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Rural China: An International Journal of History and Social Science 11 (2014) 46-87

Rural China 中国乡村研究
brill.com/rchs

The Law of the Limit to Land Productivity and China's Hidden Agricultural Revolution

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土地生产率极限法则和中国的隐性农业革命

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Abstract
Using a new concept—the law of the limit to land productivity—this article builds a three (physical, economic, and institutional) worlds' land-use model with inverse logics of different development stages in a time perspective: before, in, and after the population trap. This model extends the span of the Malthusian population model to history after the Industrial Revolution and makes static property rights theory dynamic. It argues that 1) cost/return ratios decide the effects of land rights; 2) changes in cost/return ratios alter the effects of land rights; and 3) changes in land/labor ratios first alter cost/return ratios and then patterns of land rights. Using this model and statistical data, the article, from the supply side, explores the validity of the concept of China's "hidden agricultural revolution" advanced by Philip C. C. Huang, and simultaneously tests the model's inverse logics and dynamic land rights theory. The result is that Douglass North's property rights theory has reversed the causality of things: although the state can set the property regime, it cannot control what kind of effects will flow from the regime it chooses. Hence the state should select property regimes according to their real effects rather than the effects subjectively derived from North's "theory."

Keywords
law of the limit to land productivity, Malthusian population model, static property rights theory, dynamic land rights theory, China's "hidden agricultural revolution"

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Author's Note: The author would like to thank Philip Huang, Richard Gunde, Jiayan Zhang, and Christer Gunnarsson for their valuable comments.

DOI: 10.1163/22136746-12341249

摘要
本文首先用土地生产率极限的新概念建立起一个从空间上由物质、经济和制度三个世界组成，及从时间上能揭示人口陷阱前、人口陷阱中和人口陷阱后三个不同发展阶段的反向逻辑的动态土地使用模型。此模型把马尔萨斯人口模型从原来只能解释工业革命前的历史拓展到也能解释工业革命后的历史，并把诺斯的主观唯心的静态产权理论改正为一个客观唯物的动态土地产权理论：(1)成本/回报率决定土地产权的作用；(2)成本/回报率的变化改变土地产权的作用；(3)劳均土地资源的变化先改变成本/回报率，其次才改变土地产权模式。依据此模型的构架和中国的历史统计数据，本文接着从供给角度去验证和充实黄宗智先生最近提出的中国隐性农业革命，并同时验证这一模型的各组反向逻辑和动态土地产权理论。本文的验证结论是诺斯的只有制度世界和经济世界的静态产权理论颠倒了事物的因果关系。国家虽然能决定选择何种产权制度，但无法控制何种效果会从它选择的产权制度中产生出来，因此就应按照产权制度的真实效果而非诺斯理论主观臆想的效果来选择具体的产权制度。

关键词
土地生产率极限法则、马尔萨斯人口理论、静态产权理论、动态土地产权理论、中国的隐性农业革命

The World Bank-led "reform of formalizing land rights" has largely failed in poor countries (Ostrom, 2002), where having a title has little effect on land productivity and investment (Besley, 1995; Brasselle et al., 2002; Jacoby and Minten, 2007). This "effect view" comes from the North/Thomas (1973) static model: 1) private property rights create incentives to act; and 2) incentives to act raise private rates of returns and cause growth. Thus the second view (*man can control the results of his action*) has inevitably derailed land reform since it defies Malthusian diminishing returns. But diminishing returns only show that man cannot control the results of his action, and are not the factor creating the results. To solve these problems in theory and practice, I have advanced a new concept, the physical law of the limit to land productivity, and argue that it is this limit that determines the results of farmers' actions. Wielding this concept, I have developed a new theory (Pei, 2004, 2008). From the supply side, this new theory can also substantiate the validity of the notion of China's "hidden agricultural revolution" advanced by Philip C. C. Huang (Huang Zongzhi, 2010). From the consumption-demand side, Huang has summarized the revolution as an upgrading of China's food structure of grain, meat, and vegetables from the ratio of 8:1:1 to 4:3:3, but has not shown that the structure depends on what happens on the supply side. As a step in that direction, this article, in the following section, introduces the new theory that I have developed. The article then uses this theory to analyze, first, how changing the food structure has depended on changing the planting structure, that is reducing

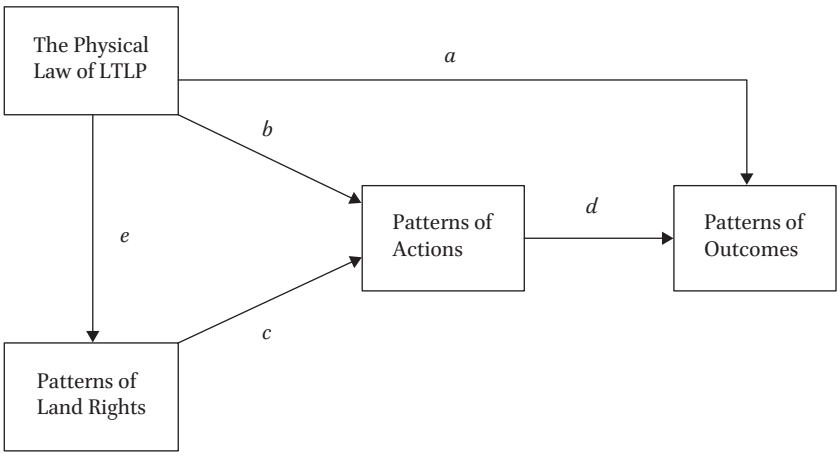
the area sown in grain and expanding the area sown in vegetables; and second, the source of the potential to raise the grain yield, which has made possible the expansion of the area sown in vegetables. The article then analyzes the various sources of change in the structure of cultivation, especially the market's role in this change. Here, in other words, I aim to answer the question: Is China's market-oriented reform the cause of China's "hidden agricultural revolution"? This question is in fact the same question of where the potential to raise the grain yield (typically measured in tons per hectare) comes from. The aim of all these analyses is to correct North's static property rights theory, which has reversed the causality of things and misled theory, policy, and reform, and then, in the last section of the article, to provide a sound theoretical basis for rural China's next institutional choice.

The Law of the Physical Limit to Land Productivity: A Missed System-Pivot

Because farmland can be simultaneously a part of nature, the property of landowners, and a means of production used by tillers, its use takes place in a triworld system: 1) the relation of population numbers to land resources and the physical laws of nature that govern crops' growth belong to the physical world; 2) the property relations of man to man, belong to the institutional world; and 3) tillers' action of how to use land according to cost/return ratios and the outcomes, to the realm of the economic world. The institutional world's land rights pattern is the result of the physical world because man-to-man property relations arise from the physical relation of population to land resources. The economic world's pattern of action and its outcomes are the joint results of the physical and institutional worlds because the physical laws of nature and land-rights patterns jointly govern how land is used.

I define the laws of nature as imposing a limit on land productivity (LTLP hereafter) set by biological laws and natural forces (e.g., the fixed flow of sunshine reaching the earth annually, seasonal changes, the alternation of day and night, temperature, land fertility, water, air, etc.), which govern the growing speed and life cycle of crops. LTLP has a relative and absolute dual nature. A relative limit refers to an *available* technology at a given stage of development. Technological advances can raise this limit in the next stage. The absolute limit, on the other hand, means the absolute existence of LTLP, which is like a glass ceiling on growth in yield, a limit imposed by biological, physical, chemical, and geographical constraints at any time and place. Advances in technology can never remove this ceiling where marginal returns to labor or capital inputs are always zero. For example, technological advances can never increase the

Figure 1. The System of Three Worlds of Land Utilization



supply of sunshine, which is almost constant from year to year. Therefore, the relative limit and the absolute limit to land productivity can be seen as identical under an *available* technology at a given stage of development.

We can visualize the inner links of the land-use tri-world system by looking at Figure 1.[1] LTLP and patterns of land rights jointly affect patterns of action, which combine with LTLP to produce outcomes. The hard restrains of LTLP affect outcomes in two ways: one path leads via patterns of action (lines *b* and *d*); the other path, line *a*, affects outcomes directly and independently of human choice. Patterns of land rights, however, only indirectly affect outcomes via lines *c* and *d* because they are soft restraints and work only via human choices and actions. Therefore, the three-worlds land-use model has four relations: 1) LTLP directly affects outcomes (line *a*) with diminishing returns as its results and evidence; 2) LTLP restricts actions (lines *b* and *d*) by fixing cost/return ratios; 3) private land rights can create incentives to act if returns exceed costs but cannot if costs exceed returns (lines *b, c*, and *d*); 4) private land rights harm others and the social general welfare if they mismatch LTLP (line *e*). For example, the exclusive right to land harms the survival of new additions to a village's population (Pei, 2004, 2008), and reduces the food supply by keeping the inverse relation of farm size to yield per hectare: that is, low in big farms, which seek more marginal returns to labor, and high in small farms, because survival forces them to exploit their own labor (Chayanov, 1966 [1925]; Sen, 1966).

[1] Figure 1 has benefitted greatly from my study of Oakerson, 1992.

But if yield per hectare had no limit, farm outputs would, like industrial outputs, not correlate to land size but to labor and capital inputs. If this were so, then the same amount of labor inputs in 1 ha or 10 ha or even 100 ha would result in the same amount of outputs. There would be no diminishing returns, no difference in actions and outcomes between big and small farms, and no need to establish land rights and to check population growth. This is why LTLP is both the cause of these issues and the benchmark to test them.

Table 1 further illustrates how LTLP exists and makes returns diminish. The first column of the table list successive units of labor or capital inputs. The second column shows land productivity or the output that a fixed area of land yields when successive units of input are expended on the area. The third column shows the marginal returns on the particular unit of input, which increase up to the 5th unit, then consistently decrease, and finally become negative. The last column shows the average returns per unit of input, which increase up to the 7th and 8th units and then decrease. If we measure in terms of the fixed area of land, the second column tells us that land productivity does not decrease until the 19th unit of input has been expended, and 324 is exactly the limit to land productivity and the benchmark, where the marginal returns change from positive to negative and land productivity changes from increasing to decreasing. It is the existence of the physical law of LTLP that causes these changes, or things would develop in the opposite direction when they become extreme. If the law were different, almost all the modes of production and distribution of wealth would be other than they are.

The Malthusian population model (1989) can be written as $AY > NS \rightarrow AY = NS$, or $AY/N > S \rightarrow AY/N = S$. A is the area of arable land (in hectares) and Y the yield of grain per ha (kg/ha). AY is the grain supply. N is number of heads and S the subsistence level in terms of grain (kg/head). NS is the demand for grain. Malthus held that growth in N can lead any country from the stage of $AY/N > S$ (everyone has a farm surplus) to the stage of $AY/N = S$ (no one has a farm surplus), because A and S are constants, and N and Y are variables to growth over time and what turns $AY/N > S$ to $AY/N = S$ is geometric growth in N (1, 2, 4, 8, 16 . . . every 25 years) vs. arithmetic growth in Y (1, 2, 3, 4, 5 . . . every 25 years), or the denominator increases faster than the numerator. But Malthus did not know what caused this divergence and diminishing returns, hence his divergence and diminishing returns are not a causal explanation but a description of a phenomenon. Now we find that acting as the glass ceiling, LTLP checks the faster growth in N by making returns diminish and Y grow arithmetically. If we use Figure 1 and its four relations to sum up, what Malthus studied are only the *results* of the first relation: the end of line *a*. What he missed is LTLP: the outset of line *a*.

Table 1. The Law of the Limit to Land Productivity as the Origin of Diminishing Returns

Input units of expenditure of labor or capital	Output or product	Marginal return to a given unit of input	Average return to per unit of labor or capital
1	5	5	5
2	20	15	10
3	45	25	15
4	80	35	20
5	125	45	25
6	162	37	27
7	196	34	28
8	224	28	28
9	243	19	27
10	260	17	26
11	275	15	25
12	288	13	24
13	299	11	23
14	308	9	22
15	315	7	21
16	320	5	20
17	323	3	19
18	**324**	1	18
19	323	–1	17
20	320	–3	16
21	315	–5	15
22	286	–29	13
23	253	–33	11
24	216	–37	9
25	175	–41	7

Source. Ely and Wehrwein, 1940: 53, table 7.

The North/Thomas model also misses LTLP, and uses the neoclassical assumption of self-interested man to claim that "given the described assumption about the way people behave, economic growth will occur if property rights make it worthwhile to undertake socially productive activity" (1973: 8). This claim only has lines *c* and *d* of Figure 1: private property rights via line *c* create incentives to act; the incentives to act via line *d* cause growth. This one-way model is

unbalanced, like a car without brakes. It only studies Figure 1's third relation, but at the same time denies that LTLP can affect outcomes via line *a* and check actions via line *b*. It actually implies that humans can control both their actions and the outcomes of their actions, which is absurd because humans cannot control the outcomes of their actions though they can control their actions. This is why the empirical studies of Besley (1995), Brasselle et al. (2002), Jacoby and Minten (2007), and others affirm that private land rights have little effect on land productivity and investment in small farms of poor countries, where land productivity is already high and close to LTLP, and hence LTLP checks actions to invest by making costs exceed returns and private land rights useless.

Another of North's (1981: 17) one-way claims is also absurd but has misled many reforms: "A theory of the state is essential because it is the state that specifies the property rights structure. Ultimately it is the state that is responsible for the efficiency of the property rights structure, which causes growth or stagnation or economic decline." The reason this "theory" is absurd is because although the state can specify the property rights structure, it cannot control the effects that will flow from the structure it specifies. Table 2 shows that the same land rights specified by the state have inverse effects at different development stages of a country or in different areas of the same country, which is absolutely not caused by the state. Therefore, in the final analysis the effects of the land rights structure are not determined by the state but by LTLP.

Table 2 is a summary of my past studies (2004, 2008). It further specifies Figure 1's tri-worlds land-use system and makes the system dynamic in a time perspective. Its columns 2, 3, and 4 represent three different development stages of a country: before, in, and after the population trap (or after industrialization). Its horizontal items reveal the inverse logics of the three stages and extend the span of the Malthusian population model—which has a time factor and hence columns 2-3 but no column 4 and an institutional world that is not its focus—to history after the Industrial Revolution. From the space perspective, its vertical items show that both the institutional and economic worlds are the results of the physical world's relation of population to land resources. The North/Thomas model has no physical world in a space perspective, so it sees the economic world as the result of the institutional world by defying the physical checks of LTLP to the institutional and the economic worlds. This static model also has no time factor and thus breaks off in time perspective and has columns 2 and 4 but no column 3. If it had column 3, it would contradict its own causality. In sum, the Malthusian model is still valid when it has continued columns 2-3 but no column 4 and institutional world 1, while the North/Thomas model is fragmented and not a valid theory when it has columns 2 and 4 but no column 3 and no physical world.

Table 2. Inverse Logics of Different Development Stages under the Law of LTLP

	AY/N > S	AY/N = S	AY/N > S
The Physical World:			
A: area of arable land	Constant	Constant	Constant
N: population under the law of LTLP	Less	Most	Least
Land per rural head	Large	Smallest	Largest
The Economic World:			
Land size per family farm	Large	Smallest	Largest
Labor inputs per ha	Less	Most	Least
Labor inputs to LTLP	Far	Closest	Farthest
Marginal returns to labor	High	Lowest	Highest
Average labor cost per kg of grain	Low	Highest	Lowest
Labor productivity	High	Lowest	Highest
Y: land productivity	Low	Highest	High
Returns to fixed capital investment	High	Lowest	Highest
Invest in farm machines?	Yes	No	Yes
Above **S:** surplus grain	Have	No	Most
Aim of farming	Survival & profits	Survival	Mainly for profits
The Institutional World:			
Transfer of land use rights	Works	Does not work	Works
Land rental markets	Work	Fail	Work
Mortgaging land titles for bank loans?	Yes	No	Yes
Credit markets	Work	Fail	Work
Exclusive land rights	Not harm SNAP*	Harms SNAP	Not harm others
Patterns of land rights	More private	More communal	More private

* SNAP = survival of newly added population.
Source. Pei, 2009: 106.

But with a greater time-space framework, Table 2 has remedied the defects of the above two and developed *a dynamic land rights theory*: 1) its vertical items from the space perspective show that the cost/return ratios determine the effects of land rights; 2) its horizontal contrast from the perspective of time shows that changes in the cost/return ratios alter the effects of land rights;

3) its three-worlds' horizontal-dynamic contrast tell us that changes in the land/labor ratio first alter the cost/return ratio and then the pattern of land rights.

This dynamic land rights theory denies the causality of the North/Thomas static property rights theory. The latter has been used to explain why the Industrial Revolution first took place in Britain, but it is precisely well-known British economic historians who do not accept the explanation of this causality. For example, the historian of the Industrial Revolution Sidney Pollard and his students describe the "new economic history" written according to this neoclassical static theory as "siren voices" (Holmes and Booth, 1991: xxiv; see also Field, 1981.). In contrast, the Malthusian dynamic theory sees the economic world as the result of the physical world. It is this causality that correctly explains human history before the Industrial Revolution. To the question of why Malthus could not foresee the Industrial Revolution, E. A. Wrigley (1988), the British expert in population history and the history of Industrial Revolution, uses the same kind of causality to answer: the British economy changed to a mineral-based energy economy after Malthus died; during his lifetime and before it had always been an organic economy in which the scope of economic activities was limited by land productivity. This was because land was not only the sole source of food and clothing, but also the basic source of energy (e.g., charcoal) and the raw materials of manufacturing and construction. This was why Malthus held that the interaction of increasing population pressure on land and diminishing returns was bound to make any country fall into the AY/N = S population trap, where income per head was fixed at the subsistence level. The extreme case provided by Malthus was China, which had fallen in the trap the earliest and the deepest.

Wrigley's concept of organic economy goes a step further toward the origin of diminishing returns, that is, the growth of all organic economies depends exclusively upon their ability to capture some part of the flow of energy reaching the earth in the form of sunlight that is transmuted by photosynthesis into vegetable matter, and then passes on through the food chain into different organic forms. The problem is that the flow of sunlight energy is almost constant every year, but population growth requires that crop yields or land productivity grow year by year. This contradiction between supply and demand can be mitigated by advances in technology, and Boserup (1965) shows that population growth has indeed induced technological progress, from forest-fallow cultivation to bush-fallow cultivation, to short-fallow cultivation, to annual cropping, and finally to multi-cropping. This process of intensified use of land leads to the development of a tool system, from the system of clearing

forestland by fire in the forest-fallow cultivation pattern to the hoe system and then to the plow system. But intensified land utilization cannot increase the supply of sunlight energy in the least. What it can do is only use higher and higher costs to capture a fraction of the flow. Hence in the framework of an organic economy, technological advances cannot change diminishing returns and make land productivity grow faster than population growth—that is to say, the population trap is inevitable.

Wrigley has demonstrated that allowed Britain to cast off the yoke of an organic economy was the exploitation of coal. In 1815 British coal output reached seven times that of the European continent as a whole. This enlarged its energy possession per head and changed its growth of labor productivity based on organic energy to growth based on mineral energy. Since in an organic economy, activities of agriculture, manufacturing, and transportation depend mainly on human and animal energy, these limited forces per se directly restrict growth in labor productivity. The heat required in manufacturing relies mainly on wood, which not only generates less heat and costs more than coal, but also increases the burden on the land. In Britain, transportation was mainly powered by horses, which, compared to coal energy, entailed lower efficiently and higher costs as well as added pressure on the land, because each horse needs 3-5 acres for fodder. In sum, when clothing, food, shelter, transportation, and energy are all extracted from a fixed area of land, they compete with each other and spread the effects of diminishing returns all over the entire economy. Therefore, the wholesale exploitation and use coal could rapidly expand the energy supply per head, the output per laborer, the income per head, the scope of raw materials and productive activities, etc. For example, using coal to fire bricks made it possible to replace wood with bricks as the main building material. The use of coal also led to the emergence and development of the power industry, the metallurgical industry, the engineering industry, the chemical industry, etc. According to Wrigley's large amount of data, especially figure 2.2 of his book (1988: 65), the basic disparity between the organic economy and the mineral-based energy economy is that the former is bound to make marginal returns diminish, output growth lower than population growth, and income per head fixed at the subsistence level, while the latter can make marginal returns increase (or the unit cost of production decrease), output growth higher than population growth, and income per head rise. Hence the Industrial Revolution was a natural outcome of the energy revolution: it could not emerge and be sustained within the framework of organic energy.

Wrigley uses a comparative analysis to demonstrate that from 1550 to 1750 Holland was more "modernized" than Britain in agriculture, industry, transport, the ratio of the urban population, the number and vitality of cities, the division of labor and specialization, the levels of wages and income per head, the autonomy and political influence of the urban middle bourgeoisie, individual property rights and legal protections, and so on. According to the North/Thomas "causality," the Industrial Revolution should naturally have taken place first in Holland, but the fact was that the proportion of the Dutch urban population and the degree of industrialization diminished during the century years after 1750. This was because what created the Dutch golden age was the fact that it not only had more peat than other European countries, but also the peat was near its inland waterway network. It was the peat resources and the low transportation cost that had supported the Dutch development of urbanization, division of labor, specialization, manufacturing, etc., although the heat energy of one ton of peat was much less than that of one ton of coal. But along with population growth and a gradual depletion of peat resources, a decline in peat possession per head was bound to lead to a decline in urbanization and industrialization. The British economy in this period, on the other hand, depended on the widespread exploitation of coal, which allowed it to catch up with and then surpass the Dutch economy, making Britain the first country to realize an Industrial Revolution.

In sum, Wrigley's historical materialism argument that the Industrial Revolution was the result of an energy revolution accords with not only history but also common sense, while the North/Thomas historical idealism argument that better-defined property rights per se caused the Industrial Revolution violates both history and common sense. Wrigley's concept of organic economy also supports the concept of limits to land productivity (LTLP), but the latter can contain the former and the former cannot contain the latter, so LTLP is a concept with more accurate and richer connotations. First, according to the definition above, LTLP not only contains what Wrigley has stressed, namely that the growth of crops is limited by the constant energy flow of sunshine, but also contains what Wrigley has not stressed, namely that the biological laws of nature also govern crops' life cycle and growing speed, although the concept of the organic economy may imply this meaning. Second, LTLP is raised to the level of a law of nature by the concept of limits and can clearly define the Malthusian population trap as a result of laws of nature, while the concept of organic economy lays particular stress on describing the organic economy per se and cannot be raised to this level. Because of this, the concept of organic

economy has a time limit and makes us think that diminishing returns will vanish once a mineral-based economy replaces an organic economy. The concept of LTLP avoids the limitation and applies to all of human history. Today's agriculture, with many modern inputs (e.g., chemical fertilizers) is no longer a purely organic economy, but the law of LTLP still exists and makes returns diminish. Third, as a macro concept, "organic economy" is unwieldy, while the concept LTLP encompasses both the micro and the macro by virtue of its axiom that yield always has an absolute limit at any time and place. Thus the former cannot but the latter can quantitatively analyze the population pressure on the land, e.g., the number of persons borne by each unit of land, the related cost/returns ratios, the related effects of land rights, etc., as listed in Table 2.

Because the concept of LTLP has these time and space features, columns 2, 3 and 4 in Table 2 can represent both three different development stages of a country—before, in, and after the population trap—and three different types of areas of a country in a space perspective. For example, a few of China provinces (Heilongjiang, Inner Mongolia, Jilin, Xinjiang, and Ningxia) can be included in the AY/N > S type of underpopulated areas represented by column 2. The great majority of China's provinces, however, must be classified into the AY/N = S type of overpopulated areas shown by column 3. Column 4 indicates that the shift of population and labor (N) to industry has changed the original AY/N = S family farms to the AY/N > S type of family farms, and hence created the other type of AY/N > S areas. A few of China provinces, such as Jiangsu, Zhejiang, Fujian, and Guangdong, can be seen as pioneers of this kind of transition. But note, they are still far from completing the transition to where land per farm laborer is even much larger than the case of the first type of AY/N > S areas, so that the logic of column 4 has replaced the logics of column 3. In another words, the logics of column 3 is their historic legacy, which is tenacious and stops them from changing to the inverse logics of column 4. Although this is true, these provinces still present clear evidence of a logical transition. Therefore, I will use evidence from China's provinces to test each set of inverse logics and the dynamic land rights theory outlined in Table 2.

Wrigley also tried to undertake similar tests in chapter 4 of his book (1988: 98-132). For example, in the organic economy, if a region according to its regional comparative advantage abandons grain self-sufficiency and grows non-grain farm produce in exchange for grain via markets, then the high transport costs of the organic economy would make it suffer a setback and fall into famine. Hence the modern rational man, individual property rights, division of labor and specialization, better transportation, expansion of market exchange,

etc., treated by conventional theories as prerequisites of the Industrial Revolution, are actually developed and perfected by largely using mineral energy in the process of industrialization, which means that they are results rather than causes of the Industrial Revolution. But in the end Wrigley only went as far as this logical reasoning and no further, because the unwieldy concept of the organic economy made it impossible to build a concrete index system (such as Table 2) to undertake specific tests. Therefore, I will also use Table 2 to test Wrigley's logical reasoning.

The Origin of the Grain Supply behind China's Hidden Agricultural Revolution

According to Huang (2010), there has been an ongoing "hidden agricultural revolution" in China, where the output value of agricultural products (in comparable prices) has grown 600 percent since 1980 or 6 percent per year, which is much higher than in the eighteenth-century English agricultural revolution and the "green revolution" of the 1960s and 1970s. The reason Huang uses the term "hidden agricultural revolution" is because this revolution is unlike the two earlier revolutions, the one that depended on raising the yield of certain crops (whereas the "hidden agricultural revolution" instead depends on changes in China's food structure), and the other, which depended on a move from low-value farm products to high-value products. Huang outlines this hidden revolution as stemming from the Chinese diet of grains, vegetables, and meat changing from a ratio of 8:1:1 to a ratio of 4:3:3. This structural change stems from the high growth of China's non-farm sector, which has raised income per head and has laid a foundation for consuming high-value farm products. Such an explanation for the "hidden agricultural revolution" from the demand side is reasonable when the amount of vegetables and meat consumed is indeed positively correlated to income level. But we still need an explanation from the supply side, because China's increasing output of meat is not like the case of some countries which depend for growth on grassland livestock husbandry; instead, China depends on an increase in feed grain. Moreover, restricted by the availability of only 2 mu of arable land per rural resident (15 mu = 1 ha), China's growth in vegetable output must be a result of the expansion of the area sown in vegetables at the price of a reduction in the area sown in grain. Thus, if there were no sustained growth in grain yields and in the total output of grain, the expansion of the area sown in vegetables and the growth in meat

output in China's "hidden agricultural revolution" would not occur. In other words, the rise in income per head cannot unilaterally drive the upgrade of China's food structure if there is no supply push from grain growth.

But according to Huang's past studies (1985, 1990), China' population growth has made not only land per head very limited but also grain yields quite high; therefore, it would be very hard to raise yields as the classic agricultural revolution did in Britain. The logics of column 3 of Table 2 also support this view. Fortunately, a few Chinese provinces can still be classified into the first type of AY/N > S areas represented by column 2 of Table 2. According to the logics of column 2 and my past predictions (1985) when working in the State Planning Commission of China, this type of area has a huge potential for raising grain yields. Hence the classic type of agricultural revolution can emerge in this type of area if there is a sudden rise in demand and prices. For example, the first English enclosure movement in the fifteenth-sixteenth centuries was induced by a sudden rise in demand for wool from the European continent. This demand could be met because there was a large supply of English land for grazing that had not been fully used. Similarly, in the nineteenth century a rise in the European demand for rice and a fall in ocean shipping costs made Thai rice production and export profitable. In order to catch hold of this profitable opportunity and encourage farmers to raise yields, the traditional Thai property rights in slavery were replaced by more precise private property rights in land (fee-simple title). But the traditional rights were just results of labor being scarcer and more valuable than land. Indeed, farmland per head increased in nineteenth-century Thailand when it still had a great deal of virgin land. These two cases support the theory illustrated in Table 2, namely that changes in the economic and institutional worlds are the result of the prior physical relation of population-to-land resources. If population growth makes land per head very limited and yields very close to LTLP, both the land rights reform of the institutional world and the classical agricultural revolution of the economic world would lack the necessary prerequisites.

Therefore, from the inverse logics of Table 2 one can infer: China's market-oriented reform and rise in grain prices induced a classic agricultural revolution in the first type of AY/N > S areas, but did not have the same effect in the AY/N = S areas and in the second type of AY/N > S areas because their potential to raise grain yields and marginal returns to growing grain were already very low. Hence they could only carry out the "hidden agricultural revolution." But if the first type of AY/N > S area had no preexisting huge potential to raise grain yields, both the classic and the hidden revolutions would lack the

necessary supply prerequisites. Now let us turn to Tables 3 and 4 to examine this deduction.

In order to be comparable, Table 3 does not use 1980 but 1985 to compare with 2010 because the household responsibility system completely replaced the collective farm system only in 1984. The regional data on land per rural head are only from 1999, but must be the most stable compared with other data within twenty-five years. We see that the provinces with more than 3 mu of land per rural head are only Heilongjiang (8.44), Inner Mongolia (7.16), Jilin (4.96), Xinjiang (4.28), and Ningxia (3.83), which is why I classify them as AY/N > S type of underpopulated areas. According to the logics of Table 2, their land productivity should be the lowest among China's provinces. Table 3's data on grain yields in 1985 confirm this deduction, except for Jilin. Hence their grain yield should have grown fastest from 1985 to 2010, which is indeed what happened. The provinces where the grain yield per ha more than doubled from 1985 to 2010 are only Heilongjiang (2.9), Inner Mongolia (2.8), Ningxia (2.5), and Xinjiang (2.2). The reason Jilin did not grow 200 percent was its much higher grain yield than the four other provinces in 1985, and the reason Gansu and Henan could grow almost 200 percent was because their grain yield was lower than that of many other provinces. Therefore, the more land per head and the lower the yield, the more likely it is that the yield can grow in the future. On the contrary, the less the land per head and the higher the yield, the harder it would be to increases the yield, which is verified by the experience of regions with the lowest growth rates (less than 1.4) of grain yield per ha from 1985 to 2010, such as Beijing (1.23), Hunan (1.26), Jiangsu (13.1), Jiangxi (1.33), Zhejiang (1.34), Sichuan (1.36), Fujian (1.38), Guangdong (1.38), Shanghai (1.38) and Hubei (1.39).

These inverse logics of Table 2 are actually the simplest logics in the world, but also the logics that the North/Thomas "theory" most wants to ignore, because the logics tell us that the real issue of economic history is not whether a country can launch an agricultural or industrial revolution, but whether a country has the preexisting physical potential to launch such a revolution. If the potential exists, any country can launch a revolution. The reverse is true if the potential has dried up. This is why many countries have had their golden age far in the past, and also why none of them can rest on their laurels insofar as economic growth is concerned.

Table 3 further shows that under the inverse logics made by the physical law of LTLP, China's provinces where the total output of grain more than doubled from 1985 to 2010 are only Inner Mongolia (3.57), Heilongjiang (3.51), Ningxia (2.56), Xinjiang (2.35), Jilin (2.31), and Henan (2.01), showing that the classic

Table 3. Farmland per Rural Head, Grain Growth in Yield per Hectare and in Total Output, and Place in the Grain Total Output Scale of China's Provinces and Municipalities, 1985-2010

	1	2	3	4	5	6	7	8	9
	Land per rural head (mu)	Grain yield (kg/ha)			Total grain output (10,000 tons)				
		1985	2010	Growth: 3/2	1985	Place in scale, 1985	2010	Place in scale, 2010	Growth: 7/5
China, total	2.07	3,480	5,524.4	1.59	3,7910.8		54,647.7		1.44
Heilongjiang	8.44	1,980	5,743.7	2.9	1,430	12	5,012.8	2	3.51
Inner Mongolia	7.16	1,770	4,912	2.78	604.1	20	2,158.2	11	3.57
Jilin	4.96	3,735	6,867	1.84	1,225.3	13	2,842.5	9	2.32
Xinjiang	4.28	2,685	5,969.5	2.22	498.8	23	1,170.7	17	2.35
Ningxia	3.83	2,145	5,410.5	2.52	139.5	27	356.5	25	2.56
Shanxi	2.95	2,700	3,813	1.41	822.7	18	1,085.1	21	1.32
Liaoning	2.85	3,375	5,688.4	1.69	976	15	1,765.4	13	1.81
Qinghai	2.81	2,595	3,755.9	1.45	100.3	28	102	30	1.02
Gansu	2.78	1,905	3772.3	1.98	530.5	22	958.3	22	1.81
Shaanxi	2.25	2,400	3,991.7	1.66	951.9	16	1,164.9	18	1.22
Tibet	2.19	2,730	5,429.8	1.99	53.1	29	91.2	31	1.72
Hebei	2.03	3,030	4,877.2	1.61	1,966.6	8	2,975.9	7	1.51
Tianjin	1.61	3,150	5,310.8	1.69	140.5	26	159.7	27	1.14
Henan	1.54	3,000	5,837	1.95	2,710.5	4	5,437.1	1	2.01
Yunnan	1.54	2,820	4,171.7	1.48	935	17	1531	14	1.64
Anhui	1.51	3,675	5,366.7	1.46	2,168	7	3,080.5	6	1.42
Hubei	1.49	4,335	6,035.9	1.39	2,216.1	6	2,315.7	10	1.04
Shandong	1.45	3,930	6,154.3	1.57	3,137.7	2	4,335.7	3	1.38
Jiangxi	1.33	4,200	5,581.2	1.33	1,533.5	11	1,954.7	12	1.27
Guangxi	1.29	3,240	5,032.1	1.55	1,117.1	14	1,412.3	15	1.26
Jiangsu	1.27	4,860	6,364.6	1.31	3,126.5	3	3,235.1	4	1.03
Hunan	1.14	4,875	6,135	1.26	2,514.3	5	2,847.5	8	1.13
Guizhou	1.08	2,685	4,978.2	1.85	595	21	1,112.3	20	1.87
Shanghai	1.07	4,890	6,738.7	1.38	213.8	25	1,18.4	28	0.55
Sichuan	1.05	4,080	5,556.5	1.36	3,830.7	1	3,192.9	5	0.83
Beijing	0.97	4,305	5,296.9	1.23	219.7	24	115.7	29	0.53
Zhejiang	0.92	4,950	6,641	1.34	1,621.3	10	770.7	23	0.48
Guangdong	0.89	3,885	5,348.1	1.38	1,737.9	9	1,316.5	16	0.76
Fujian	0.84	4,215	5,822.7	1.38	794.4	19	661.9	24	0.83

Note. 15 mu = 1 ha. Hainan was a part of Guangdong and not established as a province in 1985.
Source. *Zhongguo nongcun tongji nianjian* and *Zhongguo tongji nianjian* (1985-2011, annual).

agricultural revolution has indeed taken place in the AY/N > S type of relatively underpopulated areas. The reverse is true in the AY/N = S type of overpopulated areas and in the second type of AY/N > S areas, where the provinces with almost zero growth in total output of grain from 1985 to 2010 were, for example, Jiangsu (1.03), Hubei (1.04), Hunan (1.13), etc., and those with negative growth in total output of grain from 1985 to 2010 were, for example, Zhejiang (0.48), Beijing (0.53), Shanghai (0.55), Guangdong (0.76), Fujian (0.83) and Sichuan (0.83). Aside from the above-mentioned exhaustion of potential, the other factors that directly caused the total output of grain of these areas to fall rapidly or grow slower than their grain yield were mainly two. One was that urban expansion reduced the grain-sown area. The other was that the "hidden agricultural revolution," that is the expansion of the area sown in vegetables, reduced the original grain-sown area. Beijing and Shanghai belong mainly in the first category, and the rest of the areas mainly in the second.

Table 4 shows that from 1989 to 2010 the grain-sown area grew in only ten regions (Heilongjiang, Inner Mongolia, Jilin, Xinjiang, Ningxia, Liaoning, Henan, Anhui, Yunnan, and Guizhou), but shrank in all the other regions. This is why Table 3 shows that in the former regions the total output of grain grew faster than the growth in grain yield (except Anhui, which synchronized the two growths), and why in the latter regions the total output of grain either fell or grew slower than the growth in grain yield. We also see that from 1989 to 2010 the area sown in vegetables was expanding in both kinds of areas, except Beijing and Heilongjiang, where the area sown in vegetables fell a little. The reason the former regions could enlarge their grain-sown area and vegetable-sown area simultaneously is either because their land per head is relatively large or because they have some uncultivated land, in which case the enlargement of the vegetable-sown area would not reduce the grain-sown area. The latter regions have inverse logics. For example, Shandong's increased vegetable-sown area far exceed its reduced grain-sown area and thus can be seen as playing a 100 percent role in reducing the grain-sown area. According to this logic, the regions where the added vegetable-sown area played a 100 percent role in reducing the grain-sown area also include Hebei, Hunan, and Guangxi; the regions that played a 75 percent, 58.4 percent, 54 percent, 48.3 percent, 20 percent, and 17 percent roles in reducing the grain-sown area are, respectively, Jiangsu, Hubei, Fujian, Guangdong, Zhejiang, and Sichuan. The reason why we specifically measure these ten provinces is because, as Table 4 shows, they and the four other provinces (Henan, Anhui, Yunnan, and Guizhou) where the grain-sown area and vegetable-sown area expanded at the same time occupy the first fourteen places in the scale of increased vegetable-sown area; their

total increased vegetable-sown areas was 80 percent of that of China as a whole. This means that what was responsible for more than tripling China's vegetable-sown area more between 1989 and 2010 was mainly the rapid expansion in the vegetable-sown area in these provinces. It also means that in this period China's vegetable production followed a trend of regional concentration and specialization.

Here we encounter Wrigley's question of whether an area will fall into famine if it abandons grain self-sufficiency and grows non-grain farm products according to regional comparative advantage. To examine this question, we can observe the tendency of a rise or fall in grain output per head of the fourteen provinces shown in Table 4, and classify these fourteen provinces into three types. Henan, Anhui, Yunnan, and Guizhou belong to the first type because their grain-sown area and vegetable-sown area grew concurrently, thus a fall in grain output per head would have been most unlikely. Table 4 shows that Henan's grain output per head was 386 kg in 1989, slightly higher than China's average level in 1989, but grew to 575 kg in 2010, much higher than China's average level 409 kg in 2010. Anhui's grain output per head was always higher than China's average level and increased 70 kg between 1989 and 2010, though the increase was much lower than Henan's 189 kg. Guizhou and Yunnan's increase in grain output per head was around the amount of Anhui's increase from 1989 to 2010, but they differ from Henan and Anhui because their grain output per head is always lower than China's average level, meaning that they have always been short of grain and filled the deficit by importing surplus grain from other areas. But their increase in grain output per head was higher than China's average level (45 kg) between 1989 and 2010, so their imported grain should fall rather than rise during this period. In sum, Table 4 confirms that both grain and vegetable output per head should grow if a region can enlarge its grain-sown area and vegetable-sown area at the same time. Shandong and Hebei can be seen as belonging to the second type,[2] because their grain output per head was not reduced by their fall in grain sown-area and rise in vegetable-sown area, but grew at around the national average between 1989 and 2010.

Sichuan, Guangxi, Jiangsu, Hubei, Hunan, Zhejiang, Fujian, and Guangdong can be included in the third type of regions where the rising vegetable-sown area and falling grain-sown area caused the grain output per head to decline. From 1989 to 2010, Sichuan's grain output per head increased 14 kg in absolute

[2] According to Guowuyuan fazhan yanjiu zhongxin ketizu (2009), in this period Hebei also became an AY/N < S type of grain-shortage province that had to import surplus grain from other areas.

Table 4. Changes in Grain and Vegetable Sown Areas and Grain Output per Head, and Place on Scale of Added Vegetable-Sown Area of China's Provinces and Municipalities, 1989-2010

	1	2	3	4	5	6	7	8	9	10
	Grain-sown area (1,000 ha)			Vegetable-sown area (1,000 ha)				Grain output per head (kg)		
	1989	2010	Change (1,000 ha) 2—1	1989	2010	Change (1,000 ha) 5—4	Place in added scale	1989	2010	Change (kg) 9—8
China, total	112,204.7	109,876.1	−2,328.6	6,290.3	19,000	12,709.7		364	409	45
Heilongjiang	7,261.7	11,454.7	4,193	244.7	184.5	−60.2		465	1,309	844
Inner Mongolia	3,721.1	5,498.7	1,777.6	62.7	263.6	200.9		328	882	554
Jilin	3,430.9	4,492.2	1,061.3	178.7	245.5	66.8		566	1,036	470
Xinjiang	1,839.5	2,028.6	189.1	63.5	303.6	240.1		431	540	109
Ningxia	705.7	844.1	138.4	14.9	101.4	86.5		388	568	180
Shanxi	3,293.7	3,239.2	−54.5	116.5	228.5	112		317	310	−7
Liaoning	3,083.5	3,179.3	95.8	248.3	430.2	181.9		245	406	161
Qinghai	395.2	274.5	−120.7	6.9	43.5	36.6		254	182	−72
Gansu	2,824.8	2,799.8	−25	62.8	395	332.2		299	369	70
Shaanxi	4,106.2	3,159.7	−946.5	168.2	444	275.8		332	310	−22
Tibet	189.6	170.2	−19.4	7.7	21.3	13.6		257	309	52
Hebei	6,760.5	6,282.2	−478.3	315.1	1,138.6	823.5	4	354	419	65
Tianjin	454.7	311.8	−142.9	55.3	84.9	29.6		200	127	−73
Henan	9,262	9,740.2	478.2	417.5	1,704.1	1,286.6	2	386	575	189
Yunnan	3,527.1	4,274.4	747.3	155.6	671.3	515.7	11	276	334	58
Anhui	6,203.8	6,616.4	412.6	235.1	774.2	539.1	10	440	510	70
Hubei	5,188.9	4,068.4	−1,120.5	365.9	1,020.8	654.9	8	454	405	−49

Table 4 (*cont.*)

	1	2	3	4	5	6	7	8	9	10
	Grain-sown area (1,000 ha)			Vegetable-sown area (1,000 ha)				Grain output per head (kg)		
	1989	2010	Change (1,000 ha) 2—1	1989	2010	Change (1,000 ha) 5—4	Place in added scale	1989	2010	Change (kg) 9—8
Shandong	8,058.2	7,084.8	–973.4	390.9	1,770.8	1,379.9	1	378	455	77
Jiangxi	3,693.9	3,639.1	–54.8	243.5	521.2	277.7		428	440	12
Guangxi	3,596.9	3,061.1	–535.8	252.7	1,007.6	754.9	6	308	299	–9
Jiangsu	6,454.5	5,282.4	–1,172.1	351.6	1,229.8	878.2	3	502	415	–87
Hunan	5,330.5	4,809.1	–521.4	365.1	1,133.1	768	5	445	439	–6
Guizhou	2,467.9	3,039.5	571.6	199.1	647.9	448.8	12	225	306	81
Shanghai	416.9	179.2	–237.7	79.7	132.1	52.4		183	56	–127
Sichuan	9,671.7	6,402	–3,269.7	617.9	1,166.2	548.3	9	383	397	14
Beijing	483	223.5	–259.5	67.8	67.5	–0.3		226	62	–164
Zhejiang	3,222.7	1,275.8	–1,946.9	236.3	618.6	382.3	14	369	145	–224
Guangdong	3,967.2	2,531.9	–1,435.3	486.9	1,179.8	692.9	7	306	131	–175
Fujian	2,045.1	1,232.3	–812.8	229.1	666.9	437.8	13	308	181	–127
Hainan	547.3	437.2	–110.1	50.3	214.6	164.3		240	208	–32

Source. See Table 2.

terms, but declined relatively from 19 kg higher than the national average level to 12 kg lower than that average level, and thus Sichuan changed from a grain-exporting to a grain-importing region (Guowuyuan fazhan yanjiu zhongxin ketizu, 2009). In the other seven regions the rising vegetable-sown area and falling grain-sown area caused their grain output per head to fall in absolute terms. Guangxi is a grain-importing area where grain output per head has always been lower than China's average level, thus its fall in grain output per head from 1989 to 2010 caused it to import even more grain than in the past. In 1989 the grain output per head of Jiangsu, Hubei, and Hunan was higher than China's average level, but up to 2010 fell by 87 kg, 49 kg, and 6 kg respectively, thus these three provinces changed from AY/N > S grain-exporting areas to AY/N = S grain self-sufficient areas. From 1989 to 2010 the regions where grain output per head fell most rapidly were Zhejiang, Guangdong, and Fujian: they experienced a decline of 224 kg, 175 kg, and 127 kg, respectively. In 1989 Zhejiang's grain output per head was even higher than China's average level, but by 2010, as in the case of Guangdong, it became a third of the national average. In 2010, Fujian's grain output per head also fell to less than half of China's average. The three provinces that became AY/N < S types in this period would have fallen into serious famine if they had had no imported grain. But Table 3 shows that in these three provinces the land per rural head is less than one mu, which ranked them lowest in China, and so the change in their cropping pattern from growing grain to growing vegetables was bound to make their grain output per head fall more sharply than in all the other provinces. In sum, this structural change indeed created a tendency for grain output per head to decline in most of the above-mentioned provinces.

Thus the question becomes: from where did the AY/N < S type of areas import grain? As Table 4 shows, in 2010 the areas where grain output per head was more than 500 kg or the areas of AY/N > S type with relatively more surplus grain per head were Heilongjiang, Inner Mongolia, Jilin, Xinjiang, Ningxia, and the above-mentioned Henan and Anhui. Inner Mongolia's grain output per head increased by 554 kg between 1989 and 2010, from a point where the output per head was lower than China's average level in 1989 to a point where it was twice China's average level in 2010. This transformed Inner Mongolia from a grain-importing area to an area with surplus gain available to export to AY/N < S areas. The grain output per head of Heilongjiang and Jilin also increased, respectively, by 844 kg and 470 kg, from the level in 1989, which already exceeded China's average level by 100-200 kg, to a level in 2010 that was around three times the nationwide average. Therefore, in this period, these two provinces could also largely export surplus grain to the AY/N < S areas.

Xinjiang and Ningxia increased their grain output per head by 109 kg and 180 kg respectively in this period and thus they too could export surplus grain, but the absolute exported amount was much less than in Heilongjiang, Inner Mongolia, Jilin, Henan, and Anhui because, as Table 3 shows, their scale of total grain output was much smaller than that of the five provinces. These five provinces are ranked by China's Ministry of Agriculture among the thirteen chief grain production areas according to the criteria that their scale of grain total output is both among the first thirteen places in China as a whole and they provide 70-80 percent of China's total output of grain.

But Table 3 also shows that the total grain output of Heilongjiang and Inner Mongolia rose respectively from China's number 12 and number 20 position in 1985 to the second and eleventh in 2010, while the total grain output of Sichuan, Zhejiang, and Guangdong dropped, respectively, from the number 1, number 10, and number 9 positions in all of China in 1985 to the number 5, number 23, and number 16 positions in 2010. These distinct inverse changes not only confirm the inverse logics between the AY/N > S type and the AY/N = S type of areas as revealed by Table 2, but also tell us that China's growth center of grain production has shifted from the south to the north, especially to Northeast China, Inner Mongolia, and the Yellow River and Huai River areas 黄淮地区. Hence the millennia-long pattern of South China exporting its surplus grain to North China 南粮北调 via the Grand Canal, which was built in the Sui dynasty (581-618), was historically reversed to a new pattern whereby North China exports its surplus grain to South China 北粮南运. Many studies (see, e.g., Guowuyuan fazhan yanjiu zhongxin ketizu, 2009; Peng Chao, 2012) have described this Great Transformation, so there is no need for me to say more. What we should note is that this new pattern took shape almost concurrently with the above-mentioned regional specialized pattern of vegetable production, and thus underlay the success of China's "hidden agricultural revolution." For example, Guangdong has become the AY/N < S area that most lacks grain and each year satisfying two-thirds of its grain rations per head depends on importing surplus grain of other areas. Guangdong is also China's biggest feed-processing province, but to occupy this enviable position, it relies on North China's corn (Ding Shengjun, 2012). Thus Guangdong's increase in meat output and in vegetable-sown area would be impossible if there were no large amount of surplus grain imported from North China.

Here a seemingly contradictory question arises: Since the AY/N > S type of regions (mainly in the first half of Table 4) are not restricted by a grain shortage and thus are most able to enlarge their vegetable-sown area, while the AY/N = S type and especially the AY/N < S type of provinces (mainly in the second half of

Table 4) are most likely to be restricted by a grain shortage and hence lack the precondition necessary to enlarge their vegetable-sown area, why is it not the former but the latter that have tended to enlarge their vegetable-sown area? This question, in fact, has been answered by Table 2. Its inverse logics tell us that in the former, the land per head is large, the grain yield (the Y level) and labor inputs per ha are still low and far from LTLP, so the potential to raise Y is large and the marginal returns to labor inputs are high and the average labor cost per kg of grain must be low and it is profitable to grow grain. In contrast, in the latter, the land per head is small, and its Y level and labor inputs per ha are very high and close to LTLP. In such a setting the potential to raise Y and the marginal returns to labor inputs approach zero, and hence the average labor cost per kg of grain must become higher and higher and growing grain must become less and less profitable or even loss-making. Given the comparative costs, the state policy since 2004 to subsidize grain farmers according to the area sown in grain has actually widened the income gap between the former and the latter, because under the same grain price level the former's profits are already much higher than the latter's. Therefore, the policy can encourage the former to produce more commercial grain but has little effect on the latter. This further confirms that the same state policy has different effects in different areas, which is not intended by the state but is caused by the physical law of LTLP. Thus the AY/N = S and the AY/N < S types of areas can only depend on changing grain fields to vegetable fields in order to raise marginal returns to labor and income per head.

Since the different cost/return ratios are determined by LTLP, the vegetable yield must also have LTLP, and thus, we may ask, why will the potential to raise Y change from exhausting to increasing when an AY/N = S or an AY/N < S area turns its land use pattern from growing grain to growing vegetables? This is because the biological laws of nature make the growing speed and life cycle of vegetables faster and shorter than that of grain, and hence the number of harvests per year will increase when there is a change in land use from growing grain to growing vegetables. These different growing speeds and life cycles of different crops set by the laws of nature give South China, where vegetables can also grow well in winter, more potential to raise the Y level and returns to labor. Philip Huang (Huang Zongzhi, 2010) further defines China's hidden agricultural revolution as capital and labor dual-intensified farming. This, according to the Heckscher-Ohlin theory (Ohlin, 1933), is because the productive functions of different goods have different factor allocation proportions; for example, vegetable production per se is more labor and technology intensive than grain production and, per land unit, needs more labor, capital,

and technical inputs, such as the inputs in variety selection, proper rotation arrangements, applying fertilizer, watering, regulating soil moisture and temperature, and so on. But in the final analysis this difference still stems from the fact that vegetable production results in more harvests per year and thus growing vegetables has a higher "glass ceiling" than grain production. If there was no difference in their LTLP, the factors to produce both would have the same allocation proportion.

An implication of the Heckscher-Ohlin theory is this: an area with more labor relative to land should, according to its comparative advantage, produce and export labor-intensive goods, e.g., vegetables, and import goods produced intensively by the factor, e.g., land, that it lacks. The above data and analyses show that this regional productive specialization has arisen in rural China, and the areas with more labor relative to land indeed export vegetables after turning grain fields to vegetable fields, and solve the problem of a grain shortage after the fall in their grain-sown area by importing grain from areas with more land relative to labor. Thus, what corresponds to the shift of the growth center of grain production from the south to the north and the pattern that North China exports surplus grain to South China is another newly formed pattern wherein vegetables produced in South China are exported to North China 南菜北运. Furthermore, the new pattern involves a regional concentration of vegetable production, which includes the emergence of (1) a south-southwest winter and spring vegetable production base 华南–西南冬春蔬菜生产基地 in areas of Hainan, Guangdong, Guangxi, Fujian, southern Yunnan, and southern Guizhou, where vegetables grow well in winter and spring, to satisfy the demand of North China for vegetables during that time; (2) a Yangzi River valley winter-spring vegetable production base 长江流域冬春蔬菜生产基地 in areas of Sichuan, Hubei, Hunan, Jiangxi, Zhejiang, southern Jiangsu, and southern Anhui; (3) a Yellow and Huai River valley early spring vegetable production base 黄淮早春蔬菜生产基地 in northern Jiangsu, northern Anhui, and southern Shandong; (4) an autumn vegetable production base 冀鲁豫秋菜生产基地 in areas of Shandong, Hebei, and Henan (Guojia fazhan gaige weiyuanhui, 2012). These vegetable production bases occupy the first 14 places in the increased scale of vegetable-sown areas analyzed above. Hainan is a small province and hence cannot be included in the first 14 places, but the amount of vegetables per rural head sold in 2011 (310 kg) was higher than many other provinces, so Hainan belongs among the main provinces of South China that export vegetables to North China. However, as Table 4 shows, Hainan's increased vegetable-sown area also exceeded its reduced grain-sown area from 1989 to 2010, which made its grain output per head fall to about half of China's

average level in 2010. Hence Hainan is in the same boat with Zhejiang, Fujian, Guangdong, etc., all of which have depended on surplus grain from North China in order to turn from growing grain to growing vegetables.

In sum, the evidence supports the inference made by the theory reflected in Table 2: if the first type of AY/N > S area had no preexisting huge potential to raise grain yields, not only would a classic agricultural revolution not have taken place there, but also the "hidden agricultural revolution" would not have emerged in the AY/N = S and AY/N < S areas. This causality clearly contradicts mainstream thinking about "causality" in China: the two revolutions and changes in production and marketing patterns of China's farm produce, e.g., the long trend of South China's surplus grain flowing to North China was historically reversed to the new trend of North China's surplus grain flowing to South China, and the corresponding flow of South China's vegetables to North China, were caused by China's property-rights and market-oriented reforms. This contradiction must be resolved because causality is a matter of principle that tolerates no reversal, thus we have to answer the following question.

Are the Property Rights- and Market-Oriented Reforms the Origin of the Above Two Revolutions?

The reason we raise this question is that the different cost/return ratios among different areas and between growing grain and growing vegetables, according to the theory laid out in Table 2, are all products of the physical law of LTLP, and hence they exist independently of property rights and markets and cannot be changed by the latter. On the contrary, they can change the latter's role. By briefly reviewing the different histories of the reform of China's grain circulation and vegetable circulation, we can demonstrate that the different cost/return ratios between growing grain and growing vegetables can indeed cause the roles of property rights and markets to differ. But first, we should note that Table 2 first uses its logics to deduce why it is easier to change the circulation of vegetables from the planned to market system than the circulation of grain.

From the supply side, the higher "glass ceiling" of vegetable yields determines that marginal returns will change from falling to rising when there is a shift from growing grain to growing vegetables on the same plot. Hence it is the increasing returns that cause the mechanism of market prices to assume the role of urging vegetable farmers to increase the supply, and not that the mechanism per se can turn marginal returns from falling to rising. From the demand side,

the demand for vegetables positively correlates with the income level. The higher this level, the more vegetables are consumed or the higher the grade of vegetables consumed. The reverse is true when income is low, meaning that a low income or the high price of vegetables per se can reduce the amount of vegetables consumed. The most important thing is that reducing the amount of vegetables consumed does not threaten survival. These features ensure that, when it comes to China's vegetable circulation, transitioning from the planned to the market system should be easy. The price mechanism can promptly increase the supply of vegetables and quickly regulate the relation between supply and demand. And also it will not lead to social crisis by threatening survival.

On the contrary, the above data on the fall in grain-sown area and total grain output confirm that the role of the price mechanism is not to increase but reduce the grain supply of many provinces. Table 2 shows that this is because in the AY/N = S areas the heavy population pressure has made the Y level and labor inputs per ha very close to LTLP, so both the potential to raise Y and marginal returns to labor are approaching zero. This drives the labor cost per kg of grain higher and higher and until it exceeds the gain. If at this time farmers have ensured their own grain rations, reducing labor inputs and the Y level can raise the marginal returns. Thus from the supply side it is LTLP that causes the price mechanism to play the role of reducing rather than increasing the supply of grain. What contradicts farmers' choice is that when an area as a whole is still at the population trap stage of AY/N = S, from the demand side the S level does not correlate to income or the price of grain, that is, both low incomes and high prices cannot lower this level set by subsistence needs. Hence in the AY/N = S areas it is LTLP and subsistence needs that from both the supply and demand sides make it easy for the mechanism of price to reduce the grain supply but unable to lower the demand for grain. As a result, some AY/N = S areas become AY/N < S areas, as shown above. Thus it is also LTLP and subsistence needs that make it harder for China's grain circulation to change from the planned to the market system than is the case with vegetables.

But in the first type of AY/N > S areas in Table 2, the price mechanism plays the role of increasing the grain supply. This is because the light population pressure on land makes the Y level and labor inputs per ha far distant from LTLP, both the potential to raise Y and the marginal returns to labor high, the labor cost per kg of grain low, and returns exceed cost. AY/N > S also means that everyone has surplus grain. From the demand side, it is the surplus above the S level that makes the price mechanism work because the surplus can be sold.

However, the problem that it is hard to sell grain and the price of grain is low also exists in the AY/N > S areas because there is no population pressure forcing the Y level to rise and no shortage of grain driving the grain price up. This internal equilibrium has been broken by China's market-oriented reform and the demand for grain from areas lacking grain. The nationwide rise in the price of grain and profitable opportunities start to urge the AY/N > S areas to tap their potential to raise Y and produce more surplus grain. Therefore in this type of area, it is the low Y level, far distant from LTLP, and with a huge potential for growth and surplus grain above the S level that, from both the supply and demand sides, give the price mechanism the role of increasing the grain supply, and room to regulate the relation between supply and demand. In other words, both of them per se have price elasticity.

But in China this type of area is not widespread. Moreover, in this type of area raising the Y level and the total output of grain year after year is a gradual process, and similarly the growth in both the yield and the total output of grain cannot but be a long process. Reversing the trend of South China producing surplus grain which flows to North China and establishing a new trend of North China producing surplus grain which flows to South China can only happen step by step. This is why transforming China's grain circulation pattern from the planned to the market system is bound take longer than in the case of vegetables.

History has confirmed the above deduction, which is based on the theory contained in Table 2. China's vegetable output per head quadrupled within twenty years, from 81.7 kg in 1980, to 171 kg in 1990, and 334.5 kg in 2000 (Zhang Zhenhe, 2010: table 3). When the price mechanism of the market can lead to an increase in supply like this, it can surely replace the planned system without a hitch. In fact, the transition of China's vegetable circulation from the planned to market system took only about ten years, from 1983, when the state allowed country fair trade to recover and individuals to engage in marketing and the long-distance transportation of vegetables; to 1985, when the state opened or stopped controlling the prices of fresh fruit, vegetables, aquatic products, etc., and directed state-owned trading companies to change from the planned purchase to contracting with farmers for vegetables; to 1985-1991, when the state encouraged the development of vegetable wholesale markets in places of production and places of sales; to 1992, when governments at various levels ended the regulatory regime of vegetable production and circulation and the market system completely replaced the planned system. Within these ten years the trade share of non-state-owned vegetable companies could expand without difficulty and cause the trade share of state-owned vegetable companies to

fall from almost 100 percent to, e.g., 10 percent in Beijing, because the non-state-owned trade companies and the market price mechanism continuously stimulated the supply of production places, and timely linked and satisfied the demand of sales places for vegetables through the above-mentioned balanced, year-round vegetable supply.

Reforming the grain circulation pattern, however, took more than twice as long and experienced several setbacks. The process involved seven stages: (1) 1979-1981, when the state purchase price of grain was raised and the country fair trade in grain was reestablished; (2) 1982-1984, when multi-channel non-state businesses were allowed to trade in grain; (3) 1985-1992, when the grain purchase monopoly was changed to a system of grain contract procurement 改粮食统购为合同定购; (4) 1993-1995, when the state purchase amount was retained but prices were set at the market price 保量放价; (5) 1996-2000, when the "three policies and one reform" 三项政策一项改革 were adopted; (6) 2001-2003, when the policy of opening the main sales areas and protecting the main production areas 放开销区，保护产区 was adopted (the state cancelled orders for grain from the main sales areas and protected the main production areas by opening purchasing at a protective price); (7) after 2004, when grain prices and purchase and sale markets were fully liberated 全面放开粮价和购销市场 (Yan Bo and Chen Yuzhong, 2009).

In this more than twenty-year-long process whenever there was a decline in grain production or supply fell short of demand, the reform went backward. For example, in 1985 when the reform to change the grain monopoly purchase system to a grain contract procurement system had just begun, there was a drop in grain production such that the national per capita output of grain fell by 32 kg compared to the 1984 level. This forced the state to return to the monopoly purchase system, because in a situation where supply fell short of demand, the market contract principle prevented the state from getting the required amount of commodity grain to ensure the urban population's grain rations. The reform of 1993-1995 to retain the state purchase amount but open the grain price at the market price level was surely a more market-oriented reform, but its execution immediately encountered a fall of 11.39 million tons in the total grain output in 1994 and a sudden 40 percent rise in the grain price nationwide, which forced the state to close markets and straighten out non-state-owned grain wholesale firms, so that it could turn danger into safety by having 80 percent of commodity grain in hand. These facts once again show that the state cannot decide what kind of effects might flow from a market-oriented reform it itself designs. All it can do is go backward when it encounters these effects caused by the physical law of LTLP and subsistence needs,

which from both the supply and demand sides make it easy for the mechanism of the market price to reduce supply but unable to lower the S level. This is why when the mechanism could not ensure the urban population's grain rations, the state returned to the method of compulsory state purchases, or used the anti-price method of purchasing from farmers at high prices and selling to city residents at low prices, in order to prevent a social crisis of survival.

Regarding the different transitions of vegetable circulation and grain circulation from the planned to the market system, one can undertake a more detailed review consistent with the above outline but draw a different conclusion: the reason China's grain circulation is much harder to transform into a market system and must take longer than transforming its vegetable circulation is because the control over grain under the planned system was more rigorous than over vegetables. Thus the institutional costs of changing the former are higher than those of the latter (Zhongguo renmin daxue, 2004: 108). But this conclusion puts the cart before the horse. If China were like North America or Australia, where the grain supply always exceeds demand, there would be no need for the state to control and ensure grain security. Hence although the comparison is more detailed than what is outlined above, the conclusion is clearly drawn from North's subjective assertion: ultimately it is the state that is responsible for the efficiency of the property rights structure. The original idea of the two is the same: private property rights and the market system will never play a negative role (Zhongguo renmin daxue, 2004: 108). This idea, however, violates the common sense that everything has both positive and negative roles. It also does not conform to the historical facts: first, although the Chinese state used the same method to reform the vegetable circulation and the grain circulation, the effects were different, and, second, in China's many provinces the market price mechanism has indeed played the central role in reducing the grain-sown area and the grain supply.

By reviewing the history of moderate-scale farming operations in Southeast China, we can demonstrate that non-private property rights and nonmarket institutions have played a more positive role than private property rights and the market system in ensuring the grain security of the AY/N = S areas. It was because of this that the gradual process of reversing the long trend of South China producing a surplus of grain which flowed to North China could succeed and famine could be avoided. In other words, it was the positive role of non-private property rights and nonmarket institutions that linked the two revolutions described above and led to their success. We know that around 1985, when the trend of surplus grain from North China flowing to South China had

not yet taken shape, the rapid development of township and village enterprises (TVEs) in Southeast China led to the following three results. (1) The difference in cost/return ratios between industry and farming induced many villagers to shift from agriculture to industry and voluntarily give up the use rights to their so-called responsibility land 责任田 used to produce responsibility grain 责任粮 for the urban population's food security. This shows that the difference in cost/return ratios between industry and farming had the effect of transforming use rights (making what had been useful into what was useless) because when there were no industrial job opportunities, villagers were unwilling to give up rights that could bring them some income. (2) In order to ensure their own S level, villagers did not give up the use right over the land on which they produced their own grain rations 口粮田. (3) When the huge gap in cost/return ratios between industry and farming shifted lots of labor to industry, it also changed the land/labor ratio from the situation where there was more labor relative to land to a situation where there was less labor relative to land. This shift had many effects: it caused villagers to no longer concentrate on farming; it left much land uncultivated; it removed the role of secure land rights, no matter how long and how stable they were, from encouraging investment; and so on. The result of these changes was that grain production in Southeast China tended to shrink, and it became harder and harder for the village collectives in these areas to fulfill the state grain procurement requirements and ensure the grain security of the entire region.

In order to stop this trend of shrinking grain output and ensure that the state's grain requirements would be met, the village collectives of these areas pooled the responsibility land given up by most villagers and redistributed it to a few households willing to continue farming. This narrowed the income gap between industry and agriculture by expanding the average size of farms, transforming what had been small-scale operations to moderate-scale operations. From the perspective of property rights, the reason this redistribution of responsible land in these areas, especially in southern Jiangsu where TVEs were highly developed, could be quickly implemented was that both rural industry and farmland were owned by the same village collective. When it used collectively owned land to build rural collective industries and created new industrial jobs for the villagers, it had the right to withdraw their rights to use the responsibility land. From the perspective of the villagers, the higher income from industrial wages induced them to voluntarily give up their use right over the responsibility land. And since surrendering the right to land in exchange for the right to industrial employment was equivalent to a job change within

the same organization, what was involved was merely an issue of the internal reallocation of collective resources (Pei, 2002), and therefore had nothing to do with the transfer of property rights in the marketplace.

But it was precisely this internal reallocation of collective resources that directly changed the AY/N = S type of farms into the AY/N> S type, and thus the logics of column 3 of Table 2 were also changing into the reverse logics of column 4: (1) When the average size of family farms in southern Jiangsu expanded from about 3 mu to the AY/N> S type of family farm with about 20 mu, the land allocation system adopted when the household responsibility system was established in 1984—whereby land was fragmentation in such a way that each family farm consisted of several small scattered plots, with some good-quality land, some medium quality, and some poor—was changed so that farmland was consolidated and each family farm was relatively complete. (2) The past logic that the small AY/N = S farms made extremely little use of farm machinery and thus there was no demand for investment in machinery changed to the inverse logic whereby a high demand for machinery emerged in these areas, which created an unprecedented wave of buying farm machinery. (3) Labor productivity changed from the lowest logic shown in column 3 of Table 2 to what can be called a rising logic, because the expansion in land per unit of labor itself can directly increase labor productivity. (4) The logic of farming without a surplus shown in column 3 of Table 2 changed to the logic of farming with a surplus, because AY/N> S per se means there is a surplus above the S level. Moreover, it was this surplus that could be accumulated and used to buy farm machinery. On the other hand, if the AY/N = S type of family farm mortgages its land to secure bank loans, it will almost certainly lose the land and threaten the family's own survival. This is because the extremely small amount of land per head and the continuing diminishing returns result in no accumulated surplus and no repayment capacity.

In sum, the above four changes took place when there was no property rights and market-oriented reform at all, but they did play a role in blocking and delaying—though we cannot say "reversing"—the decline of grain production in Southeast China. In short, it was collective landownership that protected the process whereby the pattern of North China's surplus grain flowing to South China gradually replaced the pattern of South China's surplus grain flowing to North China, and thus ensured the success of the transition. These changes are clear evidence of the change from the logics of column 3 to the logics of column 4 mentioned above, and they have confirmed the dynamic land rights theory summarized in Table 2: changes in the land/labor ratio of the physical world can directly alter cost/return ratios and the logical relations

of the economic world; changes in the cost/return ratio of the economic world in turn directly alter the effects of land rights even if there is no change in the institutional world at all, such as the change of use rights which rendered responsibility land useless, the change of mortgage rights from harmful to useful, and so on.

What, then, is the factor ultimately responsible for the sudden change of the collective village from the AY/N = S type to the AY/N > S type? We know that when a village set up an industrial sector, the sector occupied part of its land and absorbed part of its laborers and the population supported by those laborers. This divided the original land area (A) and number of heads (N) into two parts: $A_iO/N_i > S$ and $A_fY/N_f > S$. A_i is the area of land occupied by industry; O is the output per ha of land devoted to industry; N_i is number of laborers and population who depend on industry to make a living. A_f is the area of farmland after subtracting the land used by industry; N_f is number of laborers and population who depend on farming to make a living. The AY/N = S village suddenly changed to the AY/N > S type because each unit of industry-used land (A_i) can absorb more labor than each unit of farmland (A_f), or industry can use less land to create more jobs and support more persons, and thus enlarge the land per farm laborer and create $A_fY/N_f > S$. This in turn is because O, the output produced from each unit of industrial land, is free of any limit on land productivity. Therefore, once the industrial sector was set up, it was bound to take the $A_iO/N_i > S$ form, and achieve an income per head higher than the subsistence level of the farm sector. Furthermore, its marginal returns were higher than those of farming. These factors thus rendered the use rights of responsibility land useless. Therefore, the origin of all the above changes is that the output of each unit of land used by industry is not constrained by any limit to the productivity of that land.

This confirms the causality Wrigley posited: the basic disparity between an organic economy and a mineral-based energy economy is that the former is bound to make marginal returns diminish, output growth lower than population growth, and income per head fixed at the subsistence level, while the latter can make marginal returns increase (or the unit cost of production decrease), output growth higher than population growth, and income per head rise. In this way, the emergence of the latter can cause the former to jump out of the population trap and change the effects of property rights, meaning that better-defined property rights were the result of the Industrial Revolution and not its cause, as claimed by North. Here, drawing on evidence from Southeast China, we have also confirmed that the concept of the limit to land productivity can more highly abstract the causality of things than Wrigley's concept of organic

economy: the basic disparity between the organic economy and the mineral-based energy economy is simply that the former faces a limit to land productivity whereas the latter does not. All the others are results of this disparity.

It was this disparity that attracted labor to industry and rendered the above four changes unable to stop labor from shifting to industry because the income earned from the expanded farms was still lower than TVE wages. This forced the village collectives of southern Jiangsu to subsidize these farms by dipping into the industrial profits 以工补农, which was a burden on the TVEs and also a cost of responsibility grain. But this cost existed only in areas where TVEs were highly developed and able to pay subsidies. Consequently, the subsidies were used to compensate for the high costs of responsibility grain and prevent the entire labor force from totally shifting to industry, and hence they were not the cause of the high costs of responsibility grain. The cause is still the original AY/N = S situation, where heavy population pressure has made the yield and labor inputs per ha very close to LTLP, and so the marginal returns to labor must be very low and the average labor cost per kg of grain must be very high. This explanation does not contradict the above-mentioned rising returns to labor caused by the expansion of the size of farms, because this rise differs from the rise in the first type of AY/N > S areas, where light population pressure on the land makes the yield and labor inputs per ha far distant from LTLP. Thus in the future the level of Y and marginal returns to labor can rise simultaneously. But in the AY/N = S areas the marginal returns to labor must further diminish in the future, and so the returns to labor rise only in comparison with the small farms of the past; that is, the only way to raise the average returns per laborer is to suddenly expand the land per laborer when, in the future, it becomes difficult to raise the Y level.

But after an expansion of land per laborer and hence a fall in labor inputs per ha, these areas, such as southern Jiangsu and Beijing's Shunyi county, could begin to replace labor with capital. Indeed, their average investment in irrigation works, farm machinery, etc., rose up to 1,000 yuan per mu (Zhang Yixin, 1997: 127). This includes investment by households specialized in growing responsibility grain 种责任田专业户 as well as investments by rural collectives in the form of pumping TVE industrial profits directly into agriculture. The latter was another way of subsidizing agriculture by industrial profits. This shows that these areas must use more total factor inputs per ha than in the past to ensure the S level, and that although the areas' family farms had changed from the AY/N = S to the AY/N > S type, the region as a whole was still the AY/N = S type. Because of population growth some provinces even became the AY/N < S type, which lacks grain, and hence must use increasingly high costs to stop

the downward trend of grain production. This is why I have pointed out in an earlier section of this article that the logics of column 3 of Table 2 are the historical legacy of these areas, a legacy that is tenacious and prevents them from changing to the inverse logics of column 4.

This policy of combating the decline in grain production by turning the equalized small family farms into moderate-scale family farms plus using industrial profits to subsidize the expanded farms 以工补农 lasted about twenty years. It accomplished its historical mission by 2001-2003, at which point a new policy of "opening the sales areas and protecting the production areas" 放开销区，保护产区 was adopted. The so-called opening the sales areas involved ending the state's assigned grain procurement and opening prices and markets in eight main grain sales areas: Beijing, Tianjin, Shanghai, Jiangsu, Zhejiang, Fujian, Guangdong, and Hainan. The so-called protecting the production areas involved the unlimited purchase of their surplus grain at a protective price, especially in the new grain-growing center in North China. According to my investigation in southern Jiangsu in 2003, this market-oriented reform was nothing but an endorsement of a preexisting pattern whereby the AY/N < S type of the main sales areas must depend on surplus grain of the AY/N > S type of the main production areas to ensure their S level (grain rations). Table 4 shows that the per capita grain output of Jiangsu province as a whole was 415 kg in 2010—slightly higher than the national average of 409 kg in that year—but southern Jiangsu had fallen into an AY/N < S crisis long before that. Its per capita share of grain output was 266 kg in 2002 and only 227 kg in 2008, while the per capita grain output of central Jiangsu and northern Jiangsu rose, respectively, from 443 kg and 495 kg in 2002 to 516 kg and 630 kg in 2008 (Jiangsu tongji nianjian, 2003-2009). In other words, the growth center of grain production in Jiangsu province, as is China as a whole, has moved from the overpopulated southern region to the relatively underpopulated central and northern regions. The success of the opening the main sales areas and protecting the main production areas reform, then, cannot be attributed to the market per se, but rather to the surplus grain imported from AY/N > S underpopulated areas and the fact that such grain costs less than the responsibility grain of AY/N < S overpopulated areas.

This cheap surplus grain of the underpopulated AY/N > S areas exported to the overpopulated AY/N < S areas had four important consequences. (1) Opening the grain market and liberalizing grain prices of the latter did not make the grain price soar as happened several times in past reforms. (2) When the former's cheap surplus grain replaced the latter's high-cost responsibility grain, it ended not only the latter's grain fulfillment task, but also the latter's

institutional arrangements designed to complete the task, e.g. responsibility farmland, specialized farm households using the land to complete that task 种责任田的专业户, using industrial profits of TVEs to subsidize these households, etc. (3) These changes in turn made it possible for villagers to respond to the different cost/return ratios between industry and farming, with the result that, freed from obstructions, all the local villagers were attracted to industry and all the local farm households disappeared. In the several villages that I surveyed, every family retains land for producing grain for their own consumption 口粮田, but none of them specialized in farming. Village cadres explained this phenomenon thus: "In the past to complete the state grain ordering task, we had spoken all the good words and used all the means [at our disposal]. Changing small-scale family farms to moderate-scale family farms and using industrial profits to subsidize the expanded farms can fill the income gap between industry and farming, but can't change their difference in labor intensity. Farming, especially during the busy season, is much harder than working at the factory regularly eight hours a day." (4) Because the grain ordering task and the system of responsibility land had ended and the local farm households had all disappeared, the village collectives leased all the responsibility land to laborers from Anhui, northern Jiangsu, and elsewhere, and the rent was paid to each local household according to size of its responsibility land, which had been divided among households in 1984 when the household responsibility system was set up.

This was how factor markets, e.g., land rental and labor markets, emerged in southern Jiangsu. This chain of changes confirms the inverse logics of Table 2: the logics of column 3 that the right to transfer land use rights to laborers from outside, the land rental market, and the market mechanism do not work were transformed into the logics of column 4 that they start to work. These changes also support the dynamic land rights theory outlined in Table 2 that changes in the land/labor ratio first alter the cost/return ratio and then alter the pattern of land rights. Evidence from southern Jiangsu shows that these institutional changes indeed took place last and they were result of the cheap surplus grain imported from North China.

If the market system had been allowed to work before this importing of grain, for example, in 1985 when TVEs developed rapidly in Southeast China and induced local villagers give up their use right to responsibility land, it would have quickly driven the entire region into famine. First, unlike the internal reallocation of collective resources, which can combat a grain production decline by changing equalized small family farms into moderate-scale farms almost overnight, the market system must go through a long process of

repeated transfers of land use rights or sale and purchase of land to enlarge the average farm size. Second, even if it has enlarged the average farm size, the market mechanism still cannot create an incentive to grow grain in southern Jiangsu, where the heavy population pressure has made the grain yield (Y) and the amount of inputs per ha extremely close to LTLP and hence the cost of growing grain is so high as to exceed the returns. This has been confirmed by my investigation. After the stage of moderate-scale operations, the land size leased by rural collectives of southern Jiangsu to each outside farmer was about two hectares, but all the market-oriented moderate-scale farms did not grow grain but grew high-value products, such as vegetables, flowers, strawberries, and even miniature trees. Among these outside farmers was a horticulturist who rented more land than others and largely grew these products using hired labor. These facts confirm the judgment made above: the nonmarket system has played a positive role while the market system has played a negative role in ensuring the grain security of the overpopulated AY/N = S and AY/N < S areas.

Statistical data also support this judgment and the results of my investigation. The per capita grain output of Jiangsu province reached its historical peak of 545 kg in 1984, then began to fall slowly. In 1999, that is after fifteen years, it had fallen to 495 kg. Thereafter it started to fall sharply, from 427 kg in 2000, to 401 kg in 2001, 395 kg in 2001, 395 kg in 2002, down to its historical low of 334 kg in 2003. It rebounded to 415 kg in 2010 entirely because of the rapid growth of grain output in northern and central Jiangsu (Jiangsu tongji nianjian, various years). That the per capita grain output of Jiangsu province fell only by 50 kg from 1984 to 1999 was no doubt a result of the internal reallocation of collective resources, which combated the grain production decline, while its sudden fall by 161 kg in the 2000-20003 period was also surely a result of the market-oriented reform to open the main sales areas and to protect the main production areas. This is fully consistent with what happened in the provinces of Zhejiang, Fujian, and Guangdong. In the 2001-2003 period when the grain ordering task of Jiangsu, Zhejiang, Fujian, and Guangdong was canceled, their grain-sown areas largely fell—respectively by 55 percent, 45 percent, 44 percent, and 38 percent of their totally reduced grain-sown areas of the twenty-one years from 1989 to 2010; between 2001 and 2003 the four provinces' increased vegetable-sown areas were respectively 33 percent, 53 percent, 17 percent, and 27 percent of their totally increased vegetable-sown areas for those same twenty-one years. These data show that the grain and vegetable planting structures in the four provinces achieved a "revolutionary" transformation in the 2001-2003 period, and also reveal the source of the transformation: the large import of

cheap surplus grain from North China made it feasible for these areas to reduce their grain-sown area without running the risk of starvation, and the reduction in the grain-sown area in turn provided the supply of land for enlarging the vegetable-sown area. Therefore, it was the import of cheap surplus grain from North China that, in these areas, ensured the success of the "hidden agricultural revolution."

In sum, these data once again confirm the inference made at the start of the section above on the origin of the grain supply behind the hidden agricultural revolution based on the inverse logics of Table 2: if China had no AY/N > S type of underpopulated area with a huge preexisting potential to raise the grain yield, the price mechanism of the market would have led neither to the classic agricultural revolution in North China nor the "hidden agricultural revolution" defined by Huang. First of all, markets cannot create the AY/N > S underpopulated areas shown in column 2 of Table 2. Second, it was the huge potential to raise the level of Y in these areas that provided the prerequisite for optimizing resource allocation nationwide and allowed the market to play a role in increasing the grain supply; that is to say, it was not the market itself that embodied the role of increasing the grain supply. Its role in overpopulated areas was merely to reduce the grain supply. The Heckscher-Ohlin theory also does not regard the market as the cause of regional specialized production and the optimal allocation of resources. The theory admits that interregional trade is based on Ricardo's comparative costs, but it tries to find what causes comparative costs. For this it assumes that the productive functions of different goods have different factor allocation proportions, but the productive function of any kind of good is identical in all regions or countries. Based on this assumption, it attributes comparative costs between regions or countries to their difference in resources or productive factor endowments, meaning that different land resources per head rather than markets are the cause of regional specialized production and the optimal allocation of resources. It holds that the market free trade in goods (e.g., grain and vegetables) can substitute for the flow of productive factors (e.g., land, labor, etc.) and thus can finally equalize factor prices (including absolute and relative prices) between trading regions. Hence if each of China's regions was the overpopulated AY/N = S type, they would have no difference in land resources per head, in comparative costs, and in factor prices, and thus the market would be unable to optimize resource allocation and equalize factor prices.

However, there is a reason why in attributing the comparative costs between regions to their difference in resources endowments the Heckscher-Ohlin theory depends the assumption that the productive functions of different goods

have different factor allocation proportions while any kind of good's productive function is identical in all regions. The reason is merely that it does not know what causes comparative costs. By comparing the production of two kinds of goods, grain and vegetables, I have shown that their difference in factor allocation proportions and in comparative costs both stem from the fact that they have different limits to land productivity, or "glass ceilings." Second, to attribute the comparative costs between regions to their difference in resources endowments is equivalent to saying that different land sizes per head can cause comparative costs. This, however, is untenable because if yields were unlimited, farm outputs would, like industrial outputs, not correlate to land size but to labor and capital inputs. In that case, the same amount of labor inputs to 1 ha and to 100 ha would get the same result in terms of outputs or returns. If this were so, the difference in the land/person ratio would never cause comparative costs. Therefore, the origin of comparative costs is the limit on land productivity. That is to say, the ultimate reason why the comparative costs to grow grain are low in the AY/N > S type of area and thus the market mechanism stimulates it to grow and export more grain is not more land per head, contrary to what is suggested by the Heckscher-Ohlin theory, but that the Y level and labor inputs per ha are still far distant from LTLP. The ultimate reason why the comparative costs to grow grain are high in the AY/N = S type areas and in the AY/N < S areas and hence the market mechanism does not stimulate them to grow grain is also not that there is less land per head, as proposed by the Heckscher-Ohlin theory, but that their Y level and labor inputs per ha are too close to LTLP.

Here my argument is that the Heckscher-Ohlin theory ignores the factors that stop it from working, that is, when the surplus grain of AY/N > S areas is insufficient to ensure the S level of the AY/N = S areas or the AY/N < S areas, these areas will not, according to the theory, engage in specialized vegetable production by turning grain fields to vegetable fields but instead will use every nonmarket means at their disposal to combat the role of the market. This is because the S level set by the survival principle is not related to the mechanism of market prices and thus cannot be regulated by it. On the other hand, when heavy population pressure in the AY/N = S and the AY/N < S areas has made the Y level very close to LTLP, the marginal returns must be very low or the average costs per kg of grain must be very high. Hence in the final analysis it is the survival principle and the limit to land productivity that are forcing these areas to use nonmarket means at any cost against the role of the market mechanism. The above historical review also shows that the two factors have invalidated the Heckscher-Ohlin theory.

Conclusion

This article has, from the supply side, substantiated China's "hidden agricultural revolution" as advanced by Huang (2010) and simultaneously demonstrated the validity of each set of the inverse logics and the dynamic land rights theory in Table 2. In the objective materialist tri-world system described in Table 2, the institutional and economic worlds are results of the relation of population to land resources in the physical world. Like other things, the institutional world's private property rights and market system have both positive and negative roles. This is caused by the physical law of the limit to land productivity and has nothing to do with the state. But in Douglass North's subjective idealistic world, it is exclusively private property rights and the market system that cause growth; they play a purely positive role. Thus stagnation or economic decline must be the result of nonmarket systems and non-private property rights created by the state. This logic means that the state not only can avoid the physical check of LTLP and unilaterally shape the property regime however it wishes, but also can decide what results will flow from the regime it has designed. This violates common sense and cannot withstand the test of history. Chen Xiwen (2012) suggests that, from a historical perspective, we should distinguish between the different types of rural social and economic formations in Eurasia and the New World before the Industrial Revolution, but he provides few specifics on the distinction. Each set of inverse logics in Table 2 makes a specific distinction. The table in effect argues that the New World countries did not experience the population trap stage and the strong physical check of LTLP, so their transition from the AY/N > S stage before the population trap (column 2) directly to the AY/N > S stage after that trap (column 4) was easy and faced no logical conflict. Their uninterrupted growth and market and private property rights systems are the inevitable results of this unique history, not a so-called product designed by the state. As the world's largest overpopulated country in the population trap for a long time, China is trying to move from the AY/N = S logical system (column 3) to the inverse logical system of AY/N > S (column 4). Though this article has only analyzed a slice of this process, it has revealed numerous obstacles and logical conflicts in this kind of transformation.

At this historical juncture, Huang, Gao, and Peng (2012) suggest that China faces a crossroads: should the basis of its main engine of production, the "hidden agricultural revolution," be changed from the current small family farm under collective landownership to the capitalist mega-farm worked by hired labor? According to North's "causality," the latter has both more exclusive

property rights and purer land and labor markets, and thus should be more able than the former to stimulate growth.[3] But Huang, Gao, and Peng have pointed to the facts to refute this causality: India's free exchange of land has created most of its poverty population—whose with an income of less than US$ 1.25 a day—with the result that the proportion of the landless population mushroomed from 25 percent in 1961 to 45 percent by 2000. China, where there is no free exchange of land, has neither landless peasants nor hired farm labor. If we turn to the theory laid out in Table 2 to explain this disparity, we could say that when both rural China and rural India were at the population trap stage of AY/N = S, China's land rights pattern matched this stage's logic. But India adopted the land rights pattern of column 4, which did not match this stage's logic and harmed the general social welfare. In the long run a good match will transform the AY/N = S stage to the AY/N > S stage more smoothly. This is the relation labeled *e* in Figure 1 earlier in this article, the key to policy-making. Its logic is similar to that in the comparison made above: if China had allowed the market mechanism to work in 1985 when TVEs developed rapidly in Southeast China and caused local villagers give up their use right to responsibility land, it would have experienced more difficulties and paid a higher price for completing the "hidden agricultural revolution." In sum, the theory laid out in Table 2 is the opposite of Douglass North's misleading state theory: the state can decide on the country's land rights pattern, but it cannot decide what kind of effects will flow from the pattern it has chosen. Hence it should select land rights patterns according to their real effects rather than the effects subjectively derived from North's "theory."

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[3] "The essence of property rights is the right to exclude" (North, 1981: 21).

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