Population Dynamics of Agrarianism in Traditional China

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with Appendix by Chien-fu Chou***

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INTRODUCTION

The periodization of history from the economic standpoint may be stated in terms of the succession of long economic epochs. According to Professor Kuznets, an economic epoch is "a relatively long period (expending well over a century) possessing distinctive characteristics that give it unity and differentiate it from the epochs that precede or follow it. An epoch innovation may be described as a major addition to the stock of human knowledge which provides a potential for sustained economic growth." [1] This epoch innovation usually implies the interplay of technological and institutional changes to exploit the growth potential.[2] Thus, according to this view, the essential events of economic history are growth related centered in the social adaptation of technology.

In particular, in Western Europe the epoch of merchant capitalism (1500-1750) was succeeded by the epoch of modern growth (1750-) which was ushered in by the industrial revolution in England. In such a historical perspective, the growth that took place in China during the eight hundred years from the early Sung to the middle of Ch'ing dynasties (ca. 1000-1800) may be viewed as a growth of an agrarian epoch. This period may be referred to as *traditional* China because the essential characteristics of growth were not yet affected by the influence of modern "knowledge" (science and technology) from the West.

According to Professor Kuznets, the epoch innovation of the epoch of modern growth is "the extended application of science to problems of economic production."[3] Furthermore, a most essential growth relevant phenomenon in the "scientific epoch" is its distinctive characteristics of marked acceleration in the rate of population growth.[4] If the characteristics of population growth and technological change are crucial for the modern growth, they are certainly more so for the agrarian epoch of traditional China. This, for example, is in essence the thesis of "high-level equilibrium

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1 Simon Kuznets, *Modern Economic Growth: Rate, Structure, and Spread* (New Haven, 1966), p. 2.
2 Kuznets, *Modern Economic Growth*, p. 5.
3 Kuznets, *Modern Economic Growth*, p. 9.
4 Kuznets, *Modern Economic Growth*, p. 34.

trap" of Professor Elvin,[5] a notable contribution to the literature of Chinese economic history.

In modern economic terminology, any such thesis of population dynamics is a "macroeconomic growth theory" – in the format of which Professor Elvin had indeed formulated his thesis – the purpose of which is to explain, with the force of logical deduction, certain essential observable growth related phenomena. The title of the book by Professor Kuznets, *Modern Economic Growth: Rate, Structure, and Spread*, cited earlier, immediately suggests that the essential observable epochal characteristics are describable in terms of the *rapidity* (i.e., the *rate*) of growth and the pattern of *sectorial composition* (i.e., the *structure*) exhibited along the growth path. From a macroscopic viewpoint, the agrarian epoch differs from the modern one mainly because it entails *slow* growth (slow population growth rate and slow gain in labor productivity) and *stable* (or stagnant) structural pattern – the most essential features being the stability of percentage of labor force allocated between the agricultural and nonagricultural sectors in an agrarian dualism.[6] Any satisfactory thesis of population dynamics for traditional China must provide explanations for these phenomena.

Professor Elvin's thesis will be summarized in section I and empirically verified in section II as a convenient point of departure for our paper as his thesis contains many valuable "theoretical components". With the quantification of the concept of technological change in section III, these components can be reformulated into a more satisfactory theory of population dynamics to explain the slow growth in section IV. The Fact that such as theory can be generalized to explain the phenomenon of *structural stability* will be presented in section V.

The central thesis of our paper aims to explain the mode of operation (i.e., the population dynamics) for agrarianism. This thesis, when correctly formulated, implies that from a long run historical perspective, the demographic phenomenon of population expansion is determined by the production related materialistic forces (i.e., technological change and augmentation of land supply). Thus in the period of our concern (ca. 100-1800), as the land frontier was gradually exhausted, it was the Chinese ingenuity of technological adaptation which has "allowed" the population to expand slowly and continuously.

These ideas are certainly not new (see below). The novelty of our paper lies partly in its more forceful and clearer analysis of the "servomechanism" of population dynamics in order to minimize the ambiguity customarily found in historical literature. Any such macroeconomic theory is, unavoidably, technical and mathematical. To facilitate communication between historians and economists, we shall concentrate on the essential ideas in the text, while relegating the technical details to three appendices. Historians who are not accustomed to reason with a language not beyond the first semester of differential calculus must read the appendices at their own peril.

[5] Mark Elvin, *The Pattern of Chinese Past* (Stanford, 1973), pp. 289-315.

[6] See Kuznets, *Modern Economic Growth*, chapters 2 and 3 on the fact that modern epoch is characterized by *fast* population growth and *drastic* structural change.

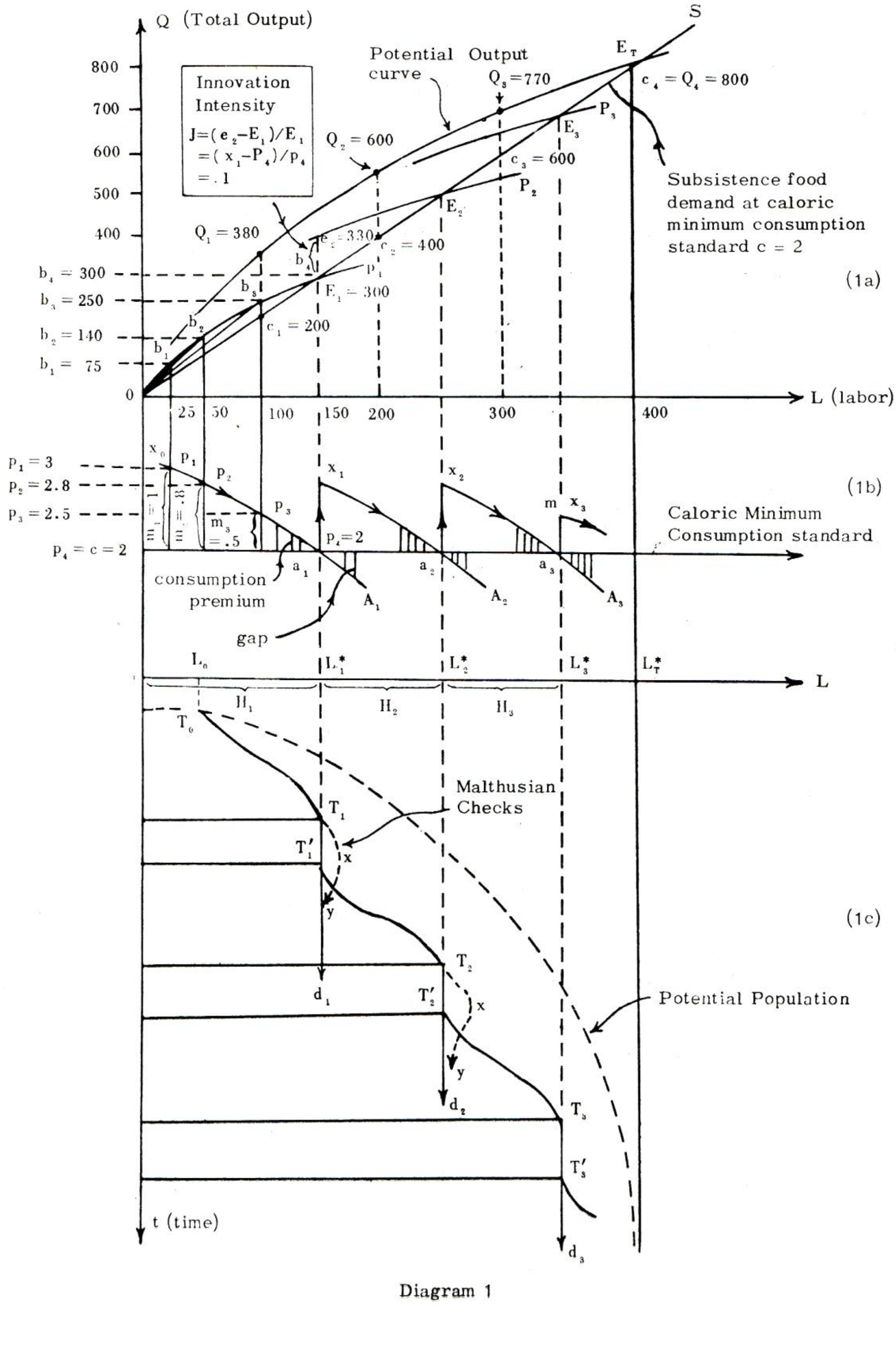
SECTION I. THE HIGH-LEVEL EQUILIBRIUM TRAP

The thesis of Professor Elvin's high-level equilibrium trap concerns an agrarian economy in which the most crucial phenomenon is the production of agricultural goods (i.e., total agricultural output, Q, measured on the vertical axis of diagram 1a) when laborers (i.e., L measured on the horizontal axis) are applied to land, assumed to be fixed. The ultimate limit of traditional agricultural technology is depicted by the potential output curve (in diagram 1a) which is convex showing the operation of the "law of diminishing returns". Throughout the eight hundred years of traditional China, the ultimate potential was never quite reached. Waves of technological innovation in the agricultural sector only raised the *actual* total output curves (P_1, P_2, P_3…) successively through time to approach the potential output curve asymptotically. Thus the impact of population pressure on total output (Q) and agricultural labor productivity ($p = Q/L$) must be gauged in terms of both an unfavorable effect due to the law of diminishing returns and a favorable effect created by technological change. These are the essential *production* related assumptions of his model.

A second set of assumptions of Professor Elvin is *consumption* related. When the per capita caloric minimum consumption standard, c, is fixed (e.g., $c = 2$) the subsistence consumption demand is represented by the straight line OS. For example, when the labor force increased from 100 to 200, 300, 400,…the subsistence consumption demand becomes $c_1 = 200$, $c_2 = 400$, $c_3 = 600$, $c_4 = 800$. The points E_1, E_2, E_3 are referred to as "intermediate equilibria" by Professor Elvin. The structure of diagram 1a, used in the original work of Professor Elvin (p. 313), is now completed. The other slabs of Diagram 1 are supplied by us to clear up some of the ambiguity in respect to the mode of operation of the agrarian system.

Rigorously, Professor Elvin's thesis hinges on the operational significance of the fixed caloric minimum consumption standard (i.e., $c = 2$ shown by the height of the horizontal line in Diagram 1b) as a controlling mechanism for population growth. When the short run total output curves is P_1, for example, the productivity for 25, 50, 100, and 150 units of labor are $b_1 = 75$, $b_2 = 140$, $b_3 = 250$, and $b_4 = 300$ respectively, leading to labor productivity of $p_1 = 75/25 = 3$, $p_2 = 140/50 = 2.8$, $p_3 = 250/100 = 2.5$, $p_4 = 300/150 = 2$, shown as the height of the short run labor productivity curve, A_1, in diagram 1b.[7] This curve which crosses the caloric minimum line at point a_1 (lying directly below the intermediate equilibrium point E_1) marks off two significant phases. The phase *before* a_1 shows a *consumption premium* (indicated by the shaded vertical gaps) which describes the excess of per capita output and consumption over the caloric minimum (e.g., $m_1 = p_1 – c = 1$, $m_2 = p_2 – c = 0.8$, $m_3 = p_3 – c = 0.5$, $m_4 = p_4 – c = 0$). The phase *after* a_1, shows a *consumption gap*, i.e., the amount by which the actual output per capita falls short of the caloric minimum.

[7] Thus the height of A_1 curve in Diagram 1b equals the slope of the radial lines, Ob_1, Ob_2, Ob_3 and OE_1, of diagram 1a.



Q (Total Output)
Innovation Intensity
J=(e2−E1)/E1 =(x1−P4)/P4 =.1
Potential Output curve
Q1 = 380
Q2 = 600
Q3=770
ET
S
c4 = Q4 = 800
P3
E3
c3 = 600
P2
E2
c2 = 400
E1 = 300
c1 = 200
Subsistence food demand at caloric minimum consumption standard c = 2
(1a)
b4 = 300
b3 = 250
b2 = 140
b1 = 75
L (labor)
p1 = 3
p2 = 2.8
p3 = 2.5
p4 = c = 2
m3 =.5
p4=2
consumption premium
gap
A1
A2
A3
(1b)
Caloric Minimum Consumption standard
L0
L1*
L2*
L3*
LT*
H1
H2
H3
T0
Malthusian Checks
T1
T1′
T2
T2′
T3
T3′
d1
d2
d3
(1c)
Potential Population
t (time)

Diagram 1

With successive technological improvements, P_1, P_2, and P_3 in Diagram 1a, the agricultural productivity curves, A_1, A_2, and A_3 in Diagram 1b, are also raised successively leading to shifts of the intermediate equilibriums, a_1, a_2, and a_3 to the right corresponding to the increasing sizes of population, $L^*_1 < L^*_2 < L^*_3$. These points mark off several phases, H_1, H_2, and H_3 on the population axis. It is apparent that these phases are technological determined when the consumption standard © is given.

The idea that the population growth rate is controlled by the consumption standard, which can be traced directly to Malthus, no doubt lies behind the reasoning of Professor Elvin. This is shown in Diagram 1c where time (t) is measured on the vertical axis pointing downward. Suppose, initially, when the short run technology P_1 (or the short run labor productivity A_1) prevails, the population is L_0 which lies inside the first phase H_1. The population growth path is indicated by the short run population growth curve d_1 (i.e., the curve T_0, T_1, T'_1). Since there is a consumption premium inside H_1, the population expands until the first "intermediate equilibrium" at L^*_1 is reached. Afterward, the population size becomes stagnant (i.e., T_1 T'_1 is vertical). This is due to a not explicitly stated (i.e., hidden assumption that the population size increases when there is a consumption premium and decreases when there is a consumption gap.[8] After the first "intermediate equilibrium", further population expansion would have brought about all the positive "Malthusian checks" such as wars, major epidemics and famines which held the population size in "checked" at L^*_1. Thus the state of technology P_1 imposes an absolute upper limit on population size (e.g., 150 million) indicated by the first equilibrium and China was temporarily trapped.

Population stagnation can only be broken by technological advancement (e.g., from P_1 to P_2) to raise the labor productivity curve above the caloric minimum consumption standard. With the emergence of a positive consumption premium once again, a second wave of population expansion is induced (shown by the short run T'_1 T_2 T'_2 curve of Diagram 1c). As before, the second intermediate equilibrium is inevitable, and it is only to be broken by another wave of innovation from P_2 to P_3.

The above process is quite independent of the potential output curve of diagram 1a. The theory of Professor Elvin is complete when this potential output is being taken into consideration, the point E_T determines an absolute upper bound for total population, beyond which population cannot expand in a "traditional society" simply because the traditional technology won't permit it. In diagram 1c, the dashed population growth curve is the potential population growth path (starting from an initial value at L_0 to an upper bound at L^*_T) which would have prevailed had the potential output curve been prevailing from the very beginning. The wave like actual growth path, however, lies below the potential population growth path and approaches the ceiling population at a later date. The above discussion, we believe, is a faithful

[8] It is the behavioristic assumption of this type which are ambiguous (as well be pointed out later in equation 3.2), especially when they are not stated explicitly. In Diagram 1c, the Malthusian check is shown by the dotted curve T_1xy which represents, first, a temporary "overshoot" of population size beyond L^*_1 to be followed by a "fall back" toward L^*_1.

interpretation of the thesis of "high-level equilibrium trap".

Many economic historians in the past have stated the problem of the population dynamics of China in more intuitive terms, i.e., not attempting to formulate any formal thesis. The well-known monograph of Professor Pi-ti Ho, for example, "aims to interpret the nature of different types of population data and to suggest tentative historical explanations as to *how and why China's population has been able to grow in early modern and modern times*."[9] On the underlined issue of population dynamics, Professor Ho timidly recognized that population growth was controlled by the per capita consumption standard when he stated that "the population growth throughout the eighteenth century assumed above was presumably connected with a standard of living" (p. 269, underline supplied). There is also the faint and vague recognition of the idea of intermediate equilibrium as the "optimum condition" determined by the technology due to "the effect of technological innovations and scientific discoveries on agricultural and industrial production."[10] Professor Ho even recognized the difference between a formal theory of population dynamics in which the law of diminishing returns naturally plays a crucial role and "fragmentary and quantitatively irresponsible statements."[11] However, one is put at a hard task to try to extract a coherent theory of population dynamics from the writing of Professor Ho similar to the thesis of "high-level equilibrium trap" of Professor Elvin. Careful examination of Professor Elvin's theory constitutes a point of departure of our paper.

SECTION II. EMPIRICAL VERIFICATION

A primary test for any theory is to examine whether the theoretical predictions can be borne out by observable facts. When we try to apply this test to the theory of Professor Elvin, we need to have economic data on the time series of population, agricultural labor productivity, per capita consumption, and acreage of cultivated land, etc. Unfortunately, for this historical phase of traditional China, we can gather estimates only for population size. This is shown in Diagram 2 based on the work of

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[9] Ping-ti Ho, *Studies on the Population of China* (Cambridge, Mass., 1959), p. xi. In this book the *interpretation of population data* is discussed in part one (under the heading of "The Official Population Record"), while the *population dynamics* is treated in part two (under the heading of "Factors Affecting Population"). In the latter subject, Ho recognized the relevance of a host of factors such as population-land relation, land utilization and food production, catastrophic deterrents, and other institutional factors, while no attempt was made to formulate a coherent thesis of population dynamics.

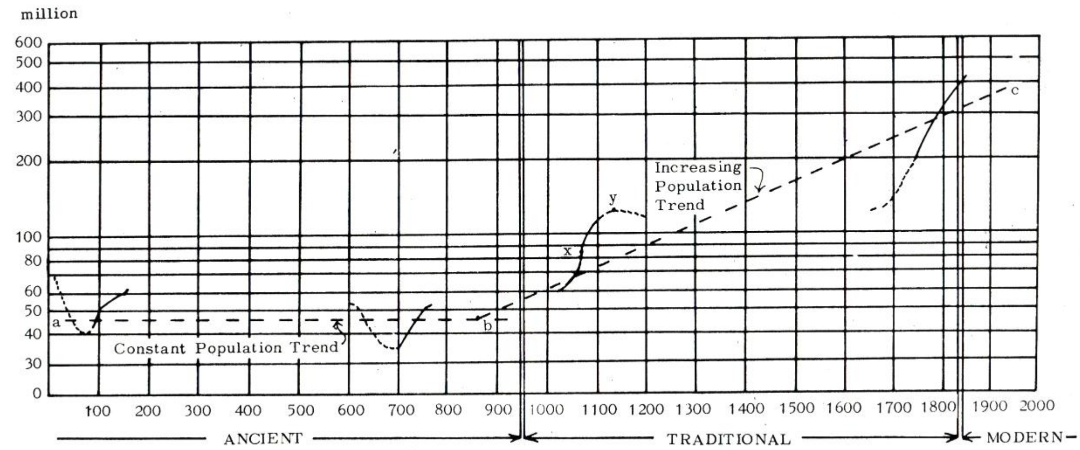
[10] See Ping-ti Ho, *Studies on the Population of China*, p. 270. "Although it is often difficult to determine exactly when and where population pressure increases, there is reason to believe that in the case of Ch'ing China, the optimum condition (the point at which "a population produces maximum economic welfare") at the technological level of the time, was reached between 1750 and 1775." Also see p. 272.

[11] In criticizing the writing of Hung Liang-chi 洪亮吉 (1746-1809), the Chinese Malthus, Professor Ho wrote, "Whereas Malthus in the revised edition of his *Essay* and especially in his later economic writings succeeded in formulating a system, Hung's ideas are fragmentary and his quantitative statements irresponsible. But by far the most serious drawback in Hung's theory of population is his failure to understand the law of diminishing returns." p. 272.

Professor Durand for the four historical periods for which data were available.[12]

Diagram 2 Growth of Population in China Proper A. D. 2–1953,
According to Emended Series of Statistics and Estimates

(Logarithmic Scale)



Source: John D. Durand, "The Population of China A. D. 2–1953," *Population Studies*,
Vol. 13, part 3 (March 1960) Figure 3.

In Diagram 2, three historical phases are marked off, namely, ancient China (terminated with the end of the T'ang dynasty), traditional China (terminated with the Opium War), and modern China (represented a long epoch of the transition of modern China). When the broken lines abc are fitted to these data by free hand, we see that the population of ancient China has a long run stable (or constant) trend (i.e., ab), while during the traditional and modern period, the population has a long run increasing trend (i.e., bc) at the annual rate of about 0.02%.[13] There is, furthermore, a wave like fluctuation of the actual population growth path around the increasing trend during the traditional phase. Thus the observed population growth path confirms the population characteristic predicted by the "high-level equilibrium trap" thesis, in respect to both the trend and fluctuation (as portrayed in diagram 1c). Thus the observed data give support to Professor Elvin's thesis.[14]

However, we would like to take issue with Professor Elvin in respect to his notion of the existence of "potential output" curve even for a traditional society. Professor Elvin observed that in agriculture, "Yields per acre were nearly as high as

[12] John Durand, "The Population of China, A.D.2-1953," *Population Studies*, Vol. 13, Part 3 (March 1960), Fig. 3.

[13] On a logarithmic scale for population, the slope of the population growth curve indicates the rate of growth of population. Thus the slope of ab is close to zero (or slightly negative), while the slope of bc is significantly positive.

[14] A more satisfactory test of Professor Elvin's theory will require the demonstration that during the fast population expansion phase (e.g., between 1700 and 1800) the per capita consumption and/or agricultural labor productivity was in fact higher than in the low population expansion phase. This has not been done precisely because of fragment data. See Dwight Perkins, *The Agricultural Development in China, 1368-1968* (Chicago, 1969), chapter 2 and appendix F.

was possible without the use of advanced industrial-scientific inputs such as selected seeds, chemical fertilizer and pesticides, machinery and pumps powered by the internal combustion engine or electricity, concrete and so on." While admitting that "it is not easy to give substantial proof that … [traditional technology]… had all reached a point of sharply diminishing returns by the later eighteenth century," he nevertheless accepted a thesis of 'technological discontinuity".[15] This concept of "discontinuity" aims to contrast the state of technological change during the agrarian epoch with that prevailing during the epoch of modern growth, à la Kuznets, in a historical perspective.[16] The thesis states, in essence, that there is a mysterious and hidden upper bound to technological change during the agrarian epoch (indicated by the potential output curve) which can only be broken by modern science and technology of the modern epoch. Thus traditional China was trapped by the limited potential of traditional technological change.

Even a casual inspection of Diagram 2 would be sufficient to convince an unsuspecting reader that Chinese population by no means has reached a ceiling by 1800. In fact, in the next 175 years (1800-1975) China has achieved at least another 250% gain in her population.[17] It is very doubtful that such a gain was due to a "discontinuous agricultural revolution" based on the infusion of modern scientific inputs imported from the West. On the contrary, agricultural economists and historians have argued that although Chinese economy had begun to change during the second half of the nineteenth century, Chinese agricultural technology had really not changed very much even as late as in the 1950's.[18] One might be tempted to argue with Professor Ho that "our historical survey and brief analysis of recent trend show that China has so far been able to achieve self-sufficiency in food. In case of a greater emphasis on agriculture she can be expected to increase her food production substantially."[19]

The upshot of the above discussion calls into question as to whether or not the thesis of technological discontinuity (i.e., potential output curve) is even remotely relevant to the economic history of China during the traditional or even the modern phase. Furthermore, this part of Professor Elvin's theory is really redundant as it is useless for the derivation of the wave like actual population growth path. Thus we will completely neglect the potential output curve. The appendectomy of this output curve by no means diminishes the positive contribution of Professor Elvin. However,

[15] Mark Elvin, *The Pattern of Chinese Past*, p. 306.

[16] For a discussion of the concept of discontinuity see, A. Gerschenkron, *Continuity in History and Other Essays* (Cambridge, Mass., 1968), pp. 32-38.

[17] See *Population Report* (published by the George Washington University Medical Center), series J, No. 13 (January 1977), p. J-250, for recent estimates of China's population growth in 1975.

[18] See A. Feuerwerker, *The Chinese Economy, ca. 1870-1911* (Ann Arbor, Michigan, 1969), pp. 72-73; *The Chinese Economy, 1912-1949* (Ann Arbor, Michigan, 1968), pp. 72-73. D. Perkins, *Agricultural Development in China*, p. 8.

[19] See Ping-ti Ho, *Studies on the Population of China*, p. 195. Professor Ho also ventured a guess that "the long-range prospect is bound to be quite different," as "more labor-intensive cultivation and introduction of advanced agricultural technology cannot in the long run prevent agriculture from reaching the point of diminishing returns." (p. 195). This pessimistic assessment by Professor Ho reserves strictly for the future and is not relevant for China up to the early twentieth century.

we need to modify his theory which makes an erroneous prediction that the population size is constant in the long run.

SECTION III. INNOVATION INTENSITY

A favorable pastime of economic historians (especially on traditional China for which historical anecdotes exist) is to catalogue in a journalistic (or encyclopedic) fashion by counting new products and new devises that appeared (e.g., cannon, handgun, clocks, telescopes, smelting of zinc, means of transportation, … and in agriculture, new seeds and new crops such as maize, peanut, and potatoes, etc.). To show "the interplay of technological and institutional changes" for the adoption of technology à la Kuznets (see Introduction), some references are usually made in respect to new organizational devises (e.g., merchant guilds, money shops, remittance banks, contractual tenant-ship, local market networks, etc.).[20] A macroscopic theory of population dynamics (e.g., in the case of Professor Elvin, the high-level equilibrium trap thesis) is then extracted from the historical facts thus displayed. However, it is never clear that *in what sense* the historical facts are essential for the macroscopic theory (see footnote 22).

A crucial *conceptual link* between the rather miscellaneous inductive evidences on technological change and the coherent macroeconomic theory is the concept of *innovation intensity (J).*[21] The importance of this concept and the necessity for its *quantification* appears not to have been sufficiently recognized by the historians. As a result, their theory tends to be vague, imprecise, and impressionistic.

From the macroscopic (or global) viewpoint, technological change is important because it affects the production relations in the transformation of inputs such as labor and land into output such as rice. The quantification of technological change requires a specification on *how much* is the output affected. Formally, the *innovation intensity (J) specifies the percentage increase in output traced to technological change when all inputs remain the same.*[22] For instance, referring to E_1 in diagram 1a, the output increases by 30 units when P_2 replaces P_1 representing an innovation intensity, J = (330-300)/300 = 0.1 or 10%. This gain is obviously traced directly to technological change because both inputs of labor and land remain constant. The hosts of

[20] We may also note that the narrative style is usually spotted with direct literal translation of Chinese quotations to present the inductive evidences.

[21] See John C. H. Fei and Gustus Ranis, *Development of Labor Surplus Economy* (Homewood, Illinois, 1964), chapter 3.

[22] Fei and Ranis, *Development of Labor Surplus Economy*, p. 77. In the article, "Skills and Resources in Late Traditional China," an essay in *China's Modern Economy in Historical Perspective* (Stanford, 1975) ed. by D. Perkins, Professor Elvin argued "that much of what happened, much of what did not happen, may be explained by a greater interest on the part of the Chinese in improving the return from already accessible natural resources than in making labor or capital more productive." (p. 86). The only operational significance of such a characterization of technological change is that the innovation is the "land augmentation" type (as, in economic terminology, "land" stands for "natural resources") which is the operational significance of the cataloguing of new products and devises by Professor Elvin mentioned above. It should be noted that innovation of *any* type will have innovation intensity (J). The theory of population dynamics based on land augmentation is presented in appendix C in which the intensity of innovation is again indispensable.

miscellaneous and institutional facts testifying to Chinese ingenuity are, indeed, useless for a macroscopic theory unless they are interpreted as supporting evidences for J.[23] Notice that this macroscopic information (i.e., J) is already contained in the diagram originally used by Professor Elvin, although he chose to ignore it. This information, however, is really crucial for "his" theory as we will now demonstrate.

SECTION IV. POPULATION DYNAMICS OF AGRARIANISM

When we explore the thesis of high-level equilibrium trap further and deeper, the really important message is a particular type of population dynamics pertinent to an agrarian economy. For the thesis states that there is an interaction between the population growth rate and technological change (all manifested through the production and consumption relations) such that the demographic phenomenon of population increases is a technological phenomenon in the long run. For in Diagram 1c, the population ceilings L^*_1, L^*_2, L^*_3 at the intermediate equilibriums E_1, E_2, E_3 are determined by the agricultural technology P_1, P_2, P_3, when the consumption standard is given. Thus the growth path of population is determined by technological *change*.

Referring to Diagram 2, we see that during the 1000 years of ancient period, Chinese population fluctuated along a constant long term trend that contrasts sharply with the fluctuation along an increasing trend of the traditional period. According to the above thesis of population dynamics, China during the pre-Sung period was in an entirely different economic epoch characterized by technological stagnation. The traditional period is a distinct economic epoch because continuous agricultural technological changes have "allowed" the population to grow.

It should be noted that population dynamics for the epoch of modern growth à la Kuznets is in some sense also a technological phenomenon. The contemporary notion of population growth rate of 2% to 3% per year is strictly a modern phenomenon and that represents at least a 400% to 500% gain from the historical level. "In short, it is only relatively recently that mankind attained both the large numbers and the high rates of growth that are characteristics of the modern era."[24] This acceleration and high rate of population growth in the modern era is a result of the reduction in death rate which, in turn, is induced by the available of "scientific knowledge" in medical science and health.[25]

Thus, traditional China during the eight hundred year period (1000-1800) is a distinct growth epoch because it has a distinct set of rules of growth (i.e., a distinct population dynamics) which is different from the earlier ancient epoch or the yet to come epoch of modern growth. This agrarian population dynamics represents a particular 'servomechanism" giving substance to the mode of operation of

[23] A quantification of the thesis of technological discontinuity also requires the J concept, e.g., the time path of J when plotted as a curve is a step function with a discontinuous point occurring at the juncture during the transitional phase (e.g., 1750-1780 in England) from the agrarian epoch to the epoch of modern growth.

[24] Kuznets, *Modern Economic Growth*, p. 36.

[25] Kuznets, *Modern Economic Growth*, chapter 2.

agrarianism. A speculation on the nature of this servomechanism constitutes the heart of theory about traditional China at the macroscopic level. Professor Elvin's work demonstrates convincingly that it is the ultimate aim of historical reasoning.

To explore the outline of the theory heuristically, let us once again refer to Diagram 2. Since the vertical axis is on a logarithmic scale, the slope of the population growth curve at any point equals the population growth rate (r). Take the growth curve between 1000 and 1200 as an illustration, where point "x" is the point of inflection while point "y" is a maximum point. This means that r increases up to "x", decreases from "x" to "y", and becomes negative after "y". Thus as the population *size* fluctuates around an increasing trend the population growth *rate* also fluctuates. Occasionally, economic historians paid certain lip services to r (e.g., during the eighteenth century, r was around 0.9% or as high as 1.5%, the highest population growth rate ever achieved in traditional China).[26] However, the significance of r is completely forgotten when a theory of population dynamics is formulated. This is, indeed, the case of high-level equilibrium trap thesis in which r plays no role. In the "servomechanism" which we will now portray, the role of r is recognized explicitly and is linked to the innovation intensity (J) defined earlier.

In Diagram 1b, the time path of agricultural labor productivity, p = Q/L, is shown by the zigzagging path $x_0a_1x_1a_2x_2a_3\ldots$ containing a horizontal movement (or a *horizontal effect*) and a vertical movement (or a *vertical effect*) that represent two causal factors that affect the value of p through time. The horizontal effect is an unfavorable productivity depressing effect brought about by population pressure. The severity of it depends upon the degree of law of diminishing returns to labor (α)[27] and is proportional to the population growth rate (r). The vertical effect is a favorable productivity raising effect brought about by technological change with a magnitude determined by the innovation intensity (J).[28] The actual rate of growth of agricultural labor productivity (h) is thus equal to the extent in which the unfavorable effect brought about by population pressure is compensated by the favorable effect due to technological change. All these can be summarized in the following equation:[29]

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[26] For the estimates of the population growth rates in different periods, see Ping-ti Ho, *Studies on the Population of China*, p. 64; John Durand, "The Population of China, A.D.2-1953," pp. 227, 238, 243-244. It should also be noted that a recent study by demographers has concluded that the population of traditional rural China had "high mortality, low marital fertility, and a rate of increase little different from zero." This discovery based on the estimates of demographic indices may have some implications for historians to reconsider the validity of the average growth rates based on the population size. See G. W. Barclay et al., "A Reassessment of the Demography of Traditional Rural China," *Population Index*, Vol. 42, No. 4 (October 1976), pp. 606-631.

[27] The zigzagging curve in diagram 1b drops faster when the P_i curves in diagram 1a have high 'curvature" representing stronger degree of law of diminishing returns to labor (α).

[28] It is obvious that when labor is constant the percentage increase of total output (Q) is the same as the percentage increase of labor productivity, p = Q/L. Hence, when labor is constant the percentage increase of labor productivity is exactly the same as the innovation intensity. This can easily be verified by the numerical example shown in diagram 1b, e.g., the percentage increase from a_1 to x_1 is also 10%, same as J = 0.1 in diagram 1a.

[29] It is defined as (dp/dt)/p. Equation (4.1) is proved in Appendix A. The theorem of this section was first proved by Jorgenson, see "The Development of a Dual Economy," *Economic Journal* (June 1961), pp. 309-334.

(4.1) $h = J - \alpha r$ ……(productivity response equation)

Equation (4.1) is represented by the productivity response curve AB in diagram 3a. The curve is negatively sloped indicating that the higher population growth rate (r), measured on the horizontal axis, leads to a lower value of the rate of increase of labor productivity (h), measured on the vertical axis. There is a critical population rate $r_c = J/\alpha$ indicated at point E where the unfavorable effect due to population pressure is just cancelled out by the favorable effect due to innovation intensity (J), resulting in stationary labor productivity through time (i.e., h = 0). This critical value (r_c) divides population pressure r into two phases, namely, the low population pressure phase ($r < r_c$) and the high population pressure phase ($r > r_c$). The labor productivity increases in the former phase (h > 0) and decreases in the latter phase (h < 0). Since the vertical intercept indicates the innovation intensity (J), a lower value of J leads to a downward shift of the productivity response curve (i.e., the dotted A'B' curve) with the lower critical population pressure r'_c at point E'.

The productivity response curve summarizes a set of farces related to the *productive* aspect of the economy. Another set of forces related to consumption is summarized by equation

(4.2) $r = G(c)$ …… (the population response equation)

where c is the per capita consumption standard. This is represented by the population response curve in diagram 3b. In this diagram the per capita consumption standard (c) is measured on the vertical axis pointing downward, while the population growth rate (r) is measured on the horizontal axis lined up with diagram 3a. The population response curve shows that the population growth rate (r) is controlled by the per capita consumption standard (c) in that better nutrition and health assured by a higher value of c generally leads to a higher growth rate of population.[30] Notice that a critical per capita consumption standard (c_E) corresponds to the critical population growth rate (r_c) in the sense that when c_E prevails, it leads to the critical population growth rate (r_c) which, in turn, leads to a stationary agricultural productivity.[31] Furthermore, the agricultural labor productivity (P) is, in fact, the same as the per capita consumption standard (c), i.e.,

[30] The idea that the population growth rate (r) is a phenomenon endogenous to a system of economic analysis as controlled by the consumption standard (c) can be traced directly to Malthus. See E. A. Wrigley, *Population and History* (New York, 1969), pp. 44-53. The classical economics referred to equation (4.2) somewhat misleadingly as "the iron law of wages," see rigorous argument in Jorgenson, *op. cit.*, pp. 312-317.

[31] Note that the population response curve begins from a point c_m indicating a caloric minimum value of per capita consumption standard in the sense that population increases (decreases) absolutely when the consumption standard is higher (lower) than c_m. In the theory of Professor Elvin, this caloric minimum value is critical (see Diagram 1a). In our theory, the critical consumption standard is c_E rather than c_m. It is apparent that the consumption standard affects the rate of reproduction of population (i.e., the population growth rate, r) rather than the population size (P) and hence the population dynamics crucially involves the adjustment through variation of r rather than P. The failure to recognize the necessary of a "dynamic formation" of the problem is the root cause of the ambiguity of the high-level equilibrium trap as well as all the more intuitively formulated thesis summarized in section I.

(4.3) $p = c$

and hence, the rate of growth of labor productivity response curve and the population response curve interact against each other in a way that proceeds as follows. Suppose the initial consumption standard c_b leads to a positive growth rate of labor productivity $h_b > 0$ (through the productivity response). The consumption standard in the next period will increase, e.g., to the level of c'_b. This will lead, in turn, through the population response and the productivity response to a growth rate of labor productivity h'_b. Thus starting from an initial point h_b in the low population pressure phase, the movement is always downward along the productivity response curve toward the critical point at E. Conversely, if the consumption standard is at a higher value at c_a that leads to a negative growth rate of labor productivity $h_a < 0$ in the high population pressure region, the productivity and the consumption standard in the next period will decrease, e.g., to the level of c'_a. Thus whenever the population growth rate is in the high population pressure region, a force is automatically induced for an upward movement along the productivity response curve toward point E.

The population response and the productivity response represent a servomechanism through which the economy will be sustained at the c_E level leading to the technological determined population growth rate r_c. In the stationary state, the economy will exhibit a slow and steady population expansion while maintaining a constant level of per capita consumption standard and agricultural labor productivity. This is, perhaps, not an unrealistic view of traditional China recognized by Professor Elvin. The stationary state is a stable one in that temporary deviation from this state will automatically invoke a pressure to cause it to move back to the stationary growth path. In this sense, traditional China was caught in a slow-growing trap.[32]

From the Sung to Ch'ing dynasties, China was trapped in such a stationary growth state. The relatively "advanced" state of agricultural technological innovation (J) had overcome the bottleneck caused by the shortage of land space and "allowed" the population to grow in more than seven hundred years. The relatively high J in the agrarian epoch is, however, really backward as compared with that prevailing in the epoch of modern growth according to the thesis of technological discontinuity, and hence the population growth rate (r) is really quite low as compared with the modern magnitude. In the population response curve if Diagram 3a, a low value of J (the vertical intercept) leads to a low value of r_c (the horizontal intercept) suggesting that in the agrarian epoch, the population growth rate (r) is determined by J in the long run. We have thus shown that the thesis based on a servomechanism (i.e., the mode of operation) of the population dynamics, when unambiguously formulated, is quite consistent with the idea that the epochal population growth rate has a technological foundation which, in turn, explains why Chinese population grew only slowly with nearly constant per capita consumption standard and labor productivity all along the

[32] The expansion was, of course, not a smooth one, but the fluctuation of population growth were about a steadily increasing trend as shown in Diagram 2. These wave like movements can be easily accommodated in diagram 3 by shifting the productivity response curve, e.g., from AB to A'B'. Hence, like the long trend, the population waves are also mainly technological phenomenon.

epoch of agrarianism.

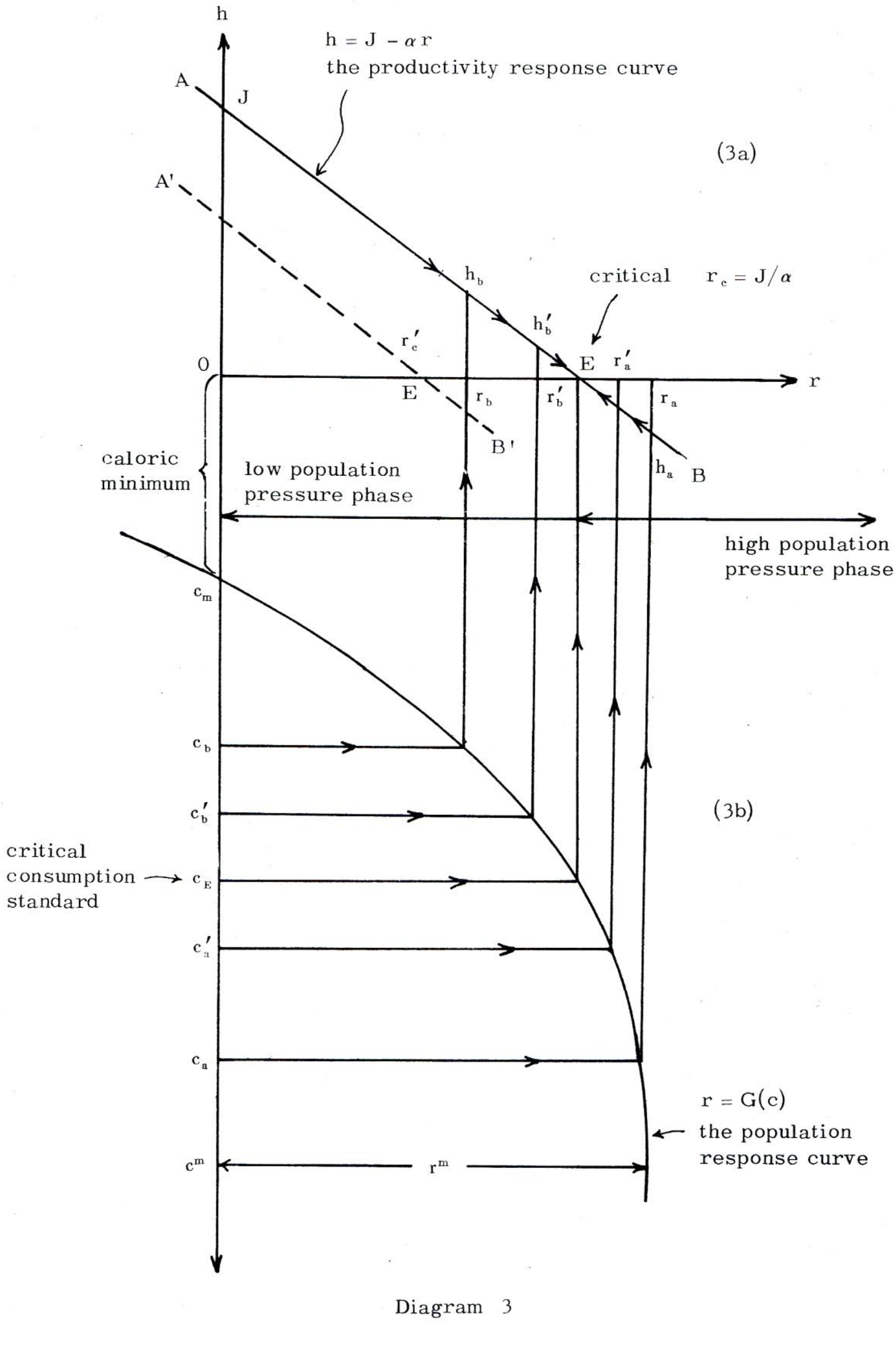

Diagram 3

SECTION V. GROWTH WITH STRUCTUREAL STABILITY

Traditional China was an agrarian *dualism* in the sense that the total population, P, was allocated either as nonagricultural labor force, W (handicraft artisans, merchants, transport laborers, soldiers, and civil servants) or agricultural labor force, L, satisfying the condition,[33]

(5.1) $P = W + L$

A basic characteristic, "structural stability", is manifested in the stability of the fraction of labor force,

(5.2) $\theta = W/P$

allocated to the nonagricultural sector (e.g., θ = 20%). In contrast to the epoch of modern growth during which the rapid increase of θ is a key growth characteristic,[34] the value of θ probably has remained essentially constant in traditional China through the eight hundred years of growth under agrarian dualism. Thus slow growth with constant θ (in addition to constant agricultural labor productivity and consumption standard) is the key phenomenon which must be explained by macro-growth theory. It is evident that the analysis in the previous section has ignored θ completely.

Heuristically, the agricultural labor force (L) must be "productive" and produces an agricultural surplus beyond what is needed to sustain themselves, if the nonagricultural labor force is to be provide with food. Throughout the long history of traditional China there has always been a belief of "exaltation of the farmer" as a flourishing agricultural sector is a prerequisite of prosperous nonagricultural activities. If the per capita consumption standard is c and the agricultural labor productivity is p, then equating the demand and supply of food, we clearly have

(5.3a) $Pc = Lp$

(5.3b) $c/p = 1 - \theta$

Equation (5.3b), which may be used as an iron law of labor allocation in agrarian dualism, states that the fraction of agricultural labor force (1- θ) is determined by the consumption standard expressed as a fraction of agricultural labor productivity. The fact that the agricultural population on mainland China remains around 80% well into the twentieth century is due to the fact that at a consumption standard c, a typical farmer has to consume 80% of the output that he produces and leaves only 20% for the nonagricultural labor force.

Thus, in order to explain the stability of θ when the population size increases, we have to explain the servomechanism of population dynamics discussed in the last

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[33] The fact that Western Europe was an agrarian dualism in this sense before the epoch of modern growth is evident from the economic tableau of the French physiocrats of the early eighteenth century. See for example, Fei and Renis, *Development of Labor Surplus Economy*, chapter 1.

[34] In the U.S., for example, the fraction of non-farm labor force increased from about 30% to nearly 95% in the span of one century (1800-1900), see L. E. Davis et al., *American Economic Growth: An Economist History of the United States* (New York, 1972), pp. 188, 199.

section to include an additional mechanism which controls the allocation of labor force between the two sectors. This means basically that, the conditions of equation (4.3) is no longer valid and must be relegated to (5.3b). The theorem, however, is quite complicated and must be relegated to appendices B and C for the interested readers.[35] We shall here only briefly discuss the nature of the analytical issues involved. Let us multiply the numerator and denominator of the left had side of equation (5.3b) by L to obtain

(5.4) $\phi_L = cL/Q = 1 - \theta$ (for pL = Q)

The economic interpretation of ϕ_L is the distributive share of agricultural output according to the labor class in the agricultural sector because the numerator cL is the wage share while the denominator is the total agricultural output. Thus equation (5.4) states that the fraction of agricultural population is determined by the labor share of agricultural output and the fraction of nonagricultural labor force equals to the rent share accruing to the landlord class. It is the landlord class with his rental income which is being used to sustain the nonagricultural labor force (i.e., soldiers, civil servants, merchants, and artisans, etc.). Hence the labor allocation mechanism is directly related to the principle of income distribution entirely within the agricultural sector.

Let one of the total output curves of diagram 1a be reproduced in diagram 4a. When the agricultural labor force is L the total output is shown by the distance of LQ, which is divided into wage share aQ and rent share aL.[36] Hence the wage share, ϕ_L = aQ/LQ, is determined by the forces of income distribution within the agricultural sector. In diagram 4b, the height of ϕ_L curve indicates the value of ϕ_L for each input point.[37] With a high population pressure we see that the distribution share to the labor class decreases.

Now, suppose at any point in time, the total population OP, marked off on the horizontal axis in diagram 4b, must be allocated partly as agricultural labor force OL and partly as nonagricultural labor force LP satisfying equation (5.1). There is precisely one solution, which satisfies equation (5.4), to this problem as indicated in diagram 4b.[38] Any other point of allocation between OP would not satisfy equations

[35] In Appendix B, we shall prove a theorem on the "inevitability of stationary-state-growth" for the special case when a Cobb-Douglas production function is used implying a constant value of ϕ_L in equation (5.4). This restricted assumption will be dropped in a more general version of the theorem proved in Appendix C, under perhaps a realistic assumption for traditional China that technological change in the agricultural sector occurs primarily for the purpose of "augmenting land supply". In economic literature, an innovation of this type is called a *land augmentation innovation* that increases the *effective* areas of cultivation when the natural area is fixed.

[36] The wage share aQ = L (aQ/L) = L tan b, where tan b is the slope of the tangential line eQ measuring the marginal productivity of labor.

[37] In the case shown in diagram 4b, the labor share decreases as land is being more intensively cultivated. This means that the law of diminishing returns to labor is operating very strongly so that in spite of the fact that the number of workers increases, the wage rate has been depressed to even greater extent, leading to a decrease of wage share. Conceptually, economists refer to this phenomenon as "substitution inelastic" (meaning that labor is a poor substitute for land as productive input), see Fei and Renis, *Development of Labor Surplus Economy*, chapter 3.

[38] To find a solution, construct the rectangle OPBA where OA = BP = 1 and where the diagonal line

(5.1) and (5.4) at the same time. The determination of the labor allocation, in turn, determines the agricultural labor productivity (indicated by the slope of the curve OQ in Diagram 4a). The complexity of the analytical issue is due primarily to the fact that in a *dualistic* economy, the determination of the agricultural productivity at the adequate food supply intrinsically involves labor allocation and agricultural technology.[39]

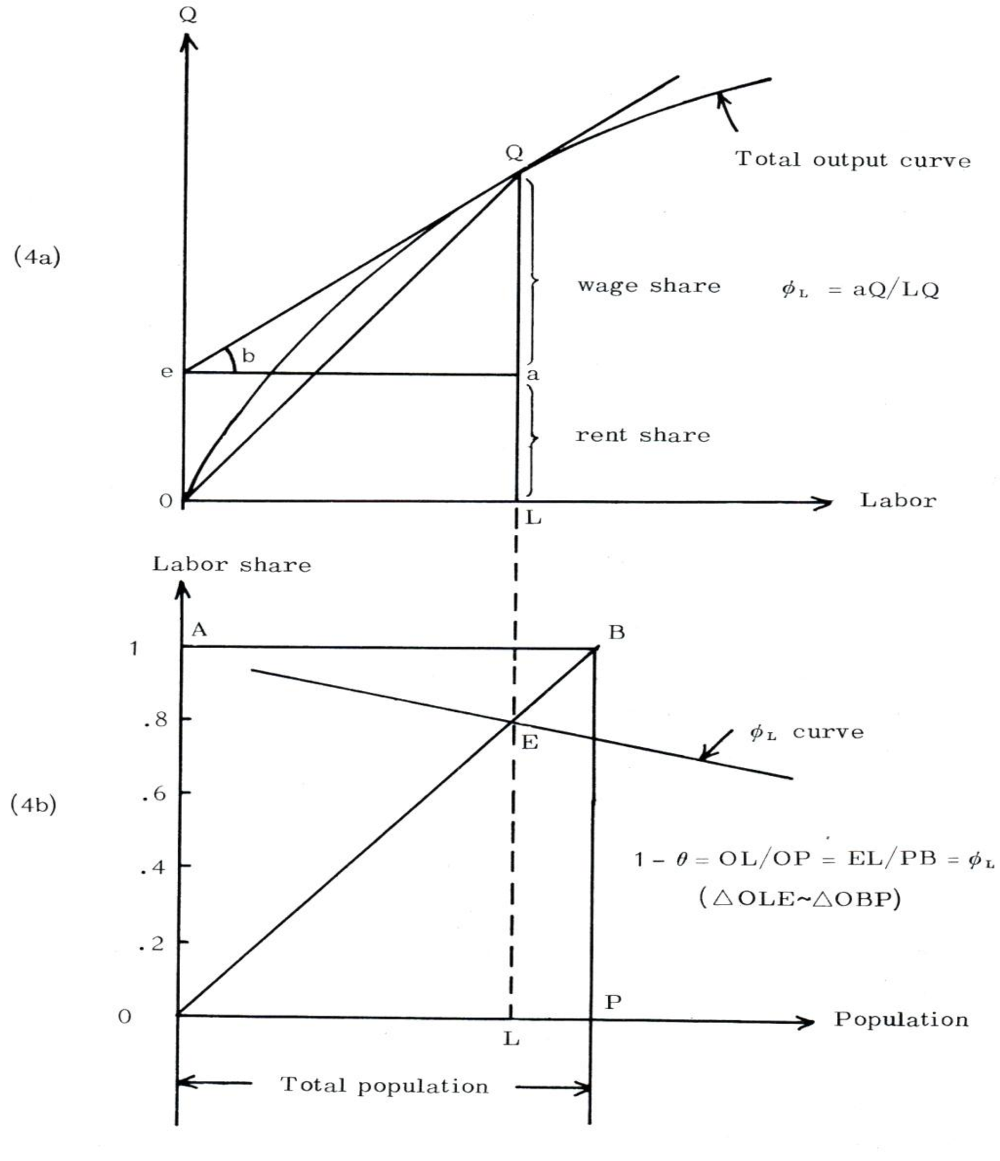

Diagram 4

OB intercepts the ϕ_L curve at E indicating the allocation point – as seen readily from the similarity of the triangles indicated in the diagram.

[39] Those who are not familiar with the type of analytical reasoning which we employ here should be reminded that when a communist authority on mainland China makes a decision as to how many laborers must be sent to the farm sector to grow enough food they consider *at least* all the issues briefly summarized in Diagram 4.

Through time innovation in agricultural sector with a given intensity of innovation occurs to raise the agricultural productivity (i.e., the favorable effect) and the population growth depresses the agricultural productivity (i.e., the unfavorable effect). A new labor allocation pattern must be found and this implies a change in the per capita consumption standard which, in turn, affects the increase of population according to the population response relation postulated in equation (4.2).

As in the last section, due to the function of the servomechanism of population dynamics, one can see that in the long run the stationary state will be reached, in which population is growing in a constant rate with stable per capita consumption standard, labor productivity, as well as structural stability measured by a constant value of θ – befitting the historical reality of traditional China. It is to be expected that in the long run, the population growth rate is determined by the innovation intensity which, in turn, explain why traditional China could only grow slowly as describe in the last section.

APPENDIX A

In this appendix, we want to derive the productivity response equation (3.1) in the text. Let a Cobb-Douglas production function be postulated in the form of

(A1a) $Q = e^{Jt} K^{\alpha} L^{1-\alpha}$ implying

b) $J = (\partial Q / \partial t) / Q = 1$ (innovation intensity)

c) $f_L = \partial Q / \partial L = (1 - \alpha) e^{Jt} K^{\alpha} L^{1-\alpha}$ (marginal productivity of labor)

d) $- L (\partial f_L / \partial L) / f_L = - (1 - \alpha) (-\alpha) e^{Jt} K^{\alpha} L^{-1-\alpha} / (1 - \alpha) e^{Jt} K^{\alpha} L^{-\alpha} = \alpha$

(elasticity of f_L with respect to L)

Thus, the innovation intensity J is defined (A1b). Furthermore, (A1d) shows that the elasticity of the marginal productivity of labor (f_L) with respect to labor (L) is α measuring the degree of diminishing returns to labor. The average productivity of labor (p) is

(A2) $P = Q/L = e^{Jt} K^{\alpha} L^{-\alpha}$

Since land is fixed, differentiating p with respect to time (t), we have

(A3a) $dp / dt = K^{\alpha} [L^{-\alpha} J e^{Jt} + e^{Jt} (-\alpha) L^{-\alpha-1} (dL /dt)]$

b) $h = (dp /dt) / p = J - \alpha r$ where

c) $r = (dL /dt) /L$ (population growth rate)

Thus (A3b) is the rate of growth of average productivity of labor. The average productivity of labor express a linear function of J, the innovation intensity (Aab), and the population growth rate r, (A3c), with constant degree of law of diminishing returns α, (A1d). Equation (A3b) is produced as (4.1) in the text.

APPENDIX B

In this appendix we want to prove that the stationary state will always be reached in agrarian dualism. Let T and L stand for land and labor respectively and let the production function be specified as the Cobb-Douglas form:

(B1a) $Q = A\, T^{\alpha}\, L^{1-\alpha}$

b) $\phi_T = (\partial Q / \partial T)\, (T / Q) = \alpha$

c) $\phi_L = (\partial Q / \partial L)\, (L / Q) = 1\text{-}\alpha$

implying the constancy of the rent share (B1b) and labor share (B1c). The time paths of total productivity P, land T, and technological factor A are given by

(B2a) $P = P_0\, e^{rt}$

b) $T = T_0\, e^{jt}$

c) $A = A_0\, e^{Jt}$

where r, j, and J represent the growth rates. The total population (P) is allocated partly as agricultural labor force (L) and partly as nonagricultural labor force (W):

(B3a) $P = W + L$

b) $\theta = W / P, \quad 1\text{-}\theta = L / P$

Let c stand for the consumption standard as well as the real wage in terms of agricultural goods. The marginal productivity of labor (implied by B1a) is equated to c to obtain

(B4a) $c = A\, (1 - \alpha)\, T^{\alpha}\, L^{-\alpha}\ (= \partial Q / \partial L)$

b) $P = Q / L = A\, T^{\alpha}\, L^{-\alpha}$

c) $\phi_L = c / p = 1 - \alpha$

where p in (B4b) is he average productivity of labor in the agricultural sector. Equating the demand and supply of food leads to

(B5a) $cP = Lp$ or

b) $L / P = 1 - \alpha$

c) $1 - \theta = c / p$ …… by (B3b), or

d) $1 - \theta = 1 - \alpha$ …… by (B4c)

The fact that θ is constant through time is assured by the constancy of $\phi_T = \alpha$ in (B1b), a property of the Cobb-Douglas production function.[40]

Now, using n_x to denote the rate of growth of variable x, (B2a) and (B5b) imply

(B6) $n_L = n_P = r$

From (B4b), we have

(B7a) $nP = nA + \alpha\, n_T - \alpha\, n_L$

b) $nP = i - \alpha r$ …… by (B2) where

c) $i = J + \alpha j$.

Equation (B7b) is the productivity responses curve. Notice that in the present version of our model, we assume that the land (T) is growing at a constant rate j (the case of a constant land supply discussed in the text is clearly a special case, j = 0). Thus, there are now two growth related factors which contribute favorably to the increase of labor productivity (p). The *intensity* of this favorable contribution (i) can offset the unfavorable contribution of population pressure (r), in their impact on the rate of growth of agricultural productivity as stated in (B7b).

When the population response curve (i.e., equation (4.2) in the text) is postulated

(B8) $r = G(c)$

The interaction between the population response and the productivity response leads to the stationary growth as shown in diagram 3.

APPENDIX C

Our analysis in appendix B based on the Cobb-Douglas production function is a special case. In this appendix, we shall construct a general theory by assuming that technological change is the land augmentation type. Thus we postulate,

(C1a) $Q = F(L, T^*)$ satisfying constant returns to scale (CTRS)

b) $T = T_0 e^{\beta t}$

c) $d = d_0\, e^{\alpha t}$

d) $T^* = T\, d = T_0\, d_0\, e^{(\alpha+\beta)t} = T_0\, d_0\, e^{\alpha' t}$ where $\alpha' = \alpha+\beta$

Equation (C1a) is a production function where the inputs are labor (L) in a natural unit and land in an efficient unit (Y*). Equation (C1d) shows that T* is the product of T (land in natural units) and d (the efficiency of T in "producing" T*). Equation (C1b)

[40] In this case, the ϕ_L curve in diagram 4b is a horizontal line. Thus for a Cobb=Douglas function, θ is constant through time, and the problem of labor allocation is determined trivially. In the next appendix, this restricted assumption will be discarded and hence θ can vary through time.

states that the supply of land is increasing at a rate β; equation (C1c) states that d is increasing at a rate α, the land augmentation rate. The idea that innovation in traditional China is of the land augmentation type is more realistic than the assumption in appendices A and B.

For analytical purposes, we want to stress output (Q), agricultural labor force (L), and total population (P) in terms of per unit land in efficient unit, namely:

(C2a) $q = Q / T^*$ …… the output per unit of efficient land,

b) $n = L / T^*$ …… the cultivation density,

c) $m = P / T^*$ …… the total population density.

Under the assumption of CTRS, the production function can be rewritten as

(C3) $q = F (L / T^*, 1) = f (n)$ ……by (C1a) and (C2a)

Equation (C3) shows that the productivity of efficient land is a function of cultivation density for the efficient land. This is shown by the increasing curve in diagram 5a. From (C3), the production function can be written as

(C4a) $Q = T^* f (n)$ implying

b) $\partial Q / \partial L = T^* f ' (n) (\partial n / \partial L) = T^* f ' (n) [\partial (L / T^*) / \partial L] = f ' (n)$

which shows that the slope of the curve in Diagram 5a is the marginal productivity of labor. This is shown by the negative sloped curve in Diagram 5b.

If c is the consumption standard, or real wage, in the agricultural sector, the competitive principle of income distribution implies

(C6a) $Q = cP$ or divided by T*

b) $q = cm$ …… by (C2a, C2c) or

c) $m = q / f ' (n) = f (n) / f ' (n)$ …… by (C5)

Thus the total population density, $m = P / T^*$, is a function of the cultivation density n, and is equal in magnitude to the ratio of average productivity of efficient land q to marginal productivity of labor f '.

Equation (C6c) is represented by the curve in Diagram 5c and is derived as the ratio of the curve in Diagram 5a and 5b.[41] Since q is an increasing function and F_L a decreasing function of n, we see the value of m increases as the population density increases. Thus the curve is positively sloped and lies below the 45 degree line in Diagram 5c. The percentage of labor force allocated in the agricultural sector is

(C7) $1 – \theta = L / P = (1 / T^*) / (P / T^*) = n / m$

And is represented by the slope of the dotted lines, OE_0, OE_1, OE_2 in Diagram 5c.

[41] In Diagram 5a, at E, f (n) / f ' (n) is represented by the ratio EB /(EB/BD) = DB = m. Thus DB is the total population per unit of efficient land and OD is the nonagricultural labor per unit of efficient land, while OB is the agricultural labor per unit of efficient land.

The population response curve is

(C8a) $r = G(c)$ where

b) $n_p = r$

and is represented by the curve in Diagram 5d. From equation (C2c) we have

(C9a) $n_m = n_p - n_{T^*}$ or

b) $n_m = r - \alpha'$ …… by (C8b) and (C1d)

The value of α' is marked off on the horizontal axis of diagram 5d.

The long run equilibrium position in a stationary state is indicated by the rectangle r_E c_E n_E m_E linking Diagrams 5dbc. To see why this is so, the low population pressure phase and the high population pressure phase are first marked off in Diagram 5d. Using the equilibrium rectangle, the same two regions are marked off in Diagram 5c. If we start from a value m1 in the low population pressure region in Diagram 5c we will determine a value c1 (with the aid of the dotted line along m_1, E_2, g_1, c_1) in low population pressure region in Diagram 5d. For this c_1, r is less than α', and hence equation (C9b) implies that m will decrease to m_2 in the next period and this leads to a higher value of c_2. Thus whenever one starts from any point in the low population pressure phase, the movement is *upward* along the population response curve in Diagram 5d. Conversely, if we start from a low value of m_3 in the high population pressure region, it will lead to a high value of c_3 causing m to increase. Thus the equilibrium position of stationary state will be reached and is a stable one.

In the long run stationary state, population is growing in a constant rate and with constant agricultural labor productivity, consumption standard, and constant fraction of allocation of population in tow sectors. In this model, α', as defined in (C1d), is a summary of the intensity of land augmentation innovation, α, and the rate of increase of land, β. These are the favorable “materialistic” forces that contribute to labor productivity gains in the short run and population growth rate in the long run. In diagram 5d, a higher value of α' will lead to a higher long-run population growth rate. Thus we see that the servomechanism of population dynamics of agrarianism is in consistent with the thesis that demographic phenomenon of population growth rate is basically determined by the “materialistic’ forces (i.e., technological change and land supply).

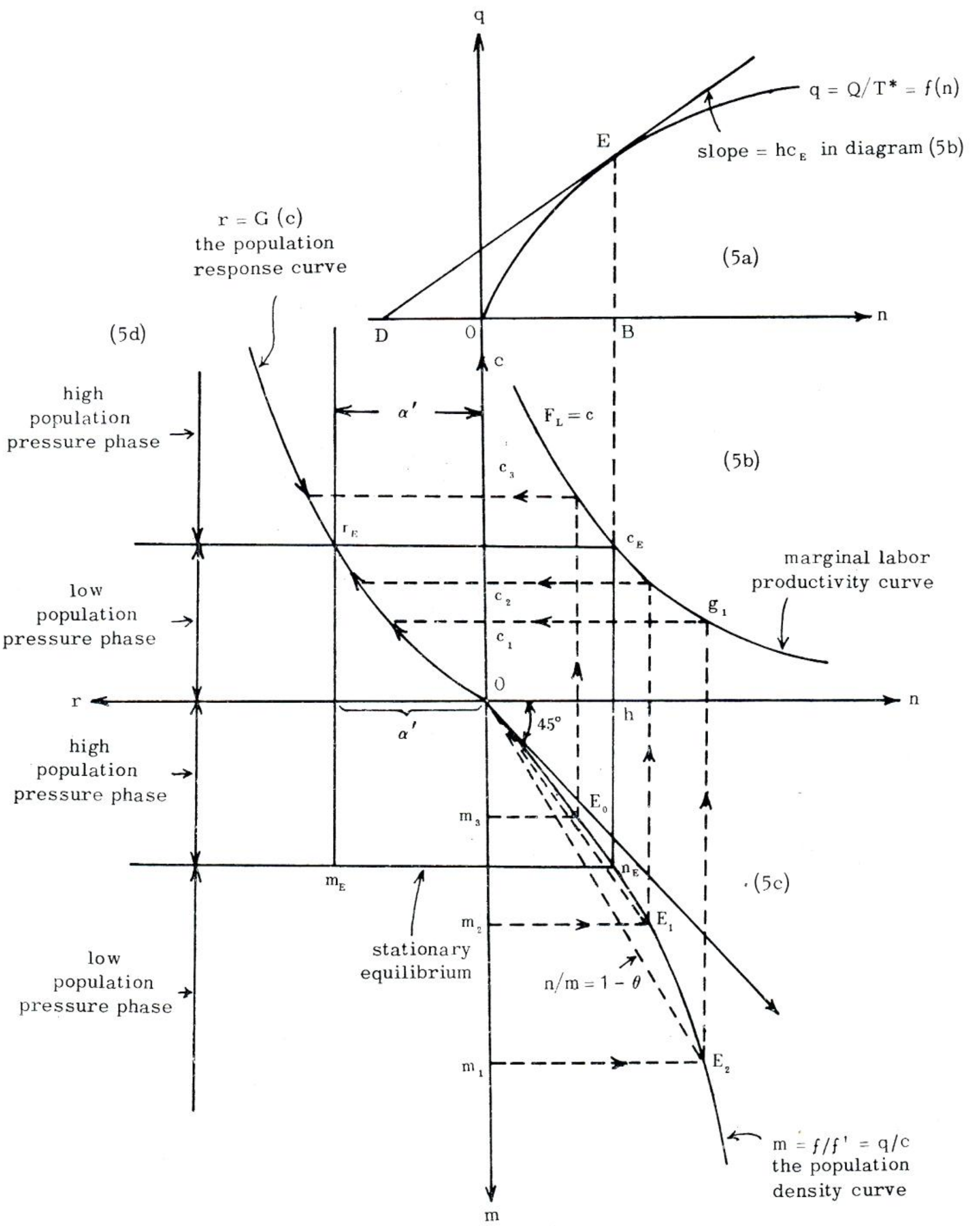
q
q = Q/T* = f(n)
slope = hc_E in diagram (5b)
E
r = G (c)
the population
response curve
(5a)
(5d)
D
0
B
n
c
high
population
pressure phase
α'
F_L = c
(5b)
c_3
r_E
c_E
marginal labor
productivity curve
low
population
pressure phase
c_2
g_1
c_1
r
0
n
α'
45°
h
high
population
pressure phase
E_0
m_3
n_E
m_E
(5c)
m_2
E_1
stationary
equilibrium
n/m = 1 − θ
low
population
pressure phase
m_1
E_2
m = f/f' = q/c
the population
density curve
m

Diagram 5