12/ In the full employment growth regime. The unutilized capital capacity at F_2 is E_2F_2 units.

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., η_N^* $(=s/k_o-r)$ and hence, in case of success (failure), the <u>degree</u> of employment gradually increases (decreases). The <u>magnitude</u> of unemployment and its direction of change are given by

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

b) $dU/dt \gtreqless o$ 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 term of the relationship between the strength of the population presume and the magnitude of unemployment through time:

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

b) moderate " " : $N_o^* s/k_o < r < s/k_o$ (U is inverse U-shaped)

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

Specifically, in the moderate population pressure case, the magnitude of unemployment will increase for a while and then start decreasing at a turning point. The length of time it takes to reveal this turning point t_n can be calculated 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 "turning point":

Table 1

TERMINAL AND TURNING POINT CHARACTERISTICS - MODEL OF STAGNANT TECHNOLOGY

$1-N^*(o)$	r	s/k_o	$(s/k_o)-r$	At Terminal Date			At Turning 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 turning point M - Success without turning point

2.12a) $N^*_o = r/(s/k_o)$ (degree of employment at turning pt.)

b) $Q^*/Q^*_o = r/N^*_o\ s/k_o)$ (Q*-multiple at turning 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 turning 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 turning 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 turning 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 turning 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 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 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 that of an 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 (full capacity growth) regime and at relatively modest multiples. In the second (full employment growth) regime per capita income is constant- and equal to labor productivity, $\bar{p}$. 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., $Q^*/Q_0^* = 1/N_0^*$. This tells us that the greater the degree of initial unemployment the greater the per capita income multiple possible. 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 underlines 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

Where technological change is accepted by planners in the contemporary less developed world the most popular type is what may be called the "big push for modernization," which means the introduction, in an unmodified form, of imported technology, of the latest and most advanced variety. This type of innovation process results 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 in radically different contexts.

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 will be depicted by the sequence A_o, A_1, A_2, representing progress toward more "capital saving" and "labor using" 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) $Q = K^{\alpha} N^{1-\alpha} \quad o < \alpha < 1$ 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:

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

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

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

d) $\eta_K = \eta_o e^{-Dt}$

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 ($\bar{K}$) from its initial value (K_o).[13] Thus, in diagram 1a, the endowment path approaches a horizontal line asymptotically.

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

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 ($i > o$) or the population growth rate ($r > o$). Thus, in case a country is determined to embark on a real big push policy, a national effort directed at austerity (raising s), birth control (lowering r) or education (raising i) will not be sufficient to allow the country to escape from economic stagnation.[14/]

Let us now reexamine what is wrong with the "big push" from the "innovation" standpoint. Let the unit contour qq' 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.

14/ This pessimistic conclusion can be easily strengthened by an investigation of the rate of growth of output (Q), employment (N), per capita income (Q/L) or 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.

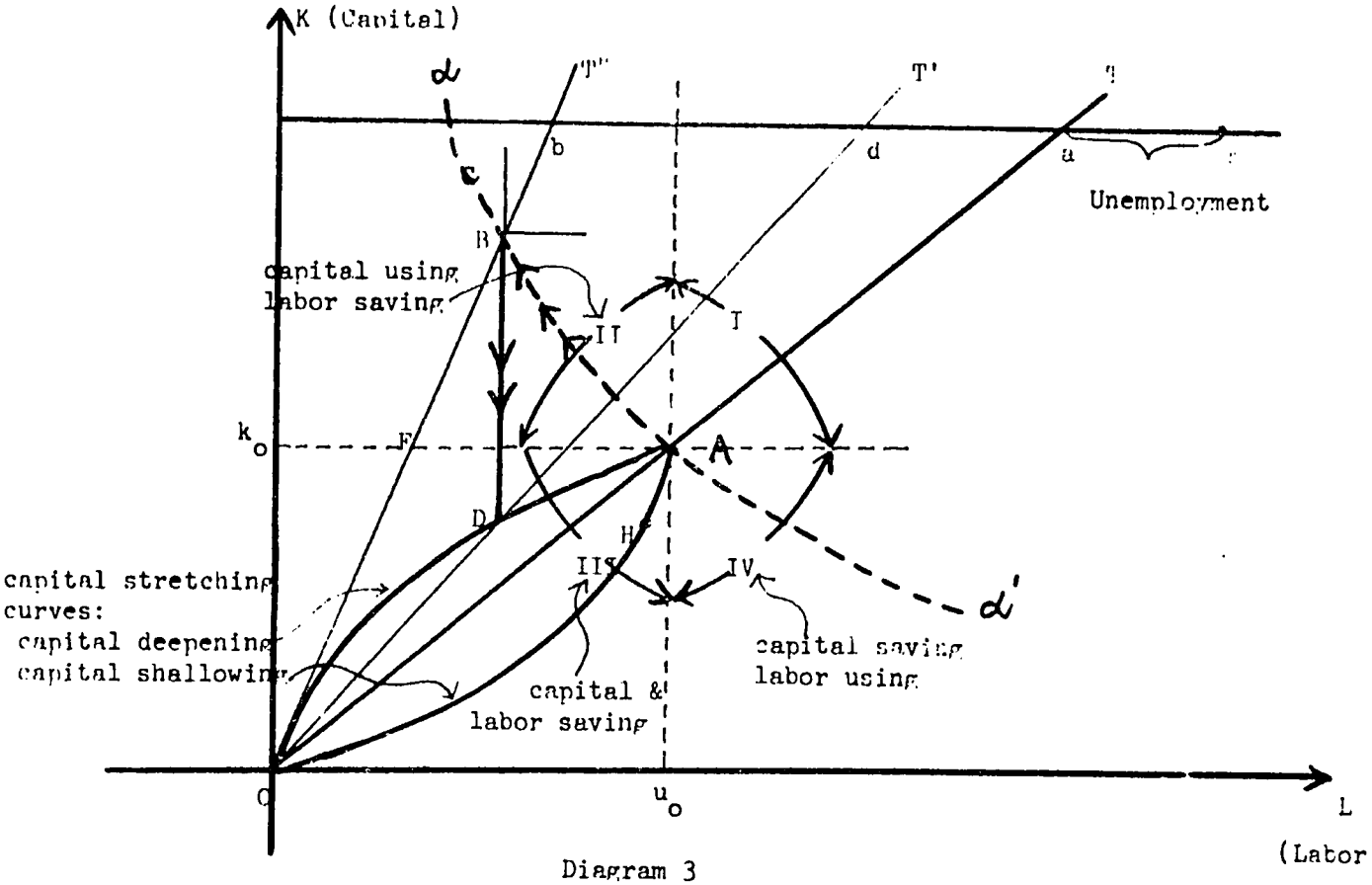

Diagram 3

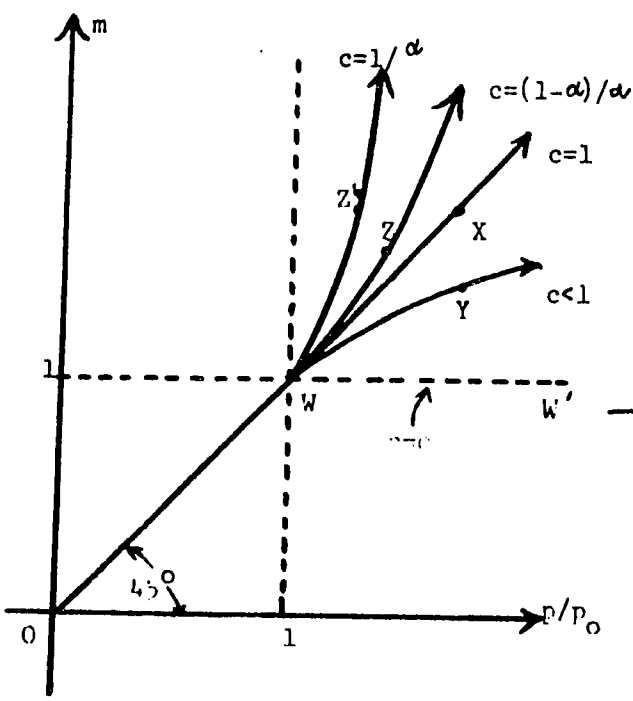

Diagram 4

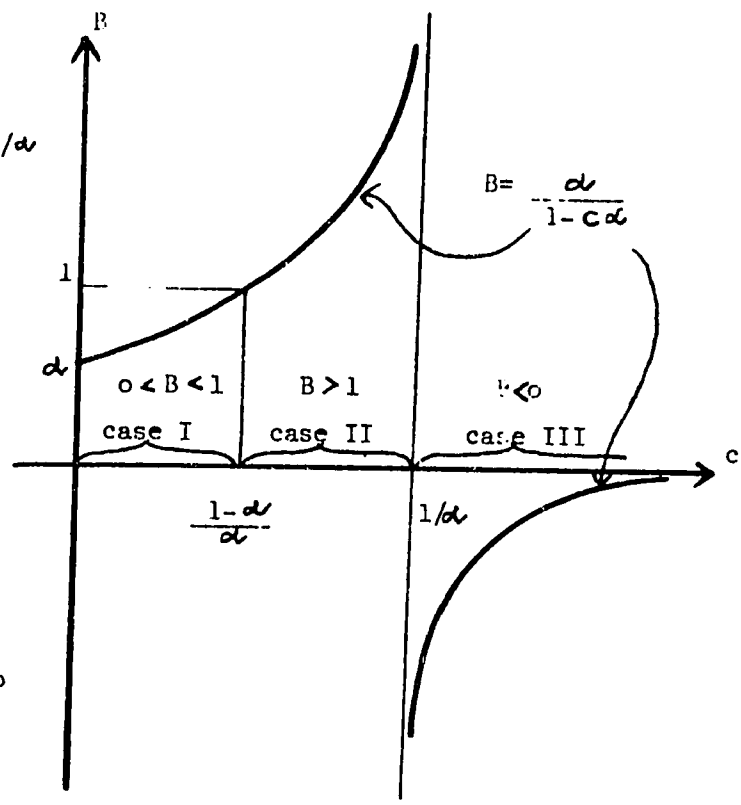

Diagram 5

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 $\mathcal{d}\mathcal{d}'$ (quadrant II), it creates more unemployment <u>and</u> depresses output.

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 [illegible] 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 enclosures under a colonial system, i.e., a small portion of the labor force is engaged in very capital intensive projects while the national scale of unemployment continues

to increase. Neither technological stagnation nor the blind use of imported technology can thus be considered as viable alternatives for the underdeveloped society. Other, more imaginative, alternatives must clearly be examined.

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 the growth performance of the contemporary underdeveloped country. We have just seen, however, that this shelf of technical knowledge must be used wisely if economic development is to really benefit from it. 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 such new innovational activity must be

in a capital-saving or labor-using direction in order to counteract the opposite effects caused by the importation of technology.

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 an 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

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

b) $k' = K/Q$

where "m" may be referred to as the degree of capital stretching and

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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).

"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 the 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 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) $m = (p/p_0)^c \qquad c > o$

where p/po 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 $\omega\omega'$, 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 the imported technology. Thus we obtain

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

b) $a = p_o^c$; $b = 1/\alpha - 1 - c$ (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:

4.4 a) $Q = Q_o K^B N^{1-B}$ 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 & $p=Q/N$)

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:

4.5) a) 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 $1/\alpha < c$

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

It is only in case one that (4.4a) resembles a genuine Cobb-Douglas production function. In case two (three), the unit production contour 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 (1.1oa) by (4.4a). In summary, there are five parameters (α, c , i , s , r) in the model summarizing the forces of innovation (α , the availability of importable technology and c, the indigenous capital stretching effort), 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) and hence to avoid the same conclusion of stagnation, we immediately come to the conclusion that there must be a "minimum domestic ingenuity level" affecting the magnitude of capital stretching, namely:

4.6) $(1 - \alpha)/\alpha < c \qquad (B > 1 \quad \text{or} \quad B < o)$

This means that unless there is sufficient indigenous innovative effort in response to the stimulation of imported technology, economic development

cannot be successful in the long run.

Turning now to the two other cases (i.e., 4.5bc), for which the minimum domestic ingenuity level 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, AHO). As we would intuitively expect, the "capital shallowing" case represents a relatively larger indigenous effort in capital stretching ($c > 1/\alpha$) and leads to a higher degree of output and employment.

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

4.7 a) $\eta_T = i/B$

b) $\eta_{k'} = i(1-B)/B \equiv -\theta < o$

c) $\eta_{\eta K} = \theta > o$

d) $\eta_K = \eta_o e^{\theta t}$ ($\eta_o \equiv \eta_K(o)$ the initial rate of growth of capital)

e) $K = K_o J^{e^{\theta t}-1}$ where $J = e^{\eta_o/\theta} > o$

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

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17/ Since (4.4a) replaces (3.1a) the growth rates in (4.7) are obtained from those in (3.2) by replacing "α" by "B".

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 distinction between the two cases, the 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 cases 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 in (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

4.8) a) $\eta_Q = \eta_o e^{\theta t} + \theta$ . . . (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 $g > o$

Hence the behavior of all these rates of growth depend 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 "turning point" with duration

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

at which the sign of 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 $u = (\eta_o/\theta) \; e^{\theta t} + gt$

The above analysis indicates that the minimum domestic ingenuity test with respect to capital stretching (4.6) is a most crucial condition for economic development as measured by the four welfare indicators in (4.8). When this condition is not satisfied, capital accumulation and growth will cease; when it is satisfied, growth will succeed in the sense that all the four indicators will continue to increase in the long run.[19] Since, as we have pointed out earlier, only the technological parameter "d" which measures the availability of imported technology, and "c" which measures the domestic effort in capital stretching are involved in the minimum domestic ingenuity criterion (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.

18/ The differential equation (4.9) can be readily solved by a separation of variables as $\int \frac{dx}{x} = \eta_o \int e^{\theta t} dt + g \int dt$ which leads to 4.12)

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 ($\eta_N^* > 0$) 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".

Section V. Verification

In the last section, we constructed a model of employment and output expansion by integrating the following growth-related factors into one framework: population growth, savings behavior, changes in labor productivity through education, innovations characterized by importation, 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 country experience is, in fact, relevant, let us briefly reexamine the essential "causal structure" of the model.

In the causal order chart of diagram 6, 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).

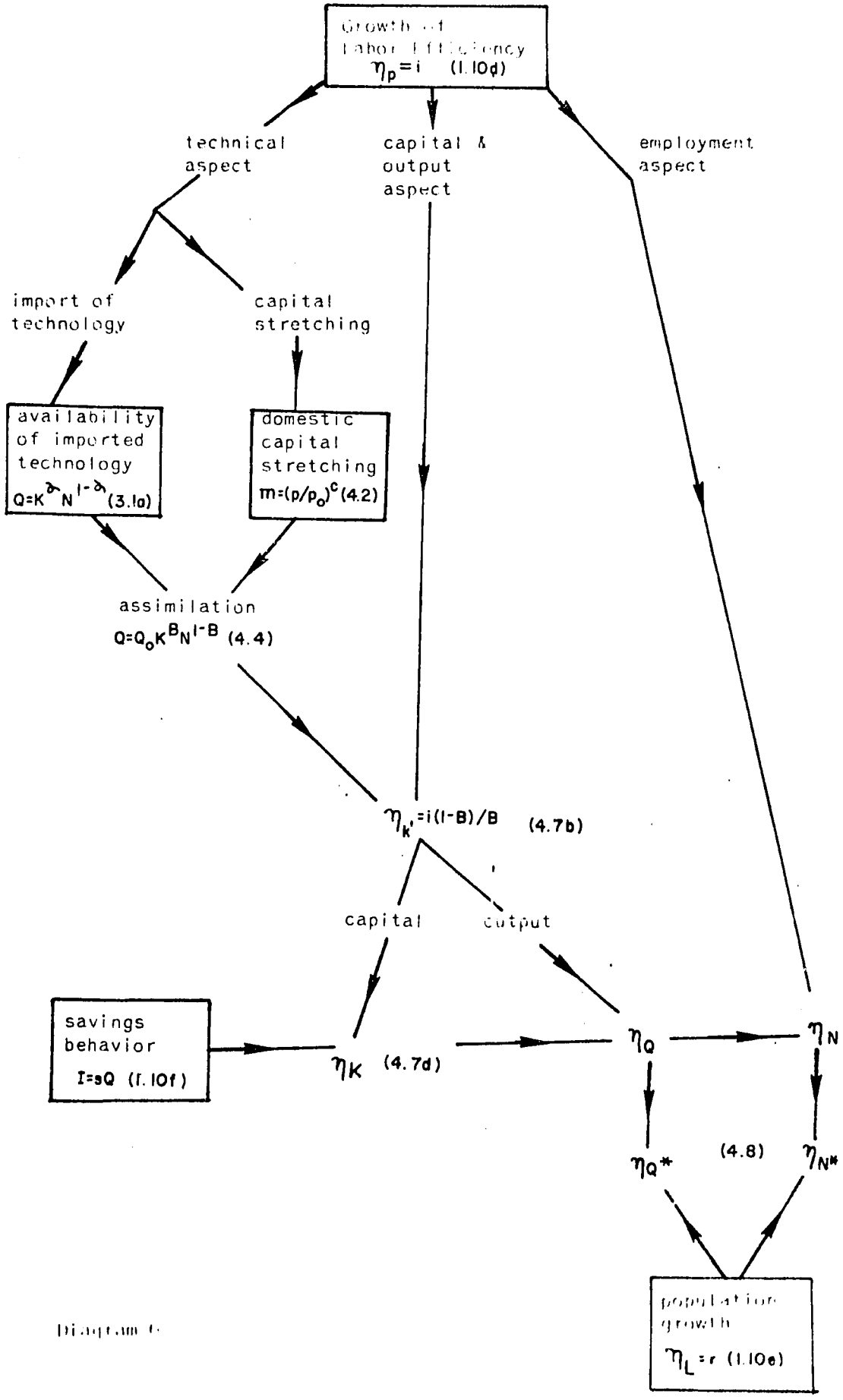
Growth of labor efficiency
$\eta_p = i$ (1.10d)
technical aspect
capital & output aspect
employment aspect
import of technology
capital stretching
availability of imported technology
$Q = K^{\alpha} N^{1-\alpha}$ (3.1a)
domestic capital stretching
$m = (p/p_o)^c$ (4.2)
assimilation
$Q = Q_o K^B N^{1-B}$ (4.4)
$\eta_{K'} = i(1-B)/B$ (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
$\eta_L = r$ (1.10e)

Diagram 6

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.

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 which causally determines other facets of growth. Furthermore, the significance of this labor productivity increase is manifested, in the first place, as a technological phenomenon via the assimilation 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 frame-work 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:

5.1) a) $p = \hat{p}_o \; e^{\hat{i}\,t}$ ..... (by 1.1od)

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 1.1oe)

f) $S = \hat{s}\, Q$ ..... (by 1.1of)

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 5.1aef ---- 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 (5.1b) with the aid of the times series of k' (observed capital-output ratio) and p. We can then use equation (5.1cd) to estimate "c" and "α". Thus all the par[illegible] 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).[20] 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 7 and 8 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.

20/ See Appendix 1 for explanation of the data sources.

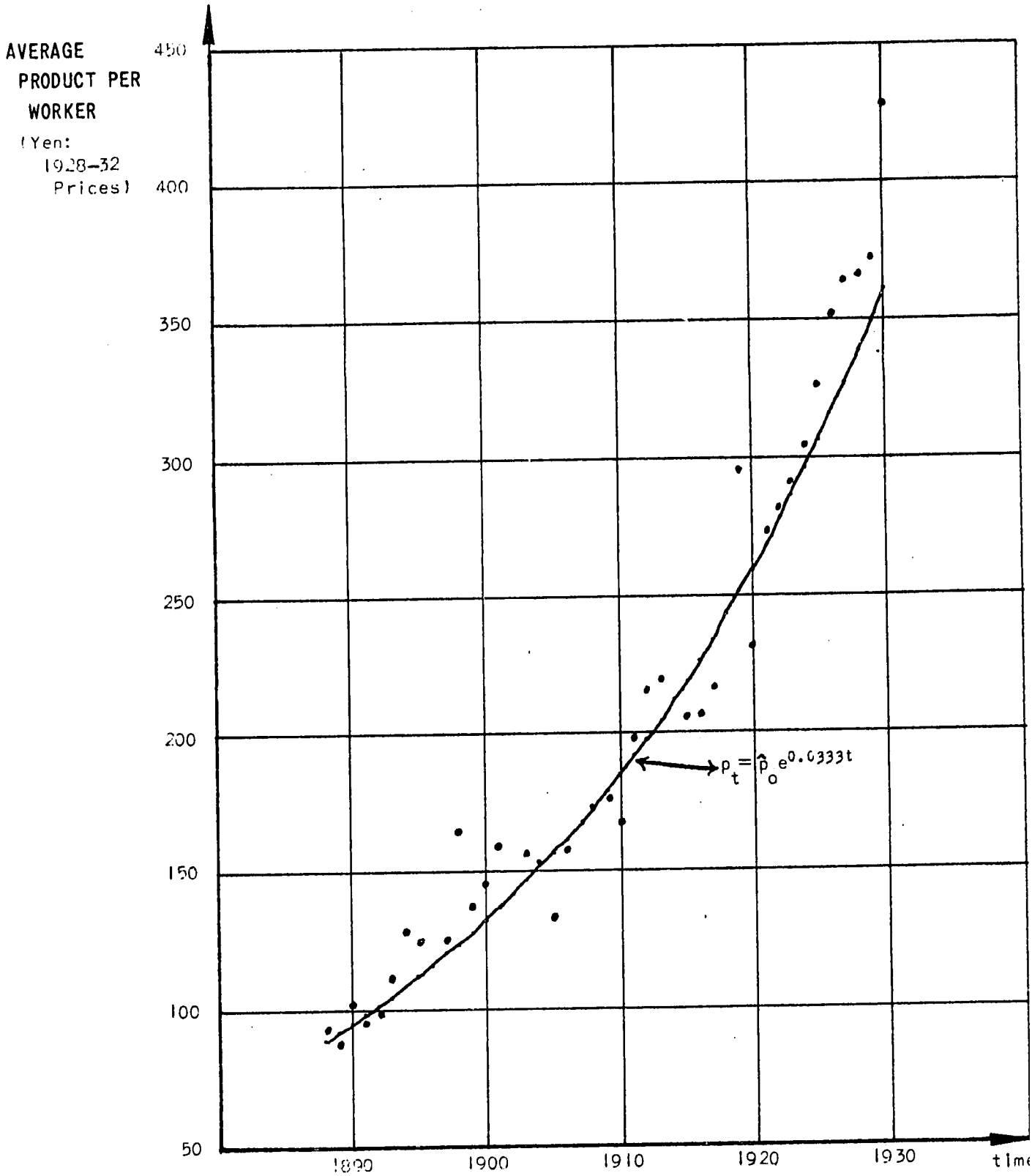
AVERAGE PRODUCT PER WORKER
(Yen: 1928–32 Prices)
450
400
350
300
250
200
150
100
50
1890
1900
1910
1920
1930
time
$p_t = \hat{p}_o e^{0.0333t}$

Diagram 7

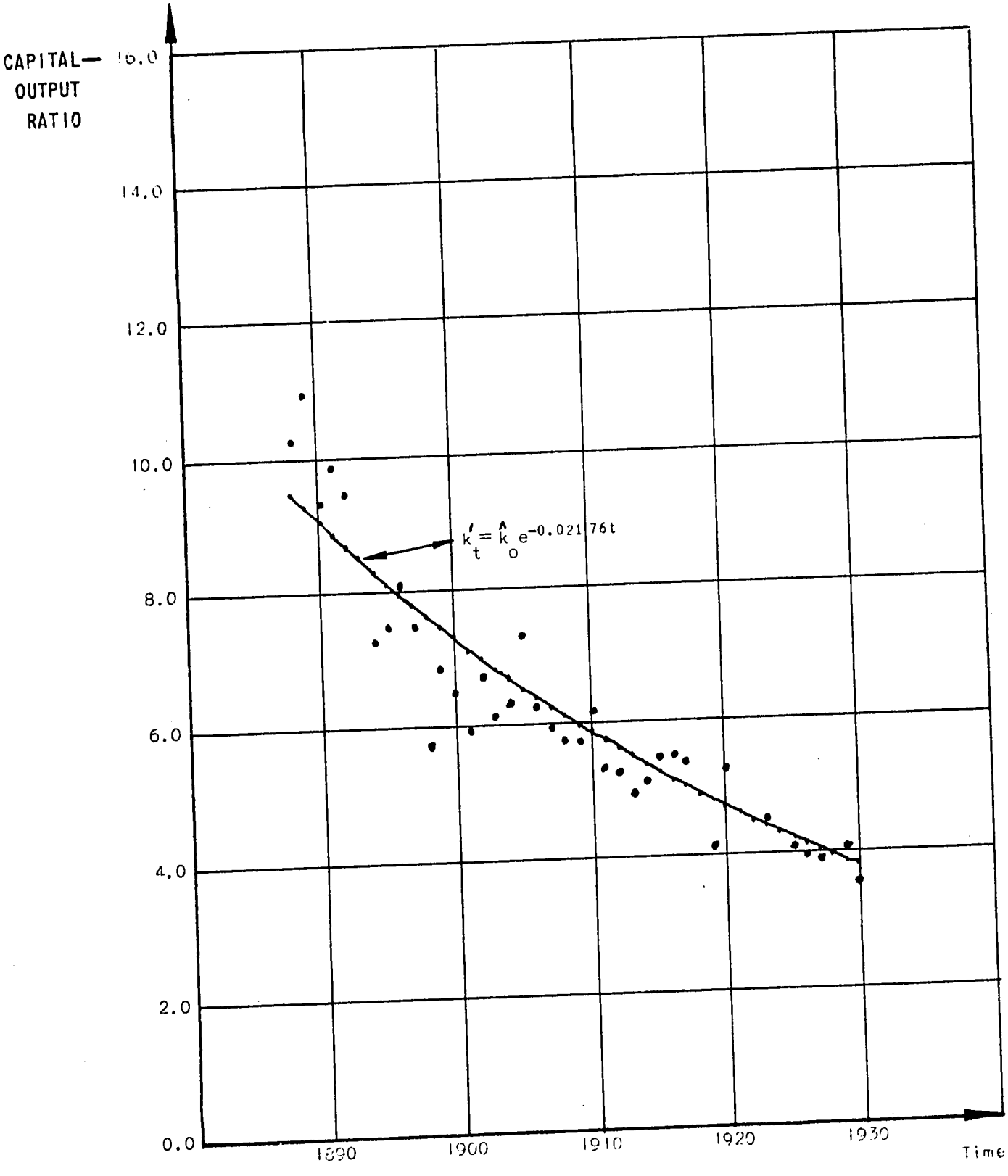
CAPITAL—
OUTPUT
RATIO
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0
1890
1900
1910
1920
1930
Time
$k'_t = \hat{k}_o e^{-0.02176t}$

Diagram 8

BASIC JAPANESE DATA

Year	Output - Q	Capital - K	Employment - N	Q/N p	K/Q k'	p	k	$\frac{\Delta K}{K}$
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
1888	2,077	21,331.8	39,362	94	10.27	89.33	9.59	.0569
1889	1,953	21,449.9	39,795	88	10.98	92.26	9.29	.0670
1890	2,318	21,580.7	40,164	102	9.35	95.19	9.09	.0632
1891	2,202	21,738.1	40,444	96	9.87	98.71	8.96	.0722
1892	2,311	21,897.0	40,772	100	9.48	102.01	8.76	.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	109.57	8.33	.0667
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	.0846
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	3,583	24,242.5	45,461	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	4,422	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	198.35	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	219.35	5.27	.0831
1916	5,523	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	35,639.1	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
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 I for explanations.

The relationship between p and k' is shown in the scatter diagram (diagram 9) in which the curve (5.1b) is shown. The regression curves of diagram 7, 8, and 9 may be summarized as

(5.2) a) $p = \hat{p}_c e^{\hat{i} t}$ 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 (5.1cd) since

(5.3a) $c = \ln \hat{a} / \ln \hat{p}_o = 1.128$ . . (by 5.2ac)

b) $\alpha = 1/(1+\hat{b}+c) = 0.67$ [21] (by 5.3a, 5.2c)

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

(5.4) $(1-\alpha)/\alpha < c < 1/\alpha$ i.e., $.5 < 1.128 < 1.5$

and hence (4.5b) is satisfied. We can immediately conclude that;

1) The development experience of Japan represents a case of "success" in the sense that the minimum domestic ingenuity criterion (4.6) 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

---

21/ The meaning of this numerical magnitude for "α" will be explained in Appendix 2.

degree of employment (N*) must increase in the long run. (See below for a "short run" analysis of these four welfare indicators.)

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).[22/]

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 6) 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

$$5.5)\ \eta_{k'} = \theta = i\,(1-B)/B \quad \text{.....(by 4.7b)}$$
$$= i\,(1/\alpha - 1 - c) \quad \text{.....(by 4.4b)}$$
$$= -\ .0216 \qquad \text{(by 5.3 and 5.2a)}$$

22/ 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.

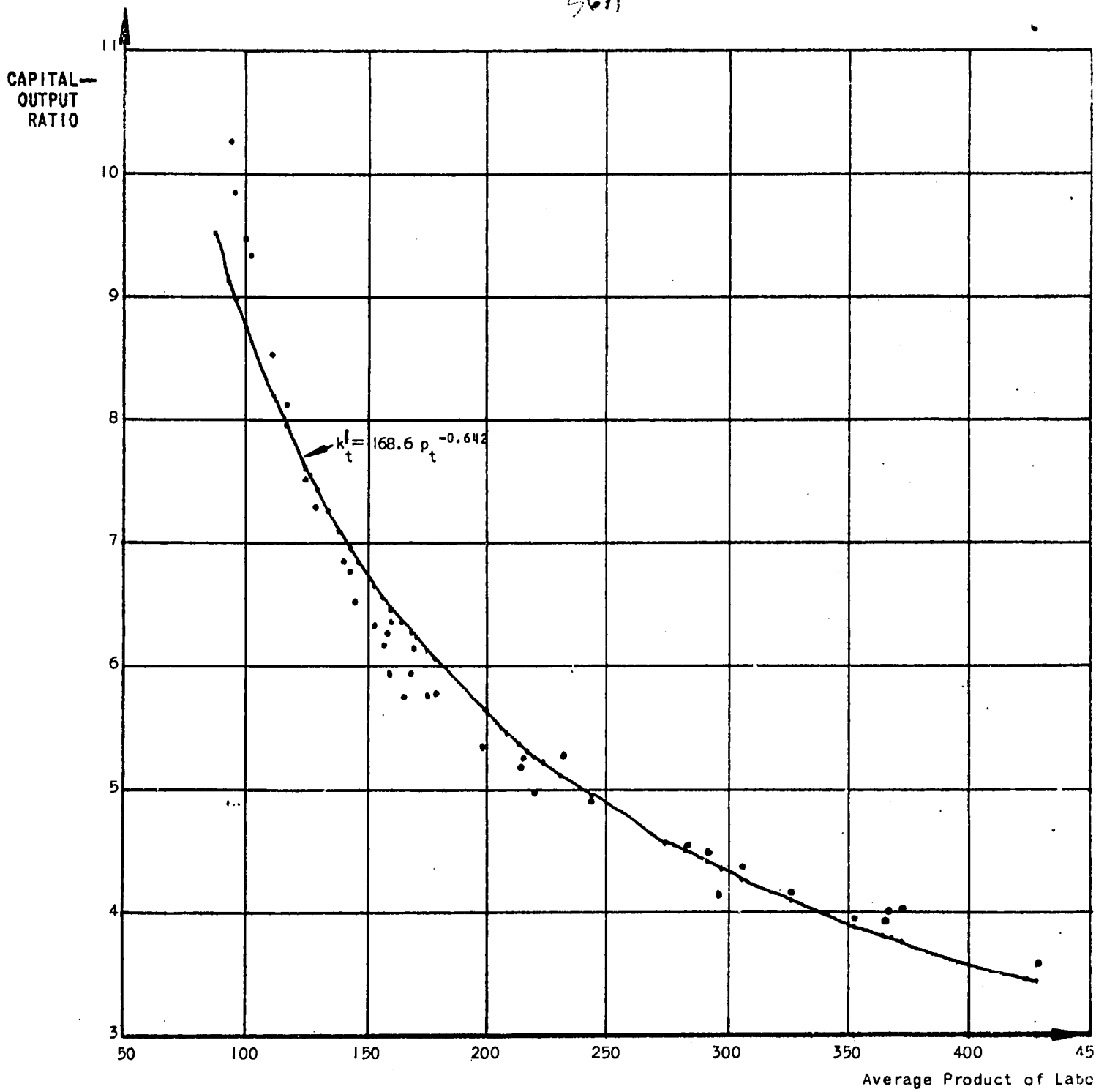
CAPITAL—
OUTPUT
RATIO
11
10
9
8
7
6
5
4
3
$k_t' = 168.6\ p_t^{-0.642}$
50
100
150
200
250
300
350
400
45
Average Product of Labo
(Yen)

Diagram 9

which shows that the predicted value for $\eta_{k'}$, i.e.-.0216, is approximately identical to its directly observed value in (5.2b) (i.e., θ = -.022).

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

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

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

5.7) a) $\eta_K = \hat{\eta}_o \; e^{\hat{\hat{\theta}}t}$ where $\hat{\eta}_o = .0064$; $\hat{\hat{\theta}} = .043$ (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 is not constant (as we have assumed) in 1.10f) but is in fact growing at the rate of about 1% a year (5.7b). For we have

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

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 6) that the more realistic savings-behavioristic assumption (5.7b) -- 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 (5.7a), 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 have

5.9) a) $\eta_Q = .0064\, e^{.043t} + .043$ (by 4.8a, 5.7a, 5.2a)

b) $\eta_N = .0064\, e^{.043t} + .010$ (by 4.8b), 5.7a, 5.2a)

c) $\eta_{Q*} = .0064\, e^{.043t} + .032$ (by 4.8c, 5.6a) 23/

d) $\eta_{N*} = .0064\, e^{.043t} - .001$ (by 4.8d, 5.7a) 23/

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 (5.9) 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 (5.9), and hence that these four growth rates have been consistently positive through time. The conclusion is that the Japanese experience not only satisfies the criterion of minimum domestic ingenuity of (4.6) but, in fact, that the innovation effort has been so successful that employment and per capita

23/ 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 two. (See appendix.)

output have been increasing from the very beginning of the growth process (i.e., the turning point phenomenon, as described by 4.11 never occurred for any of these welfare indicators). Since it is relatively easy to verify independently the rate of income and of per capita income increase, we shall concentrate in what follows on the significance of our analysis in relation to employment. Since the degree of employment ($N^* = N/L$) is monotonically increasing without bound, full employment will be reached when $N^* = 1$. Thus our model structure in the last section implies a "stages of growth thesis" composed of a full capacity growth (i.e. unemployment growth) regime, to be followed by a regime of full capacity growth.[24] At "the terminal point" (i.e. when $N^* = 1$), the economy loses its labor surplus characteristic as the economy 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.[25] We may now calculate the time required to reach the "terminal point" by first computing the growth path of N^* (by 4.12) as

5.10) a) $N^* = e^{u} / e^{\eta_0/\theta}$ where

b) $u = (\eta_0/\theta)e^{\theta t} + (\theta - i - r)t$ for

c) $\theta = .043$, $\eta_0 = .0064$, $i = .033$, $r = .0116$

By setting $N^* = 1$ in (5.10) and by making use of the convenient fact that in our model $\theta - i - r$ (=.001) is approximately zero,[26] we can solve explicitly

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

25/ 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 why 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.

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

for the duration of the process before terminal point

5.11) a) $t = (1/\theta) \ln \ln (\eta_o \theta / N^*_o) \, 0/\eta_o$ (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^*_o) around 1888. Unfortunately, we do not know of any data on unemployment (disguised or open) for these early years. Consequently, the hypothetical values of N^*_o = .6, .7, .8 and .9 (i.e. 10% to 40% of the total labor force are assumed to be openly or disguisedly unemployed in 1888.) Applying (5.10) we obtain the following results:

Initial degree of employment: (N^*_o in 1888)	.9	.8	.7	.6
Duration of unemployment phase t: (year)	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 be 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 of Japan somewhat after 1910.

We recognize the roughness of the data employed and hope that later statistical information now becoming available from the Hitotsubashi University will make it possible to improve our estimates. The model itself can be further refined, e.g. it could easily be made to accommodate capital inflows from abroad. Nevertheless, the results obtained thus far seem encouraging and yield results in support of earlier work on Japan.[27]

27/ 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' earlier work (op. cit.)

Appendix 1

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 becomes available these series should be revised.

3) Employment data (Column 4) are from Fei and Ranis (op cit), page 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 6).

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%.)

Appendix 2

In (5.3b) of the text, the estimated Cobb-Douglas coefficient is =.67. Since this coefficient is ordinarily interpreted as the "capital share of national income" and takes on a numerical value between .3 and .4 the value of = .67 needs to be explained.

In our paper, the Cobb-Douglas function (3.1a) is postulated to describe the "availability of imported technology" at its source of supply, i.e. in the industrially advanced societies. It is well known that the production structure in these industrially advanced countries the production structure is characterized through time by (i) continuous innovation and (ii) continuous capital deepening. This is depicted in diagram 10 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 points A, B, C, D, ... represents capital deepening (i.e., increasing capital per head) through time. The locus A, B, C, D ... traces out a dotted curve . It is this curve, combining the effects of innovation and capital deepening in the industrially advanced countries, which provides summary of the demonstration effect possibilities for the underdeveloped country. In other words, the technology which can be visualized and borrowed by the underdeveloped society represents the realized unit technology while the unrealized portions of contours aa', bb' cc' ... are irrelevant. Thus, the (dotted) curve of diagram 3 is really the (dotted)" ex post" curve of diagram 10.

At point B (diagram 10), for example, the Cobb-Douglas coefficient for the unit contour bb' is xB/xy which is smaller than vB/vu. This latter number (vB/vu) is the Cobb-Douglas coefficient when the dotted curve is assumed to have the form (3.1a).

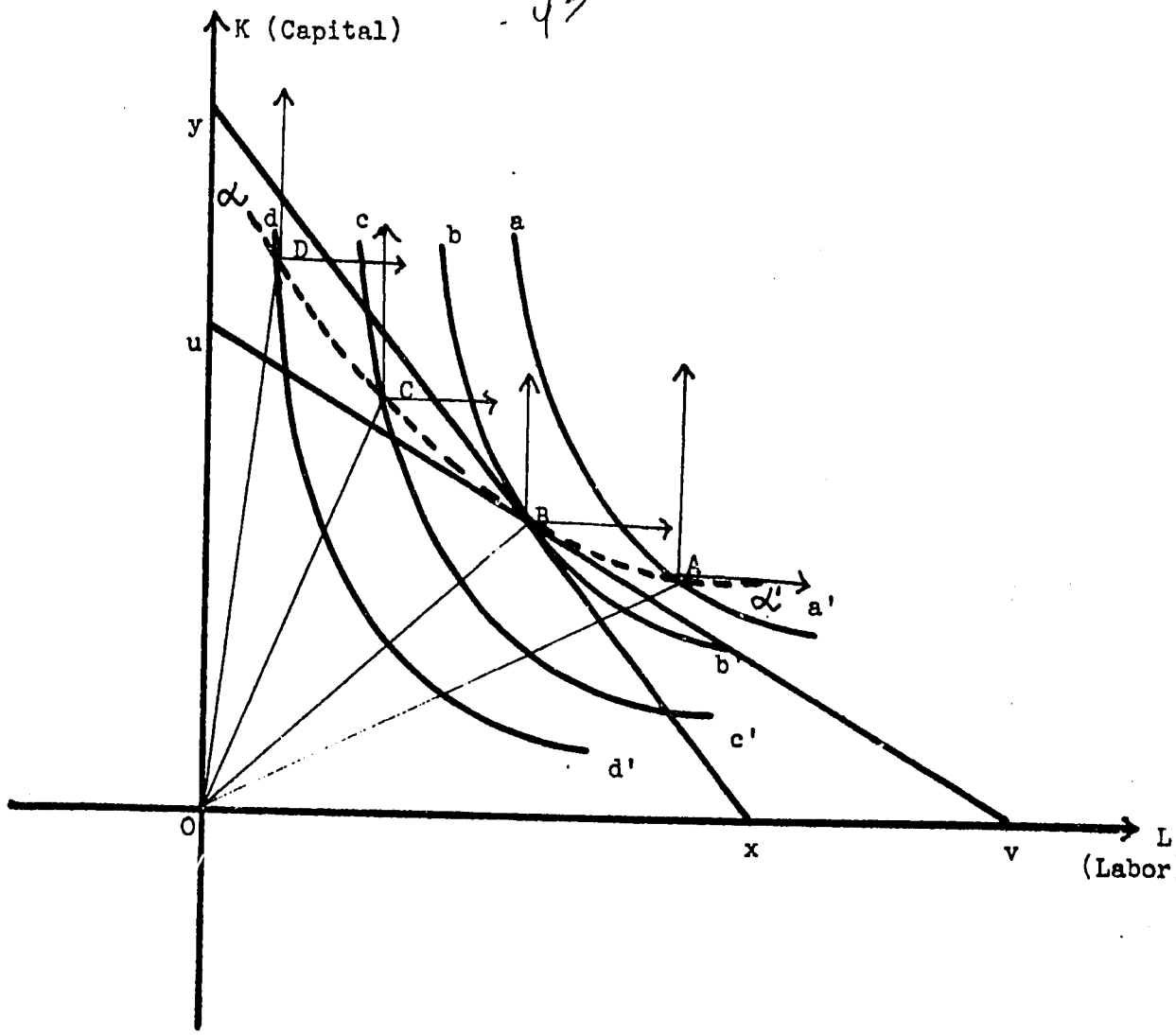

Diagram 10

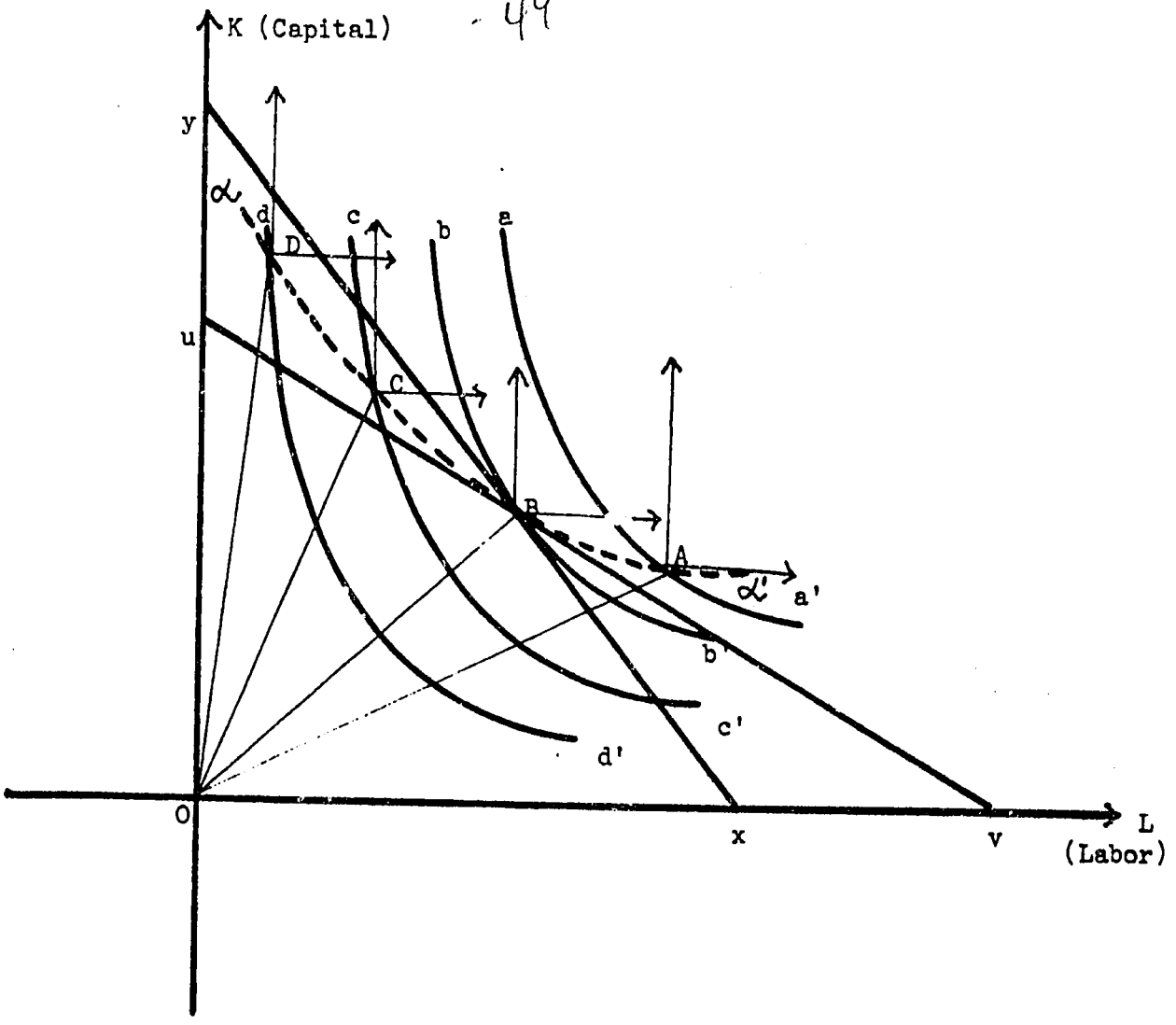

Diagram 10