Chapter 1

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Intensive and Extensive Growth in Imperial China

Analysis of economic growth generally concentrates on the nineteenth and twentieth centuries in which the pace of economic progress was unprecedented. Earlier performance has received much less attention because economic advance was at best very slow, quantification more difficult or non–existent.

However, there is a strong case for considering distant horizons in the case of China. From the eighth to the thirteenth century there was a major transformation of its economy, with a switch in the centre of gravity to the South. In the eighth century three–quarters of the population lived in North China, where the main crops were wheat and millet. By the end of the thirteenth, three–quarters of the population lived and produced rice below the Yangtse. This had been a swampy, lightly settled area, but with irrigation and early ripening seeds, it provided an ideal opportunity for massive development of rice cultivation.

Higher land productivity permitted denser settlement, reduced the cost of transport, raised the proportion of farm output which could be marketed, released labour for expanded handicraft production, particularly the spinning and weaving of cotton, which provided more comfortable, more easily washable, and healthier clothing. There is widespread agreement that this change in the locus of production and product–mix increased Chinese living standards. It also permitted a doubling of population.

China's economic advance in the Sung dynasty relied heavily on exploitation of once–for–all opportunities for switching to intensive rice agriculture. Some analysts have exaggerated the breadth of advance, believing that China was on the brink of developing a mechanised industry, but there is little convincing evidence of this.

From the thirteenth to the eighteenth century, the available evidence for agriculture and for the relative size of the urban population suggests that Chinese per capita income did not improve significantly. However, China was able to accommodate a fourfold increase in population whilst maintaining average per capita income more or less stable over the long run. The pace of growth was far from smooth. In the fourteenth and seventeenth centuries, population dropped by more than 30 million. These crises were due largely to devastation that accompanied changes in regime and to

epidemic disease (bubonic plague and smallpox). In the eighteenth century the demographic expansion was particularly large. It was in this century that traditional China's capacity for extensive growth was most clearly demonstrated.

This chapter examines the evidence for believing that the Sung period was one of intensive growth, and that the following five centuries were, with some interruptions, characterised by extensive growth. The section on agriculture illustrates the processes of technical adaptation which were necessary to sustain extensive growth.

The first section examines the system of governance in Imperial China, and the nature of the bureaucracy which fostered advance in agriculture, but put a brake on progress in other parts of the economy, maintaining an institutional framework which inhibited the growth of capitalist enterprise and restricted opportunities for international trade and exchange of ideas. The second section deals in more detail with the evidence of intensive growth in the Sung. The third analyses the institutional and technical characteristics of Chinese agriculture and its capacity to accommodate big increases in population. The last two sections cover non–farm activity of rural households, and performance in the urban sector.

Bureaucratic Governance and its Economic Consequences

For the last thirteen centuries of the Empire, Chinese rulers entrusted the administration of the country to a powerful bureaucracy. This educated elite, schooled in the Confucian classics, was the main instrument for imposing social and political order in a unitary state with twice the territory of Europe.

In the West, recruitment of professionally trained public servants on a meritocratic basis was initiated by Napoleon, more than a millennium later, but European bureaucrats have never had the social status and power of the Chinese literati. Within each country power was fragmented between a much greater variety of countervailing forces.

From the earliest days, Chinese Emperors aspired to enlist meritorious officials rather than territorial vassals. In the Han dynasty, they were recruited on a recommendatory basis, as a supplement to military and aristocratic minions. Thereafter there was a relapse into predominantly feudal regimes in a multistate polity which lasted for nearly 370 years. Bureaucratic enrolment by examination was initiated at the beginning of the seventh century. The role of bureaucracy expanded under the T'ang when the political power of the hereditary aristocracy was gradually broken (Ho, 1962, p. 259). Under the Sung, procedures for examination were improved to ensure anonymity of candidates. In the examinations the names of candidates were no longer revealed to examiners, and clerks copied the responses to avoid recognition of the calligraphy. The meritocratic basis of selection was widened by improved provision for public education. The number of graduates grew substantially. Criteria for recruitment, advancement, and evaluation were clarified. All important officials were recruited on the basis of academic performance.

Bureaucratic control was temporarily interrupted by the Mongol military occupation in the thirteenth century, but they came to recognise the usefulness of a bureaucratic mechanism for tax collection, and restored civil service recruitment in 1315.

After the collapse of Mongol rule in 1368, a meritocratic bureaucracy again became the main instrument of imperial power. The Ming and Ch'ing kept titled nobility in check, without territorial fiefs, independent military or political jurisdictions. At a very early stage, the primogeniture system of inheritance was abolished. The aristocracy became a costly fossil, with its income derived mainly from imperial sinecures, dropping in rank with each successive generation. Landed aristocracy had

already disappeared as a significant political force in the course of the Sung dynasty. Eunuchs and bondservants within the Imperial household influenced policies but posed no real threat to bureaucratic control.

The bureaucratic elite was always small in relation to the size of the country. In the sixteenth century and the first half of the seventeenth there were ten to fifteen thousand officials (Gernet, 1982, p. 393) for the whole of the empire. They staffed the Grand Council and Secretariat, the six ministries and the specialised departments in Peking, and serviced the provincial, prefectural and district administration. At the lowest level (the district — *hsien*), the magistrate was tax collector, judge, record keeper, administrator of public works and regularly present at ceremonial observances, sacrifices to Heaven, other supernatural forces and local temple gods. There was necessarily a good deal of local discretion because of the size of the country. From Canton to Peking, the normal courrier service (by foot) took 56 days each way, urgent mail 18 days and super urgent mail 9 or 10 days each way. At district level the magistrate operated his headquarters (*yamen*) with a staff of locally recruited clerks, policemen, jailers and guards. He levied taxes and maintained law and order for a district population rising from about 80 000 in the Sung to 300 000 in the Ch'ing dynasty. Below district level, control was exercised by derogation and delegation. The local gentry played an important role in settling disputes and acting as informal agents of officialdom. Neighbourhood associations were collectively responsible for local policing and tax collection. Selected commoner household heads took their turn on a rotating basis as unpaid conscript administrators to ensure that taxes were paid.

The bureaucracy were a social elite. They and their families were exempt from many types of levies, punishments and duties to which commoners were exposed. They were entitled to wear robes, buttons, belts and other sartorial signs of elevated status. These perquisites were so attractive that vast numbers of aspirants who failed to become officials nevertheless obtained degrees. Many privileges of office holders were also accorded to these degree holders and their families. They were the second layer of the social elite (often referred to as the "gentry"). Degree holders derived substantial income from landownership, mercantile activities and teaching. They enjoyed favourable tax treatment, earned extra income by acting as agents for commoners in their dealings with office holders. Thus the competitive recruitment process for officials had two important side effects: *a)* it determined the nature and content of education; *b)* it greatly augmented the prestige attached to credentials, and had a profound influence on social attitudes and social structure. Amongst the property–owning group, only the credentialled gentry had easy access to office holders.

There was no significant church hierarchy or doctrine to resist or counterbalance bureaucratic power after the important Buddhist properties were seized in the ninth century. There was continued toleration of a wide variety of religious practice, including Buddhism, Taoism, Islam in the central Asian borderlands, Lamaistic Buddhism in Tibet and Mongolia. But the official ideology was essentially secular — a set of pragmatic prescriptions for behaviour in this world, a Confucian unconcern with problems of immortality, the soul, the afterlife or God. It stressed virtue, decorum, social discipline, gentlemanly polish. It had no sacred law, no concept of sin or salvation, no social division into castes. It inculcated belief in providential harmony, promoted orthodoxy and obedience to the state. It attached little importance to personal liberty or salvation. It had no distinctive priesthood. It was a state cult whose local temples were maintained and whose rituals were carried out by the bureaucracy, with an accommodatory rather than adversarial attitude towards other systems of belief.

There were virtually no lawyers or litigation in China, and very limited possibilities for challenging bureaucratic decisions. Citizens were supposedly protected by the Confucian virtue of the bureaucracy. To discourage corruption, officials could not be appointed to positions in their region of origin, and were regularly rotated to avoid too great an identification with local interests.

Except in times of dynastic crisis, the military were usually subordinate to the civilian authorities. In the Ming and Ch'ing most soldiers came from hereditary military families. The qualifying examinations for military officials were less demanding and held in lower regard than the credentials of civil officials. The ministers in charge of the military were usually civilians.

The urban bourgeoisie (i.e. merchants, bankers, retailers, commodity brokers and shippers, entrepreneurs in industries such as textiles, clothing or food processing) were deferential to the bureaucracy and gentry and dependent on their good will. Although they had guilds and other associations to foster their interests, they did not have the city charters and legal protection which merchants had in European cities from the middle ages onwards (see Cooke Johnson, 1995 for an account of merchant activity in Shanghai from the eleventh to the nineteenth century).

Bureaucrats needed a lengthy literary education to ensure that the flow of paperwork was elegant in expression and calligraphically pleasing. Candidates for bureaucratic credentials had to learn the Confucian classics by heart. In Legge (1960) these classics with their English translation and exegetical notes take up nearly 2 800 large pages, or a total of more than 430 000 characters to be remembered (Miyazaki, 1976, p. 16). The main emphasis was on texts which were already 1 500 years old in the Sung dynasty. Thus the power of tradition and orthodoxy was reinforced, and the intellectual authority of the official elite was difficult to challenge.

The institutions of such a far–flung bureaucracy reporting to and controlled by the central authority would not have been possible without the precocious development of paper and printing. Paper was officially adopted by the court early in the second century as a replacement for silk and bamboo (though the first Chinese paper appears to have been available 400 years earlier). The first complete printed book was a Buddhist Sutra of 868, and printing became fully developed in the Sung dynasty. This facilitated the functioning of the bureaucracy, greatly increased the reading matter available in cheap form to the education process, and helped to diffuse technical know–how. Editions of the Confucian classics, encyclopedias, dictionaries, histories, medical and pharmaceutical books, works on farming and arithmetic were officially sponsored. Private firms and booksellers also promoted the spread of knowledge (Tsien, 1985).

The bureaucratic system was the major force maintaining China as a unitary state. The bureaucracy was a docile instrument of the Emperor (as long as he did not seriously breach the mandate of heaven), but exercised autocratic power over the population, with no challenge from a landed aristocracy, an established church, a judiciary, dissident intellectuals, the military or the urban bourgeoisie. They used a written language common to all of China, and the official Confucian ideology was deeply ingrained in the education system. This system was relatively efficient and cheap to operate compared with the multilayered structure of governance in pre–modern Europe and Japan. It facilitated central control by maintaining an efficient communications network and flow of information which enabled the imperial power to monitor and react to events. It maintained order without massive use of military force. It created the logistics (the Grand Canal) for feeding a large imperial capital on the edge of the Empire. It raised and remitted taxes to maintain a lavish imperial household and the military establishment. It maintained the Great Wall as a defensive glacis against barbarian invaders. Maintenance of a single economic area did not ensure a single national market for goods because of high transport costs, but it had an important impact in facilitating the transmission of best–practice technology. New techniques which the bureaucracy sponsored or favoured could be readily spread by use of printed matter. Thus the gap between best–practice and average practice was probably narrower than it was in the polycentric state system of Europe.

The economic impact of bureaucracy was generally very positive in agriculture. Like eighteenth century French physiocrats, the Emperor and bureaucracy thought of it as the key sector from which they could "squeeze" a surplus in the form of taxes and compulsory levies. They nurtured agriculture through hydraulic works. They helped develop and diffuse new seeds and crops by technical advice.

They settled farmers in promising new regions. They developed a public granary system to ensure imperial food supplies and mitigate famines. They commissioned and distributed agricultural handbooks, calendars etc.

Outside agriculture, the bureaucratic system had negative effects. The bureaucracy and gentry were quintessential rent–seekers. Their legal and customary privileges defined their status, lifestyle and attitudes. They were the group which dominated urban life. They prevented the emergence of an independent commercial and industrial bourgeoisie on the European pattern. Entrepreneurial activity was insecure in a framework where legal protection for private activity was so exiguous. Any activity that promised to be lucrative was subject to bureaucratic squeeze. Larger undertakings were limited to the state or to publicly licensed monopolies. Potentially profitable activity in opening up world trade by exploiting China's sophisticated shipbuilding and navigational knowledge was simply forbidden.

The other feature of this bureaucratic civilisation which had long–term repercussions on economic development, was the official Confucian ideology and education system. By comparison with the situation in Europe in the middle ages, its pragmatic bias gave it the advantage. The official orthodoxy was probably most benign during the Sung dynasty. Educational opportunity was widened by state schools which provided a broader curriculum than the bureaucratic academies in later dynasties. Taoism and Buddhism were in decline. Neo–Confucian thought was reinvigorated and at that time was free of the dogmatism it displayed in later centuries (see Kracke, 1953, and Miyazaki, 1976). Needham (1969) argued that the Chinese bureaucracy was an enlightened despotism, more rational than European Christendom; more meritocratic in its concentration of the best minds in situations of power and hence more favourable to the progress of "natural knowledge" than the European system of military aristocratic power. After the European Renaissance and the development of Galileian and Newtonian science, the balance of advantage changed. Needham argues that China was never able "to develop the fundamental bases of modern science, such as the application of mathematical hypotheses to Nature, the full understanding and use of the experimental method, the distinction between primary and secondary qualities, and the systematic accumulation of openly published scientific data" (Needham, 1981, p. 9). However, he adds that the European breakthrough was due to "special social, intellectual and economic conditions prevailing there at the Renaissance, and can never be explained by any deficiencies either of the Chinese mind or of the Chinese intellectual and philosophical tradition".

China failed to react adequately to the Western challenge until the middle of the twentieth century, mainly because the ideology, mindset and education system of the bureaucracy promoted an ethnocentric outlook, which was indifferent to developments outside China. There were Jesuit scholars in Peking for nearly two centuries; some of them like Ricci, Schall and Verbiest had intimate contact with ruling circles, but there was little curiosity amongst the Chinese elite about intellectual or scientific development in the West. During large parts of the Ming and Ch'ing dynasties, China virtually cut itself off from foreign commerce. In 1792–93, Lord Macartney spent a year carting 600 cases of presents from George III. They included a planetarium, globes, mathematical instruments, chronometers, a telescope, measuring instruments, chemical instruments, plate glass, copperware and other miscellaneous items (Hsü, 1975, p. 207). After he presented them to the Ch'ien–lung Emperor in Jehol, the official response stated: "there is nothing we lack.... We have never set much store on strange or ingenious objects, nor do we need any more of your country's manufactures" (Teng and Fairbank *et al.*, 1954). These deeply engrained mental attitudes helped prevent China from emulating the West's protocapitalist development from 1500 to 1800, and from participation in much more dynamic processes of economic growth thereafter.

The Contours of Economic Development

In the first millennium of the Chinese imperial state, there was little if any net growth in population, and probably not much change in average income levels. In the Sung Dynasty (960–1280) virtually all authorities agree that there was significant new momentum in the Chinese economy, with an acceleration of population growth, clear indications of progress in agriculture, increased specialisation and trade, and a more flourishing urban economy. Many writers have stressed the dynamism of this period — Liu and Golas, 1961; Hartwell, 1962, 1966 and 1967; Hollingsworth, 1969; Shiba, 1970; Ma, 1971; Elvin, 1973; Jones, 1981 and 1988; Gernet, 1982; McNeill, 1982; Bray, 1984 and Mokyr, 1990.

The main grounds for accepting the fact of acceleration in the Sung are:

i) reasonable evidence of a substantial increase in population to levels not previously reached, probably a rise from around 55 million at the beginning of the dynasty to 100 million at its end. Ho (1959) suggests the latter figure, others have higher estimates for 1280 (Zhao and Xie, 108 million; Durand, 123 million; Elvin, 140 million);

ii) a switch in the regional centre of gravity, with a substantial rise in the proportion of people in the rice growing area South of the Yangtse, and a sharp drop in the proportionate importance of the dry farming area (millet and wheat) of North China. Balazs (1931, p. 20) estimates the population South of the Yangtse to have been 24 per cent of the total in the early T'ang (around 750). Durand (1974), p. 15, shows 60 per cent living there at the end of the 12th century. Elvin (1973, p. 204) suggests that more than 85 per cent lived in South China at the end of the 13th.

Large parts of South China had been relatively underdeveloped. Primitive slash and burn agriculture and moving cultivation had been practiced but the climate and accessibility of water gave great potential for intensive rice cultivation. Substantial moves were made by Sung rulers to develop this potential, notably by the introduction of new quick ripening strains of Champa rice.

The Sung had their capital in the new centres of population, first in K'ai–feng, which was further East than the ruined T'ang capital at Ch'ang–an. In 1127, when they lost North China to invaders from Manchuria (the Chin), they moved their capital below the Yangtse to Hangchow. This city was not designed in traditional ceremonial style (see Wright, p. 65, in Skinner, 1977), but was already a large commercial centre with access to the sea. With the big influx of refugees from the North it became an exciting boom town (see Gernet, 1982). The location of the capital in South China meant that its population could be fed more cheaply in a productive rice area with ready access to transport by water. Thus the Sung were relieved of the cost of maintaining the expensive Grand Canal route which previous and subsequent dynasties needed to provide a North China capital with grain;

iii) woodblock printing techniques had been developed in the T'ang period. This, and the prior development of paper, made possible a fairly wide diffusion of illustrated books from the tenth century onwards though really large editions came only in Ming times. This was a key innovation in Chinese history. It strengthened the potential for bureaucratic education and governance, and was used by the government to diffuse best–practice technology, particularly in agriculture;

iv) in the Sung period, there was evidence that increased density of settlement gave a boost to internal trade, a rise in the proportion of farm output which was marketed, productivity gains from increased specialisation of agricultural production and an increase in handicraft production in response to higher living standards (see Bray, Liu and Golas, Ma and Shiba). The

introduction of paper money facilitated the growth of commerce, and raised the proportion of state income in cash from negligible proportions to more than half;

v) the Southern Sung initiated improvements in shipping and shipbuilding. They built a naval force of paddle wheel ships on the Yangtse to protect themselves against Chin and Mongol invasion. Capacity was greatly expanded in government shipyards and there was a significant growth of overseas trade. Nine official ports were opened to maritime commerce, though overseas trade was dominated by Canton and Ch'üan–chou (Ma, 1971, p. 37).

All of the above developments give reason to think that growth accelerated in the Sung. There was clearly an increase in the pace of population growth, and it seems likely that there was an increase in per capita income as well. However, some authors who have stressed the dynamism of the Sung seem to exaggerate its achievements:

i) Chao (1986, pp. 49–60) suggests that in the southern Sung the urban population rose to one fifth of the total and fell to a third of this proportion by 1820. The evidence for such dramatic changes is exceedingly flimsy. For the Sung he relies on dubious accounts of Marco Polo and Hollingsworth (1969) which do not deserve serious credence[1]. For 1820 he relies on Rozman (1973) without mentioning Rozman's totally different estimates for the Sung. Table 1.7 below shows Rozman's estimates which present a very different picture from those of Chao;

ii) Hartwell claims to have discovered an "early industrial revolution" in Sung China, generalising from evidence for the iron industry. He greatly exaggerates its dynamism by concentrating on its rapid ascension in eleventh century K'ai–feng. However, this local boom was caused primarily by the relocation of government — the major consumer of iron goods[2];

iii) Shiba (1970) suggests that in the Sung dynasty a "nationwide" market had emerged for rice. There was an increase in the proportion of commercial sales of standard items which started in the T'ang (Twitchett, 1968), but transport costs were too high to speak of "nationwide" markets. In fact, as Shiba (1977, p. 432) himself put it, China consisted of "semiclosed regional economies";

iv) Elvin (1973, p. 123) attributes changes to the Sung which occurred over a longer period. He suggests that "in the far south double or triple cropping of rice was almost universal", whereas Perkins (1969, pp. 44–45) suggests that the proportion was small in 1400 and expanded gradually thereafter.

None of the authors who have dealt with the Sung period have tried to quantify the achievement in macroeconomic terms. This is understandable as hard evidence is scarce. Nevertheless, it seems useful to advance a quantitative guesstimate because one is otherwise left with qualitative and literary interpretations whose meaning is very elastic. In this situation it is difficult to know the degree to which judgements diverge. The advantage of quantification is that it helps to sharpen the focus of debate.

Table 1.3 assumes that Europe and China had similar levels of performance in the first century AD. By the beginning of the Sung, there is good reason to believe that Europe had fallen substantially below Chinese levels[3]. I assume that per capita income under the Sung grew by about a third. It is probable that it fell in the fourteenth and seventeenth centuries, but over the long run in the Ming–Ch'ing dynasties, was probably roughly stable[4].

Chinese population fell by a third during Mongol rule of China. This was due *a)* to the initial savagery of the Mongol conquest and *b)* to the plague epidemic which struck in China at about the same time as the Black Death in Europe.

The Mongols took over North China in 1234. Their initial impact, under Ghengis Khan and his son Ogotai, was very destructive. North China had already suffered from hydraulic neglect (the Yellow River had burst its banks and the Grand Canal had ceased to function). Then the Mongols razed many cities, inflicted great damage on agriculture, enserfed or enslaved part of the rural population and began to pastoralise the economy to provide grazing for horses and other animals. Some North Chinese migrated South but many more were exterminated. Mongol policy changed by the time the Southern Sung Empire was defeated in 1280 (see Perkins, 1969, pp. 196–200). The first Yuan emperor Kubilai reversed the pastoralisation policy and began to sinicise his governmental apparatus. He established a military occupation which preserved the Southern Sung economy and many of its institutions.

McNeill (1977, pp. 141–44, 259–69) explains how Mongol horsemen spread bubonic plague in China just as they brought the Black Death to Europe. He suggests its heaviest incidence came in China after 1353, and that this source of mortality played at least as big a role as Mongol ferocity in reducing population. Durand (1960, p. 233) also argued that in the last phase of Mongol rule "the pandemic of bubonic plague raged no less fiercely in China than it did in Europe".

The population collapse at the end of the Yuan dynasty had its counterpart in the mid–seventeenth century transition between the Ming and the Ch'ing when savagery, smallpox and famine reduced the population by a fifth (see Figure 1.1).

There are two kinds of evidence which suggest more or less stable Chinese per capita performance in the Ming–Ch'ing. The first of these is Perkins' presumption of per capita stability in the agricultural economy (see Table 1.6 below). The second is Rozman's assessment that there was relatively little change in the proportionate size of the urban population from the T'ang to the early Ch'ing (see Table 1.7). Perkins maintains that grain output remained steady on a per capita basis, and there is little indication of change in the nature of the livestock economy. The Perkins (1969) position is much more firmly documented than that of Chao (1986) who suggests a substantial decline in per capita grain output and consumption from the Sung to the early nineteenth century.

In the absence of direct indicators for developments in the urban economy, I assume that Rozman is right in his finding that there was only a slight rise in the urban proportion of the population. This contrasts with the much faster urban growth of Europe as shown by Jan de Vries (Table 1.8).

Agricultural Performance

In imperial China, agriculture was by far the biggest part of the economy. In 1890 it still represented over 68 per cent of gross domestic product and four fifths of the labour force. These proportions must have been at least as high over the preceding two millenia. The economic and technological performance of the imperial system can therefore be judged in large part by what happened in this sector.

The Institutional Setting

In the first millennium of the Empire, people were scarce relative to the land available, so various forms of coercion were used to make farmers work harder. These included both serf and slave

labour, particularly in areas where the imperial regime had to feed the sizeable urban centres it created for administrative or military needs. Until an effective bureaucratic system was created in the Sung period, the imperial authorities delegated administrative responsibility to various types of landowning aristocrat who used servile labour.

When population growth began its long term ascension, land became scarcer. This, together with the success of a better organised bureaucracy in ousting aristocratic remnants, made it easier to move towards a system of freer labour. In these circumstances the state could successfully levy land taxes first in kind, then in money. Private landlords remained important, but were generally cronies of the bureaucracy. Their desire for serf or corvee labour declined, as the feasibility and profitability of collecting rental income increased. By the Ming dynasty, landordism had few feudal remnants. Landlords were largely non–managerial rentiers. The bureaucratic system provided the social discipline they needed, and protected their assets.

Between the Sung and the Ming dynasty, China moved to a system where production and managerial decisions in agriculture were made by peasant proprietors and tenants, who could buy and sell land quite readily, and sell their products on local markets (see Skinner, 1964–65, on the structure and functioning of these local markets). Chinese agriculture acquired an institutional order which was efficient in its allocation of resources and capacity to make technical changes as successive generations (in a system with partible male inheritance) had to make do with smaller family holdings.

Land Shortage

Because of climate and topography (large areas of mountain and desert), the proportion of land suitable for crop production is unusually small by international standards. China is a country of ancient settlement, but at the end of the twentieth century, cultivated land is only 10 per cent of the total area, not very different from the situation in countries of recent settlement, and in stark contrast to India which is able to cultivate more than half its total area, or Europe where the proportion is more than a quarter. Even the United States, where settled agriculture is much more recent, is able to cultivate twice the Chinese proportion (see Table 1.4). The Chinese man/land ratio is extreme. For every person engaged in farming, there is only one–third of a hectare of cultivated land, compared with 99 hectares in the United States.

In the past thousand years the population of China has risen nearly 22–fold, from 55 million to 1.2 billion. The government and the farm population struggled to increase the cultivated area by draining lakes, swamps, and jungles, reclaiming land from the sea, terracing hillsides, and cutting forests. They moved the centre of gravity of the Empire. In the early years, the Imperial heartland was in the northwest loess area of dry–farming. The now very densely settled area in the lower Yangtse was then a “large territory sparsely populated, where people eat rice and drink fish soup; where land is tilled with fire — the place is fertile and suffers no famine or hunger. Hence the people are lazy and poor and do not bother to accumulate wealth” (Chi, 1936, p. 98). The landscape has been completely transformed. Nevertheless, the cultivated area has probably expanded no more than four or fivefold since the Sung dynasty. To maintain living standards the Chinese were under great pressure to find new ways of extracting more food per hectare. The pressure of population on the land was always very marked by comparison with Europe. There was no common land, forests were destroyed, fallowing was abandoned eight centuries earlier than in Europe.

Double cropping, intercropping, seedbedding and transplantation were further methods for economising land. Shortage of land was also reflected in Chinese dietary habits.

Concentration on Crops not Livestock

For the past millenium, Chinese have eaten less meat than medieval or modern Europeans, milk is not consumed by adults, and there has been an almost total absence of milk products. The concentration on crop products was influenced by land scarcity, for less land is required when proteins and calories come from grains rather than animals. The meat the Chinese eat comes mainly from pigs and chickens which rely on scavenging rather than pasture. Protein intake is supplemented by soybeans and the widespread practice of fish farming in small ponds. Chinese made very little use of wool. Ordinary clothing came largely from vegetable fibres (hemp, ramie, and then cotton). Quilted clothing supplied the warmth which wool might have provided. The richer part of the population relied on the long established products of Chinese sericulture. Silk cocoons came from mulberry bushes often grown on hillsides which were not suitable for other crops.

Early advances in farm tools reduced the need for work animals. Bray (1984) gives elaborate detail of the precocity of Chinese ploughs, which had curved iron mouldboards from the Han dynasty onwards. She argues that until the eighteenth century, these were far superior to European ploughs which had straight wooden mouldboards and required powerful animal traction (teams of horses or oxen). In China a single ox could pull a better plough.

The emphasis on grain and textile fibres rather than livestock and livestock products was strengthened by official policy. The authorities preferred settled agriculturists to pastoralists, because they were easier to control and tax.

The contrast between Chinese practice and that of their Mongol and Manchu neighbours was quite extreme. In these border regions, population was small, and settled agriculture largely absent. Mongols were transhumant pastoralists living mainly from meat and milk products, moving their herds across the steppes when better pasture was needed; making extensive use of wool products for clothing and for covering their mobile homes — yurts which could be easily transported by horse traction. In the course of time, the Chinese enlarged their empire and absorbed these non–Han pastoralists, but the fringe areas were very thinly settled. In Manchuria Chinese farmers were permitted to settle only in the nineteenth century, after Russia had grabbed large parts of the empty land in Eastern Siberia.

Intensive Use of Manure

A third feature of Chinese agriculture has been heavy use of manure. Animal manure comes largely from pigs and chickens, and there was very intensive use of human droppings, in contrast to practice in Europe and India. In Europe it was only in the Netherlands and Flanders that this was widespread. The Chinese designed a special privy–cum–pigsty to collect both human “nightsoil” and pig manure. Silage techniques were used to kill off noxious and harmful micro–organisms. Many kinds of manure were manhandled in mixing it with chaff, crop waste, dead leaves, ashes, household waste, or aquatic weeds. China was well endowed with rich silt deposits and river mud which were mixed with other fertiliser elements. Commercial bean cake and green leguminous plants were also important fertilisers. The intensive use of fertiliser was induced by the relative scarcity of land.

Heavy Use of Irrigation

Chinese agriculture is heavily dependent on irrigation and careful water management, which augment fertility, reduce the risk of floods and mitigate the impact of droughts. In the northwest loess region, the emphasis was mainly on canals. Further east, in the lower reaches of the Yellow River, the problem was mainly one of flood control. In the Yangtse and Pearl River valleys irrigation was

necessary to secure regularity and manageability of water resources. In the South all farming involves detailed water management and maintenance to ensure high fertility on tiny rice paddies. China has two very large rivers. The Yellow river has a much smaller flow than the Yangtse, but carries huge quantities of silt from the west of the country, where the disappearance of forests has led to continuous soil erosion. From time to time the course of the Yellow River has changed disastrously (e.g. in 1194 and in 1855) when dynastic decline led to neglect of river management (see Gernet, 1982, for a map of successive changes of course of the Yellow River in the past three millennia).

Official activity played a major role in large scale irrigation projects, particularly in the North. South of the Yangtse where polders, levies, dikes and lake or swamp drainage were involved, the role of private associations or groups was bigger. The state has also had a major stake in hydraulic works for transport purposes. From the Sui period, the Grand Canal was developed to transport tribute grain to the imperial capital in the northwest, first Ch'ang–an, then Peking, where local farm conditions were not propitious for feeding a huge capital city.

Chi (1936) and Perkins (1969) have given a very rough quantitative picture of irrigation development by scrutinising official bureaucratic gazetteers for provinces and counties over several centuries. Perkins confined his listing to new projects whereas Chi included major repair work as well. Their sources give dates and dimensions for only a fraction of the total projects they describe. Perkins (1969), p. 338, shows that the average proportion of dated projects was less than a tenth of the total recorded. The proportion varied a good deal over time and between provinces. Nevertheless, one can reasonably conclude from Chi and Perkins: *a)* that the effort to expand irrigation was much more substantial in the thirteen centuries from the T'ang period than it had been in the first eight centuries of the empire; *b)* that the volume of construction increased in successive dynasties, except for the move from the Ming to the Ch'ing where Chi shows an increase and Perkins a decrease. Perkins' estimates are probably a better guide in this case; *c)* a third conclusion that seems reasonable is that the rate at which construction accelerated was most impressive in the T'ang–Sung period.

Table 1.5b shows that irrigated land was about 30 per cent of the cultivated area in 1400 and in 1820. Between 1820 and 1952 the irrigated proportion fell to less than a fifth, but it was very much higher than in India and Europe. In India only 3 million hectares were irrigated in 1850 (see Maddison, 1971, pp. 23–24) or about 3.5 per cent of the cultivated area. In Europe, aggregate figures are not available, but the average was probably much nearer to that in India than in China. In the United States about 10 per cent of cropland is irrigated compared with 52 per cent in China in 1995.

Chinese irrigation involved huge labour inputs, both in constructing major works and in constant maintenance. However, since the 1960s pumps and tubewells powered by electricity have reduced labour requirements significantly.

Official Encouragement of New Crops, Multicropping, Higher Yields and Diffusion of Best Practice Technology

Another feature of Chinese agriculture was its centrality in economic policy. Like the eighteenth century French Physiocrats, the Emperor and the bureaucracy thought of agriculture as the key economic sector. They helped develop and diffuse new seeds and crops by technical advice. They commissioned and distributed agricultural handbooks, calendars etc. They ensured that the advice they contained was adopted by selected farmers in different regions. Bray (1984) cites extensive bibliographies which show the existence of more than 500 (mostly official) works on Chinese agriculture (78 pre Sung, 105 Sung, 26 Yuan and 310 Ming–Ch'ing texts). From the tenth century they were available in printed form. The most remarkable was Wang Chen's *Nung Shu*. This exhaustive treatise on agricultural practice had many illustrations, with the intention of diffusing

knowledge of best practice North Chinese techniques to the South, and vice versa. The original version (1313) of this oft cited work was lost and many of its illustrations were redrawn in subsequent editions (see Bray, p. 63). She used the edition of 1783. This official Chinese literature had no counterpart elsewhere in Asia (except in Tokugawa Japan) and for a very long period in Europe. In the Roman period there were treatises by Columella and Varro, but European works in this field did not reappear until the fourteenth century. By 1700, according to Bray, the volume of European agricultural publications had caught up with the Chinese.

China's territory stretches over many climatic zones, and its biodiversity is richer than Europe because glaciation was less severe, and ancient botanical species were preserved in greater numbers. In the Imperial period, China adopted and diffused a number of new crops which became important. Tea spread widely and was subject to taxation in the T'ang dynasty. Cotton was introduced in the Sung period, and began to be widely used for cloth in the Yuan dynasty — prior to this ordinary people wore less comfortable fibres such as hemp or ramie. Sorghum was disseminated widely after the Mongol conquest. Crops from the Americas were introduced in the mid–sixteenth century. Maize, peanuts, potatoes and sweet potatoes added significantly to China's output potential because of their heavy yields and the possibility of growing them on inferior land. Tobacco and sugar cane were widely diffused in the Ming period.

From early times Chinese farmers succeeded in getting higher yields from their seeds than Europeans. Seeds were planted in rows with drills in North China; seed beds and transplanting techniques were used in the Southern rice growing areas. In China, wheat and barley yield/seed ratios were about 10:l in the twelfth century (Bray, 1984, p. 287) and a good deal better for rice. Slicher van Bath (1963) suggests that the typical medieval European yield/seed ratio for wheat was 4:1. Duby (1976, pp. 25–26) cites even more miserable results, and a 4:l yield is not out of line with what Mayerson (1981) cites for Roman times. It was not until the eighteenth century that European agriculture began to show serious improvement in this respect.

With official encouragement, early ripening seeds were developed which eventually permitted double or even triple cropping of rice. Until the beginning of the eleventh century, the total time for rice to mature was at least 180 days (4–6 weeks in a nursery bed and 150 days to mature after transplanting). The Sung emperor Chen–Tsung (998–1022) introduced early ripening and drought resistent Champa rice from Vietnam. Over time, this made double cropping feasible and allowed extension of cultivation to higher land and hillier slopes. The original Champa rice matured 100 days after transplanting. By the fifteenth century there were 60–day varieties. In the sixteenth century 50–day varieties were developed, in the eighteenth a 40–day variety, and in the early nineteenth a 30–day variety became available (see Ho, 1959, pp. 170–74). Government policy also encouraged intercropping in the North and promoted expansion of wheat as a second crop in the South.

Chao (1986, p. 199) suggests that the Chinese multiple cropping index was 0.6 in the Han dynasty in the first century (i.e. 40 per cent of land was left fallow on average), rose to 0.8 in the eighth century (T'ang dynasty) and to 1.0 under the Sung (i.e. on average there was no fallow at that time). Rice/wheat double cropping was stimulated in the South by policy incentives of the Sung dynasty, but double cropping of rice expanded rather slowly. He suggests that the double cropping ratio reached about 1.4 in the nineteenth century, then fell with the opening up of Manchuria from the 1860s when settlement by Han Chinese was permitted but where the climate did not allow double cropping. In the 1930s to 1950s the coefficient was about 1.3 and by 1995 had risen to nearly 1.6.

The figures quoted above are averages for the whole country, but the situation varies a lot by region. In the northeast and northwest the cropping index was about l in 1990 and slightly less in Heilungkiang and Inner Mongolia. In Eastern China the average was nearly 2 with a high of 2.53 in Kiangsu. Further South it was 2.44 in Kiangsi and 2.25 in Kwangtung (see Colby, Crook and Webb, 1992, p. 24).

In Europe, widespread use of fallow was common in medieval times (see Slicher van Bath, 1963, pp. 243–54), and it was not until the development of crop rotation in eighteenth century England and the Netherlands that fallow began to disappear. For Europe as a whole the twelfth century Chinese situation was not achieved until the twentieth century.

Quantifying Agrarian Performance

A good deal of information about the nature of long–run changes in Chinese agrarian performance can be found in the work of Ping–ti Ho. His 1959 book contains a detailed survey of the development of new crops and changes in practice which he gleaned from Chinese bureaucratic records (local gazetteers — *fang shih*). Thousands of these have survived from the Ming (1368–1644) and Ch'ing (1644–1911) dynasties. They cover the 18 imperial provinces and many of the 1 300 or so county (*hsien*) jurisdictions. He explains the care which must be used in interpreting figures from such sources, as incentives to report or to evade registration varied over time and place, and so did the precise meaning of traditional measures. Ho (1975) goes back further and uses archaeological and archaeobotanical evidence to examine the origins of agriculture over the five millennia before the Chinese empire was created.

He does not provide any aggregate quantitative estimates, but clearly believes that Chinese agriculture was "persistently self sustaining". Over the long run he considers that real levels of per capita consumption did not fall but were maintained by adaptive changes in technical practice. He also recognises that the process of increasing land productivity involved a gradual decline in labour productivity.

Dwight Perkins (1969) approached Chinese agrarian history in the same spirit as Ho, but made a big step forward. He presented a carefully modulated and scholarly assessment of the magnitude of movements in output and land productivity over six centuries. His basic assumption is not too different from that of Ho, i.e. Chinese traditional agriculture was successful in sustaining living standards in face of a massive population increase. He felt that his conclusion was reasonably conservative and did not exclude the possibility that there may even have been a 20–30 per cent rise in food consumption per head in the six centuries he covered.

The main productivity ratio with which Perkins is concerned is yield per unit of arable land cultivated. Given his assumption of stable consumption levels, one can infer that yield increased very considerably over the period he covers. He assumes that arable land was in constant use with no fallowing, and he ignores pasture land. His assumptions about land under cultivation and yields are backed by a good deal of evidence from provincial gazetteers.

Table 1.6 shows Perkins' (1969, pp. 16–17) simple long term assumptions converted into metric units. For 1650 and 1750 the figures of Wang (1973) were used for cultivated area. Wang was Perkins' main research assistant. His figures are consistent with the Perkins framework of analysis and use the same sources.

Perkins states his argument entirely in terms of grains which occupied 80 per cent of the cultivated land. He assimilates potatoes and other tubers to the cereal group, and assumes that output and consumption of other crop items and livestock products moved in the same proportion as cereal output. In his long run analysis he excludes forestry, fishing and hunting. His basic assumptions are that annual per capita use of grains for consumption, feed, and seed remained more or less steady in a range about 10 per cent either side of 285 kg. (of unhusked grain). Traditional inputs were seed grain, a small amount of feed grain, manure, irrigation costs, and the services of draft animals. One can assume that, for Perkins, inputs and value added moved parallel with gross output.

From Table 1.6 one can see total grain output rising by a factor of 5.3 from 1400 to 1820, i.e. in the same proportion as population. The cultivated area increased about threefold, yields by about three–quarters. The increase in yields was partly due to: *a)* multiple cropping of rice, wheat and barley which was negligible in 1400 (see Perkins, 1969, pp. 44–47); *b)* introduction of maize and potatoes from the Americas whose yield was higher than that of indigenous crops; *c)* increased input of manure per hectare as the population of humans and animals grew faster than the cultivated area.

Perkins is reluctant to characterise the improvements he describes as technical change. In fact (pp. 186–89) he describes the Ming–Ch'ing period as one of technical stagnation mainly because there was little change in farm tools. This is too narrow a view of technical change. In the period he covers there was an increase in the proportion of double cropped land, improvement in the speed with which early ripening seeds developed, an important assimilation and adaptation of new crops from the Americas, a move from hemp to cotton cultivation as clothing habits changed, widespread dissemination of sorghum, increased use of beancake as fertiliser, and an extension of the irrigated area. Much of this involved wider diffusion of best practice procedures which were already known. There was certainly an improvement in average practice and a successful effort to absorb and adapt knowledge. This long term process of assimilation should be recognised as technical progress.

Non–Farm Activity of Rural Households

Apart from their labour intensive activities in cropping, manuring and irrigation, Chinese rural households had a large range of other pursuits. These included vegetable gardens and orchards, raising fish in small ponds, sericulture, gathering grasses and other combustible material for fuel, feeding pigs and poultry. Important "industrial" activities were also centred in rural households. Textile spinning and weaving, making garments and leather goods were largely household activities. The same was true of oil and grain milling, drying and preparation of tea leaves; tobacco products; soybean sauce; candles and tung oil; wine and liqueurs; straw, rattan, and bamboo products. Manufacture of bricks and tiles, carts and small boats, and construction of rural housing were also significant village activities. It is clear from the work of Skinner (1964–1965) that Chinese farmers did not live in a subsistence economy, but were engaged in a web of commercial activity carried out in rural market areas to which virtually all villages had access. The relative importance of these rural activities grew in the Sung dynasty, together with the improvement in land productivity, rural living standards and the increased commercialisation which most analysts have discerned. Skinner (February 1965, p. 208) speaks of "intensification" of rural market activity over time due to demographic growth, but seems to doubt whether there was much change in the proportion of individual peasant activity going into such pursuits. However, a proportionate increase seems plausible because of the growing importance over the long term of cash crop items like cotton, sugar, tobacco and tea. In the nineteenth century (Table C.1) well over a quarter of GDP came from traditional handicrafts, transport, trade, construction and housing and most of these were carried out in rural areas. These activities had probably been more important for centuries in China than they ever were in Europe.

Performance in the Urban Sector

It is very difficult to assemble detailed evidence on urban economic activity, but one can use estimates of the proportionate size of the urban population as a proxy. Fortunately Rozman (1973) provides rough estimates of Chinese urban characteristics from the T'ang dynasty to 1820.

Rozman is mainly concerned with the structure of the urban "network" rather than its significance for the economy. His hierarchy describes the operational locus of the Chinese imperial

administration. The top level is the national capital with a population of around a million (similar to Beloch's estimate of the size of imperial Rome at the death of Augustus, and to Constantinople when it was at its peak as the capital of the Byzantine Empire). His next category covers secondary capitals such as Nanking. The third refers to provincial capitals and other "elevated" provincial cities; the fourth to prefectural capitals or major regional ports. The fifth refers to the lowest level of officialdom — the county (*hsien*); in the whole period he covers, their number remained in a narrow range from 1 235 in the T'ang to 1 360 in the Ch'ing (Skinner, 1977, p. 19) despite the huge increase in population. The supervisory function of officialdom was spread more thinly over time. The bottom of Rozman's hierarchy is more rural than urban and refers to local agricultural marketing areas; at that level bureaucratic control operated "only in a very attenuated form" (Skinner, 1964, p. 31).

Rozman got his basic information from regional gazetteers (pp. 341–346). His search was most systematic for the province of Chihli where the imperial capital was situated. Here he consulted 246 gazetteers of which 2 were from the sixteenth century, 40 from the seventeenth century, and 60 from the eighteenth century. For the other seventeen provinces he cites 272 gazetteers (an average of 16 per province). Of these, 4 were from the seventeenth century, 55 from the eighteenth century. The rest were at various dates up to 1936. For many towns he had no exact population figure but felt he had enough information to allocate them to one of his seven hierarchical levels (p. 5). In most provinces (p. 146) he had only a 20 per cent sample of counties *(hsien)* and prefectures *(chou)* which he extrapolated to get provincial totals. His estimates for China are an aggregation of these provincial estimates. In some cases his figures for total Chinese population deviate a good deal from the source used (compare the last two columns of Table 1.7). I have not adjusted his urban ratios for this as I am not sure to what extent his numerators and denominators are independent. It is clear, however, that his estimates are very rough.

Table 1.7 gives Rozman's estimates of "urban" population as well as the ratio one can derive for towns with 10 000 inhabitants or more. He shows an increase in the urban proportion from the T'ang to mid–Ming but no rise from mid–Ming to later Ch'ing.

Fortunately, it is possible to compare Rozman's findings for China with the situation in Europe, thanks to the work of De Vries (1984) whose results are shown in Table 1.8. He defines European urban population as those in towns with inhabitants of 10 000 or more and his ratios can be compared with those for China in Table 1.7.

De Vries' statistical procedures are much more systematic, transparent and better documented than those of Rozman. He estimates urban population at fifty year intervals from 1500 to 1800, using a database for 379 specified cities which he subdivides into six size categories. These differ in their cut–off points from those of Rozman, but the database can be reordered in the Rozman categories, for towns over 10 000 inhabitants. The De Vries estimates cover 16 countries or regions. Most of these are West European or Mediterranean. In Eastern Europe he covers only Austria–Bohemia and Poland. His urban ratios would probably have been somewhat lower if he had covered more of Eastern Europe.

If one compares the De Vries estimates with those of Rozman, it is clear that there was a very different situation in China and Europe. In the T'ang period China had an urban civilisation and Europe had none. By 1820 the Chinese degree of urbanisation was not much greater than it had been a thousand years earlier, whereas European urbanisation made a great leap forward from 1000 to 1500, and by the latter date was more urbanised than mid–Ming China. By 1800 the European urban proportion had almost doubled from the 1500 level, whereas China in 1820 had the same proportion as in 1500.

Although China had a much slower urban growth, the average size of Chinese towns was bigger than in Europe. Over the period covered by Rozman those with 10 000 or more inhabitants varied

between 41 000 and 60 000, whereas in Europe the range was from 22 000 to 34 000. The imperial capitals are estimated by Rozman to have had around a million population in all the dynasties, and there were usually some other cities with more than 300 000 (1 in the T'ang and mid–Ming, 3 in early Ch'ing and 9 in the later Ch'ing). In Europe, the four largest cities in 1500 were Milan, Paris and Venice (around 100 000) and Naples (150 000); in 1650 they were Amsterdam and Naples (175 000 and 176 000 respectively), London (400 000) and Paris (430 000); in 1800 Vienna (231 000), Naples (427 000), Paris (581 000) and London (865 000).

Imperial officialdom was of great importance in Chinese cities, not only as a proportion of population, but also in terms of power. Officialdom had a powerful role in dictating the layout of cities, it controlled communications and was not challenged by a countervailing judicial, military, aristocratic or ecclesiastical power. Their clerks and runners were locally recruited and responsible for detailed fiscal demands, for economic regulation, and exaction of penalties for crimes and misdemeanours.They had considerable power to vary these and to augment their income by dispensing favours, so the rest of the populace was in a state of dependency. The Chinese non–bureaucratic elite tended to mimic the habits and education of officialdom, and were dependent on official favours to lighten their tax burdens and get other legal privileges like immunity from corporal punishment for criminal offences. They were also eager to purchase official degree status on those occasions in imperial history when fiscal need led the government to raise money this way.

European cities were more autonomous. Most of them had charters and codes of civil law which protected the legal rights of citizens, and commercial influence was very much stronger.

Max Weber's work on China (see the 1968 translation) stressed the differences between the constraining role of officialdom in Chinese cities and the greater opportunities for capitalist development in Europe. Balazs' (1964) writings are also in the Weberian tradition. He emphasises the predatory fiscal approach of the bureaucracy, the potentially arbitrary character of the justice they dispensed which put constraints on capitalist development and inhibited risk taking. In bigger industrial enterprises, the state usually played a leading role, e.g in state iron works, imperial porcelain works, in licensing the salt trade, in control of land for urban real estate, control of communications and trade on the Grand Canal.

The striking difference between Chinese state enterprise and European commercial interests can be seen in the field of international trade. The early Ming, the Yung–lo Emperor built up a fleet of large ships for ocean voyages and sent his eunuch admiral, Cheng Ho, on major expeditions between 1405 and 1433 (Levathes, 1994). Thereafter the shipbuilding industry was neglected and foreign trade more or less prohibited. This decision cut China out of the huge expansion of overseas trade which was a key element in the development of capitalist enterprise in Europe from the end of the fifteenth century onwards.

Notes

1. Chao's exaggeration of Sung urban development derives partly from Hollingsworth's (1969, p. 246) implausible estimates of the population of Hangchow. He suggests that it was at least 5 million and probably 6–7 million; he makes no attempt to explain how it would be possible to feed such a huge agglomeration. Hollingsworth relies heavily on Marco Polo. Polo claimed that Hangchow consumed 4 338 kg. of pepper a day. Hollingsworth figures that this would require at least 5 million people to digest it. To illustrate the size of the city he quotes Polo's statement that there were 12 000 bridges. By contrast, Needham, vol. IV.3 (1971, p. 148), states that the city contained only 347 bridges in Polo's time. Gernet and Balazs, who have scrutinised the sources more seriously, suggest a population of around one million.

2. Hartwell suggested that iron production in the Northern Sung increased ninefold from 806 to 1078 and per capita output about sixfold. He regards this as an "early industrial revolution". Extrapolating from what he found for iron, he infers that there was an "impressive expansion of mining and manufacturing in eleventh–century China" (Hartwell, 1966, p. 29). Hartwell inferred iron output in 1078 from various tax returns. Assuming a 10 per cent rate of tax he estimated total taxed output to be 75 000 short tons (68 000 metric tons). He doubled this figure to take account of illegal or unrecorded production (Hartwell, 1962, p. 155). This estimate seems plausible and fairly modest in the light of his own comparative figures. It implies a per capita consumption of 1.4 kg. in 1078, compared to 3 kg in England and Wales in 1540, 6.4 in 1640 and 15.4 kg in 1796. The most implausible aspect of Hartwell's estimate is his suggestion that per capita consumption rose sixfold from 806 to 1078. He does not explain what changes in demand patterns would warrant this, and his 806 estimate is not properly documented. He deals mainly with the supply of iron to the early Sung capital K'ai–feng. A large part of demand for iron came from the central government which needed it for weapons and iron coinage. He shows (1967, p. 152) the population of K'ai–feng rising sixfold from 742 to 1078 and falling more than tenfold from 1078 to 1330. In the light of this there is nothing surprising in the rapid growth and subsequent decline of iron output in this region. Needham (1958, pp. 18–19) says that "regular industrial production of cast iron must have existed in China from the 4th century BC". Use of iron for military purposes, agriculture, building, various trades and household use had been widespread for centuries before Hartwell's period. I am therefore extremely sceptical of the representativity of Hartwell's evidence of "industrial revolution". Nevertheless, it influenced the interpretation of Sung performance by McNeill (1983), and Jones (1981, 1988).

3. In the first century, at the death of Augustus, the Roman Empire had 23 million inhabitants in Europe, 19.5 million in what became the Byzantine Empire, and 11.5 million in Africa (see Beloch, 1886, p. 507). Goldsmith (1984) produced an extraordinarily erudite, ingenious and ambitious attempt to estimate total and per capita income in the Empire at the time of Augustus. He suggests that per capita product was about two fifths of the British level at the end of the seventeeth century. Using my 1990 numeraire, this would be around $500. However, the Asian and African parts of the Empire were more urbanised than the Western Empire and Egypt's irrigated agriculture had much higher yields than those in Europe. The level in the West was therefore lower than the average for the whole of the Empire, and the non–Roman inhabitants of Europe (about 11 million in the first century) were operating near subsistence levels. In my estimate for European per capita income in the first century (Table 1.3 above), I assumed a $480 level in the Roman part, and a $400 in the non–Roman area — an average of about $450. I assumed that China and Europe operated at about the same per capita level in the first century A.D. It seems clear that after the collapse of the Western Roman Empire in the sixth century there was a significant fall in European income. Goldsmith (1984, pp. 271–72) suggests that the urban ratio (in terms of towns with 10 000 inhabitants or more) was probably around 5 per cent in the first century A.D. in the European part of the Empire. This compares with zero in the year 1000 A.D. (see Table 1.8). The urban collapse, plus the disappearance of international trade as a result of Arab occupation of North Africa and Spain, and the disappearance of the *pax romana* elsewhere, warrants the assumption of a significant drop in European income more or less to subsistence levels. From about the year 1000, the European situation began to improve. The urban population ratio

recovered to Roman levels in the fifteenth century, and thereafter there was a considerable expansion in European trade. For 1500–1820, see Maddison (1995*a*), p. 19.

4. It should be noted that Needham's view of the contours of Chinese development is different from that suggested in Table 1.3. He considers that Chinese superiority to the West stretched further back in time. His views deserve serious consideration in view of the encyclopaedic exploration of Chinese science and technology which he directed. *Science and Civilisation in China* was inaugurated in 1954 and at the time of his death in 1995, about 6 000 pages of the still unfinished work had been published. The Needham associates generally provide a comparative view of technology in China and the West, particularly in matters of chronological precedence, but they do not usually assess the economic impact of technical change. The volumes of Francesca Bray (1984) on agriculture and Dieter Kuhn (1988) on textile technology are probably the most enlightening in this respect.

   Needham's views on the contours of Chinese development are stated most clearly in *The Great Titration* (1969), which is a collection of essays published between 1946 and 1966. He perceives no great leap forward in the Sung, but stresses China's thousand year lead in siderurgy and paper, its 700 year lead in printing etc. He suggests (p. 40) in a 1961 essay, that Chinese evolution could be "represented by a slowly rising curve, noticeably running at a higher level, sometimes at a much higher level, than European parallels, between say, the second and fifteenth centuries A.D.". In a 1964 essay (p. 117), he suggests that Chinese leadership originated seven centuries earlier: "it is clear that between the fifth century B.C. and the fifteenth century A.D. Chinese bureaucratic feudalism was much more effective in the useful application of natural knowledge than the slave owning classical cultures or the serf–based military aristocratic feudal system of Europe." A second 1964 essay (p. 190) gives yet another alternative "between the first century B.C. and the fifteenth A.D., Chinese civilisation was much *more* efficient than occidental in applying human natural knowledge to practical human needs".

   It is clear that Needham's position is quite elastic in dating the origins of Chinese superiority. It is also clear that his conclusion is not based on a careful analysis of the economic significance of Chinese technology and inventive activity. His general position on East–West levels of performance was developed well before his *magnum opus* was conceived. In his early days, he was greatly influenced by Wittfogel (1931). As a Marxist, Needham believed that the West was locked into inferior modes of production (slavery and then serfdom) from which China had escaped by installing an enlightened meritocratic bureaucracy (see Needham 1969, pp. 193–217, on the Asiatic mode of production).

   I think Needham's assessment of the merits and ultimate limitations of bureaucratic power in China is reasonably valid, but meritocratic selection did not emerge before the T'ang dynasty, and it is questionable whether China in the Han dynasty had a technology and level of economic performance superior to its European contemporary, the Roman empire. Roman organisational and military skills were at least as good as Chinese. Yields in Chinese agriculture were better than in Roman Italy (see Bray, 1984 and Mayerson, 1981) but probably no better than in Roman Egypt. Roman civil engineering and architecture were better in terms of capacity to build roads, cities, aqueducts and walls made of masonry. Many of these are still visible in Europe, the Middle East and North Africa, whereas Chinese cities were made of wood and their walls were made of tamped earth until the Ming period. The Roman road transport network was more than twice as big as that of Han China, although it served a smaller population (see Needham, 1971, vol. IV 3, p. 29).

   For these reasons, I doubt whether Chinese aggregate economic performance was better than that of Europe until the collapse of the Roman empire in the West, in the fifth century A.D.