11: CHINA'S EARLY INDUSTRIAL REVOLUTION AND ITS ANTECEDENTS (10/87r; 7/89e; 10/94e, 8/95e, 9/96e)

a. When and under what circumstances did China catch up with and then move ahead of Western Eurasia technologically and in economic development? When, and why then, did Western Christendom begin to catch up with China again? What are the limits to the role of technology in economic development?

b. How might one functionally define an "early industrial revolution" in a way that distinguishes it from pre-industrial and full industrial stages? When did China's early industrial revolution begin, and what role did innovations in agriculture, transportation and manufacturing techniques at specific times play in its development? What factor was more fundamental than technology?

A. The Longest Term Economic Cycle

1. Ancient China catches up

Possibly because the western part of its heartland, Zone B, came out of the last ice age later than did most of Western Eurasia, the Chinese started out on the road to civilization and in the sophistication of its technology way behind the Middle East.

The Neolithic Revolution—at least the early, non-revolutionary parts of it—started about 10-8,000 BC in Western Eurasia and c. 6,000 BC in East Asia, a 2,000 year difference. Two thousand years is a long time in terms of an individual human life.

The Bronze Age started c. 4,000 BC in Mesopotamia and only c. 2,000 BC in East Asia. The Iron Age finally started about 500 BC in East Asia, but somewhat earlier—between 1,000 and 1,500 BC amongst the Hittites in what is now Turkey.

So the Chinese were closing the gap. By around 500 BC they had essentially caught up.

Perhaps China finally caught up after the last delay of less than a millennium because it went through a feudal process. Iron was known in China by the early part of the Zhou Dynasty, only a few centuries after it appeared in the West. But only a few pieces of meteorite iron appear in early Zhou sites.

The Chinese do not seem to have done much with iron until Spring-Autumn times, toward the end of the feudal process. Iron only became ubiquitous during Warring States times, and steel did not replace bronze in swords until Western Han.

Since iron only became common as defeudalization evolved into a number of centralized feudalisms with monetizing markets, it is tempting to connect iron's spread with this blossoming of the market economy during the latter part of the feudal process. Each of the centralizing feudal principalities contained a capital city and a number of subfief towns, among which there was much trade. This provided a market for, among many other things, objects made of iron.

2. China moves ahead

If China may be said to have caught up with the West technologically by Warring States times, it appears to have started to move ahead during Han.

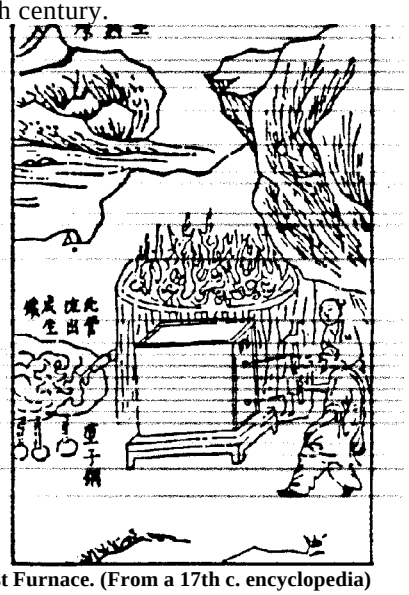
The Chinese produced iron from what amounts to a blast furnace from the very beginning of their iron age. The blast furnace merely extended the methods long used to smelt copper and even to bake pottery as far back as Neolithic times.

Yangshao era pottery was baked in a high-temperature kiln located on the side of a hill, with the fuel below the baking area. Shang period bronze smelters evolved this separation of combustion from heating further. The bronze smelter focused the heat from a separate burning chamber into the upper chamber where the copper was being smelted.

The proto-blast furnace was almost identical. Eventually, a double-acting piston bellows was attached to the smelting chamber. It provided a steady blast of air to oxidize impurities in the iron ore. The resulting molten high-carbon cast iron was then poured into clay or sand molds to produce a variety of useful objects.

This turned out to be much more productive than the characteristic West Eurasian technique of conjoining combustion and smelting by banging out the impurities from iron ore in an open hearth. This produced low-carbon wrought iron, which was then carefully turned into steel for very expensive objects, like swords, by banging a little bit of carbon back into it.

This West Eurasian process was profligate of both fuel and labor. The Chinese smelting process saved both fuel and labor, and produced an end product—cast iron—useful for many more things than either wrought iron or the expensive specialty steels that can be produced from wrought iron. The blast furnace did not reach the West until the 15th century.



Blast Furnace. (From a 17th c. encyclopedia)

We might also recall that the Chinese used a cast (rather than stamped) bronze coinage. Hand casting was cheaper than hand stamping. Casting coins justified using cheaper bronze rather than gold or silver, which were not easily available to ancient China anyway. Bronze coins could be more widely and frequently used to buy

cheaper goods more extensively than could the much more expensive gold and silver stamped coinage of the West.

Since both its technology and immediately post-feudal socio-economic order were superior to West Eurasia's, it is not surprising that China should have finally moved ahead of the West for the next dozen and a half centuries, from c.200 BC to c.1500 AD.

The Han universal state lasted at least as long as the Roman Empire in the West remained a coherent entity. Its form of organization survived its death. The pieces into which Han broke during the age of the Northern and Southern Dynasties started large and remained much more coherently governed than did post-Roman Empire Western Europe.

As a consequence, the broad, fairly secure market area of late ancient times in China continued to exist during the period of nominal disunity between Han and Sui-Tang times. Instead of a "Dark Age" of economic contraction, the Chinese economy then seems to have shot even further ahead of the West's.

The Northern Dynasties added trade with Central Asia and West Asia to their domestic market. The Southern Dynasties carried Han Dynasty marketing techniques further south into subzones B3, B4, and C2. They also began to trade with ships coming from the Middle East.

China's superiority continued to increase during Sui and Tang times. Markets became more complex. They added credit moneys and credit institutions which operated in time markets as well as in ever larger markets for goods and services for immediate delivery.

Perhaps by late Tang, and certainly by early Song, the Chinese economy had reached a level that we can plausibly label an "early industrial revolution." This is the stage (to be defined more precisely below) that has so substantially departed from the pre-industrial stage of development that it anticipates some key aspects of fully industrial life.

Song appears to have shot way ahead of most areas of contemporary Europe as it matured this early industrial revolution. By the 11th century, Song China reached a level of development that the Low Countries (Holland and Belgium) did not achieve until the 13th century, that England did not attain before the beginning of the 17th century, and the rest of Western Europe not until the mid to late 18th century.

3. Europe catches up

Nevertheless, at the very time of China's apparently greatest lead, Europe was actually beginning to catch up with it. Europe went through its own feudal process between roughly the 9th and the 14th centuries AD. By the 12th and 13th centuries, it was moving into the latter part of defeudalization, and beginning to get the same sort of stimulative effects from defeudalization that China had enjoyed 2,000 years earlier from its feudal process.

By the early 17th century, England, probably stimulated by the still earlier Netherlands and Belgian early industrializations, was also enjoying an early industrial revolution.

Only 150 years later, by the late 18th century, England "took off," as the saying goes among economic historians, into a "*full* industrial revolution." The other developed parts of Western Europe followed in England's footsteps and also passed China during the 19th century.

China was *not* regressing. Its economy continued to grow at least as fast as its population, and often faster than that. So it never regressed back from the early industrial stage. It was just that Europe had leapfrogged past it to the full industrial stage.

The world economy had completed a very long cycle: The East had started behind at the beginning of the run towards early civilization, had caught up by Warring States times, shot ahead by Han times, and remained ahead until just a few centuries ago. But then it fell behind again, starting a new long cycle.

Mediocre economic performance by industrialized Western countries since the '60s, and China's recent double-digit growth rate may be evidence for a new phase in this longest of economic cycles: It may be our turn to fall behind again.

Perhaps not too much significance should be attached to this long-term economic foot race. By comparison with the whole 300-900 century course of the history of our species, temporary lags or leads of half a dozen centuries may not amount to much.

It is one of the virtues of a broad survey course like this that it places such lags and leads in a reasonable perspective.

B. Defining an "Early Industrial Revolution"

1. Help from economic theory

a. 11th century China & 18th century England

Our next task is to define what we mean by "industrial revolution," and in particular to define the difference between "early" and "full" industrial revolution.

This is not a trivial issue, one involving mere labels. If we just look at the technology involved in industrialization (as I did in part A), we might be tempted to equate 11th century China with 18th century England, and this would be a mistake. England made more use of the shared technology

Both Chinese and English iron manufacturers invented the process of turning coal into coke (coal charcoal) and used coke to replace wood charcoal in smelting cast iron in blast furnaces. Both cultures' horologists invented or further developed true clockwork mechanisms.

Still other inventors in 11th century China and 18th century Britain created (or designed on paper) automated spinning and weaving machinery, canals fitted with double canal locks to move vessels up and down hills, and new shipbuilding and navigation techniques which permitted much larger cargoes to be reliably carried between continents on the high seas.

Both economies witnessed the takeover by the rulers of new forms of

money and credit institutions created in the markets earlier.

Nor did their annual growth rates *per capita* differ by much. Both were only c.0.5%, though by 1750 England was sustaining a 1.5% *absolute* growth rate and China's was perhaps less than 1.0%. Its much larger population was growing at a much slower rate than England's. As we will see, however, this small difference in the absolute growth rates turns out to be very significant.

The biggest difference only shows up when we examine post-11th century Chinese and post-18th century English history. England proved to be the immediate progenitor of all full industrial economies since then, but post-11th century China turned did not begin to turn full industrial until after the late 19th century. Even then, it only did so after being stimulated by Western contact.

To explain this difference, we must back off from historical narrative for a moment and see what light economic theory can shed on our problem.

b. technology vs savings/investment

Surprisingly, good economic theory tells us that technology is of less *immediate* importance for economic change than the propensity to save and use savings to invest in technology. We normally have many technological "recipes" sitting unused in the textbooks because we lack the savings to use to invest in these recipes.

All other things being equal, only increased investment can lead to any growth at all.[1] Repeated increases in investments beyond the savings devoted to repairing and replacing old machinery are needed to achieve an increasing growth rate.

And growth is the key. It is only after contemporaries perceive that a certain rate of growth is being achieved that we will find later economic historians applying the label "industrial revolution" to a particular historical epoch.

When the perceived growth rate approaches a compound rate of 0.75% to 1.0% per annum (in absolute, not per capita terms) compounded annually, the economy has reached the threshold of an early industrial revolution. When that rate comes to consistently exceed 1.5%, compounded annually, the first full industrial revolution has arrived. During later stages of full industrialization the compound annual absolute growth rate shoots past 2% to occasionally hit 3%, and eventually hits low double digits.[2]

What is the justification for settling upon these rates of growth as significant, and why worry about investment? The second of these questions is a matter of logic, so let us take it up first.

For an economy to grow, people must shift more of their expenditures than before from current consumption to savings. These savings must then be applied to investment. People must be hired to build things embodying new recipes (or build more old style machines). The new production from these investments increases the growth rate of the economy.

As an economy moves closer toward and then into an industrial revolution, it moves away from direct production of final consumption goods and toward an ever larger proportion of its economic activity consisting of indirect production. People produce ever more goods (called producers' goods) which are not themselves consumption goods, but which (with some delay) produce far more old and new kinds of final consumption goods than would otherwise be possible.

All the new technologies described in parts C and D below involve increasingly indirect production: Some new thing, not in itself a consumption good, must be produced first so as to produce many more and new consumption goods later.

This is not just an empirical observation. It is logically necessary (assuming we know what we are doing) that indirect production be much more productive than direct production. This is because we all prefer, all other things being equal, to consume *now* rather than to consume *later*.[3]

If it is true that we will always produce our consumption goods in the most direct way that we can, because that is the way to consume more of them sooner, we will only choose *indirect* production methods—i.e. methods that take longer to produce consumption goods—when we are pretty sure that those indirect methods will be so much more productive than the direct methods they replace that we will feel compensated for having had to wait to consume the goods they produce.

c. Crusoe economics

Eugen von Böhm-Bawerk (1851--1914), the Austrian School economist who first clearly elucidated this insight (his picture is on the five mark note), had a pupil, Friedrich von Wieser, who applied it to the situation faced by the fictionalized character created by Daniel Defoe, Robinson Crusoe, on his desert island. That illustration may help you to understand the implications of the general principle of indirect production.

The novel begins with Crusoe marooned by his shipmates on a deserted Caribbean island. He awakes on the beach, stands up, dries himself off, and realizes he is ravenously hungry. And so he begins to pluck berries by hand off the bushes near the beach.

Crusoe was engaging in direct production of berries. He "produced" berries (as economists use the word "produce") "directly" by picking them off the bush and bringing them directly to his mouth, not taking any time to create or use any tools.

After a while, the edge taken off his hunger, Crusoe begins to fill his pockets with berries upon which he might nibble while he thought his situation through.

[1] At first blush this may seem to contradict ideational determinism. However, if we imagine the circumstances of the first use of technology, as approximated by Crusoe's invention of the stick for knocking down berries too high to reach by hand (see below), it is clear that the *idea* for the stick had to come first, but Crusoe then had to divert labor from direct production of berries to stick manufacture (i.e. to capital building.

[2] We need not worry much about the much feared population explosion. Population growth rarely goes above 2-3% per annum, and within a few generations after full industrialization starts, it invariably falls well below 2%. China's population, for example is now growing at less than 1.5%, but its economy is growing at an 11-12% absolute rate. The absolute numbers of new Chinese—14 million new people annually—are daunting, but misleading. Cf. chapter 18 for a fuller treatment.

[3] If you were so imprudent as to deny this as you sit down to lunch, I would be justified in snatching the plate from your hands. Should you ask when I will return it, I could logically answer, "later," but need never actually give you your lunch back, since you will always prefer lunch later to lunch now.

Unbeknownst to himself, he was "saving" berries while he thought up new recipes for producing berries and other goods.

"I can," he eventually decides, "produce berries far more productively if I break off a stick from a tree, trim it carefully, and then use it to knock berries off the tops of the bushes. Berries seem to grow much thicker up there, and anyway I've already plucked most of the berries growing within hand's reach.

"But, I will not be able to keep picking berries while I seek out an appropriate stick, break it off and trim it, and learn how to use it most efficiently. I will have to pick some extra berries first, and eat a few of those while I produce the stick. Still, that is a good deal. I will consume so many more berries later as to compensate for consuming fewer berries now."

While he produced the stick, Crusoe lived austerely off the berries he had previously put in his pockets. By saving berries, devising the recipe for making a capital good (the stick), and then actually beginning to produce the stick (finding a broken branch, taking the shoots off it, etc.) he had begun to shift from direct to indirect production.

Clearly, Crusoe was better off for having gone into indirect production. That feeling was surely justified, if only from his point of view. Also, the number of his options had increased. Once the stick was finished, he could use the greater berry productivity of the stick to eat more berries, or collect the same number of berries as before more quickly and enjoy some leisure for further thought. Eventually he would design and build other tools and start producing a house, weapons, a new shirt, etc.

He had, however, committed himself to beginning a rather elaborate ongoing process. The first stick was bound to wear out sooner or later, and so he also had to budget time at intervals to produce new sticks. But since he was a man of England's early industrial stage (living in the mid 17th century), the habit of producing indirectly had already been fixed in his behavioral repertoire well before his abandonment on the island.

The Arawak Indian who later joined Crusoe on the island and whom he called Friday had to be carefully coached to help produce these tools of indirect production since his culture did not encourage him to compare consuming less now to consume more later.

Of course most production processes are much more complicated than Crusoe's shift from direct berry production to production by stick, but the principle remains the same: To shift to indirect production one must take time and save to support one's self while one thinks of a recipe that will be more productive as well as more indirect. Then, one must save so as to invest in realizing that recipe, and be patient until the new process has been completed. Also, one's social institutions ought to encourage both saving and thinking up new recipes.

d. growth rates

We can now return to our first question, on the significance of growth rates that approach 1% and then approach and exceed 1.5%, compounded annually. That question turns out to have a more empirical answer: Growth does not seem to be perceivable within single human lifetimes if it is occurring at rates much below 1% per annum, a rate which doubles the quantity of goods produced during a lifetime of about seventy years.

If none of the primary sources dealing with a period mention growth, then growth must be absent or occurring at well below a 1% rate. When the sources begin to talk of growth, the growth rate must at least be approaching 1%.

We can approximate the link between the growth rate and increases in the absolute level of production, by employing the bankers' "rule of 72" to measure the number of years it takes to double production at any given compound growth rate: We simply divide the growth rate into 72 to get the number of years it takes for the sum being compounded at that rate to double.

We can imagine the sum to be any of the commonly used measures of general economic activity, including Gross National Product (GNP)—the sum of all the market transactions and tax payments made by the people in a nation. I prefer Net Private Product (NPP) which excludes all government activity.

It does not matter which we use, since we could never actually calculate either GNP or NPP reliably even for this century. For earlier times, all we can attempt to do is indirectly guesstimate the growth rate of GNP or NNP by interpreting anecdotal evidence. Since a 1% compound growth rate will double GNP in 72 years (i.e. divide 72 by 1), we will begin to get anecdotes about growth as the growth rate closes in on 1%. With a 2% growth rate, GNP doubling will only take 36 years (72/2) and growth anecdotes will multiply disproportionately over time.

Even something approaching a 1% growth rate is high enough to make a visible difference within one person's lifetime. We begin to find in the primary sources increasing numbers of anecdotes running to this effect: "When I was a boy, I remember that this was a small town, with farms just outside the walls and in some neighborhoods even within its walls. Now the city has spread for miles beyond the walls and gardens have become rare inside the walls."

In China, such anecdotes only begin to appear in significant numbers by late Tang times and they proliferate in Song primary sources. Similar stories appear in 13th century Dutch sources and in those for Elizabethan England.

So even though there were no statisticians back then collecting GNP data, we can nevertheless infer a growth rate in China that was approaching 1%, if not by late Tang, then certainly by early Song times. That rate was sustained for a century or more then and several times thereafter.

Anecdotes reporting runaway growth —doublings between a man's youth and middle age—allow us to guess when the growth rate has passed 1.5 percent, the next threshold—the one which separates an early from a full industrial revolution.

If you are nervous about relying solely on anecdotal evidence, good economic theory also suggests that collecting data on changing market interest rates will often also provide clues on changing growth rates.

2. A clue from interest rates

a. interest rates, indirect production & growth rates

There seems to be an inverse relationship between the rate of increase in indirect production measured by the annual compound growth rate and the rate of fall in the "pure interest rate." The pure interest rate is not merely "the price of money." It is also the premium that people insist on getting later for postponing consumption now.

Therefore, at least a loose relationship must exist between the interest rate and the rate of growth in the proportion of production that is indirect. Since we have some data on interest rate changes over time, particularly for China, we might be able to use rises and falls in the interest rate over long periods to infer something about changes in the rate of growth.

When people are willing to accept a smaller premium for giving up present consumption, we can say that their *time preference for present consumption* has *declined*, or to abbreviate an awkward locution, that their time preference has declined. A lower time preference results in a lower pure interest rate; a higher time preference in a higher pure interest rate.

If people are more willing to postpone consumption, they will demand a lower premium for doing so. That premium is the pure interest rate. So, as interest rates fall, the quantity of indirect production will increase, and so will the rate of growth.

This is important because it allows interest rate trends to tell us what is happening to growth rates when little other relevant information may be available. Government statistical bureaus only started trying to measure national product more or less directly a couple of generations ago, and do not do so very accurately even now.

It so happens, however, that even Chinese official historical primary sources often mention interest rates, since Chinese governments have always tried to intervene in markets so as to change rates.

If we see market or even officially fixed interest rates going down over long periods of time, we can be tolerably sure that the pure interest rate is probably also declining. The pure interest rate is the market rate purged of risk and inflation compensation premiums, leaving only the pure premium for postponing consumption.

The very fact that we are comparing differences between average market rates between two long-term periods, allows us to assume that the difference represents a decline in the pure rate. Rises and falls in the risk and probably the inflation premiums will likely cancel each other out over the long run.

A long-term *decline* in this pure interest rate from one period to another is a rough indirect measure of *increases* in the proportion of indirect production. That in turn suggests an increase in the growth rate between the first and second period.

b. historical evidence on interest rates

Interest rates are not mentioned in the Chinese historical sources before the Han Dynasty.

Even the few interest rates mentioned during Han may have been phony—just a measure of the extent to which tax collectors were skinning tax payers over and beyond the set tax rates. Officials sometimes forced taxpayers to pretend to borrow money from local bureaus and then pay it back with a premium added. The officials called this disguised surtax the interest rate, pocketed it themselves, and only passed on the principal to the central government.

This "interest" would not have been a reliable measure of time preference, unless its rate was set in imitation of real interest rates on actual markets. Unfortunately, if they existed, market interest rates are not mentioned in the extant Han sources.

Given the fact that Buddhism had not yet appeared to create the Heavenly model for linear time and hence widespread existence of time preference, we would not expect the pre-Buddhist primary sources to yield records of many situations when true interest was being taken. Such evidence begins to show up for the Northern and Southern Dynasties.

Over the course of Tang times, we find lots of both official and market interest rates reported in the sources. They are high—approaching 100% per annum. By Song times, however, rates had fallen by nearly half to 50-60% per annum. These are market rates, not officially fixed rates. By Ming times market rates had fallen by half yet again, down to 30% per annum for market interest rates. By the 19th century, some commercial rates were under 15%.

That is, market interest rates fell by half from Tang to Song; by half again from Song to Ming and yet again by half from Ming to late Qing. Compared to England, however, even late Qing rates were high.

Now that we know what generates interest rates, we could infer (even in the absence of other information) that the proportion of production in China that was indirect had gone up by leaps and bounds between the Han Dynasty at the turn of the Christian era and the Ming Dynasty in the 15th-17th centuries, with substantial jumps also occurring during the Song period. However, during neither Song nor Ming times was indirect production as high a proportion of all production as in 18th century England.

We can surmise this from the fact that the pure interest rate in England had declined to 3 percent by the early 18th century. That would suggest that 18th century England's absolute growth rate should have been higher than 11th century China's, when the average interest rate was twenty times higher.

That difference let England build *more* copies of the technical novelties that it shared with China. That is the key factor distinguishing the English full industrial revolution from the Song and post-Song early industrial revolution.

c. credit money

Also closely linked to savings to finance indirect production is the existence of credit money. The first approximation of credit money is a receipt which functions as a kind of money substitute, a certificate attesting to the presence in the coffers of some reliable person or institution of some commodity money. The certificate is merely a handy receipt for that saved commodity money, enabling it to be exchanged for

goods or lent to some investor more conveniently.

The first full credit moneys went beyond this to introduce the time dimension. The certificate or bill represented the right to receive in exchange for the bill a certain number of commodities at some *later* time and/or some other place. People will normally only accept such a bill at a discount from its face value equal to the interest foregone until the bill can be exchanged for the commodities.

A Song Dynasty Cash Voucher. (Peng, p. 378.)

Credit money did not appear during Han. Wang Mang's high denomination coins were merely fiat money—not even money substitutes, but money supplements. Wang merely asserted (by fiat) through the label he cast onto it that a coin with a weight indicating that it should be taken as being worth about 12 Five-grainer coins was instead to be taken at a worth of 50 or 500 or 5,000 Five- grainers. He had no metal reserves to back that assertion of the face values of his coins. These values rested merely on a fiat—an order of his government.

Tang Flying Cash and early Song Exchange Notes were, at least nominally, true money substitutes and credit moneys. The face values of these paper moneys were based on reserves held by private banks or government bureaus. Their existence reflects one aspect of the institutionalization of savings.

The transformation of Exchange Notes into into government fiat money—i.e. money supplements—during Southern Song, Yuan and early Ming times, represented a setback to the institutionalization of savings, and hence reduced opportunities to increase indirect production.

This may be partly why China took so long to move from the early to full industrial stage. Though China had proto-banks very early, their issue of credit money was largely preempted by wide issue of fiat money by the Southern Song, Yuan and Ming governments. Large scale private credit money issue only resumed in large quantities during late Ming and Qing. Perhaps not coincidentally, it was then that China finally moved toward full industrialization.

Trade with the West provided the silver which enabled the Chinese market to abandon government fiat paper money and revive private credit money during the 16th century. So we must also take account of the role of foreign contacts in the transition into the industrial age.

3. Foreign contacts & novelty

The lowering of preference for the present over the future depended on the shift by almost everyone to a sense of linear time. That in turn was one of the chief secular consequences of the arrival of the Buddhist world view from abroad. The acquisition of Buddhism was by no means the only external stimulus to economic development.

A more direct stimulus to greater indirect production is to obtain recipes from foreigners either for particular new products or for new roundabout production methods for old goods.

The urban economist Jane Jacobs has plausibly argued that commercial cities are funnels for concentrating foreign ideas. Indeed, Jacobs virtually defines cities in terms of their potential function as collectors of recipes from other regions and foreign sources. Only by acquiring such recipes, she argues, can cities then become recipe generators on their own.

When cities begin to engage in trade, they also import recipes indirectly, embodied in the foreign goods. City folk deduce the recipes by which the foreign goods are made by disassembling the imported goods (this is now called "reverse engineering"). They gradually learn how to replace those imports in part by making spare parts to repair them and then altogether by assembling the spare parts into copies of the foreign goods. Finally, they improve on and begin to export these goods.

The Han Dynasty entered Central Asia in the 2nd century BC. For the next dozen centuries, China became ever more open to the other civilizations of Eurasia.

By Song times, overseas commerce had caught up with overland commerce as a source of new recipes. Several of the great port cities of Song times achieved the variety of imports and the concentration of population to begin to sustain the kinds of activities that Jacobs finds characteristic of the earlier stages of an industrial revolution.

The withdrawal of China from legal overseas trade during much of Ming, and the severe limitations placed on such trade during early-mid Qing much inhibited the Jacobs effect, but even the Lords of Merit and their conquest aristocrat allies could never altogether close China off from the outside world.

C. "Agricultural Revolutions" and "Industrial Revolutions" in General and in China

1. The coming of commercial agriculture

An "agricultural revolution" is part of the increasingly indirect production process that leads into an early and then full industrial revolution. The shift to a partially commercial agriculture—one producing in part for the market—rather than an agriculture producing entirely for subsistence, is the first step toward an agricultural revolution. Agriculture is the most important sector of all large preindustrial economies, and remains such even well into the full industrial revolution. Any change in agriculture would, therefore, make for a large

change in the economy as a whole.

As early as the time of Han Emperor Wu, we begin to find complaints made in the sources by the crypto-Legalist hard Confucians that the peasants were perversely refusing to remain peaceably down on the farm. They would get hold of a few of the new fangled Five-grainer coins, we are told, put them in their sleeves, and go off to god knows where, to buy and sell as they pleased, paying no attention to the desires of their betters in the aristocratizing meritocracy. The economic and social historian can only conclude from the growing frequency of such complaints that commercialization of agriculture had begun by then, if not before.

It takes little further investigation to suggest that part of the reason farmers began selling some of their crops was political. We know that the Han Dynasty, like Qin and some of the Warring States before it, collected a few taxes in cash. Peasants had to go to market to sell some of their produce, if only to pay these taxes.

Even modest initial monetization of agriculture would have stimulated increased production. New recipes would allow more indirect and hence more productive production even at a constant rate of saving. This in turn would cut costs and increase money profits from sale of crops even if prices remained unchanged. A farmer could sell fewer of his goods and still get the same amount of money to pay his tax. Cost-cutting and productivity increasing technological changes in fact began to proliferate during Han times.

However, I would not give government too much credit for commercialization of agriculture. Growth of the market must have come first and stimulated governments to begin collecting some of their taxes in cash. Acquisition of cash would make it more convenient for the rulers to themselves purchase goods in the market. So, ultimately it was the growth of the market that stimulated both the monetization of taxation and the commercialization of agriculture and the technological innovation commercialization evoked.

2. Advances in agricultural technology

The Chinese already had a fairly usable animal harness as early as Shang times. Horses fitted with it could pull chariots with at least some of the load on their chests rather than their necks, as was then and long remained the case in the West. By choking the animal more the harder it pulled, a neck harness kept draft animals from working as hard as they might otherwise have done.

The Chinese perfected breast harnesses during Han times. Thereafter the horse (itself by Han times bigger and stronger through hybridization of the native Central Asian pony with the larger horses of Western Asia) could pull loads entirely with the chest rather than with the neck.

A seed-drilling plow pulled by an ox wearing a breast harness. (From a 17th century technical encyclopedia)

Once horses or oxen could work more efficiently, Han shifted from the simple plow to the heavier (and more indirectly produced) cast iron-tipped moldboard plow that turned over the soil after cutting a groove in it. One variant had a seed drill behind the blade to drop seeds into the groove, and a trailing flat plate to cover the groove containing the row of seeds with loose soil. Han farmers also used an animal-drawn multiple gang harrow.

Since planting would now be in rows, weeding became simpler and less labor intensive. It paid, therefore, to go over to the more productive (under the right circumstances) grain, wheat, whose productivity would be further enhanced by such plowing, harrowing and weeding. Farmers moved away from the relatively less productive (or at least less desired) grain, millet, the growing of which did not so fully justify use of such expensive machinery.

Wheat, unlike millet, can be ground into a flour with good keeping qualities, if you have a mill to do the grinding. It therefore pays for wheat farmers (or their landlords or Buddhist monasteries) to build water-powered and animal-powered mills to hull grain and grind flour.

Such mills became common during the Age of Disunion that followed the fall of Han. Buddhist monasteries and temples concentrated the savings of their parishioners to fund this more indirect form of food production.

Eventually, mills were scattered widely over the North China countryside. Even in late Tang and Song times, many of them were still being run by pious monks as charitable aids to the peasantry, and to profit the monastic corporations, the better to allow them to spread salvation ever further among the Chinese masses.

Since wheat made into flour can be kept conveniently for long periods, saving (and hence investment) can be in the form of flour. Flour can be manufactured into steamed breads and pasta, which are more tasty than millet mush.

The Chinese did not make yeast or baking powder breads. They apparently borrowed the techniques for making steamed breads and pasta from Zone A peoples, who got them from Persians and other West Asians. Pasta and non-yeast breads were first made in the Middle East. The word (*mantou* 滿頭), used by the Chinese for steamed bread since Han times, was likely of foreign origin. (The Italians probably got spaghetti from the same Middle Eastern source long before Marco Polo.)[4]

Han used fancy gear train recipes to make expensive toys like a "south-pointing chariot" that used gears rather than a magnetic compass to keep a mechanical charioteer pointing south no matter how it was turned. During the

[4] I am indebted to Paul Buell, a leading expert on Central Asian foodways, for these two points.

millennium after Han, these recipes were applied not just to mills but to non-agricultural industrial purposes. Water-powered machines like these can even carry an economy well into the full industrial revolution. The American full industrial revolution, for example, was more than half powered by water as late as the 1880s. It was only then that steam finally generated more than half of our industrial horsepower.

As the refugee Han Chinese culture swallowed up the cultures of the south during the Southern Dynasties of the Age of Disunion after Han's fall, it became worthwhile for these migrants from the north to pick up recipes for growing new crops the southerners had already borrowed from still further south. Such sub-tropical commercial crops as tea from South Asia and sugar cane from Southeast Asia (and ultimately perhaps from Micronesia) became domesticated into China.

Both tea and sugar were inherently commercial crops. Nobody can subsist just on tea or even tea and sugar. Hence few would risk growing much of them absent a thriving market for foodstuffs in general which would let them trade their tea or sugar for grains and meats.

3. New institutions

Buddhist monasteries played a large role in all of these activities, one beyond merely financing expensive mills. They also sent religious pilgrim travelers to South and Southeast Asia, where they undoubtedly played a key role in bringing back a taste for the new crops and sometimes brought back even the seeds themselves for growing them.

Tea, for example, is traditionally associated with one of the founders of Chan (Zen in Japanese) Buddhism, the Western Asian missionary monk, Bodhidharma. He supposedly used it to keep himself awake and alert during long bouts of meditation.[5]

Monastic establishments also invented pawn shops, which provided the earliest known institutionalized form of private credit for farmers. A farmer could pawn his winter clothing at the beginning of spring to obtain seeds and enough food to see him through the growing season. Later he could use part of the harvest to repay the principal and pay the interest on the loan and redeem his winter clothing just before the weather turned cold.

Monastic establishments that ran pawn shops might also manage money depositories for the merchants. These evolved into or inspired later secular banks. Profits could accumulate as the savings needed to command resources for the various kinds of rural indirect production mentioned above.

Confucian clan foundations of Song and later times imitated the corporate principle of organization of the earlier Buddhist monastic foundations. They too carried on bank-like activities, including making subsidized loans to fellow clansmen, who could then postpone going to work for a living long enough to study for the civil service exams. After taking office as men of merit, they could repay the loans and protect the clan's interests through political means.

This last type of "investment" was, of course, a disguised form of consumption, since (unlike the Buddhist charitable activities on which it was modeled) it did not as such finance increased production of real goods or services. Nevertheless, the fields and businesses owned by clan-corporations did create new real wealth. They mobilized enough savings to increase the indirectness and hence productivity of their activities. It is just that some of that increase was diverted into the production of meritocrats whose interventions might discourage further increases.

4. Technology & investment

You should not let the great number of Chinese technological innovations distract you from the abiding economic logic involved in evaluating technology's dependent role in economic development. Technology is normally the dependent rather than the independent variable. No innovation can be used unless savings are available to invest in it. Indeed, unless they know that savings will be available, people will normally not bother inventing much new technology.

Savings, in turn, are dependent on the lowering of time preference for the present over the future. Man's necessary preference for present over future consumption can only be overcome by first teaching him to think of time as linear, and then offering him a premium—interest—for postponing consumption while the new instruments of production are built.

Even when dealing with the technology that was spun off from agriculture, we must also look for a class or classes that specialized in postponing consumption or in serving as the intermediaries between savers and those who used these savings to produce more indirectly.

(The material determinist Karl Marx coined the term "capitalists" for such people, but is it appropriate to call the abbot of a Buddhist temple a capitalist? Though I prefer calling such people "future goods specialists," I am open to suggestions for less awkward labels.)

The Buddhist monastics during early medieval times (after Han and before mid-Tang) and the men who ran or dominated the clan foundations during early modern times (Song, Yuan and Ming) were the most important but not the only such future goods specialists in the China of those times. The new commercial cities were filled with such entrepreneurs, some of them operating on a large scale.

Having issued the above warning against taking technology as the primary cause of growth, I can now risk providing some evidence for the appearance of new recipes in fields other than agriculture.

D. Technical Innovations in Transportation, Manufacture and Finance

An enormous number of technical innovations came in during the period beginning with the early iron age (c. 600 BC) and continuing into the middle iron age (c. 100-800) and the late iron age (early industrial age, beginning c. 1000).

Most of these new techniques saved

[5]Bodhidharma is also said to have kept himself awake by cutting his eyelids off, which is why he looks so bug-eyed in his portraits.

labor and raw materials to such a degree that though they required ever greater indirectness, they were more than productive enough to make up for the initial loss of time required for their manufacture. This was true even for tools that merely *eased* labor, but did not significantly *reduce* the amount of labor required to perform a particular task. People might be willing to perform *more* per day of labor that was easier to perform.

1. Transportation

Once iron digging tools became available during Spring-Autumn times, the first canals were dug. These were relatively short, and well past Warring States and Han times were used more for irrigation and drainage than for transportation.

It was not until the early 7th century AD that the first Sui emperor used tax resources to build a transportation canal network connecting the Yangzi and Yellow River valleys in the east, where the land was relatively flat. This was the first version of the Grand Canal (literally, "transport river," *yùnhé* 運河).

Once tax resources had built the Canal, some private interests could also begin to use it, since the marginal (extra) costs of using it were much less than the total original costs, which the government mostly wrote off as the price for linking the north with the south for tax grain transport purposes..

Unfortunately, even on the eastern plain, some stretches of the canal were higher than others. The only way to get from one level to the other was to construct an earthen inclined plane between these levels, and then hire a number of laborers to drag small barges up that inclined plane on log rollers.

By Song times, hydraulic engineers invented the double lock system to replace these inclined planes. The canal lock is a very indirectly produced device. It takes much time, labor and expensive timber to build the two watergates separating a lock from the two different levels at its two ends.

Once this has been done, it pays to widen and deepen the canal over its whole length. This allows the much larger and heavier barges that can be raised and lowered with much less labor via the locks to transit the canal. Tax resources must be expended not just once to build, but repeatedly to maintain this more indirectly produced mode of transportation.

Non-capital transport costs on such a canal go down dramatically. Even in market terms, the marginal costs of transporting such bulky low value goods as grain over considerable distances become bearable. Previously, such goods were only transported, even by canal, to meet *political* needs. This new form of transportation also allowed population to increase, since famines in one area could be relieved by mass shipments of grain from other regions.

Chinese use of tax resources to build the Grand Canal was roughly parallel to the use of tax money to build railroads in the Western world during the middle half of the 19th century. Prussia's state-built rail network was, for example, laid out as much for strategic as economic purposes. Similarly, the American transcontinental railroad was built with federal government subsidies during the Civil War to keep the west linked to the rest of the Union. (Antebellum Eastern and Midwestern railroads were 75% built by private capital.)

Government-owned underwater telegraph lines also seem to have been overbuilt. The British government completed the last link of its 'round the world underwater telegraph cable network at the turn of the century, just before Marconi demonstrated the wireless telegraph. One can only speculate whether NASA's space shuttles and other near space projects will prove to have helped or to have just gotten in the way of development of private space stations and space travel.

Chinese government subsidies of the canal network in early modern and modern times may have inhibited commercial use of the otherwise cheaper coastal sea route between north and south China and hence undermined China's maritime development in general. The water they drew sucked saltwater into the water table of the subzone B2-C1 border region.

The key element of Chinese canal technology, the double canal lock, was not much used in Europe until the late 17th century, some six centuries after Song China originated it. By then the Chinese early industrial revolution was in temporary arrested development. One of the signs of that decay was the abandonment by Ming and Qing of many canal locks and their replacement with inclined planes. For various reasons, the rulers were not willing to forego enough other government expenditures to generate the ongoing indirect activity needed to preserve these capital goods.

Another major Chinese innovation in inland transportation was the wheel barrow. The wheel barrow started out in Han times already a bit different from ours, which has a little wheel at one end bearing only half the weight of the load, leaving the rest to be borne by the poor fellow holding up the handles. By Song times the Chinese style, with a big wheel straddling the center of gravity and allowing the entire weight of the load to be carried by the wheel, had become ubiquitous.

A Han wheel barrow (on a Han tomb tile)

A modern wheel barrow (John Thompson *Illus-*

***trations of China and Its People,* c. 1865)**

All the operator needed to do was balance the load (helped a bit by the gyroscopic effect from the large wheel) and provide a modest lateral force to propel it forward. This was partly a labor-easing device, though compared to the carrying pole, with a basket at each end, it also saved some labor.

In north China, wheel barrows sometimes bore sails, had several operators, and carried substantial loads. European travelers brought back accounts of these giant devices, and these are said to have inspired the Dutch to invent the ice boat.

Seagoing ships, beginning in Han times and climaxing during Song, evolved dramatically. The first successful seagoing vessels in China were foreign. During late Han times, Arabs and Persians sailed dhows to Chinese waters from the Red Sea and Persian Gulf. Chinese versions of the dhow became common in southeastern Chinese waters by the end of the Northern and Southern Dynasties period. Thereafter, during Tang and early Northern Song, the Chinese expanded the size of and added all sorts of improvements to this already reliable coastal sailing vessel.

Chinese shipbuilders turned the two rear steering oars into a single sternpost rudder, which turned the ship more efficiently. They added square-rigged sails to the dhow's lateen sails, and multiplied the number and sophistication of the ropes and pulleys controlling both. Along with the new rudder, these changes eventually enabled these ships to tack into the wind more easily. To secure the safety of the ship and its cargo, they divided the hull into watertight compartments.

The Chinese also gave up the ancient world's image of the ship as a kind of artificial fish and used the duck as a model instead. Elevated sections bulged atop the front and back, like the head and tail of the duck. These also served as convenient locations for anchoring ropes and placing the steering mechanism at a useful height. Chinese naval architects preserved the smooth, fish-like lines only of that section of the ship that was under water.

Native Chinese carpentry techniques were already the world's best. Their large wooden ships were tighter and stronger than much smaller ships built elsewhere. Chinese high-seas vessels of Song times were as big as 17th century European vessels, and were far bigger than Columbus's tiny ships.

Daoist magicians had been using the magnetic compass since Han and perhaps Warring States times to play magic tricks and identify sacred locations. Not until Song times did it become a tool for navigation on the high seas.

Han geographers drew precise maps to pin down locations on land. By Song times grid coordinates appeared on maps adapted for sea navigation, though carefully drafted sets of prose directions were more important until modern times.

Clearly, by the 12th and 13th centuries, the Chinese had reached a level of sophistication in their naval architecture that the Europeans would not achieve until the 15th-17th centuries, if then. Indeed a great deal of European naval architecture, particularly after the beginning of the 16th century, rested upon such Chinese innovations. Some of the best 16th and 17th century European ships were built by Overseas Chinese craftsmen in Southeast Asian shipyards.

2. Innovations in industrial technology

Certain key goods we characteristically associate with industrial production appeared at a much earlier stage in China than in Europe. Paper and printing are excellent examples of such technological precocity.

Paper is very efficient stuff for writing on. Though more indirectly produced, it is cheaper than woven silk for use as an elegant and flexible writing material, and is more compact and cheaper to transport than the strips of bamboo which were strung together in ancient times to make non-sacred books in China. These bamboo books were as bulky as rolled-up Venetian blinds.

According to tradition, the earliest paper was made in Eastern Han times, allegedly by court eunuchs seeking a cheaper form of silk to use for imperial edicts. It was supposedly made out of broken silkworm cocoons which could no longer be unwound into long lengths of fiber for spinning into thread. Craftsmen at Court supposedly turned these broken cocoons into pulp with water and chemicals, then raised a grid through the pulp- laden water to capture a thin scum of pulp, which they then dried to form a kind of silken felt.

The above story turns out to have been just an old scholar's tale.[6] The archaeologists have dug up paper from late Warring States and Western Han sites, though it was used as a wrapper rather than for writing on at these sites. Soldiers on the Zone A frontier were still keeping records on bamboo as late as the 2nd century AD.

The earliest paper was made of hempen fiber. It turns out that pulp made solely from silk fibers may not stick together. Hemp fibers would have to be admixed with the silk.[7]

The Eastern Han court eunuch, Cai Lun, may well have ordered some of the new forms of paper as writing material for the Eastern Han bureaucracy. Soon, private innovators were using various sometimes cheaper materials for the pulp. These included rags and various wood fibers, such as the mulberry bark pulp later used to make the paper for paper money. By Song times some people could even afford to buy and use toilet paper.

Once you have reasonably cheap paper, the invention of printing becomes plausible. The principle of printing was already present on the Chinese signature seals used since ancient times. Seals used a few raised characters cut out of soft stone in mirror-image form.

During Han times a rather different technical principle was used to reproduce long literary works. Eastern Han's court had the Chinese Confucian classics engraved into the surface of a dozen stone drums in unreversed form. Scholars took paper rubbings from the engravings. Of course, unlike the seals (and

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[6] Cf. T. H. Tsien's volume 5, part I, *Paper and Printing*, in Joseph Needham, *Science and Civilization in China* (1985) for the up to date story.

[7] The NORMAL crowd claims the Chinese also smoked the stuff, but that is mostly inference and wishful thinking. Chinese commoners did, however, cloth themselves in coarse linen made from hemp until true cotton arrived from South or West Asia and became widely available during Yuan or early Ming times.

normal printing) the resulting "printed" text was white on a black background.

As was the case with so many other technical innovations, true printing was first employed by Buddhist temples. The monks cut out prayers in raised, mirror-image reversed characters on wooden blocks and took black print on white background paper rubbings off these. This practice began during the Age of Disunion. This was true printing.

By Tang times, similar wood-block printed check forms were in use by government bureaus and private proto-banks. By early Song times, the government printed the Confucian classics from such wood blocks and sold them cheaply to would-be meritocrats. The cost of a printed book was one-hundredth of the price of a manuscript copy. Cheap printing helped create the larger meritocracy of Song times and thereafter.

By mid Song times, wooden and then metal movable types were in occasional use. Since written Chinese employs several thousand separate characters rather than an alphabet, movable type was much less useful for written Chinese than it would be later in alphabet-using Europe.

Still, by Ming times private entrepreneurs printed even cheaper than before large editions of popular novels from wood blocks.

Because it so drastically reduced the prices of books, printing was having as revolutionary an effect on culture in China from the 10th century on as it did in Europe after the late 15th century.

In some respects, however, cheap books may have inadvertently inhibited economic growth since they enabled a larger pure meritocracy to educate itself and come to dominate the ruling class by late Song times. These meritocrats were both unproductive themselves and (as we saw in chapter 10) tended to subvert the productivity of participants in markets.

The elaborate gear trains invented during Han and the Age of Disunion for grinding grain had by Song times been applied to water-powered looms for weaving silk, and by late Song times apparently to multiple spindles for spinning hempen thread. In a 13th century encyclopedia (the illustration for which dates to the 14th century reprint edition), this device looks much like Hargreaves' water-powered spinning jenny of the 18th century, which is usually taken as a harbinger of the full industrial revolution in England.

Coal was being mined and used as a fuel at least by Tang times. By early Song, ironmakers began to "cook" coal in the absence of oxygen into coke—pure charcoal—and put the coke into blast furnaces to replace charcoal made from wood. This made up for the scarcity of trees near the main iron producing areas within subzone B2. This sort of thing was not done in England until the second quarter of the 18th century.

The coking process, like the spinning jenny, is usually linked to the full industrial revolution by European economic historians. And yet per capita production of iron in 11th century China was apparently only equal to per capita iron production in Western Europe during the 1720s, on the eve of the invention of the coking process in England.

Chinese pottery was much harder and more glass-like than any other culture's pottery even as early as Yangshao times. This is because Chinese kilns, with their separate firing chambers, operated at much higher temperatures.

By Han times true porcelain, using *kaolin* clay as its raw material, was occasionally being produced, sometimes glazed, perhaps accidentally. Sometime between late Han and Sui times, Chinese potters fully mastered the technique of glazing porcelain and stonewear. Three-color glazed porcelains are ubiquitous in Tang graves.

By Song times, at first state monopolies, and then private firms holding monopoly licenses manufactured a variety of glazed porcelains on a full industrial scale at places like Jingdezhen near the Southern Song capital of Hangzhou in southern C1. Ordinary stoneware was produced in massive quantities by smaller private firms scattered widely over the countryside.

The Song Jingdezhen establishments exported porcelains on such a massive scale to Japan, Southeast Asia, and even East Africa, that their shards litter some archeological sites in these places like Coke and beer bottles on a 20th century American roadside.

I do not mean to imply that China was undergoing a full rather than an early industrial revolution during Song times. Rather the opposite: I am hinting that the same technologies—the double-lock canal, the coking process, spinning jenny and English Wedgwood true porcelain— must not have been the fundamental causes of the full industrial revolution in 18th century England.

Instead, I would insist that time preferences for the present must have been sufficiently lower in 18th century England than in 11th century China to have pushed the English growth rate up to the 1.5% absolute annual compound growth rate I associate with a full industrial revolution. Song China must still have only been hovering a bit below the 1% level.

This suggests examination of financial institutions and ultimately (in subsequent chapters of this text and in greater depth in History 371) the intellectual, political and social institutions that determine or at least condition these subjectively determined time preferences.

3. Monetary and financial innovations Aborted

Even if there was not as much indirect production going on in Song China as in Hanoverian England, some of the increased indirect production implied by these innovations must have been aided by the spread of the institutionalized savings that lay behind the credit money that was becoming more common, at least in certain regions, by late Tang and early Song times.

This stimulus was eventually weakened after the government took over issue of paper money from the private banks during early Song and turned it from credit into fiat money.

The world's earliest true bank note paper money was issued by the Sichuan banks (the Sixteen Houses of Chengdu city) in subzone B3 during the late 10th and early 11th centuries. Bank notes may have been invented there because Sichuan was short of copper for coins, and found iron coins too heavy for convenience.

By the middle of the 11th century,

the government intervened by nationalizing the issue of bank notes, supposedly because these Sichuan banks periodically suspended redemption of their notes for coins because of "runs" caused by their overissue of bank notes. The Chinese bankers were apparently keeping on reserve only a fraction of the value of the notes they issued.

Of course the government did not improve matters. Since by definition it could not go bankrupt, it could overissue the notes without let or hindrance, turning them into a fiat money, with no coin backing at all, even by iron coins.

At first this system was limited to B3, but the upsets of the time of Northern Song's fall allowed the Southern Song government as well as its Jin Dynasty enemy in North China to go over to an almost purely paper monetary system, the world's first.

Aside from causing chronic inflation, this shift from private to public paper money emptied real savings from credit money. The chronic inflation also tended to both confiscate old savings and discourage new savings since each new round of notes went first to government officials rather than people producing for markets.

Bereft of their most profitable activities—the issue of bank notes and the forwarding of money from one region to another—Chinese banks developed little further during the long period from early Song until paper money disappeared during mid Ming. This limited the number of institutions which could receive savings and probably further reduced the savings and hence investment rate.

Reduced savings and investment from Southern Song through mid-Ming weakened stimuli to deepen the indirect structure of production that private banking began to provide in Europe a little later.

From the 12th through the late 16th century, the Chinese did not enjoy the equivalent of the services of the Italian bankers spreading branches of their credit institutions all through Europe and stimulating savings and investment thereby.[8]

Not until the late 16th century, when government paper money finally disappeared, and during the next several centuries private banking began a comeback in China did, perhaps, not coincidentally, significant Chinese industrial growth resume (though it was temporarily derailed again by the fall of Ming to the Manchu Qing Dynasty).

This preemption of the banking function by the government was a sign that the Chinese state was somewhat stronger vis à vis its society than European states were. Hence, though China was the first to enter an early industrial revolution, it was not the first to enter the full industrial revolution stage.

[8] Even now one of the main streets in London's financial district is still called Lombard Street after the North Italians who were the first bankers to do business there. Our very word for bank in English is derived from the Italian *banquo,* meaning the bench on which early North Italian bankers displayed the different kinds of coins they were prepared to exchange for the money their customers offered.