DISCUSSION PAPERS
Institute of Economics
University of Copenhagen

03-41

From Foraging to Farming: Explaining the Neolithic Revolution

Jacob L. Weisdorf

Studiestræde 6, DK-1455 Copenhagen K., Denmark
Tel. +45 35 32 30 82 - Fax +45 35 32 30 00
http://www.econ.ku.dk

From Foraging to Farming: Explaining the Neolithic Revolution*

Jacob L. Weisdorf†

November 4, 2003

Abstract

This paper reviews the main theories and evidence regarding the prehistoric shift from hunting and gathering to agriculture, an event which took place for the first time some 10,000 years ago. The transition, which is also known as the Neolithic Revolution, led to the rise of civilisation as we know it, and seems to have borne the seeds for the later process of industrialisation and for economic growth in general. The paper provides a brief historical survey of the leading hypotheses concerning the rise of agriculture proposed in the archaeological and anthropological literature. It then turns to a more detailed review of the theories proposed in the economic literature.

Keywords: agriculture, hunting-gathering, neolithic revolution, transition.

JEL codes: N50, O30, Q10

*I would like to thank John Chircop, Carl-Johan Dalgaard, Charles Dalli, Christian Groth, Finn Tarp, and the lunch-meeting participants at University of Malta for their comments. I am particularly indebted to Charlott H. Jensen at the Carsten Niebuhr Institute of Near Eastern Studies in Copenhagen for her comments and literary recommendation.

†Institute of Economics, University of Copenhagen, 6, Studiestraede, 1455 Copenhagen K, Denmark (Fax: +45 35 32 30 00; e-mail: jacob.weisdorf@econ.ku.dk.)

"Why farm? Why give up the 20-hour work week and the fun of hunting in order to toil in the sun? Why work harder, for food less nutritious and a supply more capricious? Why invite famine, plague, pestilence and crowded living conditions?"

Jack R. Harlan, *Crops and Man*, 1992

1 Introduction

The rise of Neolithic agriculture is unquestionably one of the most important events in human cultural history. Agriculture, or food production as archaeologists call it, appeared and spread in many different regions of the world between 10,000 and 5,000 years ago. From the appearance of the human race some 7 million years ago, until the introduction of agriculture, hunting and gathering was the only food procurement strategy practised. The transition to agriculture, which led to the rise of civilisation as we know it, has, therefore, rightfully been termed the Neolithic Revolution.[1]

The evidence of where and when wild plants and animals were cultivated and domesticated for the first time is relatively solid and dependable. So are the explanations of how hunters and gatherers actually transformed plants and animals into domesticates. But one important question is still subject to intense debate: What made human societies take the radical step from foraging to farming? The purpose of this paper is to acquaint the reader with the main theories that deal with this issue.

Traditionally, farming was considered to be highly desirable. Scholars of the history of mankind merely assumed that once humans recognised the impressive gains from cultivation and domestication, they would immediately start farming. However, over the years, studies have indicated that early farming was indeed back-breaking, time-consuming, and labour-intensive. This motivates the question posed by Jack R. Harlan, one of the great pioneers of historical ecology, in the quotation above: Why farm?

This compelling issue has puzzled the scientific community for decades. Archaeologists, agronomists, anthropologists, demographers, biologists, and historians have speculated intensively about the factors that eventually tipped the comparative advantage in favour of farming.[2] There is, however, widespread agreement that no single explanation so far proposed is entirely satisfactory (e.g., Fernandez-Armesto, 2001; Harlan, 1995; Smith, 1995).

Economists, too, have contributed to the understanding of the emergence of agriculture. In the 1990s, economic growth theorists began to examine the long transition from economic stagnation to sustained economic growth that seems

[1] The term 'neolithic revolution' was introduced by the reputable archaeologist V. Gordon Childe (1936). Some writers prefer the term 'agricultural revolution'. It is important, though, not to confuse the agricultural revolution in the Stone Age with the 'agricultural revolution' that presumably took place in the centuries prior to the Industrial Revolution.

[2] According to Gebauer and Price (1992), there are at least thirty-eight distinct and competing explanations of how farming emerged.

to have occurred with the Industrial Revolution (e.g., Galor and Weil, 1999, 2000; Goodfriend and McDermott, 1995; Hansen and Prescott, 2002; Jones, 2001; Kalemli-Ozcan, 2002; Kögel and Prskawetz, 2001; Lagerlöf, 2003; Lucas, 2002; Tamura, 2002; Weisdorf, 2003a). Inquiry into the pre-industrial economy encouraged some scholars to suggest that the rise of Neolithic agriculture had a crucial influence on later economic development. For instance, Galor and Moav (2002) suggest that the shift from the tribal family structure of hunters and gatherers to the household level family organisation of agricultural societies enhanced the manifestation of the potential evolutionary advantage of individuals with a quality-bias that favoured economic growth; Lagerlöf (2002), who investigates the institution of serfdom, argues that the birth of farming may have led to an era dominated by slavery; and Olsson and Hibbs (2002) show that the timing and the location of the transition to agriculture is strongly correlated with the distribution of wealth among today's countries.

A small but growing number of papers deal specifically with the emergence of farming. Smith (1975) examines the hypothesis that the extinction of large herding animals, due to 'overkill' by Paleolithic hunters, led to the rise of agriculture. North and Thomas (1977) argue that population pressure, together with the shift from common to exclusive communal property rights, altered man's incentive sufficiently to encourage the application of cultivation and domestication techniques. Locay (1989) studies the implications of nomadism versus sedentarism in relation to the rise of agriculture. More recently, Morand (2002) has presented a model that discusses the family's resource-allocation behaviour in relation to the shift to farming. Weisdorf (2003) argues that non-food specialists played a crucial role in the transition to agriculture, while Olsson (2003), in a framework that is able to compare a number of archaeological explanations, supports the theory that environmental factors, along with genetic changes in the species suitable for domestication, paved the way for agriculture. All of these economic theories about the origins of agriculture are addressed in detail in section 3.

The adoption of agriculture in the Stone Age certainly did more, in the long run, to alter the world than any previous human innovation. Today, agriculture almost completely dominates the way in which food is produced. However, when it comes to the share of labour involved in its production, agriculture contributes to only a small part of the world's economic activities. In the United States, for instance, which is a net exporter of food, only three percent of the labour force is engaged in food production. By contrast, the most advanced Bronze Age societies had only a few percent engaged in non-agrarian activities full-time. The transfer of labour from food to non-food activities, a transformation that is strongly linked to the process of industrialisation, has been of crucial importance to the wealth of nations. Well-acquainted with this fact, Adam Smith (1937, p. 63) noted that, "when by the improvement and cultivation of land the labour of one family can provide food for two, the labour of half the society becomes sufficient to provide food for the hole. The other part, therefore, [...] can be employed in providing other things, or in satisfying the other wants and fancies of mankind".

Probably the most important reason why the Neolithic Revolution is decisive to economic growth, is that the food surplus that early farmers were able to generate, for the first time in human history, made possible the establishment of a non-food producing sector (e.g., Diamond, 1997). The presence of non-food specialists—craftsmen, chiefs, bureaucrats, scientists, and priests—led to countless innovations such as writing, metallurgy, cities, and scientific principles, and eventually paved the way for events such as the Industrial Revolution and for the wealth of the western world.

Yet, the question still remains: why take up farming after millions of years of successful foraging? Section 2 provides a brief historical survey of the leading hypotheses that have appeared in the archaeological and anthropological literature. Section 3 offers a more detailed review of the related contributions in the economic literature. Finally, section 4 concludes.

2 The Archaeological Literature

Over the years, a variety of theories have been proposed that attempt to pinpoint human motivation and to identify the underlying causes of the emergence of agriculture. This section briefly reviews the major hypotheses proposed primarily in the archaeological and anthropological literature. Figure 1 provides a chronological summary of the theories.

In the eyes of the ancient Greeks, agriculture was the last of three stages: "[F]irst came a hunting and gathering stage; this slowly led to the domestication of animals and a pastoral nomadic stage; finally came the invention of agriculture" (Isaac, 1970, p. 3). This 'stage' hypothesis persisted in Europe throughout the Middle Ages. But whereas the Greeks had a cyclical view in mind, in which man would return to the beginning and start all over again, the modernised version postulated an evolutionary sequence from less advanced to more advanced societies in a uni-linear manner.

[Figure 1 about here: The Hypotheses]

The view of the nineteenth century scholars had changed very little in comparison to their ancient counterparts. To Charles Darwin (1868), who represented the prevalent view at the time, agriculture was simply the result of an idea that had to be discovered. He notes (*ibid.*, p. 326-7) that ... "[t]he savage inhabitants of each land, having found out by many and hard trials what plants where useful, [...] would after a time take the first step in cultivation by planting them near their usual abodes. [...] The next step in cultivation, and this would require but little forethought, would be to sow the seeds of useful plants". Behind this view lies the concept that foragers were always on the verge of starvation and that the quest for food absorbed their time and energy to an extent that prevented them from building more advanced cultures.

During the first half of the twentieth century, farming was believed to have appeared on the dry plains of Mesopotamia where the early civilisation of the Sumerians arose. For at least twenty years from the mid-1930s, the most popular theory relied entirely on the 'oasis' hypothesis (also known as the 'propinquity' or the 'desiccation' theory). In the 1930s, the end of the last ice age was thought to be a period of dryer and warmer conditions. In the Near East, a dry region to begin with, higher temperatures and less precipitation would invite not only humans but also domesticable plants and animals to take refuge in zones that were spared the desiccation—oases and river valleys. The only successful solution to the competition for food in these circumstances, the reasoning went, would be for humans to domesticate plants and animals (e.g., Childe, 1935).

However, evidence that emerged during the 1940s and 1950s showed that climatic changes had been too slow to trigger this kind of behaviour and indicated no crisis with sufficient impact to have predetermined the shift to food production (i.e., Braidwood and Howe, 1960). It also turned out that cultural changes in favour of agriculture appeared in regions where no major climatic changes had occurred and under a wide variety of climatico-ecological conditions (e.g., Perrot, 1962). Finally, it was argued that earlier interglacial warm periods had not led to the adoption of agriculture (e.g., Braidwood, 1963).

As the oasis hypothesis fell into disfavour, new ideas emerged. In contrast to the oasis hypothesis, the new theories suggested that farming resulted from opportunity rather than from need. Sauer (1952), for example, hypothesised that farming was invented by fishermen residing in regions where the abundance of resources afforded them the leisure to undertake plant experimentation. In a similar category, Braidwood and Howe (1960) suggested that agriculture was the by-product of leisurely hill-dwellers, whose habitat was particularly rich in domesticable plants and animals. These theories, referring to regions with a high potentiality for domestication, went under the 'natural habitat' or 'nuclear zone' hypothesis.

Farming, at this point, was still considered to be highly desirable. But in the 1960s, this perception was to be turned up-side down. Evidence started to appear which suggested that early agriculture had cost farmers more trouble than it saved. Studies of present-day primitive societies indicated that farming was in fact back-breaking, time-consuming, and labour-intensive (e.g., Lee and DeVore, 1968), a view that would find strong support over the years (e.g., Sahlins, 1974). In the so-called 'affluent societies', farming was not desirable; hunters and gatherers would not embark upon time-costly methods of food production unless there was good reason to do so. Farming was a last resort.

A picture began to emerge that showed that foraging communities were able to remain in equilibrium with carrying capacity when undisturbed, and that new cultural forms would result from non-equilibrium conditions. In light of the fact that climatic changes did not seem to have led to crises, and that foragers, reluctant to take up farming, decided to adopt it nevertheless, new ideas, once again proposing that agriculture resulted from necessity, emerged. Binford (1968), looking for conditions that would upset the established equilibrium in favour of increased productivity, reasoned that the shift to farming could have been caused by population pressure. This inspired Flannery (1969) to suggest that agriculture, under the pressure of an increasing population, would initially appear in regions were the need for food was most acute: not in affluent societies, but in marginal areas. This became known as the 'marginal zone' hypothesis.

Focus rapidly turned further towards the idea that population pressure was the impetus behind the shift to farming. In 1977, Cohen presented his hypothesis of global population pressure. Inspired by Boserup who argued that agricultural intensification would not have occurred without the stimulus of an increasing population (e.g., Boserup, 1965), Cohen believed that population growth was a general phenomenon that occurred frequently throughout human history (Cohen, 1977). This, he reasoned, had led to over-population on a global scale some 15,000 years ago, a conclusion that seemed to be in accordance with the fact that, at that time, the human species, departing from Africa, had colonized all the inhabitable areas of Europe, Asia and the New World.

The stress brought about by increasing populations and depleted resources meant that people had to expand their subsistence to include less favoured foods of greater abundance. This widening variety of wild plants and animals in the diet of hunters and gatherers was well-supported in archaeological findings, a process which Flannery (1973) referred to as the 'broad spectrum revolution'. Moreover, megafauna extinction prior to the Neolithic Revolution, i.e., the disappearance of large herding animals such as the mammoth and the woolly rhino, was also interpreted as evidence of population pressure and went under the 'overkill' hypothesis (e.g., Martin, 1967; Roberts, 1989). The 'population pressure' hypothesis accordingly implied that the only successful way that a rapid increasing population was able to deal with declining resources was to embark upon agriculture.

In all parts of the world where adequate evidence is available, archaeologists have found that increasing population densities appeared in relation to the rise of agriculture (e.g., Diamond, 1997).[3] Population growth certainly explains why agricultural intensification could not have been reversed. Once the population has increased, the 'ratchet effect' makes it impossible to go back to less intensive ways of food procurement. However, there is a chicken-and-egg issue to this: did human societies domesticate plants and animals as an adaptive response to population pressure, or did domestication give rise to a larger population?

Population pressure and depleted resources are bound to eventually cause a decrease in people's dietary intake. As dietary stress leads to marks on the human bones and teeth, the population pressure hypothesis is testable using methods of physical anthropology. Since early hunter-gatherers were relatively well-nourished and free of disease, the dietary stress brought about by the pressure of an increasing population among later hunter-gatherers would then have marked their skeletons. However, studies of skeletal remains have failed to show nutritional stress immediately prior to plant domestication. In fact, in some in-

[3] According to Kremer (1993), the number of humans on the planet 300,000 years ago is estimated to be a total of one million. At the time of the Neolithic Revolution some 10,000 years ago, there was an estimated 4.5 million people. At the time of the Roman Empire, roughly 8,000 years later, there were 170 million people worldwide. This implies that the average annual population growth rate during those eight millennia was more than 80 times higher than that of the previous three hundred thousand years. If we include the two millennia taking us to the present-day, the average annual growth rate over the past 10,000 years has been more than 400 times that prior to the Neolithic Revolution.

stances the health of the last hunter-gatherers in a region where agriculture was adopted appears to have been significantly better than that of the first farmers (Cohen and Armelagos, 1984). Moreover, as animal extinction has not been shown to have happened in any of the right places at any of the right times, the population pressure hypothesis has further been discredited (Fernandez-Armesto, 2001).[4] In general, the idea of a global food crisis no longer seems convincing (Milthen, 1996).

Due to insufficient evidence in favour of the hypothesis of demographic pressure, still other explanations began to appear. With lacking evidence of dietary stress among foragers, it was once again back to the view that farming arose from opportunity. In the 1980s, contributions started to appear that increasingly stressed the continuities rather than the contrasts between foraging and farming. Concepts like, 'human-plant symbiosis' and 'people-plant interaction' were introduced. These comprise an unintentional process by which human intervention, selection, and replanting (i.e., man's environmental manipulation) eventually, by accident, created strains of plants and animals that depended upon human assistance for their survival, and likewise, that humans depended upon themselves. These theories did not intend to address the question of *what* made human societies move from a primary dependence on wild foods to a primary dependence on cultivated ones. They merely put emphasis on the fact that the path to agriculture could have been an evolutionary process, building on Darwinist elements (e.g., Rindos, 1984), and that there seemed to be a positive relationship between the energy input into food procurement and the output per unit of area of exploited land (e.g., Harris, 1989).

In the 1990s cultural or social theories explaining why communities with stable populations and abundant resources eventually introduced domestication were proposed. Hayden (1990), for example, envisions the rise of agriculture as resulting from what he calls 'competitive feasting'. His idea is that food was regarded as a source of social prestige, and that early domestication took place in order to create delicacies for families or individuals who wanted to improve their social status. Hayden's 'competitive feasting' hypothesis, however, has not received much support. It appears that early domestication unambiguously consisted of important foods rather than delicacies (e.g., Smith, 1995).

Milthen (1996), a physiologist who focuses on the capacity of the human brain, argues that early humans, even though they possessed the knowledge of how plants and animals reproduce, simply could not have entertained the idea of domesticating plants and animals. Hence, in Milthen's view, the origins of agriculture 10,000 years ago lie not least in the way in which the natural world was thought about by the modern mind.

In the latter part of the 20th century, more detailed environmental studies led some scholars to return to the idea of climatic changes as the impetus to take up farming. It has been proposed that as the ice sheets of Europe retreated, leading to warmer and moister conditions, hunters and gatherers were able to exploit an

[4] Still other evidence seems to indicate that population growth was the consequence rather than the cause of the adoption of agricultural (see, e.g., Brorson, 1975).

increasing number of productive food plants, which increased their population (Legge and Rowley-Conwy, 1987). But between 10,800 and 10,300 years ago, a global climatic downturn, known as the 'Younger Dryas', bringing colder and drier environmental conditions (and even drought), occurred. This climatic episode decreased the yield of wild cereals, and thus could have motivated the so-called Natufians communities of hunters and gatherers in the Levant to cultivate wild cereals (Bar-Yosef and Belfer-Cohen, 1991). It has also been argued that since evidence indicates that the emergence of sedentary communities in the Near East took place between 13,000 and 10,000 years ago, it was inevitable that the level of food procurement would need to increase, because the constraint on population growth imposed by the mobile life-style had been relaxed (Bar-Yosef and Belfer-Cohen, 2000).[5]

Though many of the theories presented in the archaeological and anthropological literature fit well on a regional level, no single explanation appears to be universally applicable (e.g., Fernandez-Armesto, 2001; Harlan, 1995; Smith, 1995). In the section below, we turn to examining how the economist motivates the shift from foraging to farming.

3 The Economic Literature

Despite its tremendous importance in regards to economic growth and the wealth of nations, very few attempts have been made by economists to explain the Neolithic Revolution. Those that deal with the issue naturally divide into two categories. One category consists of three contributions: two that came in the 1970s, one examining the 'overkill' hypothesis (Smith, 1975), and one dealing with the differences in the nature of property rights in foraging and farming (North and Thomas, 1977); and one that came in the late 1980s, dealing more broadly with the archaeological and anthropological theories from an economic perspective (Locay, 1989).

The other category consists of four recent contributions (Olsson and Hibbs, 2002; Morand, 2002; Olsson, 2003; and Weisdorf, 2003b). As mentioned in the introduction, most of these belong to a branch of the growth literature that deals with very long-run economic development and the emergence of 'modern' economic growth. This section reviews both categories of papers. For a summary of the economic literature, see Figure 2. However, before we start the excursion, it is useful to look at some expositional similarities of the models.

[Figure 2 about here: The Economic Literature]

Two aspects are shared by nearly all contributions. First, *how* agriculture was invented is generally not an issue. Regardless of whether this is explicitly stated, all papers seem to agree with the view in Olsson and Hibbs (2002), who, inspired by Diamond (1997), note (p. 8) that the first domesticates "probably

[5] See also Lemmen and Wirtz (2003) for a paper that examines climatic variability in relation to the rise of agriculture.

appeared near latrines, garbage heaps, forest paths and cooking-places where humans unintentionally had disseminated seeds from their favourite wild grasses, growing nearby".

Second, all contributions, with the exception of one, can be examined within the context of a simple, comparative static economic model. Figure 3 provides a graphic representation of this model. The Figure illustrates the relationship between the size of the labour force and the marginal product of labour.

[Figure 3 about here: The Standardised Model]

When examining the Figure, the following should be noted. First, when the size of the labour force is below L_2, man's effort is devoted exclusively to foraging. The reason is that as long as $L \leqslant L_2$, the marginal product of labour in foraging exceeds that of farming. Second, for sufficiently low levels of labour, i.e., when the size of the labour force is below L_0, labour productivity in foraging is constant when additional labour is added. The latter property occurs as long as there is empty land that surplus labour can migrate to.[6] Third, when the size of the labour force is between L_0 and L_2, additional labour, running up against the land constraint, is subject to diminishing returns. Finally, note that once the size of the labour force surpasses L_2, additional labour enters agriculture. Henceforth, a larger labour force increases the share of labour engaged in farming. Note also that farming exhibits constant returns to labour, which reflects the abundance of land suited to this purpose at that time.[7]

Obviously, all contributions that are based on this standardised model start their analysis at a point where the size of the labour force falls between 0 and L_2, meaning that to begin with, the entire labour force is devoted to foraging activities. Assume for the sake of argument that we start with a situation where the labour force has a size of $L_1 \in (L_0, L_2)$. From here, there are three changes that can account for the transition to agriculture: (i) a downward shift in the value of the marginal product of labour in foraging; this corresponds to a downward movement of the MP_{HG}-curve (Figure 4); (ii) an upward shift in the value of the marginal product of labour in farming; this corresponds to an upward movement in the MP_{A}-curve (Figure 5); and (iii) an expansion in the size of the labour force (Figure 6). In each of the three cases, the economy enters a regime of mixed activities.[8]

Note that in terms of this representation, Childe's (1935) oasis hypothesis,where desiccation decreases the wild resources, shifts the MP_{HG}-curve downward as illustrated in Figure 4. The theories of Darwin (1868), Sauer (1952), Braidwood and Howe (1960), and, to an extent, also Harris (1989) and Rindos

[6] Archaeologists refer to this as an 'open donor system' (see Binford, 1968, pp. 329-30).

[7] The illustration would carry the same message with diminishing returns to labour in agriculture as well. The requirement would then be that the labour productivity in agriculture declines less than that in hunting-gathering when there is an increase in the size of the labour force.

[8] Note that there will be agricultural *specialisation* only if the shift in the marginal product of labour is so pronounced that labour productivity in farming exceeds labour productivity in foraging for *all* levels of labour.

(1984) (who suggested that man eventually became better acquainted with their later domesticates (in fact, Childe also proposed this)), consists of an upward shift in the MP_{A}-curve as illustrated in Figure 5. Finally, the population pressure theories of Binford (1968), Flannery (1969), and Cohen (1977) are identical to an increase in the size of the labour force as illustrated in Figure 6.

[Figures 4-6 about here: Comparative Static]

Since the majority of the contributions can be interpreted in terms of Figure 3, their results are essentially the same. That is, the three changes mentioned above, acting individually or in concert, will eventually lead to the rise of agriculture. The purpose of the following is, therefore, to disentangle each contribution's story of the *underlying* causes that led to the changes that eventually tipped the comparative advantage in favour of farming.

Excessive Hunting In the 1970s, when the archaeological community seemed to think that agriculture emerged as a result of necessity, Smith (1975) examined the so-called 'overkill' hypothesis, i.e., the theory that the extinction of large herding animals some 10,000 years ago was due to excessive hunting (see page 6 above).[9, 10]

An important aspect of Smith's (1975) model is that he identifies a list of parameters that reflect the growth rate and value of the biomass upon which hunters subsist. Though somewhat more comprehensive than the models reviewed below, Smith's framework, in its simplest form, is nevertheless interpretable in terms of the standardised model explicated above. Smith reaches the expected conclusion that an increase in the size of the labour force increases the share of labour in agriculture. This result matches the outcome indicated in Figure 6. Furthermore, in Smith's model, climatic deterioration adversely affects the reproduction rate or the food availability of the hunted biomass, which increases the share of labour in agriculture through a decrease in the labour productivity of hunting. This corresponds to the illustration in Figures 4. Smith does not discuss the effect of changes in agricultural productivity and therefore has no conclusions related to the illustration in Figure 5.

The fact that Smith's model identifies a line of parameters that reflect the growth rate and value of the biomass upon which hunters subsist, allows him to reach a number of conclusions that differ from the results in most of the remaining economic models. Most importantly, his model shows that improvements in hunting efficiency has an adverse effect on the growth rate of the hunted biomass. Since lower biotic growth encourages agricultural effort at the expense of hunting, more efficient hunters may actually *increase* the share of labour in farming. This result, which seemingly runs counter to the outcome indicated in

[9]Obviously, Smith's hypothesis came prior to the evidence that indicated a missing link between animal extinction and the rise of agriculture (see page 7 in section 2).

[10]Smith (1992) again touches upon the subject of prehistoric economic development, but does not focus on the rise of agriculture; rather he deals more broadly with the emergence of humankind, with the importance of human capital accumulation, and with how we were shaped by economic principles.

Figure 4, is to be seen in light of the time aspect. The short-run effect of an increase in hunting efficiency is always an increase in per-capita output of the hunter. But when the increased efficiency lowers the stock of animals, it gradually decreases the marginal productivity of labour in hunting. Improvements in hunting efficiency therefore eventually correspond to the illustration in Figure 4.

Smith's model does not provide any new insights with regards to the causes of Pleistocene extinction (*ibid.*, p. 750). However, the general task of his paper—comparing free-access hunting to socially optimal resource regulation—relates to an issue that was picked up a few years later by two economic historians, namely, the question of prehistoric property rights.

Property Rights In their paper, North and Thomas (1977) claim to provide a new explanation for the emergence of agriculture.[11] Engaged in the field of economic history, their model is not expressed in terms of mathematics but relies entirely on an illustration that is similar to that in Figure 3 on page 9 above.

In essence, the idea in their paper is the following. Throughout the Stone Age, new technology, from time to time, improved the level of productivity in foraging as well as (latently) in farming. In the short run, as indicated in Figures 4 and 5, the model is therefore inconclusive with regards to whether the occupational outcome favours foraging or farming. But due to inherently different property rights associated with the two types of activities, we are told, the comparative advantage eventually comes out in favour of farming. The reasoning runs as follows:

Common property rights, which are assumed to prevail among foragers, potentially cause incentive failure. Bands of hunters and gatherers have an incentive to ignore certain costs of their activities, which results in over-utilisation of resources, causing the productivity among foragers to decline. This, the authors assert, is troublesome to the extent that population pressure prompts bands of hunters and gatherers to compete over resources. It is argued (*ibid.*, p. 237) that, "[i]n the world of prehistoric man those bands that attempted to adjust their population to the size of the local resource base would eventually lose out to those bands that encouraged large and increasing populations". This is so because "the larger the population, the better its chances of successfully excluding others" (*loc.cit.*).

In contrast to the common property rights prevailing among foragers, primitive farming, it is said, must have been organised under exclusive communal property rights. The authors argue that, "[i]t is inconceivable that, from the very beginning, the first farmers did not exclude outsiders from sharing the fruits of their labour" (*ibid.*, p. 235). Furthermore (*loc.cit.*), "the band in principle at least could have exploited its opportunities in agriculture by constraining its members with rules, taboos, and prohibitions, almost as effectively as if private

[11] A similar version of their paper is found in North (1981). See also Pryor (2003) concerning the subject of property rights and the rise of agriculture.

property rights had been established".[12]

This means that farming has the advantage over foraging in terms of efficiency of the property rights. Accordingly, higher productivity in both sectors, in the long run, increases the rewards of pursuing farming, while those in foraging are dissipated. In terms of Figure 3 above, the short-run effect of higher labour productivity corresponds to an initial upward shift in the MP_{HG}-curve. This attracts labour resources to the foraging sector and hastens the depletion of the stock of wild food held as common property. Thus, in the long run, the MP_{HG}-curve gradually shifts downward to a point below its initial position.[13]

Moreover, with common property rights there is little incentive for the acquisition of superior technology and learning. In contrast, exclusive property rights that reward the owners provide a direct incentive to improve efficiency and productivity. The inherently different property rights therefore eventually tip the comparative advantage in favour of farming, whose labour productivity, in due course, will exceed that of foraging.

In effect, the fundamental force driving the transition to agriculture in the North-Thomas model is the same as that proposed by Binford (1968), Flannery (1969), and Cohen (1977), namely, the persistent pressure of a increasing population (see page 5 above).

Nomadism Locay (1989) presents a technical framework which is also interpretable in terms of Figure 3 above. He deploys a two-period, overlapping generations model (with children and parents), where parents produce children as well as food from both of which they derive utility. Food production takes place using either hunting-gathering or agriculture. Both types of production are subject to constant returns to land and labour, but Locay assumes that hunting-gathering, compared to agriculture, uses land relatively more intensively than labour. Moreover, the costs of producing children, measured in units of food, are assumed to increase with the household's degree of nomadism (see below). Within this framework, Locay considers the effect on the chosen method of food procurement of the three trivial changes indicated in Figures 4-6.

An interesting refinement in Locay's model, which takes the analysis of the shift to farming somewhat further, is the inclusion of nomadism. Nomadism, i.e., the degree to which the household periodically shifts camp, is said to influence the household's behaviour in a number of ways:

The disadvantage of nomadism is that it appears to decrease agricultural productivity because, in Locay's words (*ibid.*, p. 740), "one cannot farm and move around a great deal". Moreover, nomadism adversely affects the cost of children, meaning that for a given level of food output, nomad parents, compared with sedentary ones, devote relatively few units of food to child rearing in relation to their own food consumption.

[12] The weak link in this theory, as pointed out by Persson (1988, p. 20), is the implicit assumption that foragers are unable to develop this sort of exclusive claim on territory.

[13] This conclusion is similar to that in Smith (1975), although Smith's model generates the result in a somewhat more sophisticated manner.

When nomadism is practised despite these inconvenient features, it is because it confers some benefit in terms of travel distance. The members of a settled community, Locay argues, must, at least occasionally, travel long distances from the camp so as to reach the various parts of their territory that are exploited. An alternative strategy is therefore to engage in nomadism. The shorter travel distance from the temporary settlement accordingly means that more time is left for subsistence activities. Thus, whereas nomadism is assumed to decrease agricultural productivity, it simultaneously increases time spent obtaining food goods.

As with nomadism, the size of the household's land holding is assumed to have a dual effect on parents' food output. On the one hand, more land units increase labour productivity when producing food. On the other hand, for a certain degree of nomadism, a larger land holding means that less time is left for producing food due to an increase in travel distance.

With the inclusion of nomadism and its effects on the costs of children, the adoption of agriculture in Locay's model has important implications for both standards of living and the growth rate of the population. With regards to Figure 5, Locay shows that an increase in agricultural productivity provokes a decrease in the degree of nomadism, which in turn makes parents substitute away from food consumption and towards raising more children. Indeed, in some cases, Locay argues, the decrease in the degree of nomadism may increase the relative costs of parental food consumption, consequently leaving parents with an overall decrease in utility from adopting agriculture (*ibid.*, p. 746-47). This conclusion seems to accord well with archaeological evidence.

With regards to decreasing labour productivity among hunters and gatherers illustrated in Figure 6, Locay, like Smith (1975) and North and Thomas (1977) before him, refers to over-hunting as the impetus to take up agriculture. More interesting, also with regards to Figure 6, is that Locay presents a scenario where persistent population growth among hunters and gatherers eventually leads to a decrease in the land holdings of the household, thus creating population pressure. In Locay's model, the direct effect of declining land holdings per household is to lower the benefits from nomadism, which induces the household to increase its degree of settlement. The effect of declining land holdings on the number of children is therefore ambiguous. The less land that is exploited, the smaller, Locay assumes, is the positive effect from nomadism on the time spent in subsistence activities. Less land therefore, on the one hand, decreases parents' food output. This causes both the number of children and parental consumption to decline. Meanwhile, the lower degree of nomadism at the same time has a positive effect on the number of children, since a more sedentary life-style reduces their costs. Locay therefore arrives at the astonishing conclusion that, if the latter effect dominates the former, population pressure actually make parents *increase* their level of fertility. The population pressure accordingly becomes more pronounced, thus further decreasing the household's land holdings and increasing the degree of sedentariness, which favours agriculture over hunting-gathering.

Locay's result of increasing sedentariness among hunters and gatherers prior to the adoption of agriculture fits well with the archaeological evidence (e.g., Bar-Yosef and Belfer-Cohen, 1989). Moreover, due to the relatively more intensive use of land in hunting-gathering, decreasing land holdings makes agriculture relatively more attractive. Hence, a positive population growth rate among hunters and gatherers in Locay's model will thus clearly lead to the rise of agriculture.

Biogeography From the contributions of the 1970s and 1980s, we now turn to the latest economic theories on the origins of agriculture. Explaining the dominance of the western world, Diamond (1997) argues convincingly that geography has affected both the productivity and the prosperity of contemporary nations. This inspired Olsson and Hibbs (2002) to study the effect of biogeography on long-run economic development. The term biogeography will be explained below.

Although they do deal with the rise of Neolithic agriculture, Olsson and Hibbs are not so much concerned with *why* agriculture was adopted. They take for granted that once affluent societies of hunters and gatherers discover the capacity of seeds to germinate, an event that probably happened incidentally, "[m]ore conscious experimentation was presumably [...] carried out" and "[o]bserving the immediate and impressive gains from such experiments, a transition then follows within a relatively short span of time" (*ibid.*, p. 8).

With this in mind, Olsson and Hibbs set out to explore a possible link between initial biogeographical endowments, such as species of plants and animals suitable for domestication, and subsequent economic development. The authors suggest that biogeographical endowments are crucial to the timing of the transition to agriculture.[14] Since the surplus generated from agricultural production made possible the establishment of a non-food producing sector whose members significantly promoted development in knowledge and technology (e.g., Diamond, 1997), regions that adopted agriculture at an early point in time accordingly achieved an initial advantage over less fortunate regions. The authors assert that the impact of this lead is still detectable in the contemporary international distribution of wealth.

Constructing a theoretical framework that captures the features suggested above, the authors regress the present level of income per-capita in 112 countries on measurements of prehistoric geographic conditions and biogeographical endowments. They come up with the remarkable result that variation in these variables explains as much as half of the international variation in per-capita income.

Inter-Family Exchange Turning to a purely theoretical paper, Morand (2002) develops a model that deals with the long-term interaction between population and modes of production. His framework, which is also compatible with the

[14] This idea is related to Braidwood's 'nuclear zones' (see page 5 in section 2), which were areas where plants and animals were better suited to domestication than others (see also Braidwood, 1963).

standardised set-up expounded on page 9, extends from early times of hunting-gathering to modern times of industrial production, in-between which, agriculture prevails. While the shift from agriculture to industry is examined in a large number of recent papers (see, e.g., Hansen and Prescott, 2002; Lucas, 2002; Galor and Weil, 2000; Kögel and Prskawetz, 2001; Lagerlöf, 2003; Jones, 2001; Kalemli-Ozcan, 2002; Tamura, 2002; Weisdorf, 2003a), our interest here solely concerns Morand's explanation of the transition from foraging to farming.

A central theme in Morand's model is the relationship between the modes of production and the nature of transfers between the members of the household. There are three kinds of household members: children, adults and elders. Inter-family exchange depends on the mode of production. Morand assumes that foraging activities suit only adults who, according to a sharing rule obtained as the result of a bargaining process, share their food with the elder members of the family. In contrast, farming allows both adults and elders to participate in the food quest, and is why the sharing rule is abandoned once farming is adopted.

Inter-family exchange also concerns the relationship between adults and their children. Adults can invest in both the quantity and the quality of their children, the latter being measured in terms of human capital. Since Morand allows for human capital accumulation only among farmers, an assumption perhaps subject to some criticism, foraging adults care only about the *quantity* of children. However, in consideration of the sharing rule and the preceding bargaining process, children have an ambiguous effect on the well-being of the foraging adult. More children increases the adult's expected old-age consumption, but at same time, more children weaken the adult's bargaining power.

Considering the effect that children have under the different modes of production, the adult chooses an optimal level of consumption as well as a level of fertility. Next, the adult compares the expected utility attained from foraging and farming, respectively. Assuming that the parameter values are such that the expected utility attained from farming is sufficiently low to begin with, foraging becomes the chosen food procurement method. That is, we are at $L = L_1$ in Figure 3 on page 9 above. From here, the changes needed to tip the balance in favour of farming are considered.

The key parameter influencing the behaviour of foragers, Morand argues, is the availability of wild resources. In terms of Figure 3, the availability of wild resources influences the position of the MP_{HG}-curve. Wild resources may be adversely affected by changes in environmental conditions. To begin with, Morand assumes that foragers respond to such changes in three ways: by increasing their mobility, by broadening their diet, and by decreasing their fertility (or, if possible, the costs of child rearing).[15] However, at the time when agriculture emerged, these means presumably have all been used. Morand envisions the following causation, which is in line with the proposals in the archaeological literature (see section 2). First, increased climatic variation during

[15] In effect, one response may affect the other; increasing mobility, for instance, due to the immobility of pregnant and lactating women, is likely to influence the costs of child rearing (*ibid.*, p. 11).

the late Pleistocene caused hunters and gatherers to adopt a broader diet (the 'broad spectrum revolution' mentioned on page 6 above). Second, during the early Holocene, the warmer trend of the Pleistocene that caused populations of hunters and gatherers to expand, was interrupted by a climatic downturn (the 'Younger Dryas' mentioned on page 8), which brought drier and cooler weather. This limited the availability of wild resources and prompted hunter-gatherers to contract to a few resource-rich watering holes (the 'oasis' hypothesis mentioned on page 4 above). The concentration of people in these oases, combined with the fact that mobility was no longer an option and that the broadening of diets had already taken place, left hunters and gatherers with the one possibility: taking up farming.

In addition, and in accordance with the 'human-plant symbiosis' (see page 7 above), Morand mentions that the sedentariness in the small oases (*ibid.*, p. 13) "generated a change in the interaction between people, plants and animals that gradually increased the expected returns or yields of agricultural production". This, in Morand's model, translates into an increase in utility attained from farming, shifting the MP_{A}-curve in Figure 3 upward. Whereas the latter causation suggests that agriculture arose from opportunity, the former (in the paragraph above) indicates that it resulted from necessity.

Morand's framework adds to the list of parameters that can be used to explain the rise of agriculture. By including the probability of surviving into old-age, Morand is able to examine the death risk of different types of foraging activities (e.g., big game hunting versus tuber gathering). Furthermore, in Morand's model, war against competing groups in areas subject to population pressure, a theme also important in the North-Thomas model above, is likely to adversely affect the probability of surviving into old-age.

Non-Food Specialists A model that, in contrast to Morand's, deals exclusively with the rise of agriculture is presented by Weisdorf (2003b). In this set-up, there is no boundary distinction between foraging and farming. The model is therefore not interpretable in terms of the standardised framework illustrated in Figure 3. Instead, Weisdorf proposes a ladder of technical steps ranging from foraging to farming, where each step implies a higher availability of food per unit of land, but simultaneously implies an increase in the amount of learning time required in order to obtain it.

A novel feature in Weisdorf's model is the inclusion of leisure time in the individual's preference function. With individuals deriving utility from leisure, the adoption of methods that increase the availability of food per unit of land, thus decreasing the individual's time spent obtaining food, at first, appears to be attractive. However, since such methods also require more time spent learning how to use them, the adoption of methods that increase the output per unit of land turns out to have an ambiguous effect on an individual's leisure time.

At low levels of technology, the time-saving effect on food procurement outweighs the time-costly learning effect. Thus, as new methods gradually appear, which in the Stone Age is likely to have happened incidentally, the members of the community can increase their leisure time by putting these into practice. However, a level of technology is eventually reached at which the learning time becomes so pronounced that the adoption of more productive methods would cause an unequivocal *decrease* in the individual's leisure time. This causes a reluctance towards the adoption of time-intensive food procurement methods, which are implicitly identified as being agricultural. As a result, methods that would increase the availability of food per unit of land, though accessible, may not be put into practise. That is, invention and innovation do not necessarily go hand in hand.

Like North and Thomas (1977), Weisdorf claims to provide a new explanation for the emergence of agriculture. It is argued that since farming appears to be more time-costly than foraging, agricultural methods are not adopted unless the individual is willing to accept the decline in his leisure that is associated with their adoption. Claiming that archaeologists and anthropologists tend to underrate the universally observable fact that individuals are known to trade off leisure for non-food goods, the main argument in Weisdorf's paper is that the adoption of agriculture implies the presence of non-food specialists.[16] The reason is that non-food specialists, through their goods production, are capable of compensating the loss of leisure of those individuals who engage in agriculture. In effect, a division of the community's labour force between food and non-food activities may thus aid the adoption of agriculture.

Weisdorf then introduces a set of 'redistribution costs'. It is argued that societies that divide their labour force between food and non-food activities, are subject to costs of collecting and redistributing goods and foodstuffs. Since division of labour is found only in societies that practise methods of farming, and not among bands of hunters and gatherers, only farming communities defray the costs of redistribution. It is then shown that the redistribution costs postpone the adoption of farming techniques for a period of time during which there is technical stagnation. That is, methods of foraging are practised despite the fact that more productive farming methods are available, a result that is in accordance with the observation of a time lag between the invention and the innovation of agriculture (e.g., Harlan, 1995; Milthen, 1996).

The adoption of agriculture does not take place until the community gains access to methods that are sufficiently productive to cover both the costs of redistribution and the individual's compensation for his loss of leisure. Once sufficiently productive methods eventually become available, there is a discontinues jump in the level of the applied technology, a jump which is identified as a 'Neolithic revolution'.

In order to show that agriculture could have been adopted independently of demographic variations, Weisdorf assumes a constant population. Unfortunately, this makes the model incapable of explaining the vast increase in the population density that seems to accompany the transition to agriculture (see page 6 above).

[16] Non-food goods, in Weisdorf's model, are synonymous with handicraft consumption goods such as housing, clothing, cooking tools, pottery, or more luxurious goods such as pearls and other kinds of ornaments. In a more broad sense, it can also include protection and salvation.

Demographic Growth A model that deals specifically with demographic changes in relation to the rise of agriculture is found in Olsson (2003), who, like Locay (1989), sets out to compare a number of archaeological and anthropological explanations concerning the emergence of agriculture. Here, we are back to the boundary distinction between foraging and farming, and Olsson's framework is therefore interpretable in terms of the standardised model in Figure 3 on page 9 above.

In Olsson's model, the individual's only concern is to allocate his labour between foraging and farming in an optimal manner. In optimum, a condition which Olsson refers to as the 'agricultural transition condition' (ATC), individuals allocate their labour such that the marginal product of labour in farming equals that in foraging. Initially, though, parameter values are chosen such that the marginal product of foraging in optimum exceeds that of farming, i.e., such that the ATC is not fulfilled. In terms of Figure 3, this corresponds to a situation where $L = L_1$.

Olsson's model introduces a number of new features compared to what we have seen above. One aspect concerns the growth rate of the population among foragers and farmers, respectively. Olsson assumes that individuals involved in foraging are subject to 'Malthusian' population growth. That is, population growth is possible only when labour productivity progresses. Since labour productivity in both sectors responds only to changes in the natural environment (and possibly to time), an increase in the forager's family is more or less left to chance. In contrast, Olsson identifies the population growth among agriculturists as 'Boserupian'. Due to their sedentary life-style, which reduces the costs of raising children, and to the fact that land, for the purpose of agriculture, was not constrained at the time, individuals involved in farming are assumed to increase the size of their families regardless of whether or not productivity improvements appear, i.e., in an exogenous manner.[17]

In order to reach an interior solution where both foraging and farming are practised, the ATC needs to be fulfilled. In Olsson's model, the four underlying factors that have the potential to create the three changes illustrated in Figures 4-6, are environmental, demographic, cultural, and external. Environmental and demographic changes represent the traditional factors that are expected to affect the marginal product of labour and the size of the labour force, respectively. Cultural and external changes are added in order to capture the themes of some of the alternative explanations of the origins of agriculture.

Cultural changes are embodied in a parameter which is included in the individual's preference function. The size of this parameter measures the degree to which agriculture is preferred or opposed. Such preferences, Olsson mentions, could be founded, for instance, in religious beliefs (*ibid.*, p. 14). In terms of the illustration in Figure 3, changes in this cultural parameter shift the MP_{A}-curve upward (in the case of 'preferred') or downward (in the case of 'opposed'). In consequence, Olsson's model indicates that cultural changes alone are capable

[17] Olsson does acknowledge, however, that the population growth among agriculturalists will eventually return to that of the Malthusian type, once the agricultural economy becomes so widespread that it runs up against the land constraint.

of causing the transition to agriculture.

External changes, in accordance with the 'people-plant interaction' hypothesis (see page 7), may appear in terms of unconscious or incidental positive externalities arising from human intervention with plants and animals. Such changes lead, for example, to genetic alterations that improve the species' suitability for domestication. This, in Olsson's model, translates into an increase in labour productivity in farming, i.e., an upward movement in the MP_{A}-curve in Figure 3 as illustrated in Figure 5.

An important refinement in Olsson's model compared with others is that once the ATC, for one reason or another, is fulfilled, the labour force is bound to increase. The reason is that individuals who embark upon farming, are subject to Boserupian rather than Malthusian growth. Thus, once farming has been introduced, population growth gradually increases the share of labour involved in agricultural activities. This, in Olsson's model, has important implications with regards to the standards of living in the aftermath of the transition to agriculture. Olsson considers a community that shares its total food production equally among its members. From having the entire labour force engaged in foraging, a sudden increase in agricultural labour productivity causing the ATC to be fulfilled, immediately increasing standards of living of the community members. This is illustrated in Figure 7, where the area B is the additional total output that the community shares when agriculture is adopted.

[Figure 7 about here: Olsson's (2003) Result]

However, once agriculture is adopted, standards of living may eventually decline as the size of the community's population gradually increases. This is the case when foraging workers, whose total number is not influenced by the increase in the size of the labour force, are more productive than those in farming. The extra output that the foragers, in comparison to farmers, are capable of generating (the area marked A in Figure 7), when equally shared, reduces into less and less goods per individual the more individuals there are to share it.

Since there are no 'positive checks' among farmers, i.e., growth in the size of the farming household is not affected by the household's consumption level, standards of living may eventually fall below those that prevailed prior to the adoption of agriculture. In terms of Figure 7, this is the case if the average marginal product of labour (which asymptotically approaches the marginal product of farming labour, MP_{A}, when L increases) is smaller than the average productivity of the L_1 workers prior to the upward shift in MP_{A} (i.e., the area A+C+D). Olsson's population dynamics thus enable him to provide an answer to the puzzling question of why still more people went into agriculture despite the fact that it invoked a decrease in standards of living.

In the final part of his paper, Olsson confronts his model with evidence from one of the earliest farming sites, the Jordan Valley. He concludes that environmental factors, along with genetic changes in the species suitable for domestication, at least for this specific region, were factors most likely to have paved the way for agriculture.

4 Concluding Remarks

The purpose of this paper was to acquaint the reader with the main theories and evidence on the origins of agriculture. Section 2 provided a brief historical survey of the leading hypotheses that have appeared in the archaeological and anthropological literature, while Section 3 offered a more detailed review of the related contributions in the economic literature.

There seems to be widespread agreement that no single explanation so far proposed is entirely satisfactory (e.g., Fernandez-Armesto, 2001; Harlan, 1995; Smith, 1995). However, for the theorist interested in motivating the transition from foraging to farming, new evidence is constantly appearing. For instance, there is evidence that indicates that sedentariness occurred prior to and independent of the transition to agriculture (Bar-Yosef and Belfer-Cohen, 1989, 2000), and that tools for agricultural production were available to the foragers who eventually took up farming (Bar-Yosef and Kislev, 1989). Evidence also suggests that agriculture appeared in relatively complex, affluent societies, where a wide variety of foods were available (e.g., Bar-Yosef and Kislev, 1989; Price and Brown, 1985; Smith, 1995), and that these societies were circumscribed by other societies whose environmental zones were poorer in resources (Smith, 1995). It also appears that the egalitarian nature of foraging societies was replaced by hierarchical social structures among agriculturalists (e.g., Diamond, 1997; Fernandez-Armesto, 2000; Price, 1995), and that bands of hunters and gatherers had a communal organisational structure, whereas household level organisation prevailed among farmers (e.g., Gebauer and Price, 1992).

References

[1] Bar-Yosef, O., and A. Belfer-Cohen (1989), "The Origins of Sedentism and Farming Communities in the Levant", *Journal of World Prehistory* 3, pp. 447-497.

[2] Bar-Yosef, O., and A. Belfer-Cohen (1991), "An Early Neolithic Village Site in the Jordan Vally", *Journal of Field Archaeology*, 18, pp. 405-424.

[3] Bar-Yosef, O., and A. Belfer-Cohen (2000), "Early Sedentism in the Near East", in *Life in Neolithic Farming Communities: Social Organization, Identity, and Differentiation*, edited by I. Kuijt, Kluwer Academic/Plenum Publishers, New York, pp. 19-37.

[4] Bar-Yosef, O., and M.E. Kislev (1989), "Early Farming Communities in the Jordan Valley" in *Foraging and Farming: The Evolution of Plant Exploitation*, edited by D.R. Harris and C.C. Hillman, Unwin Hyman, London, pp. 632-642.

[5] Bender, B. (1975), *Farming in Prehistory From Hunter-Gatherer to Food-Producer*, St. Martin's Press, New York.

[6] Binford, L.R. (1968), "Post-Pleistocene Adaptation" in *New Perspectives in Archaeology*, edited by S.R. Binford and L.R. Binford, Aldine, Chicago, pp. 313-341.

[7] Boserup, E. (1965), *The Conditions of Agricultural Growth*, Earthscan, London.

[8] Braidwood, R.J. (1963), *Prehistoric Men*, University of Chicago Press, Chicago.

[9] Braidwood, R.J., and B. Howe (1960), *Prehistoric Investigations in Iraqi Kurdistan*, University of Chicago Press, Chicago.

[10] Brorson, E. (1975), "The Earliest Farming: Demography as Cause and Consequence", in *Population, Ecology and Social Evolution*, edited by S. Polger, Mouton, The Hague, pp. 53-78.

[11] Childe, V.G. (1935), *New Light on the Most Ancient East*, Routledge and Kegan Paul, London.

[12] Childe, V.G. (1936), *Man Makes Himself*, Watts and Co, London.

[13] Cohen, M.N. (1977), *The Food Crises in Prehistory: Overpopulation and the Origins of Agriculture*, Yale University Press, New Haven.

[14] Cohen, M.N., and G. Armelagos (1984), "Paleopathology at the Origins of Agriculture" in *Paleopathology at the Origins of Agriculture*, edited by M. Cohen and G. Armelagos, Academic Press, Orlando, Florida, pp. 585-602.

[15] Darwin, C. (1868), *The Variation of Animals and Plants Under Domestication*, Appelton, New York, volume I.

[16] Diamond, J. (1997), *Guns, Germs, and Steel: The Fates of Human Societies*, W.W. Norton, New York.

[17] Fernandez-Armesto, F. (2000), *Civilizations*, Macmillan, London.

[18] Fernandez-Armesto, F. (2001), *Food: A History*, Macmillan, London.

[19] Flannery, K.V. (1969), "Origins and Ecological Effects of Early Domestication in Iran and the Near East", in *The Domestication and Exploitation of Plants and Animals*, edited by P.J. Ucko and G.W. Dimbleby, London: Duchworth, pp. 73-100.

[20] Flannery, K.V. (1973), "The Origins of Agriculture", *Annual Review of Anthropology*, 2, pp. 271-310.

[21] Galor, O., and O. Moav (2002), "Natural Selection and the Origin of Economic Growth", *Quarterly Journal of Economics* 117, pp.1133-1191.

[22] Galor, O., and D.N. Weil (1999), "From Malthusian Stagnation to Modern Growth", *American Economic Review* 89, pp. 150-154.

[23] Galor, O., and D.N. Weil (2000), "Population, Technology, and Growth: From Malthusian Stagnation to the Demographic Transition and Beyond", *American Economic Review* 90, pp. 806-828.

[24] Gebauer, A.B., and T.D. Price (1992), "Foragers to Farmers: An Introduction", in *The Transition to Agriculture in Prehistory*, edited by A.B. Gebauer and T.D. Price, Prehistory Press, Madison, Wisconsin, pp. 1-10.

[25] Goodfriend, M. and McDermott, J. (1995), "Early Development", *American Economic Review* 85, pp. 116-133.

[26] Hansen, G.D., and E. Prescott (2002), "Malthus to Solow", *American Economic Review* 92, pp. 1205-1217.

[27] Harlan, J.R. (1992), *Crops and Man*, American Society of Agronomy. Maddison, Wisconsin.

[28] Harlan, J.R. (1995), *The Living Fields: Our Agricultural Heritage*, Cambridge University Press, Cambridge.

[29] Harris, D.R. (1989), "An Evolutionary Continuum of People-Plant Interaction" in *Foraging and Farming: The Evolution of Plant Exploitation*, edited by D.R. Harris and C.C. Hillman, Unwin Hyman, London, pp. 11-26.

[30] Hayden, B. (1990), "Nimrods, Piscators, Pluckers and Planters: The Emergence of Food Production", *Journal of Anthropological Research*, 9, pp. 31-69.

[31] Isaac, E. (1970), *Geography of Domestication*, Prentice-Hall, London.

[32] Jones, C.I. (2001), "Was an Industrial Revolution Inevitable? Economic Growth Over the Very Long Run", *Advances in Macroeconomics* 1, pp. 1-43.

[33] Kalemli-Ozcan, S. (2002), "Does the Mortality Decline Promote Economic Growth", *Journal of Economic Growth* 7, p. 411-439.

[34] Kögel, T., and A. Prskawetz (2001), "Agricultural Productivity Growth and Escape from the Malthusian Trap", *Journal of Economic Growth* 6, pp. 337-357.

[35] Kremer, M. (1993), "Population Growth and Technological Changes: One Million B.C. to 1990", *Quarterly Journal of Economics* 108, pp. 681-716.

[36] Lagerlöf, N.-P. (2002), "The Roads to and from Serfdom", Concordia University, mimeo.

[37] Lagerlöf, N.-P. (2003), "From Malthus to Modern Growth: Can Epidemics Explain the Three Regimes", *International Economic Review*, 44, pp. 753-777.

[38] Lee, R.B, and I. DeVore (1968), *Man the Hunter*, Aldine, Chicago.

[39] Legge, A.J., and P.A. Rowley-Conwy (1987), "Gazelle killing in Stone Age Syria", *Scientific American* 275:2, pp. 76-83.

[40] Lemmen, C. and K.W. Wirtz (2003), "A Global Dynamic Model for the Neolithic Transition", *Climatic Change* 10, pp. 1-35.

[41] Locay, L. (1989), "From Hunting and Gathering to Agriculture", *Economic Development and Cultural Change* 37, pp. 737-756.

[42] Lucas, R.E. (2002), *Lectures on Economic Growth*, Harvard University Press, Cambridge.

[43] Martin, P.S. (1967), "Prehistoric Overkill", in *Pleistocene Extinctions*, edited by P.S. Martin and H.E. Wright, Yale University Press, New Haven, pp. 75-120.

[44] Milthen, S. (1996), *The Prehistory of the Mind: A Search for the Origins of Art, Religion and Science*, Thames and Hudson, London.

[45] Morand, O.F. (2002), "Evolution Through Revolutions: Growing Populations and Changes in Modes of Production", University of Connecticut, mimeo.

[46] North, D.C. (1981), *Structure and Change in Economic History*, W.W. Norton, New York.

[47] North, D.C., and R.P. Thomas (1977), "The First Economic Revolution", *Economic History Review*, 30, pp. 229-241.

[48] Olsson, O. (2003), "The Rise of Neolithic Agriculture", University of Goteborg, mimeo.

[49] Olsson, O., and D. Hibbs (2002), "Biogeography and Long-Run Economic Development", *Eurpean Economic Review (forthcoming).*

[50] Perrot, J. (1962), "Palestine-Syria-Cilicia" in *Courses Toward Urban Life*, edited by R.J. Braidwood and G.R. Willey, Aldine Publishing Company, Chicago.

[51] Persson, K.G. (1988), *Pre-Industrial Economic Growth: Social Organisation and Technological Progress in Europe*, Basil Blackwell, Oxford.

[52] Price, T.D. (1995), "Social Inequality at the Origins of Agriculture", in *Foundations of Social Inequality*, edited by G.M. Feinman and T.D. Price, Plenum Press, London, pp. 129-151.

[53] Price, T.D., and J.A. Brown (1985), *Prehistoric Hunter-Gatherers: The Emergence of Food Production*, Academic Press, New York.

[54] Pryor, F.L. (2003), "Economic Systems of Foragers", Swarthmore College, mimeo.

[55] Redman, C.L. (1978), *The Rise of Civilization: From Early Farmers to Urban Society in the Ancient Near East*, W.H. Freeman and Company, San Francisco.

[56] Rindos, D. (1984), *The Origins of Agriculture: An Evolutionary Perspective*, Academic Press, London.

[57] Roberts, N. (1989), *The Holocene: An Environmental History*, Basil Blackwell, Oxford.

[58] Sahlins, M. (1974), *Stone Age Economics*, Aldine, Chicago.

[59] Sauer, C.O. (1952), *Agricultural Origin and Dispersal*, American Geographical Society, New York.

[60] Smith, A. (1937), *An Inquiry into the Nature and Causes of the Wealth of Nations*, W. Strahan and T. Cadell, 1776; reprinted, Modern Library, New York.

[61] Smith, B.D. (1995), *The Emergence of Agriculture*, Scientific American Library, New York.

[62] Smith, V.L. (1975), "The Primitive Hunter Culture, Pleistocene Extinction, and the Rise of Agriculture", *Journal of Political Economy*, 83, pp. 727-755.

[63] SMITH, V.L. (1992), "Economic Principles in the Emergence of Humankind", *Economic Inquiry*, 30, pp. 1-13.

[64] TAMURA, R. (2002), "Human Capital and the Switch from Agriculture to Industry", *Journal of Economic Dynamics and Control* 27, pp. 207-242.

[65] WEISDORF, J.L. (2003a), "From Stagnation to Growth: Revisiting Three Historical Regimes", *Journal of Population Economics (forthcoming).*

[66] WEISDORF, J.L. (2003b), "Stone Age Economics: The Origins of Agriculture and the Emergence of Non-Food Specialists", Discussion Paper No. 03-34, University of Copenhagen.

The Period:	The Hypothesis:	Its main idea:	The Reason for leaving it:
?-1930s	The 'Stage' hypothesis	Agriculture was the final stage in a uni-linear development path	External pressure was believed to have generated the transition
1930s-1950s	The 'Oasis' hypothesis	The shift was motived by changes in environmental conditions	Climatic changes too slow; earlier interglacial periods did not result in the adoption of agriculture
1960s	The 'Natural Habitat'/-'Nuclear Zone' hypothesis	Abundance of leisure led to plant experimentation	Evidence suggested that farming arose out of necessity rather than opportunity
1960s-1980s	The 'Marginal Zone' hypothesis	The shift was generated by population pressure in infertile zones	The first domestications took place in resource-abundant societies
	The 'Population Pressure' hypothesis	The shift was generated by population pressure on a global scale	Skeletal evidence did not indicate a food crisis
	The 'Overkill' hypothesis	Animal extinction indicated the presence of a food crisis	Animal extinction and agriculture did not occur together, neither geographically nor chronologically
1980s-1990s	The 'People-Plant Interaction' hypothesis	The shift resulted from unintentional human behaviour/manupulations.	(Still under consideration)
	The 'Human-Plant Symbiosis' hypothesis	Land exploitation and energy input are strongly correlated	(Still under consideration)
1990s-2000s	The 'Competitive Feasting' hypothesis	The first domestications were delicacies	The first domestications were important foods
	The 'Younger Dryas' hypothesis	The shift was motived by changes in environmental conditions	(Still under consideration)

Figure 1: The Hypotheses

The Contribution:	The Key Determinant:	The Main Argument:
Smith (1975)	Animal extinction	Excessive hunting favoured agriculture
North and Thomas (1977)	Property rights	Common property rights among foragers cause incentive failure, whereas exclusive communal property rights among farmers do not
Locay (1989)	Nomadism	Population pressure made foragers more settled, which favoured farming
Olsson and Hibbs (2002)	Biogeography	Biogeographic endowments were crucial to the timing of the transition to agriculture
Morand (2002)	Inter-family exchange	Changes in external forces determined the modes of production and the nature of transfers between household members
Weisdorf (2003)	Non-food specialists	The emergence of non-food specialists was crucial to the adoption of labour-costly agricultural methods
Olsson (2003)	Population growth	Higher population growth among farmers relative to foragers pushed people into agriculture

Figure 2: The Economic Literature

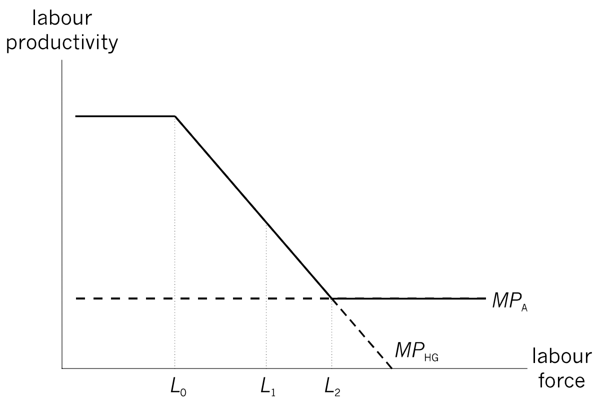

Figure 3: The Standardised Model

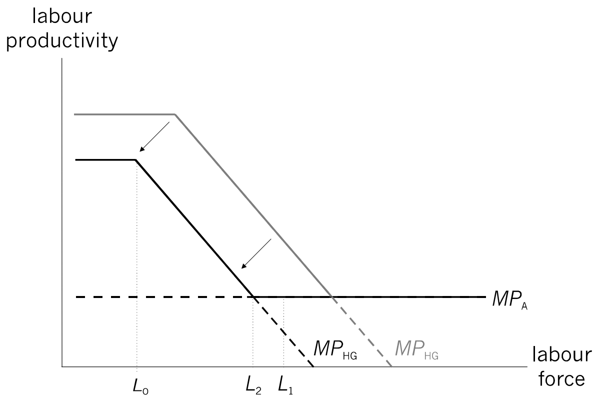

Figure 4: Lower Productivity in Hunting-Gathering

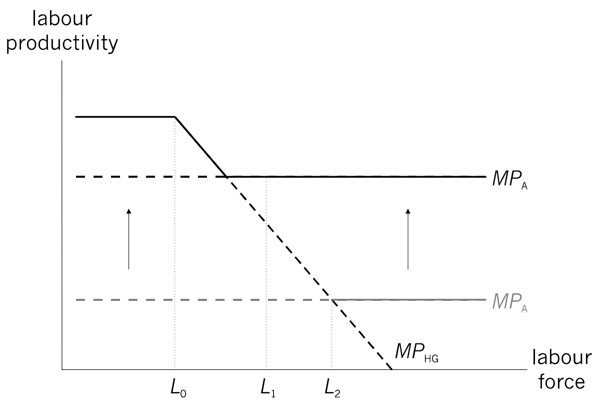

Figure 5: Higher Productivity in Agriculture

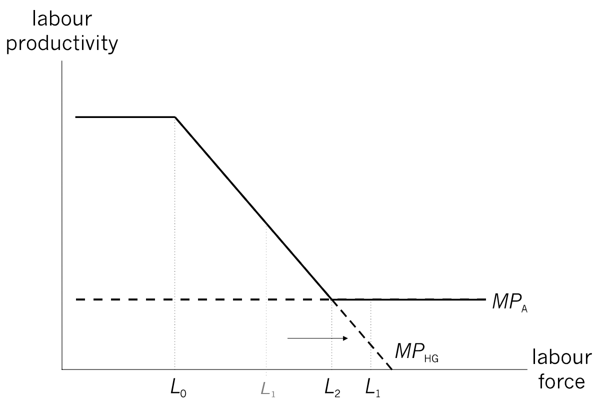

Figure 6: A Larger Labour Force

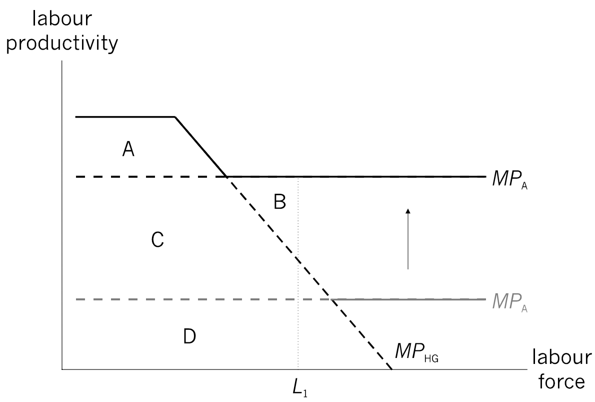

Figure 7: Olsson's (2003) Result