

A Long Phase of Growth 400 BC-200 AD

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Over the last two-three decades, the interest in economic growth has extended from research into the modern world to that on early modern, medieval and ancient history. The main aim of this *Cambridge Economic History of the Greco-Roman World*¹ is to analyse the long phase of growth, from 1000 BC until 200 AD, of a pre-modern agrarian economy.

The interest in the dynamics of the ancient civilisation is apparent when we compare this work to the well-known previous reconstruction of the ancient economy by M.I. Finley, published in 1973.² In less than 40 years, the perspective on antiquity has radically changed. While Finley's concern was the difference in the organization and structure of the economic activity in the ancient world compared to that of our modern world, this recent endeavour focuses primarily on the dynamics or the performance of the ancient economy, as explained in the introduction (p. 3). At the time of Finley's work, literary documents continued to be the main source of information whereas this work is, as the introduction explains, supported by a huge amount of information acquired from recent research into "inscriptions, papyri, coins, and mute archaeological data" (p. 1).

In my comments, I will deal only with the Roman economy and will try to discuss both the material provided by the book and the explanations proposed by the authors. I will begin (section 1) with the model of the population-economy relationship proposed by W. Scheidel in chapter 3 and will recall both the features of the long phase of growth during Roman antiquity (section 2) and the explanations suggested (section 3). In the conclusion (section 4), we will consider the constraints to growth at work in this as in any other pre-modern agrarian economy.

1. *Population-economy*

1.1. *A model.* In order to summarize the book in a concise way, I will use, with a few changes, the figure presented by W. Scheidel on "population size and surplus for given resources and technology" (p. 51), originally

¹ *Cambridge Economic History of the Greco-Roman World*, W. Scheidel, I. Morris, R. Saller (eds.), Cambridge, Cambridge University Press, 2007. All the pages quoted between brackets in the paper refer to this work.

² M.I. Finley, *The Ancient Economy*, Berkeley-Los Angeles, University of California Press, 1973.

elaborated by R. Lee with the aim of explaining the economy-population interrelationship in pre-modern societies.³

While in the figure by Lee total output is a function of population or labour, I present the same production function in its so-called intensive form; that is divided by one of its variables; in this case capital (see the Figure in the Appendix).⁴ Thus, in the following figure, the product per unit of capital (Y/K) is a function of labour per unit of capital (L/K). This small change provides the possibility of examining at the same time both the influence of labour and capital on the level of product. In capital I include not only produced resources, as is ordinarily the case, but also non-produced, that is natural, resources.

In this figure, whenever labour (or population) increases more than capital and resources (both included in K), we move to the right of our graph on the horizontal axis, that is, towards a region where the slope of the curve of the product Y/K becomes lower. Whenever, by contrast, capital or natural resources rise more than labour (or labour diminishes because of some epidemic), the denominator rises in absolute or relative terms and we move to the left of our production function. Moving to the right, we proceed towards the region of decreasing returns and diminishing output per capita, whereas on moving to the left we proceed towards the high returns to labour, since both capital and resources, the factors cooperating with labour, rise in relative terms and labour, as a consequence, becomes more productive. The straight line (S) represents the need for subsistence and rises together with both labour and resources. The message of the graph is that, whenever labour rises with respect to resources, product rises less than proportionally due to decreasing returns. The final result is stagnation or decline; unless some external variable does not allow the displacement above the curve of product in the direction of the arrow.

1.2. *The external variables.* The displacement of the production function in the direction of the dotted curve is the consequence of some external variable, that is a variable not included in our graph, that allows production to be higher, with the use of the same factors. Technology, institutions and climate, do not appear in the graph due to their being external factors.

Labour productivity and GDP per capita are not directly represented. However, if we assume that labour (L) coincides with total population, per capita GDP is the tangent to the curve (as represented in the graph). As soon as the slope of the tangent diminishes, moving towards the right, per capita GDP also drops. If labour corresponds, as it actually is, to a share of population equivalent to workers, and not to the whole population, then the tangent to the curve represents marginal labour productivity, a determinant of GDP and a high proportion of gross output in the form of labour incomes. It can be seen that the displacement of the production function to the left (the dotted curve) results in rising labour productivity.

In brief, the general view presented in the book is that in the very long term, this phase of ancient growth resulted in diminishing returns to labour, since, as in any pre-modern agrarian economy, labour rose significantly more than capital and resources. Capital can be invested in order to increase the efficiency of labour. Natural resources can also be increased

³ R. Lee, "Population Homeostasis and English Demographic History", in R. I. Rotberg and T. K. Rabb. (eds.), *Population and Economy*, Cambridge, Cambridge University Press, 1986, pp. 75-100.

⁴ This theme has been more widely developed in S. Capasso, P. Malanima, "Economy and Population in Italy 1300-1913", in *Popolazione e Storia*, 2, 2007, pp. 15-40.

with the investment of labour and capital. In the long term, however, this ancient economy, like other pre-modern agrarian economies before and after, was unable to allow a self-sustained increase of output and standard of living; as it has been the case during the last two centuries. In our previous graph, the ancient economy moved from left to right (although some displacement to the left of the curve of product resulted in a deceleration of this tendency).

First of all, let us recall, some facts supporting the perspective of the slow growth and final decline of the ancient civilisation. Subsequently, we will look at the explanations.

2. *Ancient growth*

2.1. *Population.* We shall first of all consider population. Although, views continue to diverge on the population of the ancient world, scholars do agree on the overall upward trend. In 800 BC some 20 million people lived around the Mediterranean sea whereas in 200 AD the population of the Roman empire numbered 40 million or even 60-70 million (p. 47), according to the different figures proposed in different chapters of the book.

It is known that some authors contributing to this collective work share different views on Roman demography. However, in his chapter, W. Scheidel presents, in a certain respect, an intermediary position between the high and low calculation of the Roman population. While on specific figures some disagreement exists, the logistic curve of population (p. 48) suggests a long-term view of "population under Roman control" on which several scholars would agree; although, as we know, some of them would be ready to suggest a higher level at the end of the curve. Colonisation of new soils accompanied the increase of population around the Mediterranean and north of the Alps. Several maps included in the volume suggest the investment of labour and capital in order to extend the arable land and support the rising population.

2.2. *Urbanisation.* Rising population and colonisation of new lands do not necessarily imply forms of intensive growth, characterised by increase of per capita output and subsequently of consumption and standard of living. However, the opinion shared by the authors of this volume is that ancient growth meant not only demographic rise and extension of the arable lands, but also a rise, although very slow, in the average income. There is evidence that urbanisation rose significantly. Some big cities, primarily Rome, Carthage, Antioch, Alexandria and Ephesus, were large metropolises, surrounded by a huge number of medium and small centres. In the 1st century AD about 2,000 cities existed within the Roman Empire, when Italy boasted 430 towns (Scheidel, pp. 78-9). As a comparison, it may be remembered that in 1800, only 1,600 European towns counted more than 5,000 inhabitants and, among those, 440 were located in Italy.⁵ Since it is not known how big the ancient towns were, it is impossible to make a precise comparison. Urbanisation was, however, correlated with increase in marginal labour productivity both in agricultural and urban economy. In the

⁵ From the new database of European cities from 1300 until 1870, utilized in P. Malanima, "Urbanisation 1700-1870", in S. Broadberry, K. O'Rourke (eds.), *Cambridge Economic History of Modern Europe*, forthcoming.

Roman world, urbanisation took place, as can be seen, in the left part of our graph, where high returns to labour prevail.

2.3. *Per capita output.* According to the estimate of per capita GDP proposed by R.W. Goldsmith⁶ and the revision by A. Maddison,⁷ in the age of Augustus the average for the empire was 380 sesterces and for Italy 534 sesterces. These values were, in the view of Maddison, respectively 42 and 59 percent of that of late 17th century England. Although it is impossible to demonstrate that in Roman Antiquity the relative level of per capita GDP was much higher and similar to that of late 17th century England, there are, however, many doubts on the reliability of Goldsmith's and Maddison's evaluations of the difference between Roman civilisation, on the one hand, and 17th century England on the other.⁸ In our view, it seems much more plausible a similarity between the level of per capita GDP in Italy at the time of Augustus and the most advanced regions of early modern Europe. In any case, the rise in per capita GDP between 200 BC and 100 AD was modest indeed; although perhaps higher than 0.1 percent per year suggested in this *Cambridge Economic History* (p. 5). Regarding the chronology of growth, N. Morley suggests that, although "the economy of the Principate experienced some measure of growth, the great expansion of activity had already taken place under the Republic" (p. 589). In his chapter W. Harris as well emphasizes the achievements and economic progress in the late Republic.

2.4. *Growth.* Several chapters suggest the view of a relatively high standard of living in the last century BC and the 1st AD, when this ancient phase of growth reached its zenith.⁹ Evidence of this high standard of living is often quoted in the book: the number of shipwrecks (Morley, p. 572), the concentration of lead in the air (Kehoe, p. 548), meat consumption and even stature (Jongman, pp. 603 and 613-4); although the evidence regarding stature is still relatively weak. A rise of 25 percent in average consumption is suggested between 800 BC and 200 AD (p. 11) and this figure rises to 50 percent, when a comparison is made between 1000 BC and 200 AD (Scheidel, pp. 43-4). Other evidence of intensive growth is the frequently mentioned rise in the level of inequality (Lo Cascio, pp. 620 ff.; Jongman, pp. 615 ff.). Rising inequality is ordinarily correlated, in pre-modern agrarian economies, with per capita growth and rising complexity of the economic and social structure. Whenever the average income rises, private demand of commodities and services widens, intermediate social groups develop, and a tiny minority enjoys considerable wealth. By contrast, as per capita income diminishes, the opposite occurs. In these cases a simplification of economic and social life takes place. The wide majority of the population is equal in poverty; demand for private consumption diminishes and intermediate groups disappear. Income is more polarized than before, but, overall,

⁶ R.W. Goldsmith, "An Estimate of the Size and Structure of the National Product of the Early Roman Empire", in *Review of Income and Wealth*, 30, 1984, pp. 263-88.

⁷ A. Maddison, *Contours of the World Economy, 1-2030 AD. Essays in Macro-Economic History*, Oxford, Oxford University Press, 2007.

⁸ E. Lo Cascio, P. Malanima, "GDP in Pre-Modern Agrarian Economies (1-1820 AD). A Revision of the Estimates", in *Rivista di Storia Economica*, XXV, 2009, pp. 391-419.

⁹ See the fine reconstruction by W.M. Jongman, "Gibbon was Right: the Decline and Fall of the Roman Economy", in O. Heckster, G. De Klein, D. Sloopjes (eds.), *Crises and the Roman Empire. Proceedings of the Seventh Workshop of the International Impact of Empire*, Leiden, Brill, pp. 183-99.

it is less unequally distributed whenever we move towards the diminishing returns of the right part of our graph. On the left side of the Kuznets' turned U curve of inequality, intensive growth means rising inequality, while diminishing per capita income means declining inequality.

2.5. *Crisis*. Although, as A. Giardina states (pp. 743 ff.), there is some hesitation today in speaking of a crisis of the Roman empire, the book suggests that the long phase of growth, which lasted about a millennium, finally ended around the last decades of the 2nd century AD and during the 3rd. The economic trend was moving in the direction of low returns to labour, on the right side of our graph. There is evidence, during this last phase of the Roman antiquity, of a worsening of living conditions, diminishing stature (Jongman, p. 607), decrease in maritime exchanges and drop in economic activity, as shown by the reduction in lead concentration in the Greenland ice sheet (Kehoe, p. 548). The Antonine Plague, which started in 165 AD and spanned two decades, represented for the Roman world what the Black Death was for the medieval civilisation. A mortality of about 20 per cent, as suggested by Giardina (p. 757), brought about a new equilibrium between population and resources. In our graph, the equilibrium was restored in the direction of high returns to labour on the left side, since the fall in labour meant a diminution in the ratio L/K . However, it is important to notice, as suggested by E. Lo Cascio in the last pages of his chapter (and by Giardina), that demographic fall implied a reduction of state revenue and subsequently decline in its capacity of organisation and defence.¹⁰ Late antiquity was a period of economic, social and political weakening.

The previous synthetic view of the volume primarily refers to the centre of the empire: Italy. However, a merit of this work is the breadth of the geographic approach. It can be clearly perceived that Mediterranean regions followed specific development paths and that the chronology was far from similar. In Parts II, IV and VII, several chapters are devoted to the economies around the centre. Reading Part VII in particular, the chronological differences are emphasized within the Euro-Mediterranean world among Western Provinces (Ph. Leveau), the Eastern Mediterranean (S.R. Alcock), Egypt (D.W. Rathbone) and the Frontier Zones (D. Cherry).

2.6. *Summary*. The evidence of growth and decline can be summarized by saying that the long phase of ancient growth spanned the several stages of rising population, urbanisation, output and consumption. During this long phase both the standard of living and inequality rose: such as in the first half of the curve, in our graph. This phase of growth was followed by a period of decline in the economy and, as a consequence, institutions, on the centre and right of our graph. The complex organisation of Roman civilisation was followed by de-structurization and finally decline.

The view proposed in the book, and here synthetically recalled, seems convincing only when set against a background of continuous demographic growth, especially in the centre of the Empire, between the late Republic and the first century AD. It is known that quantitative evidence on demography is scanty and that opposite views have been presented in the far and recent past on the level of ancient population. This long-term

¹⁰ This thesis is developed in E. Lo Cascio, "La dissoluzione dell'impero romano d'occidente: la <<spiegazione demografica>>", in G. Cacciatore, M. Martirano, E. Massimilla (eds.), *Filosofia e storia della cultura. Studi in onore di Fulvio Tessitore*, Napoli, Morano, I, pp. 157-82; and Id., "Il declino economico dell'Italia romana e il declino dell'impero: due scenari a confronto", in *Rivista di Storia Economica*, XXII, 2006, pp. 41-57.

ancient growth from increasing returns towards decreasing returns can only work whenever both population density and pressure on resources rise. The model in the background of this work speaks of population rise and not “of population decline”.¹¹ The “need” of a demographic growth is more evident whenever we look at the theoretical approach prevailing in this history of ancient economy.

3. Explanations

3.1. *Classical approach with institutions.* In a collective work of this nature, it can often be difficult to find a common line of thought. However, in the volume in question a common perspective is to be found. The authors of the several chapters mainly agree with a classical explanatory framework, sometimes defined as Malthusian; inappropriately, I would say, since the Malthusian interpretation was, after all, shared by the economists from A. Smith to D. Ricardo and J. Stuart Mill. The scheme of the book fits the classical picture of the interrelationships man-environment or population-economy.

The classical approach is completed, however, by an institutionalist perspective, as stated at the beginning with a quotation by D. North (p. 1). Institutions play an important role in several chapters. They can be seen as special innovations able to combine production factors in a diverse way and raise the level of economic efficiency. Notably, in the chapter by B.W. Frier and D.P. Kehoe, institutions are represented as an important “exogenous factor affecting productivity in the Greek and Roman world” (p. 113). In our graph, institutions displace the production function, in the direction of the arrow, and allow the maintenance of a high level of labour productivity and average income.

War and conquest did not mean capital formation, but only transfers of capital, notably in the form of booty and taxes, towards Italy. They supported, however, the formation of institutions favourable to growth through the creation of a single monetary area, the spread of Roman measures and Roman language. The consequence was the reduction of transaction costs in the Mediterranean and the wide area subject to the Roman Empire. The elimination of piracy and the diffusion of “common legal rules, especially in the field of commercial law” (p. 626), played an important role, according to E. Lo Cascio. Institutional developments allowed for easier mobilization and distribution of resources and were “the key to Roman power” (Morley, p. 570).

3.2. *The endogenous approach.* The so-called endogenous growth theory is not yet embodied in the standard economic historical approach.¹² It could be usefully exploited by historians in the same way as it is nowadays by economists. Knowledge is the mainspring of growth, since the main determinant of growth is the exchange of useful knowledge among the protagonists of economic activity. It is not exogenously determined, but endogenously by the same variables included in the intensive production function. The growth of population itself implies an increasing efficiency. When

¹¹ I quote here the recent P. Turchin, W. Scheidel, “Coin Hoards speak of Population Declines in Ancient Rome”, in PNAS, October 13, 106, n.° 41.

¹² See, in any case, the book by J. Mokyr, *The Gifts of Athena. Historical Origins of the Knowledge Economy*, Princeton, Princeton University Press, 2002.

population is scarce, as in central-southern Italy in the 7th-5th centuries BC, the possibilities for human interaction are also scarce. Economic life is characterized by the so-called “poverty trap”, such as in the first part of our graph. A poor country is simply too poor to achieve sustained economic growth. The standard of living is close to the line of subsistence (S in our graph) and useful knowledge does not develop. Stagnation prevails. If population begins to rise, often under the impulse of some external contact, the division of labour begins to spread and increase the productive capacity; human interchange becomes much easier. The formation of towns, that is of centres where human contacts are much more frequent among ever bigger groups of people, imply an accumulation of knowledge and a rising dynamism; although, as suggested by W. Harris, “Rome’s rulers showed virtually no interest in human capital or popular education” (p. 539). Probably the contacts of the Romans with the Greek colonies in the South and the Etruscan civilization in the North, described in the chapter by J.-P. Morel, allowed the more backward Roman tribes to escape the “poverty trap”. Demographic growth and especially urban development favoured division of labour and accumulation of knowledge. Human cooperation and exchange were the bases of the increasing returns represented in the first part of our graph. The formation of a metropolis such as Rome, allowing contacts and relationships among different cultures, contributed significantly to the accumulation of knowledge and the formation of a cultural background favourable to economic expansion.

4. *The constraints*

4.1. *Techniques.* In past dualistic agrarian economies, the urban sector often progressed due to the progress of technical knowledge and improvement in economic institutions, whereas the countryside, by contrast, stagnated. We know that innovations also spread into the Italian countryside under the impulse of the growing population, as shown by Sallares (pp. 27 ff.) and D.P. Kehoe (pp. 543 ff). Intensification, according to the use of the word by E. Boserup,¹³ progressed through the spread of the polyculture (p. 551), three-field rotation and even convertible husbandry. Although Boserup considers these forms of intensification as true agrarian advances, they are normally correlated with demographic pressure and represent ways to escape poverty through the increase in land productivity. Our graph shows how product per unit of land (Y/K) rises, while, labour productivity declines (the slope of the tangent to the curve Y/K is diminishing). Intensification is correlated with decline in per capita product. After some progress in agriculture during the republican epoch, in the early empire agriculture is likely to have stagnated rather than progressed.

Stagnation in the countryside is the main obstacle in the path of development of past agrarian economies, since the energy able to support any economic activity originates in the countryside. We cannot but agree on the view expressed several times by A. Wrigley regarding the “organic economies” of the past and the obstacles to growth deriving from their energy system.¹⁴ Several years ago, C.M. Cipolla expressed a similar view,

¹³ E. Boserup, *The Conditions of Agricultural Growth*, London, Earthscan, 1993 (1st ed. 1965).

¹⁴ See notably E.A. Wrigley, *Continuity, Chance and Change. The Character of the Industrial Revolution in England*, Cambridge, Cambridge University Press, 1988.

although with different words.¹⁵ The adjective “organic” is probably not a good choice when we try to characterize past energy systems. “Organic”, in fact, means Carbon compound, and we know that Carbon compounds (coal, oil, natural gas) are still the basis of our modern energy systems. In a sense ours is much more “organic” than the dominating ones of the past.

In the chapter by H. Schneider, we see that ancient Roman economy was much more innovative than often supposed in the past. Schneider reacts to the view that “technological development in antiquity never implemented advances that were actually quite possible” and that “ancient technology had, on the whole, been characterized by stagnation” (p. 144). In the Mediterranean water power exploitation progressed and wind-sails became much more frequent. Numerous other devices were introduced able to support the workers in their daily toil.

4.2. *Energy.* However, the main energy sources of the classical world were the same as those of other past civilisations dating from 5-4,000 years BC until the 19th century. Food was the original source of energy and had been the only one for several million years. Firewood, the second source, began to be exploited between 1 million years ago and 500,000 with the discovery of fire. Finally, between 5,000 and 4,000 years BC, working animals, the third source, were introduced into agriculture and transportation. The following big jump in energy availability occurred with the steam engine and the wide introduction of coal as the main fuel.

The differences in food consumption per capita among diverse past agrarian civilisations can never be too ample. Average food consumption provides approximately 2,500 kcal per day in any past and present civilisation. Firewood consumption is always highly correlated to the average temperature. We know from the data referring to early modern Mediterranean regions that wood consumption was around 1.5 kg per day per head. It provided, that is, a little more than 5,000 kcal, industrial uses included. Much more uncertain is feed consumption for working animals in per capita terms. In order to reach a reliable estimate, we would have to know how many animals were employed in agriculture and transportation and then divide the feed intake, about 20,000 kcal per day per animal, among the inhabitants. The result would be the energy availability per head deriving from this energy carrier; such as the coal consumed by a steam engine is divided by the population in order to estimate per head consumption of energy. Very little is known on the subject of livestock in agriculture and transport during Roman antiquity.¹⁶ D.P. Kehoe recalls that “livestock-raising was of central importance to agriculture in the Roman world” (p. 551). Evidence concerning the following epochs suggests a ratio of a draft animal every 5-6 people. Thus, assuming this ratio population-working animals, to the 7,500 kcal per capita per day, from food and firewood, we would have to add 3-5,000 kcal, thereby reaching approximately 10-13,000 kcal that is the level of everyday consumption of Mediterranean countries such as Italy, Spain and Portugal

¹⁵ C.M. Cipolla, *The Economic History of World Population*, Harmondsworth, Penguin, 1962.

¹⁶ See G. Kron, “Roman Livestock Farming in Southern Italy: The Case against Environmental Determinism”, in M. Clavel-Léveque, E. Hermon (eds.), *Espaces intégrés et gestion des ressources naturelles dans l'Empire Romain*, Franch-Comté, 2004, pp. 119-34; Id., “Archeozoological Evidence for the Productivity of Roman Livestock Farming”, in *Münstersche Beiträge zur Antiken Handelsgeschichte*, 21, 2, 2002, pp. 53-73.

in around 1800.¹⁷ Water and wind power added very little (ordinarily less than 1-2 percent) to this energy balance. Today, in Western Europe, the energy consumed is about 150,000 kcal per capita per day.

Only a relatively low share of the energy intake was converted into actual work and useful heat: around 15 percent and perhaps less, that is 1,500-2,000 kcal; less than the calories provided by a 100-watt lamp over a 24-hours or by a Watt steam engine working for 5 minutes. If we exclude firewood, used only to engender heat and light and to melt metals, but not to provide mechanical work, everyday consumption of food for humans and feed for working animals was 6-7,000 kcal. Assuming an efficiency of 15 percent, the actual available work was around 1,000 kcal or 4.18 Megajoules, corresponding to the energy provided by a 100-watt lamp working 11-12 hours or a Watt steam engine working for 3 minutes.

4.3. *Changes in the energy balance.* When looking at the past ancient economies from the viewpoint of energy two elements are worth mentioning:

1. *a favourable climatic phase.* Roman growth coincided with a favourable climatic epoch, as clearly stressed by R. Sallares in his chapter on ecology, where the author mentions the "Warm Roman Period peaking at about AD 150" (p. 19). Both Roman and medieval growth coincided with favourable climatic phases, which permitted the cultivation of more northerly lands and an increase in arable cultivation on the hills. In a sense, natural capital increased and energy supply on the whole increased with it. In the L/K ratio in our graph, the denominator was rising. It contributed to the persistence of a long phase of high returns in the first section of our graph;
2. *the invention of slavery,* that is of the "slave mode of production", as remembered by A. Giardina in his chapter on pp. 755 ff. The ancient civilisation added a new working animal to the traditional agrarian civilisation; a working animal more versatile than those already in use and able to be exploited not only in cereal and vineyard cultivation, but also in domestic services and industry. We have just seen that the actual mechanical work was likely to be around 1,000 kcal per head per day. W. Harris suggests the existence of "four to eight million slaves and serfs in the Roman empire" (p. 527). Since the efficiency of the human body as a converter of energy is around 15 per cent, the work done by a slave was around 350-400 kcal or 1.46-1.67 Megajoules. The use of a slave every 3-4 free men implied some 100-150 kcal per head or 0.42-0.63 Megajoules and so an increase of 10-15 percent in the meagre energy availability of these 3-4 men. The warm climate did not derive from any conscious choice by the human beings. In the case of slave labour it was different. Slavery was a main technical innovation of the ancient agricultural civilisation in the field of energy. As M. Weber already suggested in his essay on the end of the ancient civilisation, the slave was

¹⁷ For data on Italy and Spain in the 19th century, see B. Gales, A. Kander, P. Malanima, M. Rubio, "North versus South: Energy Transition and Energy Intensity in Europe over 200 Years", in *European Review of Economic History*, 2007, 11, pp. 219-53.

as essential in the ancient economy as a blast-furnace in the age of coal.¹⁸

Conclusion. The low availability of mechanical work was the primary constraint to the productive capacity of any pre-modern agricultural civilisation based on an organic vegetable energy system. The growth potential of the ancient energy system was very modest. Furthermore, it was extremely hard to increase energy availability. When all energy comes from the soil in the form of phytomass, increasing returns from knowledge and institutions are not able to overcome the constraints of the energy system. The economy supported by vegetable energy cannot but proceed along the path of diminishing returns to labour, as seen on the right side of the graph.

The wide variety of material provided by this important volume can be summarized, saying that:

1. the ancient Greco-Roman period was actually characterized by both extensive and intensive growth;
2. institutional and technical innovations, the accumulation of useful knowledge, favourable warm climate and slavery were the external and internal factors supporting this long period of growth;
3. demographic growth began, from the late 1st or during the 2nd century, to jeopardize the high returns.

From the second half of the 2nd century, the decline in temperature which, so to speak, reduced capital in the form of arable farming and energy availability per worker, deeply contributed to the displacement towards the right side of the graph, Labour productivity dropped and the conditions were set for the end of a long phase of feeble growth of this pre-modern traditional agrarian civilisation.

¹⁸ M. Weber, "Die sozialen Gründe des Untergangs der antiken Kultur", in Id., *Gesammelte Aufsätze zur Sozial- und Wirtschaftsgeschichte*, Tübingen, Mohr, 1924.

Appendix. A Synthetic View

The following figure is nothing but a synthetic summary view of the book. Dates and explanations merely recall the information provided in the work and recalled in the previous pages. They are set on the background of the production function taking into account their approximate chronology.

