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LDC INNOVATION ANALYSIS AND THE TECHNOLOGY GAP

John Fei

Gustav Ranis

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John Fei*
Gustav Ranis*

Increases in material welfare, i.e. economic progress leading to increases in per capita consumption, can be achieved in the long run as the consequence of many factors, including capital accumulation, improvements in the quantity of human resources, and technological change. However, both economists with a theoretical and those with an empirical and historical bent[1] have increasingly come to the conclusion that, in the long run, technological change is the most crucial--as well as the most difficult to get a hold of. On the one hand, the theoretical economists have reminded us of the inevitability of stagnation in per capita income if capital accumulation alone is at work.[2] On the other, those with an historical interest have identified modern growth, as the Western world has experienced it over the past 200 years, as an epoch characterized by the routinization of innovations.

When we accept such a long run historical perspective, the development of a "typical" contemporary LDC may be viewed as focussed on transitional growth, i.e. that period of some 30-50 years during which the country shakes off its economic heritage of pre-modern stagnation[3] and moves

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[1] e.g. R. M. Solow, "Technical Change and the Aggregate Production Function," RES, August 1957; and S. Kuznets, Modern Economic Growth, New Haven: Yale University Press, 1966.

[2] e.g. R. M. Solow, "A Contribution to the Theory of Economic Growth," QJE, February, 1956; T. W. Swan, "Economic Growth and Capital Accumulation," Economic Record, November 1956; and J. Fei, "Per Capita Consumption and Growth," QJE, February 1965.

[3] In many a contemporary LDC, this heritage is that of a pre-independence open agrarian society operating typically as a colonial appendage to a mature industrial country.

*Professors of Economics, Yale University, New Haven, Connecticut.

into an epoch of modern growth. Economic progress in general, and innovations in particular, must be viewed in the context of this transition.

At the present time our understanding of transition growth and of the role of innovation in it, are both admittedly still in a rather embryonic state. Consequently, any search for a better understanding of LDC technological change, i.e. any attempt to theorize on this important subject in a viable fashion, must begin with some historical perspective, and proceed to propose an analytical framework. It is the purpose of the present paper to attempt this twin task.

What is imperative about an historical perspective in which to imbed the analysis is that it provide a major focal point for deciding what factors out of the multitude of possible observations are essential and relevant--and which may be set aside as of secondary importance, at least as a first approximation. In section I, we shall try to cultivate this historical view by contrasting the role of innovation in the typical LDC with the role of innovation in the industrially mature economy. Such a comparison then permits us to conclude that the major factors relevant to the innovational process in the LDC's--our main concern--include (i) changes in the quality of domestic entrepreneurship, (ii) changes in the factor endowment over time, and (iii) the possibility of the international transfer of technology. These are the facets that will be explored as part of our analytical framework in sections II to V.

This analytical framework of ours represents little more at this time than a preliminary attempt to let empirical insights, based mainly on the transitional growth experience of post-Meiji Japan be integrated into a rather crude theoretical framework. To date, the innovational process has not yielded easily to analysis in any context, developed or underdeveloped--and it would be presumptuous for us to expect to change this situation in the context of this paper. While we think we have made some progress, especially in linking the element of rational choice to the innovation inducement mechanism, the whole set of issues broached here is sufficiently complicated to threaten to involve us in a rather ambitious reformulation of development theory--something we have clearly not attempted. But even a first approximation must give due recognition to some of the following factors: (i) the relationship between rational entrepreneurial decision-making and the feasibility of technological borrowing abroad (section II); (ii) the high cost of technological borrowing initially due to entrepreneurial immaturity--and the subsequent act of unconscious innovation as these entrepreneurs gradually learn by doing in the course of the transition process (section III); and (iii) the attempt, later, by maturing entrepreneurs to consciously adopt biased innovations in response to changing factor endowments (section IV). Our overall analytical framework, resulting from a synthesis of these elements in the context of a phase of transition theory, will then be subjected to some statistical verification (section V).

I. Innovations in Historical Perspective

Since most of our knowledge about technological change is necessarily derived from our understanding of industrially advanced countries, it behooves us to make a preliminary assessment of the extent of transferability of that knowledge, i.e. to what extent the knowledge of innovations pertinent to "mature industrial capitalism" is useful for the understanding of an underdeveloped country engaged in this transition. We propose to examine the transferability of innovation analysis from the point of view of (1) the socio-economic significance of innovations, (2) the sources of innovational ideas, and (3) the innovation-motivation mechanism proper. As we will discover, there exist significant differences between the rich and the poor countries in all three of these dimensions.

1. The Socio-Economic Significance of Innovation

Economists are normally concerned with social as opposed to private objectives. In a wealthy industrial society, three types of socio-economic problems may be said to have motivated economists' interest in innovations: (i) economic instability, (ii) distributional equity, and (iii) long run stagnation. The relationship between innovations and instability stems from the fact that economic fluctuations are caused mainly by fluctuations of investment which, in turn, may be traced to the lack of dependability in the appearance of innovational ideas to be accommodated by capital accumulation.[1] The issue of "distributional

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[1] c.f. J. A. Schumpeter, The Theory of Economic Development, Cambridge, Mass.: Harvard University Press, 1934; and Karl Marx, Das Kapital, London: George Allen & Unwin, Ltd., 1943.

equity" stems from the natural focus of a wealthy society on issues of distributional conflicts (e.g. the distribution between labor and capital) which are affected by the factor bias of innovations. The distributional equity issue, moreover, has implication for long run stagnation in that the natural tendency for the profit rate to decline in the long run as the consequence of capital deepening must be compensated for by innovations if secular stagnation is to be avoided, i.e. if the capital owning class is to be induced by a high enough profit rate to take the risk of investment and the exploration of new ideas.

The problems of instability and of distributional sensitivity are mainly problems of mature twentieth century capitalism in which innovational activities are assumed to have become institutionalized and routinized. This group of social problems is very different from that faced by a contemporary LDC in the course of transition. Here the crucial socio-economic problem, one which lies at the heart of the transitional problem and tends to perpetuate LDC poverty, is not the erratic up-and-down quality of innovational activities but rather their absolute low level. As a consequence, instead of "instability" and "distributional equity" the analysis of LDC innovations must be focussed on (i) the origins of innovational capacity and (ii) the impact of innovations on relative factor utilization.

One of the most important "cultural" achievements during the transition phase is to acquire increased innovational capacity, and a major purpose of any analysis of innovational activity must be to study the process by which this ability is acquired. This, in turn, requires an understanding of the precise nature of entrepreneurial decision making, given inherited human resources.[1] For it is by the very process of the formation and the execution of entrepreneurial decisions that entrepreneurship is developed in a learning-by-doing context. In this respect, the analysis should focus naturally on the identification of the particular entrepreneurial tasks which need to be performed in the transition process.

From the socio-economic point of view, the impact of innovations must be assessed in terms of their efficiency in utilizing the resource endowment of the country. As a general rule, we may visualize that, during the transition process, an LDC moves from an almost exclusive reliance on land-based natural resources (e.g. in primary product exports) to the utilization of its human resources (labor and entrepreneurship) and, still later, of its skill and capital resources. Thus, the impact of an innovation in the "early," i.e. land-based or labor surplus phase, must be gauged mainly in terms of its labor using (or capital saving) impact in meeting the basic requirements of efficiency. The common sense of the matter is that as long as there is a marked discrepancy between factor endowment and factor utilization, given a particular state of the arts, innovations should be "biased" in a labor-using direction, as a learning effort in the use of the country's relatively abundant resource (i.e. labor) and in conserving the relatively scarce resource (i.e. capital). For an LDC in transition, the innovation effects could thus be statistically summarized in terms of changes in the overall capital-labor and capital-output ratios, at least for the industrial sector.

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[1]Including such cultural factors as secularism, nationalism and a belief in the equality of access to scarce resources.

In summary, the two objectives of LDC innovation analysis, augmenting innovational ability and improving the related efficiency of resources utilization, are critical growth related objectives, i.e. objectives oriented toward increasing the output capacity of the economy. These objectives are quite different from the emphasis on instability and/or distribution in the industrially advanced countries where long term growth can be taken more or less for granted.

2. The Sources of Innovational Ideas

The defining property of twentieth century industrial capitalism is the institutionalization of innovation activities. This process results from decades of cost-benefit analyses guiding the direction of R and D expenditures to explore the knowledge frontier, with the benefits reaped in terms of the actual industrial adoption of new ideas. Thus the sources of innovational ideas reside in the exploration of new knowledge. Moreover, full analysis of the institutionalization of the exploration process itself necessitates distinguishing between private (profit-seeking) and public (e.g. military-related) innovations.[1]

The situation is again entirely different for an LDC in transition. Here, the source of technological ideas is not the simple consequence of the exploration of the knowledge frontier. Rather, the most important source of new technology is the transfer via the importation of ideas already proven to be industrially feasible in the industrially mature countries. Cost-benefit analysis and the role of government in

[1] W. Fellner, "Trends in the Activities Generating Technological Progress," AER, March, 1970.

the innovation process are largely irrelevant, since the "cost" aspect is trivial, i.e. except for search costs, innovational ideas are relatively freely available to the latecomer. Thus, for an LDC, the focal point of the analysis of innovations is more likely to be the absorption process proper, i.e. how foreign innovational ideas are transferred and possibly modified. Specifically, such analysis can be expected to be more concerned with the level of efficiency over time in the process of borrowing and simply transplanting knowledge--as well as with the efficiency of the domestic assimilation and innovation processes "on top of the" imported technology.

In the total technology absorption process we may usefully distinguish between two facets, a private innovation process and a social innovation process. Like its counterpart in the industrially advanced countries, the private innovation process refers to the conscious calculations and actions of private profit seeking entrepreneurs, with respect to profits and losses, as related to, among other elements, factor bias in technology transfer. The social innovation process, on the other hand, refers to more unconscious acts of learning by doing, partly by entrepreneurs and partly by other economic agents, in the process of technological assimilation. As we shall argue, such "unintentional" social innovations may be quite important, especially in the early phase of transition when the domestic entrepreneurship is, as yet, underdeveloped. This type of innovation, which may have just as much "employment" and "output raising" effects as the conscious private type, is peculiar to an LDC under transition, i.e. it represents a category of innovations not ordinarily emphasized in the mature industrialized society where the effects of most innovations tend to be "internalized" or "imputed," This unintentional or social variety of innovation, it should be emphasized, is likely to come earlier in the life of an LDC since inefficiencies arising from pure transplantation are eliminated as domestic entrepreneurs become more experienced.

3. Innovation-Motivation Analysis

With respect to the analysis of the private or conscious motivation of innovation, the focal point in the industrially mature countries has been on the entrepreneurial calculation of the anticipated saving in factor cost.[1] A most important type of information relevant to this calculation is usually provided by the state of anticipation with respect to the supply of labor. This includes both (i) the anticipation of the real wage trend--generally upward in mature societies and (ii) the anticipation of other (non-wage) difficulties in dealing with labor unions--generally upward too. For both these reasons, innovations in mature capitalist societies have had an inherent labor-saving bias, i.e. as exemplified by the marked trend towards "automation."

Once the LDC entrepreneur is capable of making rational economic calculations, a similar innovation motivation analysis can be applied here. There are two points which need to be emphasized in this context. First, the full flowering of labor union development is a phenomenon still mainly reserved for the mature economy,[2] and hence the analysis of

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[1] W. Fellner, Trends and Cycles in Economic Activity, New York: Holt, Rinehart and Winston, 1956.

[2] Less true for LDC's which are at a later stage of transition, e.g. Latin America.

innovations can be simplified by the assumption of a trend towards perfect competition in the labor markets. Second, instead of anticipating continuing marked increases in the real wage, we may distinguish two stages of LDC growth: a first stage characterized by an approximation to the "unlimited supply of labor" condition and hence the anticipation of fairly constant or only gently rising real wages; and a second stage characterized by anticipation of substantially increasing real wages. One of the major elements of contemporary growth theory enables us to accept this distinction as an operationally relevant one.[1]

II. A Pure Model of Technology Transfer

In the context of any "pure" theory of technological transfer, at least three facets must be specified: (1) the availability of technology from abroad as described by the technology shelf; (2) the process of technological borrowing from that shelf based on rational entrepreneurial calculations; and (3) the implications of such borrowing for "growth," i.e. the tendency for capital deepening or shallowing, for employment and output generation, etc. These three facets will be examined in turn. Moreover, it should be understood that the "pure model" represents merely the skeleton of our analysis which will be modified and expanded in the subsequent sections

1. Technology Shelf

The important fact that, for an LDC, the primary source of technological ideas is from abroad may be described by the existence of a

[1] J. Fei and G. Ranis, Development of the Labor Surplus Economy: Theory and Policy, Homewood, Ill.: Richard Irwin, Inc., 1964; and also J. Fei and G. Ranis, "On the Empirical Relevancy of the Ranis-Fei Model of Economic Development: A Reply," to be published in the AER.

technology shelf, containing technologies of production which, either in the present or at some time in the historical past, have been demonstrated to be feasible in the industrially advanced countries, and from which an LDC can borrow freely. The technology shelf is given by the curve SS' in diagram (1a) in which labor (capital) is measured on the horizontal (vertical) axis. A typical point A_i on this curve represents a pair (n_i, k_i) in which n_i is the labor coefficient and k_i is the capital coefficient. The point A_i may be referred to as a unit technology in that it describes the amount of labor inputs (n_i) and of capital inputs (k_i) required to produce one unit of output. The idea of a unit technology assumes factor complementarity and is shown diagramatically by the fact that the point A_i is the "corner point" of an L-shaped production contour (U_i) producing one unit of output.

Suppose the size of the capital stock for the whole industrial sector is K, as measured on the vertical axis. Then, when, for example, the unit technology A_1 is chosen from the shelf, it can be operated at a definite scale producing K/k_1 units of output and employing Kn_1/k_1 units of labor. In diagram (1a) the radial line through point A_1, i.e. the radial line with a slope (k_1/n_1) intersects the horizontal line through point "K" at a point "c_1." This point "c_1" is the "corner point" of an L-shaped production contour indexed by V_1--producing K/k_1 units of output and employing Kc_1 $(=Kn_1/k_1)$ units of labor. Thus, associated with any technology choice (in this case A_1), the degree of capital intensity (i.e. capital per head, k_1/n_1) is determined. The size of the capital stock "K" thus determines the amount of labor force ($K c_1$ here) which can be efficiently accommodated for each technological choice.

The complementary nature of capital and labor in the unit technology (e.g. A_1) can alternatively be shown by means of the TPP_L (total productivity of labor) curve oa_1b_1 in diagram (1b). This TPP_L-curve has a radial, i.e. homogeneously linear portion, Oa_1, before the size of the optimum labor force (Kc_1 in diagram 1a) is reached, and a horizontal portion, a_1b_1, beyond that point.[1] Thus, when the size of the capital stock K is given, by varying the unit technology A_o, A_1, A_2...on the shelf SS' in diagram 1a, we can determine a family of TPP_L curves (Oa_ob_o, Oa_1b_1, Oa_2b_2...in diagram (1b).

The technology shelf contains information on techniques demonstrated to have been feasible at some point in the historical past somewhere in an industrially advanced country. The fact that curve SS' (diagram 1a) is negatively sloped serves to emphasize the fact that, with respect to the more recent vintage of advanced country technology, i.e. as we move upward to the left along the shelf, A_o, A_1, A_2...three long run trends may be observed: increasing labor productivity (i.e. decreasing values of n_o, n_1, n_2...), continuous capital deepening (i.e. increasing slopes of radial lines OA_o, OA_1, OA_2...), and increasing capital-output ratios (i.e. increasing values of k_o, k_1, k_2). The first two properties are among the well known "stylized" facts of economic growth in the history of the mature economies.[2]

[1]Given the capital stock, e.g. K and the unit technology e.g. A_1, the optimum labor force (kn_1/k_1) is an optimum in the sense that it represents the minimum amount of labor required to produce the maximum produceable output.

[2]e.g. Kaldor, "A Model of Economic Growth," E.J., December, 1957 and Fellner, Trends and Cycles in Economic Activity, op. cit. The third condition, that of an increasing trend in the capital-output ratio, could easily be modified in our above analysis. For example, the technology shelf SS' is a horizontal line for a constant "k", clearly not an impossible case; an upward sloping curve would indicate a declining "k", an unlikely world in which increases in labor productivity in the industrial countries do not have to be "bought" at the price of higher capital-output ratios. Empirically the downward sloping shelf, as we have pictured it, seems the most realistic.

2. Technological Borrowing and Rational Entrepreneurial Action

Let us assume that, in addition to the technology shelf itself, we also know the value of the real wage, i.e. the height Ow of the horizontal supply curve of labor ww' in diagram (1c). From this we can construct a curve depicting the total wage bill, i.e. the radial line OG in diagram (1b), the slope of which is the real wage. If the technology chosen by the entrepreneur is A_1, for example, then profits π_1 are maximized at the point a_1 where the gap between the OG and the TPP_L-curve Oa_1b_1 is at a maximum. In other words, that amount of labor input which maximizes profits is precisely the previously defined optimum labor force, i.e. that labor force which, for the given capital stock, leaves neither labor nor capital disguisedly unemployed. This simple property follows directly from the competitive assumption, i.e. the fact that the real wage is constant and given for all firms.

When the size of the capital stock (K) is fixed, a rational entrepreneur will thus seek to adopt (i.e. borrow) that technology choice which maximizes the rate of return to capital. In diagram (1b), alternative maximum profit levels π_o, π_1, π_2 represent the anticipated profit stream associated with each alternative technology choice--under the assumption of the expectation of near constancy of the real wage. A rational entrepreneur under these circumstances will adopt that technology which yields the maximum profit. In diagram (1b), the equilibrium technology choice turns out to be A_1, leading to the maximum profit π_1.

This equilibrium condition can be shown explicitly by treating the "envelope curve" a_2, a_1, a_o as an ex ante TPP_L curve.[1] For each amount

[1]This is reminiscent of the putty-to-clay idea in the growth theory literature (see E. Phelps, "Substitution, Fixed Proportion, Growth and Distribution," International Economic Review, 1963.

of labor employed the curve shows the maximum output which can be obtained by a suitable technological choice. It so happens that the maximum output is obtained when the optimum technology, consistent with the given labor force, is chosen. The *ex ante* MPP_L-curve, i.e., the slope of the *ex ante* TPP_L curve, is the demand curve for labor as depicted by the negatively sloped MM curve in diagram (1c). Where this demand curve intersects the horizontal wage line ww' e.g., at a point E, the equilibrium position is determined.

The above skeleton of a theory of rational entrepreneurial behavior shows that the technology choice can be deduced from a calculation of the rate of return to capital--which in turn can be traced to the combination of anticipated domestic real wage behavior and the technological information available from abroad. The result of such an entrepreneurial choice is not only the determination of the rate of return to capital (π_1) but also simultaneously of the degree of capital intensity (k_1/n_1) and of the total volume of labor which can be absorbed (wE).

3. Overall Implications for Growth

The above framework for analyzing technological choice also provides the groundwork for determining the impact of growth. In this simple model growth may be defined in terms of increased capital accumulation and increased employment opportunities. Both of these will be clearly affected by the anticipated long run behavior of wages. As pointed out earlier, wages may be assumed to be held roughly constant or increasing only modestly during the early labor surplus phase of transition, and to increase rapidly at the later phases when that labor surplus no longer overhangs the market.[1]

Thus far we have kept the capital stock constant at K. Now let the increase of that capital stock through time be represented by the points K, K', K"...on the vertical axis in diagram (1a). The larger capital stock will lead to "higher" demand curves for labor MM, M'M', M"M"... in diagram (1c), leading to increases in labor absorption. When the real wage is constant, the amount of labor force absorbed will always be proportional to the size of that capital stock. Starting from the initial point "c_1" in diagram (1a) the expansion path would then be indicated by the locus of points R', R", R'"...which fall on a radial line. Conversely, when the real wage is increasing (i.e. as represented by the dotted curve from the point E on), the expansion path will show a capital deepening tendency, as shown by the locus of points E', E", E"'... . These conclusions follow readily from the assumption of constant returns to scale.

In summary, we can thus see that the main implication of our view of LDC innovation behavior is that the behavior of the real wage, as it makes itself felt through the choice of technology, determines the extent of capital intensity, i.e. a rapid increase in the real wage will induce rapid capital deepening. The pace at which employment opportunities are generated is thus controlled by capital accumulation, as modified, in an adverse direction, by the capital deepening tendency resulting from wage

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[1]Other, exogenous, pressures may combine with the termination of the unlimited supply of labor condition to differentiate this second phase from the first. As wages rise, moderately in phase 1 and rapidly in phase 2, the slope of the wage bill curve OG in diagram 1b shifts up and the maximum profit point shifts to the left.

increases. These simple relations must now be modified to accommodate other important dimensions of the technology transfer process.

III. "Social" Innovation Activities

For a less developed country in transition, an important source of productivity gain may be traced to the elimination of inefficiency in the course of the above described process of technology transfer. As perfected and developed in the industrially advanced countries, such technologies assume certain factor efficiency and organizational efficiency which may be lacking in an LDC. The most important manifestation of factor efficiency is, of course, labor efficiency which can be traced to such factors as cultural heritage, accumulated experience, education, etc., the precise relationships as yet incompletely specified. In organizational efficiency, we may include entrepreneurial capacity as well as organizational capacity traceable to economies of large scale production. While we are not yet ready for finely specified answers, we may assume that both of these types of efficiency are related to learning by doing processes.

The aforementioned inefficiency is operationally described by an increment in the real cost (i.e. real capital cost and/or real labor cost) which an LDC will have to incur, over and above that implied by the technology shelf, i.e. over and above the costs per unit of output prevailing historically in the advanced countries. In diagram (2a), the SS' curve represents the technology shelf containing unit technologies A_o, A_1, A_2...,and TT' represents the unit technologies after unit technologies A_i have been transplanted into the LDC and converted into

B_o, B_1, B_2...at lower levels of efficiency. The incremental real costs due to inefficiency are indicated by the vectors (i.e. arrows) $\overline{A_oB_o}$, $\overline{A_1B_1}$, $\overline{A_2B_2}$...which have a "direction" (i.e. slope) and a "magnitude" (i.e. length). Notice that these arrows point to the North-East (i.e. they are positively sloped), indicating the fact that capital and/or labor coefficients will be increased as a consequence of the existence of inefficiencies.

Generally speaking, an LDC will incur a heavier real cost if it attempts to import technologies with a more recent vintage, i.e. further away from their own experience. This is shown by the increasing length of vectors $\overline{A_oB_o}$, $\overline{A_1B_1}$, $\overline{A_2B_2}$,...as we move to the left. Our conjecture is that these arrows will also become steeper indicating the fact that as the LDC attempts to import technologies of a more recent vintage, i.e. "beyond their reach," the incremental real cost per unit of output is oriented increasingly toward capital rather than labor. This is due to the fact that the efficiency of modern capital intensive production depends more and more on organizational capacity as well as the ability to maintain and repair the capital stock. On the other hand, when an LDC attempts to import a technology of a considerably older vintage, e.g. a U.K. textile mill of vintage 1890, the total inefficiency the borrower will have to worry about may be absolutely smaller and the inefficiency of the labor force may be relatively more important.

Suppose, the size of the capital stock OK is given (in diagram 2a). In diagram (2b), let MM be the demand curve for labor, i.e. the <u>ex ante</u> MPP_L curve as previously introduced, corresponding to the given technology shelf, and let NN be the effective demand for labor corresponding to the transplanted shelf TT'. When an LDC strives to eliminate the above inefficiency over time, we can think of the movement from the TT' curve back to the SS' curve as an innovation in the ordinary sense which can be measured with respect to (i) the intensity of innovation and (ii) the degree of labor saving bias. The fact that the length of the arrows $\overline{A_1B_1}$, $\overline{A_2B_2}$...increases indicates innovations with increasing intensity. The fact that, on the same radial line (e.g. OQ) the slope of SS' (e.g. at A_2) is less steep than the slope of TT' (e.g. at B_2) means that the innovation is biased in the labor saving direction. Thus in diagram (2b), it should be noticed that as compared to MM, the effective demand curve raises the MPP_L for technologies of an older vintage, while depressing the MPP_L for those of more recent vintage. This is due to the fact that, for technologies with older vintage, the low innovation intensity effect is over-whelmed by the "very labor-saving innovation" effect. For technologies of more recent vintage, the high innovation intensity effect which raises the MPP_L overwhelms the weak labor saving effect, leading to a net increase in the MPP_L.

When an LDC, after initial technological transplantation, finds itself confronted with such inefficiencies along TT', for each level of the real wage the amount of labor employed and the degree of capital intensity will be different from that prevailing in the lending industrially advanced countries. When the real wage is relatively low (e.g. ow_1 in diagram 2b), the LDC will employ more labor than was the case historically abroad (i.e. $w_1 e_1 > w_1E$). From the auxiliary radial lines OQ and OJ, in diagram 2a, we can see that the technology selected by the LDC, given the real wage at ow_1, is B_2, transplanted from A_2, while, historically, the industrially advanced country, at the same real wage level, would have chosen a technology (e.g. A_3) which represented a higher degree of capital deepening. Notice that there is little difference between the total output produced at A_3 (i.e. K/k_3) and at B_2 (i.e. K/k_2'), i.e. there is no a priori reason for us to know whether A_3 or B_2 is in a "higher" position. Thus the incremental employment of QJ units of labor on the same capital stock represents the entire incremental real cost due to labor inefficiency.

Given a real wage at a somewhat higher level, we may note that the above situation is reversed. Here the depressing effect of MPP_L leads to the employment of less labor than was the case historically in the industrially advanced countries (i.e. $w_2e_1' < w_2E'$). In diagram (2a), at the given higher real wage level, the technology chosen by the LDC is B_5 (transplanted from A_5) which represents a higher degree of capital intensity than that prevailing historically in the advanced countries (i.e. A_4). Because of this inefficiency, the country now pays a double penalty in terms of output loss, i.e. the loss of output is $Q(1/k_4 - 1/k_5')$. In other words, the economy loses output on the given capital stock both because it chose a technology which is more capital using (i.e. by moving from A_4 to A_5) and because of the inefficiency in the utilization of that technology (i.e. by moving from A_5 to B_5).[1]

[1]For lack of a better name, the above phenomenon may be referred to as a "diseconomy" of premature modernization. Such "diseconomies" always occur when the country is as yet not very efficient, requiring the use of relatively more capital and resulting in a lowering of the MPP_L. The inherent paradox can be seen in the transplantation of a "supermodern factory" seemingly completely out of line with the prevailing relatively low level of real wages. The introduction of such a plant may be viewed as necessary to raise the MPP_L to a high enough level to compensate for the inherent inefficiency. Differently put, in diagram (2b) we see that as the real wage level is raised to w_3, it will become uneconomic for any technology to be borrowed by the LDC while some technology will still be economical in the lending country.

For an LDC which normally finds itself with such inefficiencies as part of its colonial heritage, their elimination over time clearly constitutes a major source of innovation, leading to gains in output capacity per unit of input. In diagram 2a such "innovations" may be represented by the gradual movement of the TT' curve through time towards the SS' position. In diagram (2b), similarly, the NN curve can be pictured as swivelling in a clockwise manner towards the MM position. It is then also easy to trace the impact of such innovations. For a relatively low level of the real wage such innovations lead to capital deepening, i.e. e_1, e_2, e_3 ...E. Little effect on raising output is recorded, with the main impact of innovation the laying off of some redundant workers per unit of capital stock. For a relatively high level of the real wage, the impact of this type of innovation leads to capital shallowing, i.e. e_1', e_2', e_3'...E' as more labor is employed per unit of capital. However, the major gain is now measured in terms of increased output brought about through a more effective use of the scarce capital stock.

The existence and elimination of these inefficiencies modifies the conclusions for the LDC's growth path as analyzed in the last section. For the low wage case (Ow_1) in diagram 2a, the expansion path as a result of only capital accumulation would, in the absence of elimination of inefficiencies, have followed the radial line JP (as we noted earlier). The elimination of inefficiencies, on the other hand, leads to a growth path QH, marked by a capital deepening tendency, which "catches up" with the JP path over time. For the high wage case (Ow_2) the growth path Q'H' now shows a capital shallowing tendency approximating the radial path J'P' over time.

For an LDC in transition, we can realistically visualize a situation in which the real wage increases only gradually as long as labor surplus overhangs the market. In the absence of the "inefficiency" element, we note an initial capital deepening phenomenon, induced by this wage increase--as analyzed in the previous section. When the argument of this section is added, however, we can see that while, in the early phase, the country will show a tendency toward capital deepening, this tendency may give way to some capital shallowing later. This is true if the elimination of inefficiencies is sufficiently important to swamp the effects of moderate wage increases over time. Moreover, this capital shallowing phase is seen to be accompanied by a substantial growth in income because of the huge output-raising effects associated with gains in the efficiency of using capital. This capital shallowing phase is likely, however, to go on forever and will eventually give way to capital deepening when this source of gain in efficiency is exhausted and the capital deepening effect, due to an accelerating real wage increase, begins to dominate.

IV. The Motivation for Innovational Bias

The unintentional or "social" innovation of the last section is the result of learning by doing processes which are themselves a by-product of growth. This contrasts sharply with the important intentional type of innovation which we will be concerned with in this section, i.e. as a consequence of a conscious entrepreneurial attempt to further reduce the real output costs (in terms of capital or labor inputs) in the process of technological assimilation. The core of this theory, as in the mature countries, must be a rational innovation motivation analysis at the level of the individual entrepreneur. Since the amount of possible reductions in real costs, or innovational intensity, is, of course, constrained by the expansion of the entrepreneurial knowledge frontier, there is little that economists can say, on *a priori* grounds, about the magnitude of possible cost reductions. What the economist can hopefully speculate about on such *a priori* grounds is limited to the direction of the factor bias of innovations, which is what will be emphasized in this section.

In diagram (3a), let the point A (i.e. the point (n,k)) represent a pre-innovation unit technology. The real cost reducing effect of an innovation is to shift this point towards the South-West (e.g. towards point D) which represents a reduction in the labor and/or capital coefficient. In the same diagram, we have shown two special extreme cases: a move from A to A', which may be called a pure capital saving innovation (i.e., yielding a reduction of the capital coefficient only and leaving the labor coefficient constant), and a move from A to A", a pure labor saving innovation. Useful *a priori* reasoning about the innovation-motivation mechanism is usually limited to showing why entrepreneurs should attempt to orient their innovational effort in either of these directions.[1]

Suppose the size of the capital stock (K) is given. The TPP_L-curve corresponding to the pre-innovation technology (i.e. at point A) is shown by the curve oab in diagram 3b. For the two extreme cases

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[1]In the context of this paper the costs of R and D and of search are neglected.

(i.e. A' and A"), the post innovation TPP_L-curves are also shown in the same diagram (3b). For the case of the labor-saving innovation (A"), the TPP_L curve shifts to oa"b. Notice that the effect of this innovation is to reduce the optimum amount of labor employed by ΔL, e.g. through automation; there is no output raising effect whatsoever for the maximum output obtained because the value of the capital-output ratio is assumed to be unchanged. For the case of the capital-saving innovation (A'), the post innovation TPP_L-curve is shifted to oa'b', implying that more labor will be employed (i.e. by an increment of ΔL units) and that total output will be raised (i.e. by ΔQ).[1] The key analytical issue before us is in which direction will the profit maximizing entrepreneur orient his innovational effort?

In diagram (3b), given a real wage at W, let the total wage bill line OW be shown, leading to a pre-innovation rate of return to capital π. If the labor saving innovation is adopted, the incremental profit is $\Delta\pi$. which is brought about entirely by a saving in wages, i.e. $\Delta\pi = W \times \Delta L$. Since there is no output raising effect, the source of additional profit resides entirely in the reduction of the labor force (e.g. through automation) and the consequent saving in the wage bill. On the other hand, if the capital-saving innovation is adopted, the incremental profit is Δg (note that dd'a'a is a parallelogram) which is proportional to two factors: (i) the increment in employment $\Delta L'$ and (ii) the degree of exploitation per unit of labor $n - w$ (i.e. $\Delta g = \Delta L'(n - w)$). Here the extra innovation profit (Δg) is larger the larger the additional labor absorption ($\Delta L'$) and the higher the degree of exploitation $(n-w)$.

[1]The radial portion of the TPP_L curve coincides with the pre-innovation curve because of the assumed constancy of the labor coefficient.

It is then easy to see why, in an industrially advanced country, innovations tend to be biased in a labor saving direction. Under competitive assumptions the most important reason is that in such countries the degree of labor exploitation, n-w, tends to be low, i.e. the wage tends to be a relatively high fraction of labor productivity and hence the profit margin tends to be low. Under these circumstances, the saving associated with labor saving innovations tend to be large and, at the same time, the extra profits due to capital saving innovation tend to be small. This is clearly seen in the extreme case when the wage bill curve (OW) is steep enough to coincide with the TPP_L-curve oa, implying zero profits before innovation. In this case, the extra profit due to the labor saving innovation is ja" (ja" = $\Delta L \times n$), while the extra profit due to a capital saving innovation is zero.

This "static" argument would be strengthened if the entrepreneur can be viewed as anticipating a rising trend in real wages. For the only way in which said entrepreneur can protect his profit margin (when threatened by wage hikes) is through adopting labor saving innovations. Capital saving innovations will not help when the profit margin is threatened.

We may cite two additional arguments based on market imperfections which tend to strengthen the above conclusion. First, labor saving innovations result in lower levels of employment and hence in a lessening of the entrepreneurial dependence on labor--thus minimizing labor control problems. Second, labor saving innovations, to the extent that there is little or no output raising effect, lessen the entrepreneurial task in having to create new markets, which can be a serious problem in a wealthy economy constantly threatened by a deficiency of aggregate demand.

When we turn the argument around, we can see why, in an LDC, the entrepreneurial effort is generally oriented in the opposite or capital saving direction. When the wage bill is relatively low and the profit margin (i.e. the degree of labor exploitation n-w) relatively high the entrepreneurial preference clearly lies in the capital saving direction. For example, in the extreme case where the wage is zero (i.e. OW coincides with the horizontal axis), the gain in profits due to a labor saving innovation approaches zero (i.e. $\Delta\pi = 0$), while the gain in profit due to capital saving innovation is equivalent to the gain in output (i.e. $\Delta g = \Delta Q$). On top of these competitive arguments we can again add a couple of non-competitive ones, i.e. (1) entrepreneurs in LDC's are likely to be more paternalistic or "family oriented" and motivated by a desire to provide employment opportunities for relatives as long as there is no extra cost; and (2) there is generally greater pressure for output expansion in economies characterized by poverty and Say's Law.

Returning now to diagram (3a), let us assume that, historically, the initial technology in the industrially advanced country was at point A. We may then let the shaded area represent the set of newly possible unit activities resulting from the R and D expenditures, bounded by the knowledge frontier FF'. The choice of the post-innovation technology is then shown to be at point A_1, as determined, on the one hand, by the new knowledge frontier and, on the other, by a desire for maximum labor saving as argued above. It is in this manner that the technology shelf SS' itself has been built up historically in the mature economy.

A contemporary LDC, on the other hand, faced with technology shelf SS', will mainly be concerned with engaging in capital-saving innovations in accordance with our earlier analysis. For example, if unit technology A_1 is borrowed, such innovation may bring the actual unit technology down to point C. Choices along curve CD', the post-assimilation locus of unit technology, thus represents all the points describing the net result of moving along the technology shelf SS' plus the capital-saving innovation. The actual final resting place will be determined by profit maximization as described earlier.

V. Summary and Statistical Implementation

As we pointed out in the introduction, any study of LDC innovations must be related to phases in the transition to modern growth. This problem is, in turn, intrinsically related to the development of entrepreneurship and to the improvement in the efficiency of resource utilization once entrepreneurial capacities improve.[1] In this connection, we have made two special assumptions. On the one hand, we assume that the LDC under consideration is of a labor surplus type. This means that it fits the general description of a country initially marked by a substantial overhang of unemployed labor leading to approximate constancy of the real wage--or only moderate increases in the wage--with rapid increases in the real wage to follow later in the transition process. On the other hand, we assume that the importation of technology from abroad represents the dominant source of innovational ideas. While both assumptions somewhat delimit the generalizability of our theory, we believe that our approach is addressed to an important type of contemporary LDC.

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[1]In an open economy, the first phase is often highly correlated with a so-called import substitution regime, the second with liberalization and export promotion.

The major theoretical conclusions of our paper can be derived from a synthesis of the arguments presented earlier. The central notion of a transition period of 30-50 years for the typical contemporary LDC is accepted. The various phases which make up that transition are a reflection of the more or less natural maturing process with respect to (i) the development of entrepreneurship and (ii) changes in the basic endowment condition, i.e. from a labor abundant to a labor scarce situation.

In the first phase of the transition we envision that entrepreneurs are still very inexperienced, at least as far as industrial activities are concerned. Innovations at this time are mainly of the unintentional or unconscious variety exemplified by the elimination of inefficiencies inherent in the process of technology transfer. In this first phase, since the real wage remains low, innovations, as we have seen, tend to be labor saving in nature, with little output raising impact. Thus we would expect to observe moderate rates of growth of output or capital stock--due to the relative inexperience of the entrepreneurs and the consequent inefficiency of the emerging industrial structure.

In the second phase of transition entrepreneurs have become more experienced. As a result the unintentional (or unconscious) type of innovation gradually gives way to the more conscious type. In this phase, in contrast to the first, there is a deceleration of the capital deepening process or, when carried to its logical conclusion, the possibility of some capital shallowing. Two arguments may be cited in support of this conclusion. First, as long as the real wage remains low, the capital deepening effect traceable to residual innovations of the unintentional variety is gradually swamped by the effects of the intentional type which is, as we have seen, mainly capital shallowing in nature.[1] The conclusion is that such capital shallowing or reduction in capital deepening should be what we expect of any rationally operating labor surplus economy in which relatively mature entrepreneurs, for the first time, learn to make use of the relatively abundant factor, i.e. labor. It is for this reason, that we expect rapid growth, both in terms of a higher rate of capital accumulation and a higher rate of per capita income, to accompany the capital shallowing process.

In the third phase of transition the innovation effect may be traced entirely to the conscious type of innovation--as the unconscious variety is completely exhausted. Now the innovation bias gradually shifts from labor using to labor saving. This tendency toward capital deepening becomes pronounced when, with the elimination of the economy's surplus labor and the consequential sustained increase in the real wage, innovation takes on the character typical of an industrially advanced economy. Capital deepening will be accompanied by a slowing down of the growth rate, as the surplus labor (a hidden source of saving) runs out and the economy gradually closes its technology gap with the advanced countries. Once development becomes more skill and capital-based, the economy relies more and more on her own internal entrepreneurial talents to fashion the initial innovational breakthroughs.

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[1]When the real wage climbs to a relatively higher level, even the unintentional type of innovation will have capital shallowing consequences.

In diagram 4, the time series for capital per head (K/L), the real wage (w), and the rate of growth of the capital/stock (η_K) for the industrial sector of Japan are shown. The 50 years of transition experience, between 1880 and 1930, can be seen, by inspection, to be divisible into three possible sub-phases marked off by the two vertical lines in 1905 and 1917. The year 1917 moreover appears to be a major turning point, marking off the labor surplus phase from the phase characterized by the exhaustion of the labor surplus in agriculture.[1] To us, the operational significance of the turning point is that, in the labor surplus phase, there is strong population pressure keeping the real wage from rising very much and inducing labor-using innovations. This contrasts sharply with the rapid wage increase after 1917, which, according to our analysis, induces entrepreneurs to innovate in a labor-saving direction.

Based on these data, the average annual rate of increases of the real wage (w), capital per head (K/L) and capital stock (K) are presented in Table I. The significance of the turning point in 1917 is seen by a comparison between rows (III) and (IV). Moderate annual increases of real wage before 1917 (1.7%) give way to much higher rates of increase (4.4%) thereafter. Equally striking contrasts are shown for the rate of capital deepening (from 1.2% to 4.0%) and for the rate of growth of capital (from 2.9% to 4.4%) as between before and after the turning point.

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[1] Fei and Ranis, Development of the Labor Surplus Economy: Theory and Policy, op. cit.

Table I: Average Annual Growth Rates

	real wage (w)[1]	capital per head (K/L)	capital (K)
Before 1917:			
(I) 1880-1905	1.8	1.2	2.3
(II) 1905-1917	1.6	4.0	4.4
(III) 1880-1917	1.7	2.1	2.9
After 1917:			
(IV) 1917-1929	4.4	4.0	4.4

Note: [1]The real wage figures are based on a moving average beginning in 1880.

The year 1905 also appears to have some significance, by inspection of diagram 4, possibly dividing the labor surplus phase into two sub-periods. For the period prior to 1905, there is a span of 25 years of near constancy of capital per head (1.2% per year in Table I), indicating a tendency towards "capital shallowing growth."[1] This is a significant phenomenon in the transition of a labor surplus economy. It signifies that entrepreneurs have, during this relatively long stretch of time, developed sufficient maturity and experience to be able to utilize the relatively abundant factor (i.e. the endowment of cheap labor) by innovating in a labor using direction on top of the imported technology.

This rather remarkable entrepreneurial performance, of course, did not just happen but has to be viewed as resulting from the development of entrepreneurship in the earlier period. Our data begin in 1880 which is more than a decade after the Restoration in 1868. For the earlier period, in spite of the absence of reliable statistical data,

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[1]Earlier data led us to the conclusion of actual capital shallowing for this period (Fei and Ranis, op. cit.). But the important point is that there is little capital deepening in spite of the increase in the real wage.

there is ample qualitative evidence of the kind of inefficiencies, based on the immaturity of entrepreneurs just moving from agrarian and commercial pursuits into attempting to organize a "modern" industrial sector, which characterized phase one in the analysis of our paper.[1]

The period between 1905 and 1917 may be viewed as a transitional subphase between agricultural labor surplus and its ultimate exhaustion. During this subphase, the forces leading to the turning point begin to assert themselves. Entrepreneurs are, by now, fully matured. The fact that the real wage has climbed to a relatively higher level now induces them to begin to shift somewhat toward labor saving innovations.[2] The result is that, after 1905, there begins a decided trend towards capital deepening growth, i.e. from 1.2% before to 4.0% thereafter (see Table I).

The rapidity of growth of the economy as a whole during the 50 or so years of transition reflects three types of forces: (i) an entrepreneurial maturing process, (ii) the process of gradual exhaustion of the economy's surplus labor, and (iii) the gradual narrowing of the technology gap (or the exhaustion of the advantage of the economy's

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[1]This evidence includes the massive scale of early, rather frantic attempts to borrow technology, including whole factories, from abroad, once the economy had been unceremoniously opened up after centuries of isolation. Secondly, the fact that many of the early factories were built by government on an experimental basis and sold to the private sector by around 1890 indicates the reduction of initial inefficiencies as the increased competence of private entrepreneurs could be harnessed. If we had the data our theory would predict finding capital deepening in the early post-Restoration years and an assist to the capital shallowing tendency already noted above, thereafter.

[2]In addition to this conscious innovation argument is the capital shallowing effect traced to the exhaustion of the unconscious innovation possibilities accompanying the elimination of organizational inefficiency.

"latecomer status.") The first factor is the basic cause of the acceleration of the rate of expansion, especially in the early phase. The other two factors contribute to a deceleration effect on the rate of expansion. When we take the rate of capital accumulation as a proxy for the rate of growth of the whole economy, we can detect, in diagram 4, a long-run inverse U-shaped curve (seen more clearly by the dotted curve fitted by free hand). This curve reaches a peak just before the turning point when the surplus labor is exhausted and when the economy's entrepreneurs have become fully matured.[1]

Any study of the transitional growth process through an investigation of macro-economic data pertaining to the whole economy must be accompanied by a reasonable theoretical framework. As noted earlier, the analysis of this paper constitutes only a preliminary attempt in this direction. If nothing else, we have demonstrated that what lies behind such macro data as capital-output and capital-labor ratios is an extremely complicated set of phenomena involving, inter alia, the development of entrepreneurship and the coming into play of an entrepreneurial innovation inducement mechanism in assimilating imported technology, while making efficient use of a country's domestic resources. It is our hope that our theory can be refined and some of our behavioral relations specified by more thorough empirical investigation in the future.

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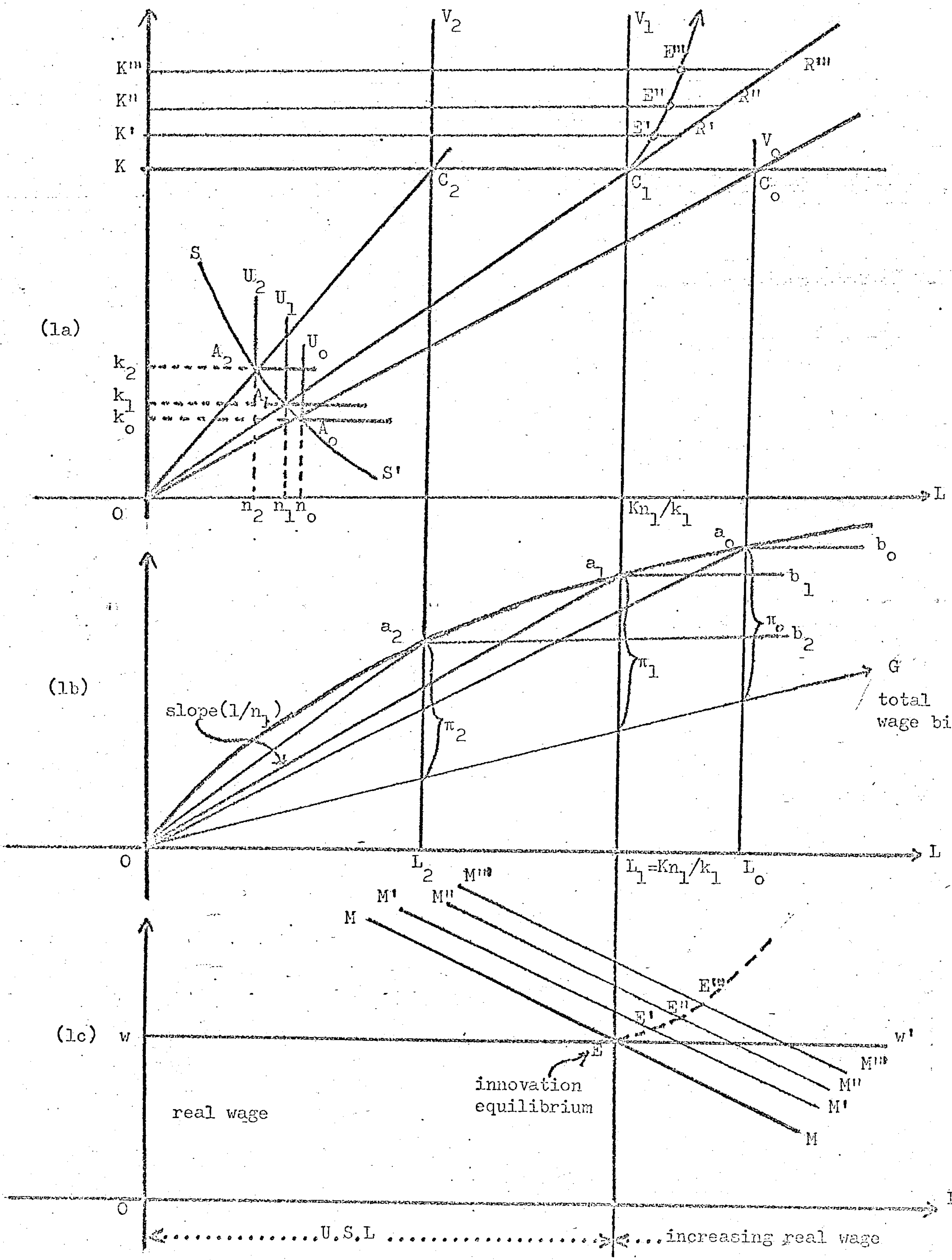
[1]From Table I we see that the rate of growth of capital increases from 2.3% to 4.4% annually (see rows I and II). During the post-1917 period, the rate of growth of capital drastically decreases from its earlier peak as can be seen from the diagram, and could be observed statistically by calculating η_K for shorter time periods.



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V2
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Ao
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increasing real wage

diagram 1

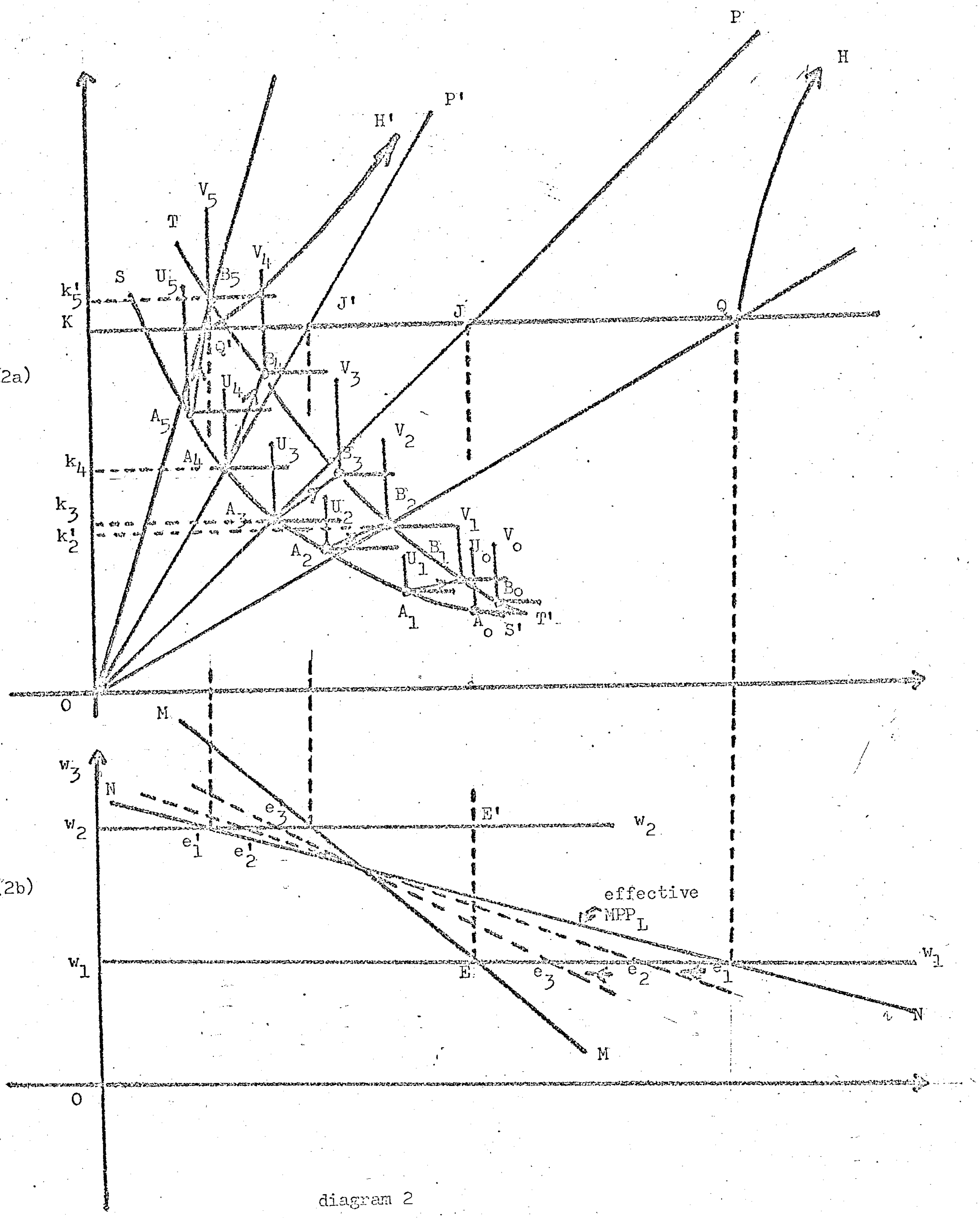
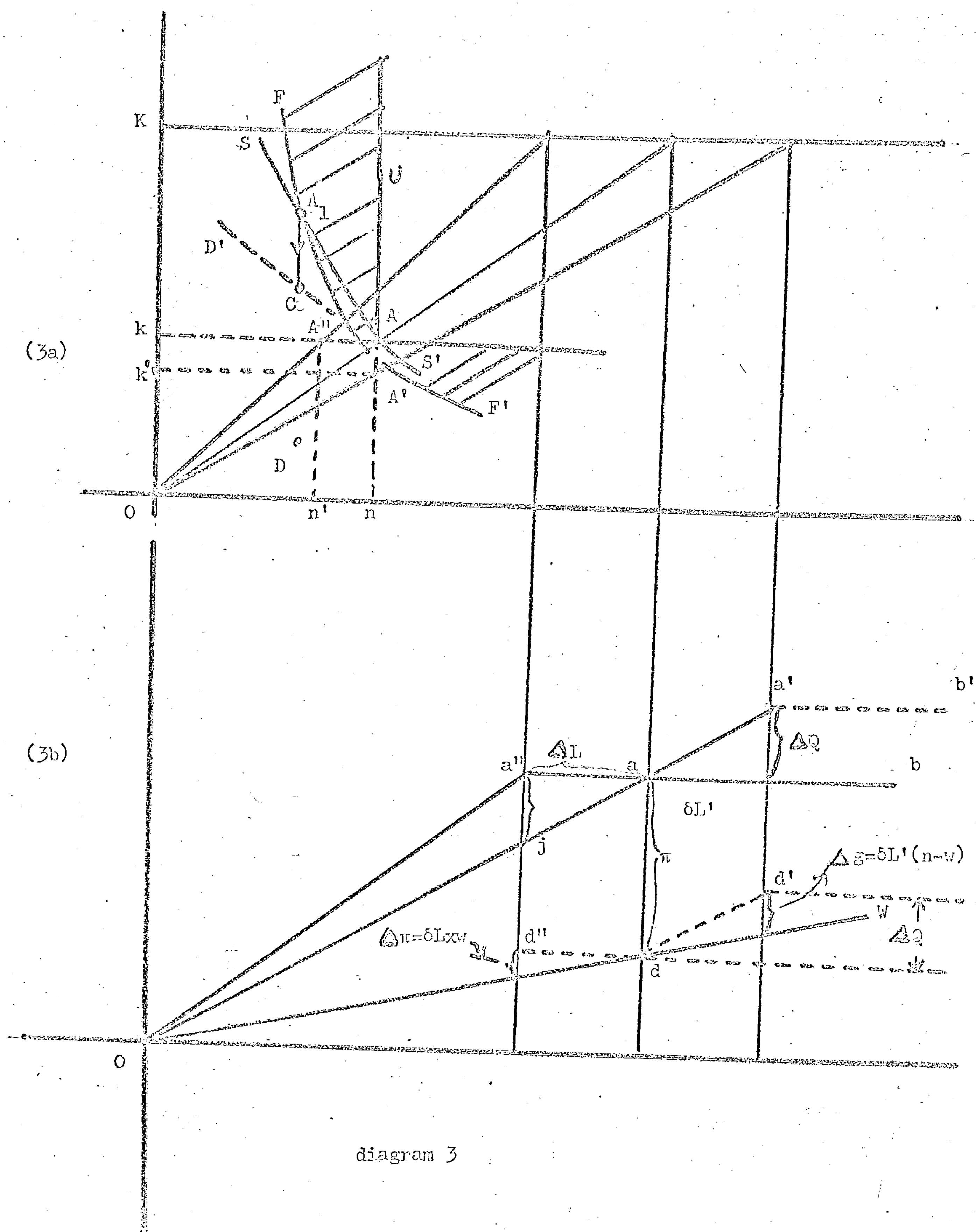


diagram 2


(3a)
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Δg=δL'(n-w)
d'
W
Δπ=δLxw
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diagram 3

Diagram 4

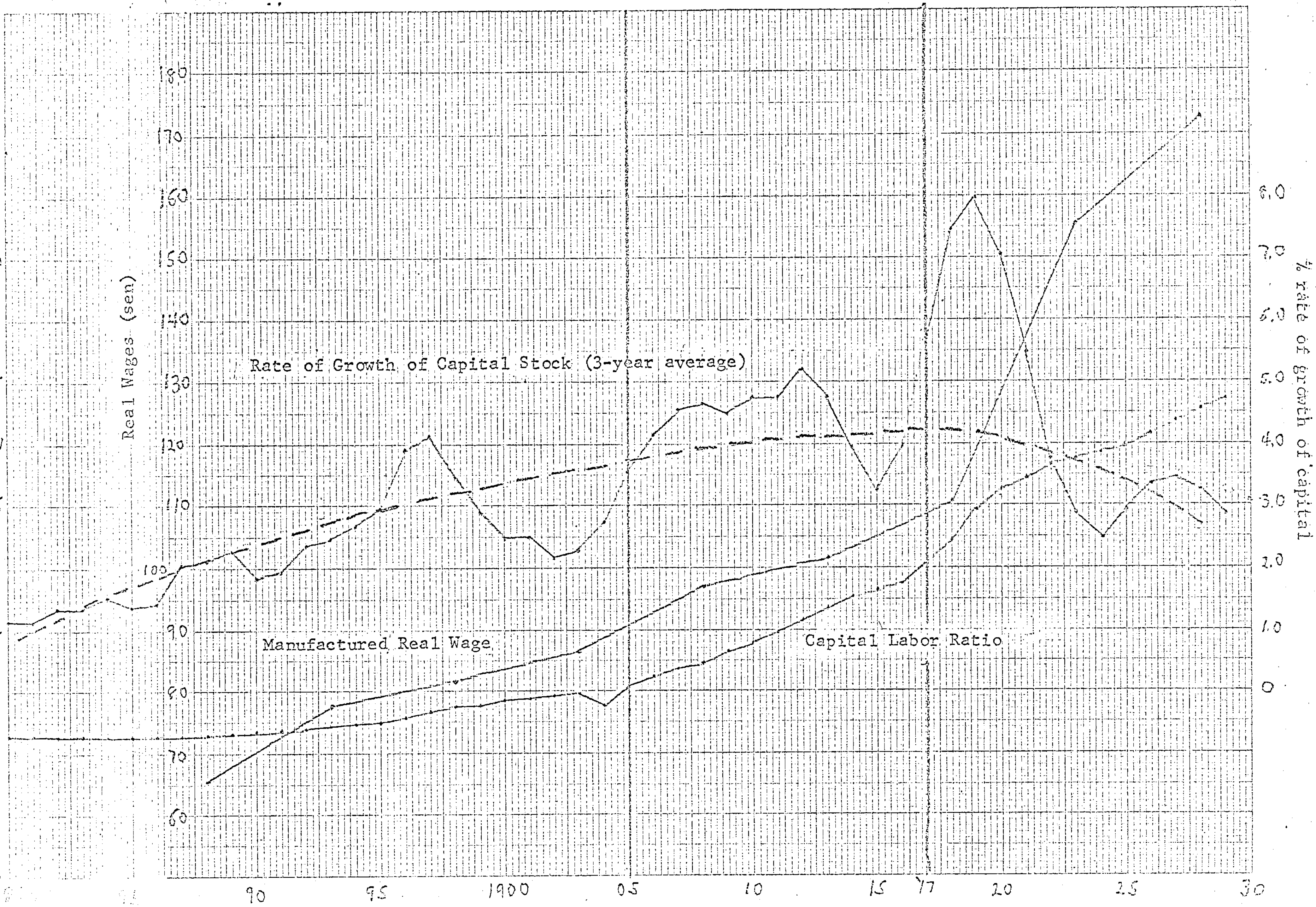
Real Wages (sen)
% rate of growth of capital
Rate of Growth of Capital Stock (3-year average)
Manufactured Real Wage
Capital Labor Ratio
180
170
160
150
140
130
120
110
100
90
80
70
60
90
95
1900
05
10
15
17
20
25
30

Diagram 4

Sources:

Manufacturing Real Wages are from Hakchung J. Choo, "On the Empirical Relevancy of the Ranis-Fei Model of Economic Development: Comment," American Economic Review, to be published.

Capital stock estimates are from Estimates of Long-Term Economic Statistics of Japan Since 1868, Vol. 3, pp. 149-151, Total Net Capital Stock excluding Residences.

Employment data from Ohkawa, The Growth Rate of the Japanese Economy Since 1878, p. 145 with "total gainfully occupied population" serving as an approximation to "total employment."