# English and Welsh Agriculture, 1300-1850:

# Output, Inputs, and Income

by

Robert C. Allen

Professor of Economic History
Nuffield College
New Road
Oxford OX1 1NF

email: bob.allen@nuffield.oxford.ac.uk

January, 2005

Measuring the growth of output and productivity have been central questions in English agricultural history. They have been approached in different ways by different groups. On the one hand, there are the historians and geographers who base their work on sources like estate records, probate inventories, and so forth. Some of this research has become statistical in recent years as large data sets have been compiled. The measurement of productivity has focused on biological indicators like crop yields. A long run objective of this school is to measure the growth in agricultural production 'from the ground up' by aggregating local studies of land use, livestock, and yields so that national totals can be calculated. Chartres (1985) and Holderness (1989) took big steps in that direction for 1500-1850, and Campbell (2000) has done the same for 1300. Indeed, Campbell and Overton (1991) have estimated total grain production from the middle ages to the nineteenth century. No one, however, has yet examined the combined trajectory of crop and livestock output from 1300 to 1850, and that is a goal of this paper. Recent research by Brunt (2002, 2004), Clark (1998a, 1999, 2001, 2002a), Campbell (2000), Turner, Beckett, and Afton (1997, 2001) have expanded the available information, and made this a propitious time for an attempt.

Economists are the second group to have studied English agricultural history. Measuring agricultural output 'from the ground up' has been a slow and laborious enterprise, and economists are not a patient lot. In addition, they are often more concerned with the causes of economic growth and the interaction between agricultural and industry than with the details of issues like estate management, and they have mastered a different methodology that raises its own questions and suggests novel approaches to historical analysis. As a result, economists are often interested in different productivity indicators–total factor productivity, output per worker, real rents, for instance–and propose new ways to measure agricultural output. These have included (1) adding up the land, labour, and capital incomes generated by agricultural to determine the current value of output, which is then deflated by an index of farm product prices to calculate real output (Deane and Cole 1969, Clark 2002b), (2) using a demand curve to extrapolate output growth from population, income, and prices changes (Crafts 1976, Jackson 1985, Clark 1993, Clark, Huberman, Lindert 1995, Allen 1999, 2000), and (3) simply extrapolating farm output from population (Deane and Cole 1969, Overton 1996)–a less sophisticated version of (2). Novel attempts to measure productivity include using the share of the population in agriculture to infer output per worker (Wrigley 1985, Allen 2000), using piece rates to compute the labour apparently required to plough an acre or thresh a bushel (Clark 1991), and deflating rents to measure total factor productivity (McCloskey 1972, Allen 1982, 1992, Turner, Beckett, and Afton 1997, Clark 1998a, 1998b). Many times series of agricultural prices, wages, and rents have been compiled (Bowden 1967, 1985, John 1989, Allen 1992, 1999, Turner 1997, Clark 1998a), and this is another fact that makes this a good time to attempt a comprehensive treatment.

At the moment, the historians and the economists live in 'peaceful coexistence' based on a spirit of tolerance (more approaches to history are better than less) and in the hope that–in the long run–the various approaches will add up to a consistent account of agrarian change. But do they really? We hope–but we do not know–that an output estimate derived from a demand curve is the same as what one would get by adding up the production of all the farms in the country. We hope–but we do not know–that the productivity story suggested by real rents corresponds to the story implied by rising crop yields, the spread of better breeds, and changing land use.

The methodological aim of this paper is to show that we can, indeed, give a consistent account of English agricultural history in which the approaches suggested by economists cohere with the information compiled by geographers and historians. I will do this by estimating net agricultural output 'from the ground up' for 1300, 1500, 1700, 1750, 1800, and 1850. The result is then compared to other approaches inspired by economics.

Cross checks are a key feature of the methodology of this paper. I estimate output 'from the ground up' by aggregating the net output of eighteen commodities[1] with unchanging prices. This is checked against the results of demand curve reconstructions: how much did output have to grow to match changes in population, income, and prices? A second check comes from valuing output in each year with the prices of that year and comparing the total to the sum of factor earnings when the land, labour, and capital used in production are also valued at the current rents, wages, and capital prices. This comparison provides a very important check on the choice of uncertain parameters relating to farm output. Further checks come from two other ratios. One is days worked per farm family. If the questions is: could the farm population have cultivated the posited arable acreage, this ratio is a first check. A second important ratio is per capita calorie production and consumption (when allowance is made for international trade). Population estimates cannot be pushed so high that calorie consumption becomes too low.

These cross checks are most important for the middle ages. Between 1750 and 1850, the difficulties in estimating farm output are minor, and the various approaches are easily reconciled. Uncertainties increase for 1700, become imposing for 1500, and daunting for 1300. Historians disagree about key parameters for this period like the population and the arable acreage, and it is necessary to use all approaches and cross checks to find a way through the possibilities. Later a section will be devoted to the problems of 1300.

## A New View of the Agricultural Revolution

The second aim of the reconstruction is historical rather than methodological. The reconstructions point to important conclusions about the pace, character, and consequences of agrarian change in England and Wales. Before looking at the calculations, I summarize these findings.

### agricultural revolution: when? how much?

Fundamental questions are: By how much did agricultural output and productivity increase? When were the main periods of advance? Output rose by a factor of 4.5 between 1300 and 1850. The most important periods of expansions were 1500-1750 and 1800-50. The last half of the eighteenth century, when the parliamentary enclosure movement was at its peak, was notable for the slow growth in output.

Productivity also grew continuously over long periods. Corn yields doubled between 1300 and 1700, grew little in the eighteenth century, and then increased by another fifth in the first half of the nineteenth century. Livestock yields rose by an even greater amount–about four fold from 1300 to 1850. Labour productivity grew by about 40% between 1500 and 1700 and

---

[1] Wheat, rye, barley, oats, beans and peas, potatoes, beef, mutton, pork, wool, hay sold to towns, hides, cheese from cows, butter from cows, cheese from sheep, butter from sheep, fluid milk sold to towns, flet cheese. In all cases, output is net of that used as an input in agriculture.

another 40% in the first half of the nineteenth century. The growth of total factor productivity (TFP) depends critically on how the inputs are measured. 'Natural units,' uncorrected for quality improvements, imply a four fold rise in TFP between 1300 and 1850. Accounting for quality improvements cuts that increase. If productivity is the metric, the agricultural revolution was a long drawn out affair.

## agricultural revolution: what changed?

The statistical reconstructions also have important implications for our understanding of the character of agricultural change. In particular, they emphasize the importance of the livestock sector, a point emphasized by Campbell and Overton (1992). The volume of livestock products increased more rapidly than the production of crops. Livestock amounted to less than half of agricultural output in 1300 and considerably more than half in 1850.

The rapid growth in livestock output is closely connected to an important change in agricultural land, namely a massive improvement in grassland quality. In 1300, most grass was poor quality common pasture. By 1800, 15 million acres had been enclosed and improved. Better grazing underpinned the rise in livestock production.

There were also improvements in arable farming. New crops–peas, beans, turnips, clover, potatoes–were introduced, and corn yields rose. Much of the output of the new crops was fed to animals, and much of the rise in corn yields was an indirect and unanticipated consequence of the cultivation of the peas, beans, and clover that improved fertility by fixing atmospheric nitrogen. Thus, to a significant degree, the improvements in arable farming were driven by the growth of the livestock sector. It has long been recognized that English farming was mixed husbandry in which the arable and pastoral activities were mutually supportive. (O'Brien 1996). The point emphasized here is that within that context the growth in livestock production was the active agent responsible for most of the improvements. The production of corn has received more attention from historians than the production of animal products, and that balance needs to be not redressed but reversed.

Why did the livestock sector grow so rapidly? Its growth reflected the high wages generated by the British economy (Allen 2001, 2003). After the Black Death, the real wage shot up, and it remained high for two centuries since the population remained at a low level. After 1550, real wages fell in much of England as the population increased. Living standards, however, remained high in London as the city exploded. In the seventeenth century, the high wage economy spread across the country under the impetus of growing success in world trade. It was the high incomes generated by the nonagricultural economy that created the demand for animal products that led to the transformation of agriculture as a whole.

This conclusion has some implications for the debate on open fields and enclosures. In recent years, the debate has swung in favour of the open fields since they adopted many of the new crops and realized high productivity in grain farming in the eighteenth century (e.g. Allen 1992, Clark 1998a). However, the centrality of livestock highlighted by this paper probably required the enclosure of common pasture. Consequently, the enclosure movement made a more important contribution to productivity growth than the revisionists have allowed.

## agricultural revolution: ramifications

The statistical reconstruction also has implications for three important consequences of agrarian change.

First, despite its achievements, the record of English agriculture in feeding the people was mixed. The production of calories per head of population was very low in 1300 (1791 calories per person per day) and leaped up after the Black Death to 3396 in 1500. Production and consumption rose until 1750 when both began to decline. Calorie production dipped to 1970 per person per day in 1850. Rising food imports cushioned the drop, so per capita consumption was 2525. The average real wage rose during the Industrial Revolution, but the increase was due to the growth in the consumption of manufactures that more than offset a decline in food.

Second, rising labour productivity did contribute to the release of labour for manufacturing, but improved agricultural performance was only one of three important factors in that process. As noted, increased food imports were critical in feeding the urban population during the industrial revolution: in an important sense, labour release 'fed on itself' as the released labour produced manufactures that were exported to pay for the food it ate. In addition, labour release was accomplished by cutting food consumption. The high level of per capita calorie production in early modern England meant that labour could by deployed away from agriculture by reducing everyone's food ration. For these reasons, the share of the English population in agriculture fell much more rapidly than agricultural labour productivity increased.

Third, landowners were the major beneficiaries of productivity growth in farming. Between 1300 and 1500, their position deteriorated as the rent of land dropped and their share of agricultural output declined. After 1500, however, the trend reversed. The real rent of land rose at least ten fold, the real wage showed little advance, and the share of income going to land owners reached a greater value after 1700 than in 1300.

## Part I: Measuring Aggregate Inputs and Output

Measuring agricultural output 'from the ground up' is done by multiplying harvested acres and livestock numbers by yields of the crops and animals. I begin with the estimates of land use and livestock, then discuss their yields, and finally add up production to get agricultural output.

### A. Inputs: Land

Table 1 summarizes the estimates of land use. While these are subject to many qualifications and emendations, they define the main quantitative dimensions of English and Welsh agriculture. The figures for the eighteenth and nineteenth centuries are based on contemporary estimates. The figures for 1300 and 1500 are much more conjectural since there is no evidence of the total acreage under cultivation. We can advance tentative conclusions, however, since some possibilities are more plausible than others.

I begin with the arable acreage. The 12 million acres shown for 1300 is suggested by needs of the population, which is assumed to be 5 million for England and Wales (about 4.5 million for England and the rest for Wales). The size of the population, is of course, controversial with estimates ranging from 3.7 to about about 6.5 million for England alone (Smith 1991, Campbell 2000, p. 403). 5 million for England and Wales is in the low to middle portion of the range. With the yields used here, 5 million people and 12 million arable acres imply a per capita calorie consumption of 1791 per day. This is very low by international standards, and the population could not have survived had the food supply been much less. Anyone arguing for a larger population must, therefore, also argue for a larger arable acreage or higher yields. There is little chance that the arable acreage was much greater: While land certainly went out of cultivation after the Black Death, much new land was brought into cultivation. The 12 million acres posited for 1300 is already slightly in excess of the arable acreage in 1800. Could it have been as great as in 1850? It is hard to see how. Higher productivity is a live option and has been advocated by some historians. The problem with this claim, however, is that higher productivity implies a value of farm output that was much larger than the sum of wages, rents, and profits implied by medieval sources. In our present state of knowledge, the balance of the probabilities, therefore, indicates a population of 5 million for England and Wales in 1300 with 12 million acres under the plough. I will review the matter again after all the dimensions of agriculture development have been discussed.

The population dropped substantially in the fourteenth and fifteenth centuries with both the timing and the magnitude subject to dispute. I use a figure of 2.5 million for 1500. This is not the lowest in the literature, but it is consistent with Wrigley and Schofield's (1981) reconstruction. I do not posit a comparable fall in the arable acreage. Since per capita food consumption was so low in 1300, the income elasticity of demand for food must have been high, so there would have been great eagerness to raise the acres cultivated per person. The population was certainly able to cultivate the 9 million arable acres shown for 1500, as will be seen. This acreage expansion generated a significant rise in food grown per person. A higher standard of living is consistent with the view of the fifteenth century as the golden age of the English labourer.

By 1700, we are on charted, if not firmer, ground since there are contemporary estimates of the arable acreage beginning with Gregory King (1696). While these figures are venerable, they must be regarded cautiously. King's reputation rests on his estimate of population. It was accurate since it was based on the hearth tax returns, but King did not have comparable sources for other figures and frequently changed his mind during the course of his investigations–a point made by Cooper (1967) and Holmes (1977)–and comparison of his social table with occupational evidence shows serious discrepancies (Lindert 1980). In the absence of any other basis for proceeding, I use King's estimates of arable and grass but with misgivings. More contemporary estimates are available for the nineteenth century, and my estimates of arable and grass in 1800 and 1850 are based on those of Capper, Comber, and Caird, as explained in Allen (1994).

Table 1 makes an important point about the arable acreage: Over the half millenium it changed remarkably little. There was a drop after the Black Death and an upward jump during the first half of the nineteenth century, but little long run trend. Over the same period, the English and Welsh population increased almost four fold. How were those people fed?

Part of the answer lies in the changes in cropping summarized in Table 1. The medieval crop distribution is based on Campbell's figures for the cultivation of demesnes. Whether peasants cultivated their land in the same way is controversial, and Campbell has suggested they grew less wheat and more 'inferior' grains. This is hard to believe since the inferior grains had such markedly inferior yields that they generated much less food per acre. (This result is shown by reassigning land from wheat to barley and oats and calculating the production of calories.) While there is more information for eighteenth century cropping, the bounds of uncertainty are still large. Thus Chartres (1985) and Holderness (1989, p. 145) have both estimated grain output in 1750 for different volumes of the Agrarian History of England and Wales, and their results differ significantly. For the eighteenth century, I followed Brunt's (2004) estimates. These show a considerably larger fraction of land under wheat than some others, especially for the early part of century. This is important in determining the rate of growth of agricultural output: wheat generated considerably more revenue per acre than other grains, so shifting land into wheat increased the rate of growth of output. Conversely, opting for a more stable structure of land use implies a slower growth in arable production. Following Brunt makes the estimates of agricultural production grow at a rate more in accord with the estimates of output derived from a demand curve.

Bearing in mind their weaknesses, the statistics on cropping make several important points. First, the share of fallow dropped--mainly after 1700. Second, wheat cultivation remained remarkably stable. Third, the share of land planted with barley, oats, and rye declined throughout. Fourth, the cultivation of fodder crops–peas, beans, turnips, and clover–increased markedly. The cultivation of peas and beans expanded before that of turnips and clover. Between 1300 and 1500, peas and beans rose at the expense of oats. Not only was the greater cultivation of fodder fundamental to the expansion of the livestock sector, but peas, beans, and clover were legumes whose culture increased soil nitrogen levels, and more nitrogen was central to explaining the increase in cereal yields between 1500 and 1700.

Table 1 shows that changes in grassland were even more dramatic than changes in arable. The acreage of meadow–that is, grass that was mown for hay–was roughly constant, although hay yields rose over time, and hay production was further boosted by the cultivation of clover on the arable. What was most impressive was the increase in 'pasture' and the decline in 'common'. The former rose from roughly one million acres in 1300 to nine million in 1700 to16.5 million in 1800. Exactly what this means is less certain. This pasture was enclosed pasture and did not include grass that was organized as commons. These must have been vast in the middle ages although their dimensions were intrinsically uncertain. While there were fewer cattle in 1300 than in 1800, there were as many sheep and probably more draft animals. The sheep were probably running over as much land in 1300 as 500 years later. Consequently, I estimate the acreage of medieval commons as 20 million acres–that is, 34 million acres (the maximum agricultural acreage in England and Wales) less the land otherwise used for arable, meadow, and pasture. This procedure is applied to later dates as well.

Between 1300 and 1800, there were two types of changes in pasture. One was tenurial–the commons were enclosed. The second was technological–the quality improved. It is often said that simply putting a fence around land will not increase its productivity, but that was not necessarily true for grass. In upland England and Wales, fencing the land did raise its quality since the fence was a wall made from stone picked off the fields being enclosed. Removal of the surface rock increased the proportion of the field supporting grass and thus raised its productivity. The rise in pasture quality supplied more food to animals and contributed to the rise in their productivity. Other implications of this change in organization will be discussed as well.

While most of England and Wales may have been used for grazing in the middle ages and early modern periods, the quality of this land, as noted, as low compared to the pasture and meadow shown in Table 1. King valued the pasture at 9s per acre and the common at only 1s 1d. The differential and the consequences of improving grassland can be measured by forming an index of the quantity of land where the quantities of pasture, meadow, and common are weighted by King's rental values. The result is shown in Table 1. The index rises by about three fold between 1300 and 1850, while the total quantity of land used in agriculture (34 million acres), of course, stayed the same.

Table 1 emphasizes an important feature of English agricultural history that is often overlooked, namely, changes in the management of grassland and improvements in its quality. Arable farming has received disproportionate attention in assessments of agricultural advance, and the aggregate record, despite the weaknesses of the statistics, emphasizes the need for redressing the balance.

## 2. Capital

The provision of capital in English agriculture was divided between landlords and tenants. In the modern period, most fixed capital–buildings, fencing, roads, tile drains--was supplied by the landlord. I concentrate on investments by tenants since improvements like new buildings are manifest in these accounts as improvements in the quality of land and were paid for in the rent. Tenants drained their farms and undertook improvements like marling whose effects lasted a long time. These appear as labour in my accounts. In this section, I am concerned with livestock and implements.

The principal animals were sheep, hoggs, cattle (including cows, calves, and animals raised for meat), and draught animals (oxen and horses). The numbers for 1850 are anchored on the annual agricultural returns which began in 1867. Earlier figures are largely based on ratios of animal numbers to acreage as indicated by estate and farm accounts. Campbell (2000, p. 136) derived such ratios for 1275-1324 from demesne accounts. Campbell (2000, p. 158-9, 2002) has urged that peasants kept fewer cattle but more sheep than these figures imply. Indeed, the demesne ratios do not imply enough sheep for England's wool exports and domestic consumption. I have followed Campbell's lead and increased the demesne sheep ratio by 50% while cutting the cattle ratio by one third in order to estimate ratios for agriculture as a whole. I estimated animal numbers for 1500 by applying Campbell's (2000, p. 136) demesne ratios for 1400-49 to the 1500 arable acreage. It might be noted that about 40% of the draught animals were horses in 1300 and 50% in 1500, while horses were predominant thereafter (Langdon 1986, p. 205, 255) For 1700, Gregory King's estimates were used except for horses where Brunt's careful analysis has led to a significant downward adjustment.[2] The horse populations for 1750-

[2]I am grateful to Liam Brunt for showing me his preliminary analysis of the horse population in the eighteenth century.

1850 are based on Feinstein (1978, p. 70), Holderness (1989, pp. 147-74), and Allen (1994, p. 109).

Table 2 summarizes the history of the number of livestock. Cattle numbers more than doubled between 1300 and 1500 and then increased another third to 1700. The number of cattle dropped in the eighteenth century and then rebounded slightly to 1850.[3] The hogg population also increased secularly, but the populations of other livestock traced other trajectories. The number of draught animals declined in the long term. This was due both to the replacement of oxen by horses and to the economies in the use of draught teams by large scale farms (Allen 1988a, 1992, p. 214). The number of sheep dropped after the Black Death and did not regain its 1300 level until the first half of the nineteenth century. Table 2 does not provide prima facie evidence for a rise in livestock intensity in English farming over the early modern period.

Implements were the other type of farmer-supplied capital. Kitsikopoulos' (2000, pp. 247-8) peasant farm model assumed that an 18 acre farm had one plough (worth 3s 6d), one cart (13 s), and other implements worth 4s implying a total of 1.139 s of implements per acre of arable. Holderness (1988, pp. 30-1) argued that 'a mixed arable holding of 150-200 acres in the early nineteenth century required one wagon, two or three carts, two or three pairs of harrows, two or three ploughs, and probably also a roller and a winnowing machine." Including horse harness, hurdles, and other equipment implies an investment of £1 per arable acre plus £0.4 per acre of grass. These rose to £1.4 and £0.65 per acre, respectively, in 1860.

Implements per acre were much higher in the nineteenth century than in the fourteenth, and the question is when this rise occurred. Bowden's (1985, p. 90) analysis of farm income c. 1700 assumes the increase happened later: ""In sum, it seems unlikely that the appliances employed on an arable undertaking of 100 acres would normally cost more than, say, £15"–that is, 3 s. per acre. I have followed Bowden's lead for 1700 and, correspondingly, assumed implement intensity was unchanged between 1300 and 1500. I assigned intermediate values for 1750.

## 3. Labour

Broadly speaking, there are two approaches to the measurement of agricultural labour. The first is the 'agricultural population' (people working in agriculture or deriving an income from it). The advantage of this measure is its ease of implementation: censuses often classify people by their principal occupation, or the agricultural population can be estimated by applying extraneous ratios to assign people to sectors (Wrigley 1985, Allen 2000). There are two disadvantages to this measure, however: some people worked in more than one sector, so there is ambiguity, and the time worked per year by a member of the 'agricultural population' was not constant.

[3] Holderness argued that the average milk yield of a cow rose in the second half of the eighteenth century as commons were enclosed and their poor quality stock replaced with fewer, but more productive, animals. Assuming the same number of cows in 1750 as in 1700, which I have done, captures this process whereas Holderness' lower estimate of the cow population in 1750 does not.

The solution to these problems is to measure labour by days worked (hours would be even better). How can they be determined? One approach is to use farm accounts or similar data that record employment. Arthur Young's survey of farms is one example from the eighteenth century (Allen 1988a). The problem with data of this sort is that only hired labour is recorded in such records and the labour of the farm family is excluded. This must be estimated–or guessed at–and either approach introduces error. Medievalists have pursued this method for demesne agriculture where the chances of success are greater since, in the cases of large demesnes, all of the labour was either hired or servile and consequently should show up in the accounts (Thornton 1991, Fox 1996, Karakacili 2004). While only a handful of demesnes have been studied in this way, the results provide an important check on my estimates.

A second approach, and the one pursued here, is to calculated the days worked on farms on a task by task basis. From the acreage, the number of animals, and the yields, one can work out the time needed to operate the farm. This procedure can be consistently applied across centuries, and the results compared to the other methods of measuring farm employment.

At the outset, a few general points about this method should be highlighted. First, what makes it feasible is that many tasks in arable farming were standardized, frequently costed, and often paid with a piece rate. Thus, for ploughing, harrowing, seeding, reaping, threshing, and so forth, the number of times the task had to be performed and the time it took can be reasonably well established. Medieval estimates of the time required can be compared to nineteenth century ones, and there is impressive similarity if the tasks are defined narrowly. These tasks comprised a large share of the labour input. Furthermore, the similarity between medieval and nineteenth century labour requirements indicates that serfdom had no apparent effect on the time taken to do a job.

Second, some tasks, obviously, were much more variable–the time spent weeding, or breaking clods, or scouring furrows, or carting corn, or hauling and spreading marl. Some farmers devoted more time than others to these activities depending on the economic incentives of the day, the size and lay-out of their farms, and their assiduousness. I have cross checked values from different periods and have used either common values, values scaled to output where that was appropriate, or values that reflected the general degree of labour intensity as suggested by other indicators. Clearly, however, there is uncertainty. In the final analysis, however, the estimates of days worked imply costs that are consistent with the value of farm production.

Third, the main source for these data are cost estimates of farming, and they give a spuriously precise impression of the required time, which must have had a significant random component that is hard to assess retrospectively.

Fourth, the costs–hence labour requirements–must be expressed as functions of acreage or yield (as appropriate) so that the labour requirements can be brought into conformity with the acreage, animal numbers, and yields for England as a whole. The labour required for some tasks (e.g. ploughing) was proportional to the acreage, while the labour for others (e.g. threshing) was proportional to the yield. Some employment in dairying was proportional to the number of cows, while other jobs were proportional to the milk produced. Once these proportionality relations were established, the labour requirements can be scaled to the agriculture of the day.

Batchelor's General View of the Agriculture of the County of Bedford (1808) was the most important source of costing information. He devoted a hundred pages to a task by task discussion of all aspects of farming to develop costs for model farms. Previously, I have used this information to compare agricultural costs to revenues in 1806–with good success. As a test of the cost model, it was used to predict costs for 1770. These predictions were compared to cost estimates derived from the hundreds of farms surveyed by Arthur Young in his tours (Allen 1992, pp. 162-3). There was good correspondence between the Batchelor cost model and Young's data. This gives some confidence that Batchelor's cost accounting is reliable.

By dividing costs by the wage rate, labour requirements per task were computed. Indeed, Batchelor usually estimated costs by first estimating employment and often gives enough details, so that the labour requirements coefficients can be ascertained directly. Based on the descriptions of the activities involved, it was usually clear whether employment was proportional to acreage, yield, animals or whatever.

Since farming may well have been different in earlier centuries, an alternative model of medieval agriculture was put together from medieval sources. Kitsikopoulos' (2000) careful study of peasant household budgets was the benchmark for this exercise. Other sources, however, were also consulted including medieval treatises like Walter of Henley (Oschinsky 1971) and the work of historians like Stone (1997).

The medieval task model was evaluated through several comparisons. The first was comparison with the Batchelor model. When tasks were narrowly defined the agreement was usually close. Comparisons like this included the days of labour needed to plough an acre of land or the time to thresh a bushel of barley. Where discretion was more important, discrepancies were larger. The number of times the fallow was ploughed, for instance, was not fixed, nor was the time devoted to weeding a wheat field. In general, Kitsikopoulos set these labour requirements at lower levels than did Batchelor. Indeed, when the Batchelor model was tailored to medieval conditions, it indicated more days worked per acre than did Kitsikopoulos' accounting.

The idea that medieval employment was actually higher than implied by Kitsikopoulos' coefficients is buttressed by other comparisons. Stone (1997), for instance, proposed much higher labour requirements for mowing grass, and Stone's coefficients are closer to Batchelor's. More encompassing are comparisons of the total days worked (as implied by the Kitsikopoulos' employments) with the days worked in arable operations per arable acre on demesnes where this has been directly measured. These studies require complete accounts so that the days worked by serfs can be added to those worked by free labourers. Thornton's (1991, p. 205) study of Rimpton found that 13.6 days were worked per arable acre in 1275-1324, while Fox (1996, pp. 544-5) calculated 13.4 and 13.7 days at Pilton and Ditcheat. In a study of eight manors in Huntingdonshire, Karakacili (2004) found arable employment per arable acre varied between eight and fourteen days. Only the low end of Karakicili's range coincides with Kitsikopoulos' accounting–namely, about eight days per arable acre. The upshot of these considerations is that I raised the discretionary employment levels for tasks like weeding to eighteenth century levels. These are more in accord with the findings of Stone (1997) and provide a closer fit with the measured employment levels on most of those demesnes that have been studied intensively.

By all accounts, labour intensity declined between 1300 and 1500. Bowden's (1967) assessment of farm costs and profits shows discretionary employment at a low level. I have followed his lead and reduced farm employment levels accordingly.

What do the estimates of labour requirements tell us about the history of English agriculture? To highlight the important points, it is useful to divide agriculture into arable and pastoral components. Table 3 shows the breakdown for days worked and the ratio of days worked to acreage. There is no ambiguity about acreage for arable operations, but a range of values are possible for pastoral. One can define pastoral acreage as meadow plus enclosed pasture (surely too narrow a definition) or as meadow, enclosed pasture, and common (perhaps too broad), or, finally, as 'improved grass equivalents," i.e. meadow, pasture, and common where the latter is reduced to 'improved grass' by multiplying the acreage of common by the ratio of the rental price of common to the rental price of arable and meadow as reported by King.

Table 4 makes several important points. First, labour per acre in arable operations was remarkably constant across the centuries. Between 1300 and 1850, labour intensity rose by about one third. There was some fall-off in labour intensity after the Black Death, followed by slow growth thereafter. The improved husbandry of the eighteenth century led to little additional employment, contrary to the views of Chambers (1953).

Second, the same cannot be said for pastoral farming, but the matter is complicated by the various ways of measuring pastoral land. Dividing pastoral employment by the total acreage of pasture, meadow, and common shows an increase in days worked per acre from 3.8 in 1300 to 10.0 in 1850. This increase parallels the improvements in grassland quality already discussed. On the other hand, the ratio of employment to the sum or of pasture, meadow, and common or to 'improved grass equivalent acres' shows a drop in employment. The decline arises since the calculation assigns all of the labour in cheese and butter making to the small improved acreage in the early centuries and, so, may not be very revealing of livestock management itself.

Third, by the nineteenth century, when the improvement of commons was as complete as it would get, the labour intensity of pastoral husbandry was about two-thirds that of arable. A similar reduction in employment is implied by the statistical analysis of the sample farms Arthur Young collected in his tours (Allen 1992, pp. 159-63).

How many days per year were farm families working? We can compare the total number of days worked to estimates of the agricultural population prepared earlier (Allen 2000). On the assumption that a household averaged 4.5 people, Table 3 shows how the number days worked by the average farm family changed over time. In 1300, the average family worked an average of 309 days, that is, a bit more than one person-year of labour. By 1500, this had jumped to 522 days–approximately two person years–and it remained at that level until 1850. This labour was probably supplied by a man working full time, and by some combination of his wife and children working part-time. Table 3 indicates that almost half of the agricultural population was unemployed in 1300 defining full employment in terms of the behaviour of the next five centuries. These considerations also imply that the population in 1500 could cultivate the acreage indicated in Table 1.

B. production

The estimates of output are built up from estimates of land use and livestock numbers. For 1700-1850, these are based on contemporary estimates. For 1300 and 1500, they are based on Campbell's analysis of demesne records and probate inventories. These estimates are less reliable than those for the eighteenth century due to the uncertain size of the population and economy, as will be explained.

crop yields and output

Table 5 shows the crop yields. They increased almost three fold between 1300 and 1850. A few comments on them are in order.

The yields for 1300 are derived from Campbell's (2000, pp. 312-3, 332-4) assessment of demesne yields. The notes to Table 5 show his estimates of yields net of seed and the corresponding seed rates. These are summed to estimate gross demesne yields. The problem is how to go from demesne yields to yields for the whole agricultural sector. The demesnes comprised only about 25% of the total. What the peasants reaped on the other three quarters is unmeasured and has been the subject of controversy: some have thought that the peasants grew more since they were working on their own account; others that they reaped less since they had fewer livestock, which gave them less manure, and since the power of the lords to arbitrarily expropriate income reduced the peasants' incentive to increase production. A common response to these uncertainties is to assume that peasant and demesne yields were equal. On this assumption, however, the value of agricultural income greatly exceeded the sum of labour, land, and capital income. The simplest way to bring them into conformity is to assume that peasant yields for crops and animals were 90% of demesne yields. One can ask whether crop yields or animals yields should be reduced more or less, but an average reduction of this magnitude is the only way to reconcile the value of output with the input prices observed for the medieval economy. Assuming that peasant yields exceeded demesne yields is even less tenable than the assumption of equality since the imbalances in the income account become greater, the larger the presumed productivity advantage of the peasants.

I show yields about one third higher in 1500. Probate inventories have been used to estimate yields starting in the early sixteenth century, but there is uncertainty about the results since the calculation requires that harvesting costs be estimated and added to the value of grain in the fields before yields are computed. I have argued that these costs have often been underestimated and that yields were a few bushels higher than other investigators have calculated (Allen 1988c). Making an allowance for those changes is one reason that higher yields are shown in 1500 than in 1300. Another reason is the comparison of the value of output with agricultural income: Lower yields imply a smaller total income, which, in turn, implies a very low implicit wage. Such a low wage is implausible. Working out production and income in 1500 is a delicate balancing act, and the yields shown in Table 5 are a 'best guess' solution.

The yields shown for 1700 are very much higher. Again, the issue is controversial and has been the subject of considerable debate with views oscillating wildly. Much work has been done on probate inventories, but the procedures are controversial, and results are scattered (Allen 1988c, Glennie 1991, Overton 1979, 1991). Recently, Brunt (2004) has studied eighteenth century wheat yields and concluded that 20 bushels per acre was the average in 1700. Also Turner, Beckett, and Afton (2001) studied farmers' account books and extracted yields across the eighteenth century. Table 5 is based on their findings.

Information about yields after 1750 is more abundant. Young recorded much information on his tours in the late 1760s. Even more information becomes available around 1800 with the

Board of Agriculture county reports and some national surveys. The situation is clear from then on.

The important conclusion indicated by Table 5 is that crop yields were rising throughout most of the period 1300-1850 with a hiatus for most crops during the eighteenth century.

Why did yields rise? Three factors can be highlighted. The first is the spread of legume cultivation indicated in Table 1. This increased the stock of soil nitrogen and thus its fertility (Allen 2004). The second was the increase in improved pasture shown in Table 1. This land was often organized in convertible husbandry systems in this period, and that practice also raised soil nitrogen stocks in the arable. The third was improved selection of seed that allowed the plants to take better advantage of the greater stocks of soil nitrogen. The fourth was improved implements and is manifest as an increase in implement costs per acre in Table 9.

<u>animal yields</u>

Calculating animal production is more complicated than calculating corn output. For corn, gross output is the product of two terms--the planted acreage and the yield per acre. For animals, a third factor must be introduced–the proportion of animals involved. To compute the production of mutton, for instance, one multiplies the number of sheep by the fraction of sheep slaughtered by the meat obtained per animal. The fraction of animals slaughtered–or of cows milked or of sheep shorn–depends on the management scheme of the herds, and that must be specified.

Holderness (1989, p. 147) linked livestock numbers to meat production by observing that “it seems to have been accepted by most writers that a quarter or slightly more of the stock of cattle and sheep were killed every year for meat.” Luccock’s (1805) account of England’s sheep c. 1800 is a case in point. He gave careful attention to the age structure, natural mortality and slaughtering pattern. The upshot is that about 25% of the adult sheep were slaughtered each year, and I have used that proportion for other years as well to estimate mutton production. Likewise, all of the sheep were shorn for wool. Lucock calculated that the wool provided by shearing sheep that died naturally and shearing lambs was very small, and I have not included estimates of it. Similar analyses were undertaken for cattle and pigs. When the proportions slaughtered and shorn are multiplied by herd sizes and yields per animal, Holderness’ estimates of total meat and wool production are closely replicated. Using the same methodology makes it possible to compute comparable output figures for earlier years.

Table 6 shows the yields assumed for the animals. Productivity increased at least as sharply for animals as it did for crops. Corroboration for these figures comes from residual productivity calculations showing that the price of cows, for instance, rose with respect to the prices of butter, cheese, labour, and the rent of pasture. Discussions of productivity in English farming have often emphasized issues related to corn–cropping patterns and yields per acre–with animals featuring in the discussion mainly as sources of manure. The balance needs to be redressed and equal attention given to the livestock sector. Its impact on overall efficiency was as great as corn’s.

Why did animal productivity rise? Genetics and environment each played a role. The feed available to animals in 1300 was meagre by comparison with later centuries. Two developments relieved that constraint. One was the cultivation of fodder crops (beans, turnips, and clover shown in Table 1), and the other was the vast increase in improved pasture (Table 1). Better nutrition contributed directly to greater production. In addition, breeds were improved. Tan (2002) has emphasized the rationality of open fields in conjunction with a village bull, but the system inhibited selective breeding to improve the cattle. The development of a market for stud animals, and the eventual emergence of breeders like Robert Bakewell contributed to the improvement of the genetic composition of English animals.

<u>production–constant prices</u>

Net agricultural output is the total value of the net production of the various commodities. The current value of production is obtained when each year's output is valued with the prices of that year. "Real" agricultural output is obtained by valuing the net output of all years with a common set of prices.

To compute net output, farm goods used up in the production of agricultural products must be subtracted from gross output. The principal intermediate inputs were corn used for seed and fodder fed to animals. Seed corn was computed by multiplying the sowing rates shown in Table 7 by the acerages in Table 1. Three types of fodder were netted out. First, all grass and hay were regarded as an intermediate input except for the hay sold to horses off the farm. Second, oats consumed by farm horses were calculated by multiplying the annual feed rate per horse by the number of farm horses. These animals did well in the early modern period, for their intake of oats rose from 16 bushels per year in 1300 (Langdon 1982, 1986) to 52 bushels in the nineteenth century. Third, most of the peas and beans grown in England were treated as fodder–27% in the eighteenth and nineteenth century according Clark, Huberman, and Lindert's (1995) estimates.[4] For 1300 and 1500, I increased the proportion to 50%. Little exact information is available for this period (Campbell 2000, p. 229), but high fodder consumption provides a better reconciliation of income and cost.

There is no reason to prefer the prices of one year to those of another in computing real income. If the growth of output depends on the choice of prices, there is an 'index number problem'. To explore this eventuality, all possibilities have been calculated, and the series are shown in Table 8. They do not disagree in any important way, so there is not a serious index number problem. In the measurement of productivity, I use a geometric average of the indices using prices of 1300 and 1850 since that gives a central set of values. However, the choice makes very little difference.

How does the direct measurement of real output compare to reconstruction based on population change and on a demand curve? Table 8 contrasts the three series. Between 1500 and 1850, there is little difference between the demand curve and real output calculations: In that period, each validates the other. The extrapolation of output based on population, however, grows much more rapidly than the other two after 1750. The reason is that per capita agricultural production was not a constant (as that method assumes). Instead per capita food production was declining, and that drop means that population extrapolations overstate output growth.

---

[4]I am grateful to Peter Lindert for giving me copies of the underlying spreadsheets.

There is a major discrepancy between the approaches for 1300. The demand curve approach assumes that the income elasticity of demand for agricultural goods was 0.5 throughout. This was probably not true before 1500. In that period, the demand curve approach matches the real output calculation assuming that the income elasticity of demand for agricultural goods was close to 1.0. As we will see soon, per capita calorie consumption in 1300 was very low, so it is not surprising that food consumption rose in step with income. Also, the availability of goods besides food was much narrower than in later centuries. After 1500, per capita calorie consumption was higher and more alternative goods were available, so that extra income was spent disproportionately on nonagricultural goods, and the income elasticity of demand dropped to 0.5.

The geometric index of real output has several important implications for agricultural history. First, there was little change in production between 1300 and 1500. This is a surprise in view of the contraction of grain cultivation, but that reduction was balanced by an increase in livestock operations. Second, output rose two and a quarter times between 1500 and 1750. This was the first phase of the agricultural revolution. Third, there is some disagreement between the demand curve reconstruction and the direct measurement of output change for the last half of the eighteenth century. The former indicates static output (in this model the rise in the real price of food indicates that the growth of demand was not matched by an increase in farm output), while the latter indicates continued output growth. Neither measure supports the view that the parliamentary enclosures led to a remarkable increase in agricultural production. Fourth, output growth accelerated noticeably between 1800 and 1850. Whether this was the pay-off to the enclosure movement or had some other cause is worth further investigation.

Output–sum of incomes

The net output of agriculture can also be valued with the prices of each year–1300 output with 1300 prices and so forth–to determine the current value of agricultural production. Table 9 shows the results. Current agricultural output rose rapidly over time because real output and prices both increased. Indeed, the ratio of output in current prices to output in constant prices is an implicit index of agricultural products, and that index is also shown in Table 9.

The current value of agricultural output is useful in measuring GDP (an option not pursued here) and because of its relationship to factor earnings: The value of net agricultural output in current prices equals the total income earned in agriculture–the sum of wages, profits, and rents to land. This identity allows income and product to be compared and the requirement that they be equal imposes a serious constraint in estimating the sectoral accounts. The implications of this requirement have already been referred to. Here I will review the estimates.

One check on my estimates is to compare them to those of other historians. For 1800 and 1850, there are several estimates, and they agree–indeed, perhaps too well. Deane and Cole's estimate applies to Great Britain and includes forestry, fishing. Eliminating Scotland alone would cut it by 10%, and that reduction is necessary for comparison with mine, which applies to England and Wales. Likewise, the contemporary estimates are sums of incomes of social classes and possibly overstate agricultural incomes. Clark's estimates are conceptually the closest, although his exclude Wales. The similar values for the nineteenth century seem to provide mutual confirmation.

There are no estimates for 1300, but Clark (2002b) has also estimated agricultural income for 1500. He arrives at a higher value than here. Examining the component incomes shows why. There is not much difference in our estimates of labour income. He puts total wages in 1500-49 at 46 million shillings per year, while I calculate it at 44.3 million. The big differences are in capital costs (16 million versus 6 million shillings) and rent (32 million shillings according to Clark versus 12 by my reckoning and including tithes of 4 million). His capital cost figure is higher because he extrapolates backward with an eighteenth value for capital per acre–a procedure that assumes away the long run rise in capital intensity. His rent figure is higher both because he overestimates rent per acre and the number of acres, as we will see. These differences are important: Clark's high estimate of farm income in 1500 underpins his view that there was little growth in income between 1500 and 1800 and hence no agricultural revolution, so it is important to get straight on capital costs and rent, to which we now turn.

land and rent

The income due to land is rent, and total rent income equals the cultivated land multiplied by the rent per acre. The questions are: what was the rent and what was the corresponding acreage?

An important point about rents is that they were assessed on the 'improved' acreage and conveyed rights to use the unimproved land. Thus, in England in 1300, I estimated the improved acreage at 14 million consisting of 12 million acres of arable, 1 million of meadow, and 1 million of enclosed pasture. In addition, there were another 20 million acres of unimproved, common pasture. Rights to use the common were acquire by renting improved land, and payments for common rights were included in the rents for arable, meadow, and enclosed pasture. Consequently, if we found the average rent per acre from medieval sources, we would calculate the rental value of all 34 million acres by multiplying the average rent we found by the 14 million acres of improved land (not by the 34 million acres in use). This principle applies throughout the period, but has the greatest impact in the calculations for 1300-1700 when common grazing was so important. In any event, Table 1 contains the acreage for the calculation.

The next issue is determining the rent per acre averaged over arable and improved grassland. This has been a subject of great dispute. At the outset it should be said that commercial rent (not 'feudal' or customary rent) is what is needed. The consensus at the moment is that class conflicts between peasants and lords had been fought to a standstill by the end of the thirteenth century, and peasants paid lords a wide range of rents reflecting the various resolutions of these struggles. However, by 1300, commercial land values had rise above these 'feudal' rents (Hatcher 1981, Kanzaka 2002). The feudal economy can, therefore, be thought of as a market economy subject to 'lump sum taxes and transfers' from the peasants to the lords. These transfers are not part of our calculations. Instead, land and labour are valued at their market clearing prices.

For 1300, the inquisitiones post mortem provide values per acre of land as do estate documents recording leases. The latter give higher values, and they may be indicative of the commercial value of the land, although the point has been debated (cf. Hatcher 1981 and Dyer 1989). Clark (n.d.–'Microbes and Markets') has pulled together much of this information and used regression analysis to extract the value of arable and meadow land c. 1300. These figures are considerably above those in the inquisitiones post mortem, but comparison of incomes with agricultural output gives no indication that they are too high. I estimate the total rental of English and Welsh land in 1300 by multiplying these rents by the improved acreages in Table 1.

Big disagreements surround the measurement of rent between 1500 and 1850. Since Gregory King (1696), commentators have estimated the total rent of English farm land. In addition, estate rentals and valuations are sources that have been used by several investigators to construct rent series (Norton, Trist, and Gilbert 1891, Allen 1992, p. 172). Turner, Beckett and Afton (1997) have examined many estates sources for 1690-1914, and Clark (1998a, 2002a) has assembled a database from the reports of the nineteenth century Charity Commission and used it to estimate rents in the early modern period. While the sources are diverse, there is consensus about the typical rent in the first half of the nineteenth century, and that consensus is shown in Table 10.

Disagreement about the history of rent become greater, the further back one goes. For the early eighteenth century, the rents shown in Turner, Beckett, and Afton (1997) are low if interpreted as a national average (Clark 1998b, Solar 2004), and I have used higher values.

The uncertainty about rent is also great for 1500. Clark (2002a, 2002b, n.d.) has produced a variety of figures. His suggestion that the average rent in 1500 was one shilling per acre assessed on approximately 32 million acres is far too high. As Table 9 indicates, replacing total rents, tithes, and taxes of 12.2 million shillings with 32 million results in a sum of factor incomes 30% more than my estimate of the value of net output. While one can argue with the details of that calculation, it is hard to see how such a high rent could justified. In any event, one shilling per acre cannot be applied to all 32 million acres. Valuing the 12 million improved acres at 12 d. an acre produces a total much closer to balance, although still too high. In another paper, Clark (n.d., "Microbes and Markets,") has inferred rents from late medieval manorial surveys. These give lower values and ones that are in accord with the midland estate sources that I used to estimate average rents in the south midlands. These rents also balance the income and product accounts of this paper. I have also used these rents for 1300 for similar reasons.

<u>Labour and wages</u>

I have computed labour incomes by multiplying the number of days worked by a wage rate. Most work was done by men, but some was performed by women who were paid at a lower rate. Hence, I first divided the total work into male and female days according to the traditional division of labour. I assumed the female wage was half the male wage, and valued each accordingly.

The values I have used for the average male wage are shown in Table 11. Determining it was difficult for several reasons. First, much work was paid on a task basis, and the corresponding daily rate was not always obvious. Second, wages were lower in the north than in the south for much of the period. Furthermore, the differential narrowed in the eighteenth century. We have a series of male wages for the south running back to the thirteenth century, but the southern wage must be adjusted downward to estimate the average national wage. Clark (1999, 2001, 2002b, 'Microbes and Markets') has used later regional wage data to estimate the relationship between the national average and the southern wage level and then extrapolated the national average back in time, but there is intrinsic uncertainty, and the results are variable. Table 11 shows the values I have used for the calculations of this paper.

Capital and profits

Capital is probably the most conjectural component of the income calculations. A conventional formula for capital costs is the purchase price of the asset multiplied by the depreciation rate plus an interest rate. I assumed a 10% depreciation rate for implements for 1300-1750 and a 20% depreciation thereafter in view of the more rapid innovation in equipment. For livestock, values can be obtained from documentary sources and interpreted as purchase prices. Depreciation is trickier. Horses had no residual value at the end of their working life, so I estimated the depreciation rate as 10% on the assumption of a 10 year life. Overaged cattle and sheep, however, were eaten and so did not depreciate. I have, indeed, included the value of their meat as output.

The interest rate in the calculations should be the interest rate that farmers could have obtained for their money had they not invested it in animals and equipment. There is little direct evidence on this question. Clark, ("Microbes and Markets," p. 33) presents data showing the rate of return on rent charges between 1300 and 1500, and I have used these interest rates. However, it remains an open question whether village capital markets were well integrated with those of the aristocrats investing in rent charges. For later years, I have assumed a 5% interest rate.

Part II: Putting it all together: England in 1300

I have reviewed the details of the figures, some of which are more reliable than others–at least when considered on their own merits. An important reason for settling on the values I have chosen, however, is their implications for each other. To see the force of these constraints, I will review the estimates for 1300 where all elements of the procedure come into play. 1300 is the most problematic year since none of the key aggregates (population, cultivated area, etc) are well established. The output estimate for 1300 is, therefore, the most provisional. One reason for reviewing the details of the estimating procedure is to highlight the ways in which it is robust as well as its areas of greatest vulnerability and potential revision.

Figure 1 is a flow diagram that outlines the arguments relating to 1300. There are two starting points. The first relates to the productivity of demesne agriculture vis-a-vis peasant agriculture. We have much information about he former and little about the latter. As noted previously, some medievalists regard the peasant sector as more productive than the demesne sector, others as less productive. Comparison of farm revenues to costs (valuing inputs at their market prices) has an important implication for this debate: it is impossible to balance revenue and costs if the productivity of peasant agriculture exceeded the productivity of the demesne sector. There is just too much revenue to go around. In principle, one could object that this excess was absorbed by the lords as 'exploitation' in some form, but that objection is not open to the proponents of a high productivity peasant sector since they are also the historians who regard serfdom as an unimportant institution in 1300 and who, indeed, see the economy of that period as a market economy. As I argued earlier, the easiest way to reconcile revenues and costs is to rate the peasant sector at 90% of the efficiency of the demesne sector.

The second starting point is the arable acreage in 1300. I assessed it at 12 million acres. If the arable acreage were greater, output, employment, income per head, food intake, and the standard of living would all have been higher. In 1850, the arable came to almost 15 million acres. Could it have been as high or higher in 1300? The answer seems to be no, in view of the later history of acreage expansion. The arable acreage increased 3 million acres in the first half of the nineteenth century. Detailed study of where that increase occurred indicates that it was not in places that were cultivated in 1300. Indeed, there was much expansion of the arable acreage after 1500 in places that were not arable in 1300. In broad terms, the history of the arable was the following: After the Black Death there was a decline in the arable acreage in densely settle parts of the country. By 1850, this decline was more than matched by increases in the arable acreage elsewhere. In view of these trends, it is hard to see how the arable acreage could have been larger than 12 million in 1300.[5] Nevertheless, this is an area that deserves more study and that might be revised.

The conclusions about peasant productivity and the arable acreage have serious implications for the total production of calories and thus of the population. We will review the calorie estimates shortly, but here it might be noted that per capita calorie production in 1300 was only 1791 calories per person per day assuming a population of 5 million for England and Wales (i.e. about 4.5 million for England, itself). This is an extremely low number: 1500 calories per day is conventionally regarded as the intake required for basal metabolism and thus for survival. The UN Food and Agricultural Organization, Production Yearbook, reports statistics on calorie availability that are comparable to these. Few countries have averages as low as fourteenth century England. Many medievalists have argued for a larger population than 5 million for England and Wales. That is impossible given the productivity and acreage assumed here. To repeat, arguing for higher productivity creates a huge excess of revenue over cost. More cultivated arable would have yielded more calories and could have been accomplished by the agricultural workforce, so arguing for more than 12 million arable acres looks the only way to argue for a population greater than 5 million for England and Wales. But the claim that the arable acreage was greater than 12 million is hard to square with the history of acreage expansion.

## Part III Implications of the estimates

### A. Standard of living

The estimates of agricultural output have important implications for the standard of living. Before the nineteenth century, international trade in food was small, so domestic production determined the food supply and, hence, the average level of nutrition. Income

---

[5] Campbell (2000, p. 389-90) deploys these arguments in favour of a maximum of 10.5 million for England itself–not markedly less than the 12 million acres assumed here for England and Wales.

distribution, of course is an issue, but average food consumption is a basic indicator of living standards.

Table 12 shows the average production of calories per person per day from 1300 to 1850. By adding net food imports, average calorie consumption over the same period is found. This measure of the standard of living changed dramatically over the period.

Calorie consumption was low in 1300--1791 calories per person per day. This was supplemented with calories from poultry, hunting, and fishing, but it is hard to believe that those sources radically increased food availability.

The population fall after 1348 led to a marked improvement in the food situation. By 1500, per capita calorie production and consumption had jumped to 3397. This is of the same order as rich countries today. Calories from grain rose by 63%, while calories from animal products doubled. Although there was some fluctuation, the standard of living continued to rise until the middle of the eighteenth century.

After 1750, population grew faster than output–a pattern that led to rising food prices and falling real wages; i.e., the market solved the mismatch between supply and demand by awarding the food to those with the most purchasing power. By 1800, per capita calorie production was sliding, but imports offset much of the decline. Even though they increased substantially, they were not large enough to prevent consumption from dropping in the middle of the nineteenth century. In 1850, per capita calorie production had fallen to the1300 level, but the huge volume of food imports prevented a comparable drop in consumption.

Nevertheless, per capita calorie consumption in the middle of the nineteenth century was lower than at any other time since the Black Death. There has been a lively debate about average height of the British population during the industrial revolution (Floud, Wachter, and Gregory 1990, Nicholas and Steckel 1991, Komlos 1993, Floud, Wachter, and Gregory 1993, Grubb 1999). Table 12 is easier to reconcile with the pessimistic view that mean height was falling after 1750 rather than with the contrary view that the 'biological standard of living' was improving.

B. Income Distribution

The distribution of income looms large in English agricultural history. Sometimes, as in the Corn Law debates, the issue is consumers versus producers. More often, however, the question is the division between different rural groups. We can study either the fraction of total agricultural income going to different groups or the different trajectories of factor returns. Both point to similar conclusions.

Table 13 approaches distribution from the point of view of price movements. Indices of "real" prices are shown; that is, the price series are deflated by a consumer price index. The evolution of the real price of farm products illuminates the division between consumers and producers. Agricultural goods were at their most expensive in 1300 and declined thereafter. Except for 1800, when the real price rose near to pre-plague levels, the price of agricultural goods was always below the 1300 peak.

Table 13 also shows the history of real farm wages and the real rent of land. (No series is shown for the real profit rate since the sectoral accounts are constructed on the assumption that it equaled the interest rate, which was unchanging for most of the period.) Real wages leaped up after the Black Death, and the fifteenth century was, indeed, the Golden Age of the English farm worker, as Phelps-Brown and Hopkins (1956) proclaimed. Thereafter, the real wage slumped back to the 1300 value and remained a little above that level until the middle of the nineteenth century when a general rise in living standards began (Allen 2001).

While workers gained little from agricultural progress in the early modern period, landlords gained greatly. The real rent of land dropped after the Black Death but rose sharply after 1400 reaching a level in 1850 that was four and a half times that of 1300. Landlords were the principal beneficiaries of the Agricultural Revolution.[6]

The shares of income going to land, labour, and capital tell a distributional story that is broadly similar (Table 14). Labour received half of the agricultural income in 1300. This surprisingly high fraction indicates the low productivity of medieval farming. After the Black Death, labour's share jumped to 70% and then dropped to little more than a third in ensuing centuries. The share of land dropped between 1300 and 1500, and then rose to absorb half of agricultural income. In the eighteenth and nineteenth centuries, landlords did very well, indeed.

C. Labour productivity

There are many productivity concepts. I have earlier discussed biological indicators like the yields of crops and animals. I turn now to economic indicators and begin with output per worker. This is of considerable interest since higher farm labour productivity means that a smaller fraction can feed the population.

Dividing the index of agricultural output by the number of farm families or by days worked measures output per worker (Table 15). Measuring labour by farm families implies a very low level of labour productivity in 1300 since days worked per family were so low and concentrates the early modern growth in productivity in the first half of the eighteenth century. Measuring labour by days worked gives a less erratic pattern of labour productivity change and down grades the progressiveness of the entire eighteenth century.

Table 15 compares these indices with two earlier labour productivity indices based on the presumed sectoral distribution of the population. Wrigley's estimates show the fastest productivity growth. His estimates assume that per capita consumption of agricultural goods and days worked per year by each farm family were both constants. (These assumptions mean that output per worker in agriculture equals the reciprocal of the agricultural share of the work force subject to a foreign trade adjustment). These assumptions were a good place to start, but neither turns out to have been true. The assumption that per capita consumption was constant is particularly critical. Relaxing it, as in Allen (2000), leads to lower rate of productivity growth over the long run. The findings of that study are confirmed here.

Recently Karakacili (2004) has estimated medieval arable labour productivity from demesne accounts and concluded that "before the Black Death [it] either surpassed or met the literature's best estimates for English workers until 1800." Karakacili's preferred productivity index is the gross output of grain divided by the total days worked in arable farming including

[6]In this table rent is total rent, tithes, and rates divided by the 34 million acres of land in agricultural use. Dividing the income by the index of land gives a similar result but less dramatic result.

soil preparation, cultivation, harvest, and threshing. Since my procedure details these figures, it is easy to calculate Karakacili-type indices. The results do not support her conclusion. Table 15 shows labour productivity indexed with a value of one in 1500. Productivity was only one fifth higher three centuries later–a result perhaps in keeping with the Karakacili view. The pertinent test of her ideas, however, involves comparing 1300 with 1800. That comparison shows a 70% rise in output per worker since productivity, defined by her index, grew considerably between 1300 and 1500. This is not the conclusion she reached in her study of the Ramsey estates.

Why did Karakacili come to a different conclusion? Many factors may have been involved,[7] but one stands out: Her nineteenth century figures were not constructed in the same way as her medieval figures. For 1300, she divided bushels of grain harvested by days worked in growing it. For 1800, however, she estimated output by deflating the total value of farm output (including livestock products) with a wheat price to create 'wheat equivalents' and then divided that by an estimate of years worked. Wheat prices, however, were inflating much more rapidly than other agricultural prices, and so she underestimated corn output in the nineteenth century. On the input side, non-arable work was included in the labour. How that affects the answer is unclear. In the event, she underestimated labour productivity in 1800 and, hence, labour productivity growth between 1300 and 1800. When a consistent procedure is used for the two years, output per year worked in grain production rose impressively--from 197 to 335 bushels.

D. Total Factor Productivity

Productivity is the ratio of outputs to inputs. TFP (total factor productivity) is the most encompassing of these indicators since it is the ratio of output to all inputs used in farming. Amongst economists, it is the holy grail of productivity indices.

TFP can be measured in many ways. Some are supposed to correspond to each other, while others do not. The first distinction is between 'primal' and 'dual' measures. Primal measures directly implement the definition of TFP as the ratio of total output to total inputs. In this approach, the inputs are aggregated as they appear in the production function. The most common assumption is the Cobb-Douglas function in which case inputs are aggregated as a weighted geometric average in which the weights are the cost shares of the inputs. This production model presumes that the cost shares remain the same even if input prices change, and that assumption is often untrue. When it fails, it is still possible to justify a Cobb-Douglas form using average shares: Either one can argue that the deviations are random (and therefore use the average shares) or that the true production function is translog (a generalization of the Cobb-Douglas that allows shares to vary) in which case, average shares turn out to be appropriate.

Dual measures of TFP are derived from the cost or profit functions implied by profit maximization. The intuition is that a more efficient firm can profitability produce at lower cost than a less efficient firm, so efficiency can be inferred from the ratio of input to product price. Or, to give the theory an agrarian spin, a more efficient farmer can pay a higher rent than a less efficient farmer and still realize the same return on his time and money. Applying this model

[7] Karakacili's medieval estimate of labour productivity also looks high due to exceptionally high yields on some of her demesnes, e.g. 23 bushels per acre in Elton, 17 in Abbots Ripton, and 15 in Warboys. These high values suggest her sample is unrepresentative.

requires aggregating the prices of land, labour, and capital and comparing them to an index of agricultural prices, or, equivalently, deflating rents by an index of product and other input prices. Either approach can be done in a way that should give the same answer as the primal index of TFP, but the requirements for consistency are extreme and rarely met.

Table 16 compares various TFP calculations. A common feature is that all of them measure inputs in 'natural units'–an issue to be taken up shortly. Since the inputs are measured in the same way in all rows, comparing them indicates the import of different indexing procedures. The important point, in this regard, is that the differences are not large. Rows 1 and 2 show two primal calculations and 3 and 4 show dual calculations. Rows 1 and 3 use the same input shares throughout (.49 for labour, .39 for land, and .12 for capital). These are overall averages. The calculations, thus, assume the data were generated by a Cobb-Douglas technology. Rows 2 and 4 use chain linked Divisia indices in which the average shares for each successive pair of years are used to weight the input changes between those years. These rows correspond to a translog production function or cost function.[8]

All rows tell a similar story–there was considerable productivity growth from 1300 to 1750, stasis in the second half of the 18th century, and then renewed productivity growth from 1800 to 1850. Rows 1 and 3 diverge the most, while rows 2 and 4 track each other closely. This difference is expected since the Divisia indices correspond to functions expected to track the true technology more closely. It is very helpful that the primal Cobb-Douglas index in row 1 tracks the Divisia indices closely. I will exploit that feature in the next section.

## Accounting for the Agricultural Revolution

Why did productivity increase? What changes in practice were responsible for the rise in TFP in Table 16? Questions like this arose as soon as TFP was measured, and there is a standard approach to answering them, which involves refining the measurement of the inputs. This is a good place to start in analyzing the agricultural revolution.

First, what is the relationship between input measurement and the explanation of productivity growth?. The answer begins with Solow's (1957) classic paper that analyzed early twentieth century American growth and found that most of it was due to rising TFP rather than capital accumulation. But what was TFP (or the residual, as it came to be known)? Subsequent investigators tried to account for it by changing the units in which inputs were measured. In Solow's original work, labour was measured as total hours worked–so called, 'natural' units. These failed to take account of the effect of education, which was embodied in labour and raised its productivity. The importance of education can be inferred by measuring labour in 'efficiency units' where each hour worked is weighted by the wage corresponding to the educational

---

[8]Row 2 presupposes a translog production function, while row 4 presumes a translog cost function. Since these are not dual to each other, different technologies are assumed. The situation is different in rows 1 and 3, which presuppose the same technology by virtue of the theorem that the Cobb-Douglas cost function of row 3 is dual to the Cobb-Douglas production function of row 1.

attainment of the worker concerned. Since the average level of education was rising, labour in efficiency units grew faster than labour measured in natural units (total hours worked). Since TFP growth was the growth rate of output minus the growth rate of inputs, increasing labour growth decreased TFP growth. The decline in the TFP growth rate measured the contribution of education to economic growth. Adjustments of this sort reduced the residual to zero and 'accounted for' TFP growth (Jorgenson and Griliches 1967).

This approach can be applied to the agricultural revolution since inputs can be measured in two or more ways. Table 17 shows calculations using a Cobb-Douglas production function with average shares. An output index using 1750 prices is used since it is necessary to supplement the prices with the value of forage, and prices are available for this in Young (1770, IV, p. 502).

Row 1 reports results using the most natural measures of the inputs--counts of their number irrespective of quality or intensity of use–the agricultural population, the numbers of animals, and the total of improved and unimproved farm land (34 million acres). This gives the most substantial growth in efficiency: TFP in 1850 was 2.64 times the 1500 level, and farming in 1300 was only 62% as productive as farming in 1500.

In row 2, labour is measured as days worked, and in row 3 as male equivalent days. There is scarcely any difference between these rows. Measuring labour by days gives almost the same result post-1500 as measuring it by the agricultural population, but significantly raises 1300 productivity relative to 1500. These changes reflect the rise in days-worked per family between 1300 and 1500 and the trendlessness of the ratio thereafter. The conclusion from the refinement of the measurement of labour is that the growth in employment per farm family significantly increased agricultural performance in the late middle ages.

Next consider land. One of the major changes in English farming was the expansion of improved arable and pasture at the expense of rough gazing and waste. The impact of that change on productivity can be seen by recalculating the TFP index using the index of land in efficiency units to measure the land input. I constructed the index by weighting the various kinds of land by their rental values according to Gregory King. The result, in row 4, is a cut in TFP in 1850 relative to 1500 from 2.56 in row 3 to 2.03 with smaller cuts across the eighteenth century when more farmland was still common pasture. The implication of improving the measurement of land is that much of the apparent growth in TFP in English agriculture was really the result of investments in land quality.

What of capital? We can also refine its measurement and cut the residual further, but the adjustments are even more problematic than those for labour and land. Implement quality certainly improved, and better tools (e.g. improved ploughs as emphasized by Brunt 2002) accounted for some of the rise in TFP. Unfortunately, the measurement of implements is based on such scattered information that refining the measure is difficult.

Some conjectural calculations can, however, be made for livestock. The issue is why their yields were so low in the middle ages. Was it bad nutrition or bad genes? The latter would count as an improvement in the quality of capital, and the index of capital should grow more rapidly as a consequence. Trow-Smith (1957, p. 122) has made some suggestive observations: He noted that on the best managed medieval demesnes, cows gave 120-150 gallons of milk per year and less on "normal demesne or villein farm[s]." Then he added: "The mediaeval cow was admittedly woefully underfed even upon the best holdings, the only additional feed given beside the natural grazing being some hay or, more often, only straw. If, in these conditions, the cow could give 150 gallons of milk a year, then her potential yield was probably nearly 300 gallons with a sufficient diet." 300 gallons was less than the 440 gallons a year realized on the generality of farms in 1850, and half the 600 gallons that Holderness (1989, p. 169) argued were achieved by the most productivity dairies. Comparing best with best suggests that the medieval cow was half of a nineteenth century cow in terms of genetic potential. Breed improvements, in other words, account for a doubling of the medieval milk yield, while improved nutrition accounted for even more. This hypothesis can be incorporated into the productivity calculations by rating a medieval cow as half of an 1850 cow. I interpolate the discount factor for intervening years.

A similar discount probably applied to sheep. Trow-Smith (1957, p. 123) reckoned that the medieval sheep was similar to hill sheep of his day. They had similar milk yields, weights, and lambing rates. Improved lowland sheep, of course, realized higher yields.

Row 5 shows a calculation in which medieval capital is set at half the productivity of nineteenth century capital. In the early modern period, capital quality rose, and TFP growth was cut accordingly. The result is to impute some of the growth in TFP to improved breeds of livestock, but this source of advance was less important that the improvements in land quality.

The effect of these calculations is to 'account for' more than half of the growth in residual productivity between 1500 and 1800: TFP in 1800 is cut from 1.80 to 1.34 as it is imputed to the growth of inputs–especially improvments in land quality. Some TFP in 1850 is also accounted for, but much more of that remains unexplained.

What explains the unexplained growth in TFP? An obvious source of improvement not thus far analyzed is the 'arable revolution'–land use became more intensive after 1500, forage crops were cultivated, and crop yields increased. These changes can be incorporated into the analysis by simulating output rather than by refining input measurement. In particular, I have argued that the greater cultivation of peas, beans, and clover increased corn yields by 4 bushels per acre (or more) by fixing atmospheric nitrogen (Allen 2004). The cultivation of these crops as well as turnips created fodder that also accounted for some of the growth in livestock output. To gauge the quantitative impact of these changes, I have recalculated farm output assuming (a) that the 1300 cropping pattern was maintained throughout, (b) reducing corn yields by 4 bushels per acre in 1700-1850, and (c) reducing the value of livestock production by the value of the cultivated clover and turnips no longer produced. Allowance is made for the implied changes in employment. Table 17 shows the resulting TFP index in row 6. While there is an upward blip in TFP in 1700-50, the impressive result is that TFP did not grow between 1500 and 1800. The arable revolution, thus, explains the remaining growth in productivity in the early modern period. Productivity in 1850 is also cut, but there still remains significant TFP growth between 1800 and 1850 that is not yet accounted for.

## III. Conclusions

Constructing consistent sectoral accounts has proven to be remarkably revealing about the pace, character, and causes of agricultural progress in England. Many of the important parameters are hard to pin down. The advantage of pursuing measurement from the consumption, production, and income sides concurrently is that each provides limits to the other. The need for consistency rules out many possibilities.

This investigation has shown that agricultural output grew about four fold from 1500 to 1850. Growth was meager from 1300 to 1500, accelerated from 1500 to 1750, slowed down in the second half of the eighteenth century, and grew briskly in the first half of the nineteenth.

The history of productivity differed in some respects. Between 1300 and 1500, there was marked productivity growth due in part to the greater number of days worked per year by the farm population. Productivity continued to grow rapidly to 1750 largely because of yield increases due to the spread of nitrogen fixing crops, many of which were fodder crops that improved livestock feed, and improvements in the quality of grassland, which also improved animal nutrition and thereby boosted the production of meat, wool, butter, and cheese. Improvements in breeds also made a small contribution in this regard at the end of the period. The 'classic agricultural revolution' lasting from 1750 and 1800 and concurrent with the parliamentary enclosures and the onset of industrialization did not exist. Instead, there was a long agricultural revolution that preceded the industrial revolution. This long revolution may, indeed, have been longer than previously imagined–beginning as early as the fourteenth century and lasting until 1750. Concurrent improvements in arable and livestock operations were involved. The latter was the more important.

Agricultural productivity grew rapidly in the first half of the nineteenth century. More research is required to relate the productivity growth of this period to the changes in technique discussed by agricultural historians.

Despite the productivity growth, English agriculture had a very mixed record in feeding the people. In 1300, English agriculture supplied barely enough food to support the population. The population decline after the Black Death was not matched by a comparable decline in cultivated land with the result that days worked per farm family increased sharply as did output per family. The result was a large increase in the consumption of calories per head of the population. Increases in production in the next two centuries more than kept pace with the population. After 1750, the situation deteriorated as population growth accelerated and food production increased at a much slower rate. Calorie production per capita declined to a level in 1850 that was scarcely above the level of 1300. Massive food imports cushioned the drop, but calorie consumption per head in 1850 was 34% less than it had been a century before. Real wages may have risen in the industrial revolution, but the rise was due to the increased consumption of manufactures rather than food.

While the comparison of open and enclosed farming has not been emphasized here, the findings of this paper have implications for the 'open field debate'. In recent decades, the pendulum has swung in favour of the open fields as institutions capable of sustaining agricultural progress. This revisionism is founded on comparisons of arable agriculture under open and enclosed management. Nothing in this paper calls those comparisons into question. Indeed, the importance attached to legume cultivation strengths that revisionism since open fields did adopt these crops. What this paper does, however, is emphasize the importance of livestock and, specifically, the improvement of grassland quality, as central to English agricultural development. Some of the improvement in grassland quality came from enclosing itself when field division was accomplished with walls made from stone removed from the surface of the land. Quality was improved and maintained by careful tending of the grass itself. Would those expenditures have been incurred if the land had remained common? There are numerous examples of community control of herd size to prevent the overgrazing of commons, but not–at this time–of communally organized cultivation of the grass itself. Perhaps enclosure was necessary for the improvements in English livestock. This question should certainly be a focus of research.

Table 1

Land Use
(Millions of acres)

| | 1300 | 1500 | 1700 | 1750 | 1800 | 1850 |
|---|---|---|---|---|---|---|
| arable | 12.0 | 9.0 | 11.0 | 11.2 | 11.6 | 14.6 |
| fallow | 4.0 | 3.0 | 3.3 | 2.5 | 1.5 | 1.8 |
| wheat | 2.7 | 1.8 | 1.4 | 2.1 | 2.5 | 3.6 |
| rye | .6 | .2 | .9 | .5 | .3 | .1 |
| barley | 1.5 | 1.5 | 1.9 | 1.7 | 1.3 | 1.5 |
| oats | 2.7 | 1.3 | 1.2 | 1.4 | 2.0 | 2.0 |
| beans/peas | .6 | 1.2 | 1.3 | 1.3 | 1.2 | 1.0 |
| turnips | 0 | 0 | 0.4 | .75 | 1.3 | 2.0 |
| clover | 0 | 0 | .5 | .75 | 1.2 | 2.2 |
| potatoes | 0 | 0 | .1 | .2 | .3 | .4 |
| meadow | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 |
| pasture | 1.0 | 4.0 | 9.0 | 12.0 | 16.5 | 15.0 |
| common | 20.0 | 20.0 | 13.0 | 9.8 | 4.9 | 3.4 |
| total | 34.0 | 34.0 | 34.0 | 34.0 | 34.0 | 34.0 |
| index | 17.5 | 18.9 | 25.6 | 28.9 | 34.0 | 34.2 |

NB: index uses king's relative prices to aggregate arable, pasture, meadow, and common. The index is expressed in "1800 acres."

Table 2

Livestock
(Millions of animals)

| | 1300 | 1500 | 1700 | 1750 | 1800 | 1850 |
|---|---|---|---|---|---|---|
| <u>cattle</u> | 1.67 | 3.48 | 4.50 | 4.50 | 3.51 | 4.18 |
| Cows | .58 | 1.20 | 1.55 | 1.55 | 1.21 | 1.44 |
| Calves | .58 | 1.20 | 1.55 | 1.55 | 1.21 | 1.44 |
| Beef cattle | .52 | 1.08 | 1.40 | 1.40 | 1.09 | 1.30 |
| <u>sheep</u> | 22.8 | 12.0 | 16.6 | 16.6 | 20.0 | 26.7 |
| <u>Hoggs</u> | .95 | 1.05 | 1.30 | 1.70 | 1.90 | 2.30 |
| <u>Draught</u> | 1.36 | 1.20 | .50 | .75 | 1.00 | 1.25 |
| Horses | .54 | .48 | .50 | .75 | 1.00 | 1.25 |
| oxen | .82 | .72 | 0 | 0 | 0 | 0 |

Table 3

Days worked per Farm Family

(Millions except days per family)

| | 1300 | 1500 | 1700 | 1750 | 1800 | 1850 |
|---|---|---|---|---|---|---|
| Ag population | 3.82 | 1.85 | 2.86 | 2.70 | 3.23 | 3.90 |
| Ag families | .849 | .411 | .636 | .600 | .718 | .867 |
| Days worked | 262 | 215 | 291 | 334 | 384 | 473 |
| Days/ family | 309 | 522 | 457 | 564 | 535 | 545 |

Note:
Ag population- Allen (2000)except for 1850, which was computed from Deane and Cole (1969, p. 142).
Ag families-Ag population divided by 4.5
Days worked-computed from farm labour models
Days per family-days worked divided by ag families

Table 4

Days worked per Acre

| | 1300 | 1500 | 1700 | 1750 | 1800 | 1850 |
|---|---|---|---|---|---|---|
| arable labour/arable land | | | | | | |
| overall | 12.2 | 10.4 | 11.1 | 13.4 | 15.1 | 16.0 |
| Pastoral labour/pastoral land | | | | | | |
| pastoral land defined as-- | | | | | | |
| meadow, pasture and common | 3.8 | 3.9 | 5.7 | 6.5 | 7.7 | 10.0 |
| Meadow,pasture | 41.8 | 19.3 | 13.0 | 11.3 | 9.9 | 12.1 |
| Improved equiv | 14.9 | 11.2 | 10.6 | 10.0 | 9.4 | 11.7 |

Table 5
Crop Yields

| | 1300 | 1500 | 1700 | 1750 | 1800 | 1850 |
|---|---|---|---|---|---|---|
| Crops: gross yields, bushels per acre | | | | | | |
| wheat | 10.7 | 14.0 | 19.0 | 20.0 | 20.0 | 28.0 |
| Rye | 10.4 | 14.0 | 19.0 | 20.0 | 22.0 | 28.0 |
| Barley | 16.3 | 17.0 | 29.0 | 30.0 | 30.0 | 35.0 |
| Oats | 11.3 | 14.0 | 21.0 | 35.0 | 38.0 | 40.0 |
| Beans/peas | 11.8 | 14.0 | 19.0 | 20.0 | 20.0 | 28.0 |
| Potatoes | – | – | 150.0 | 150.0 | 150.0 | 150.0 |

Note:
The yields for 1300 are constructed from Campbell's demesne yields on the assumption that peasants farmed 75% of the arable and reaped 90% of the demesne yields. The demesne yields equal the values (net of seed) shown by Campbell (2000, pp. 332-4) plus seed (Campbell 2000, 312-3). The figures were as follows:

| | yield net of seed | seed | gross demesne yield |
|---|---|---|---|
| wheat | 8.8 | 2.8 | 11.6 |
| rye | 8.4 | 2.8 | 11.2 |
| barley | 13.4 | 4.2 | 17.6 |
| oats | 7.4 | 4.8 | 12.2 |
| beans/peas | 10.0 | 2.8 | 12.8 |

Table 6

Animal Yields

gallons or pounds per animal

| | 1300 | 1500 | 1700 | 1750 | 1800 | 1850 |
|---|---|---|---|---|---|---|
| milk, gal | 93 | 150 | 300 | 330 | 380 | 440 |
| Beef/cow or ox | 208 | 225 | 260 | 400 | 500 | 700 |
| Veal/calf | 29 | 33.75 | 39 | 45 | 75 | 105 |
| Mutton/sheep | 20 | 25 | 30 | 52 | 60 | 70 |
| Wool/sheep | 1.4 | 2.0 | 3.3 | 3.5 | 3.5 | 4.5 |
| Pork/pig | 59 | 64 | 64 | 95 | 110 | 125 |

Table 7

Seed Rates (bushels/acre)

| | 1300 | 1500 | 1700 | 1750 | 1800 | 1850 |
|---|---|---|---|---|---|---|
| wheat | 2.8 | 2 | 2 | 2 | 2 | 2 |
| Rye | 2.8 | 2 | 2 | 2 | 2 | 2 |
| Barley | 4.2 | 3 | 3 | 3 | 2.5 | 2.5 |
| Oats | 4.8 | 4 | 4 | 4 | 4 | 4 |
| Beans/peas | 2.8 | 3 | 3 | 3 | 3 | 2.5 |

Table 8
Alternative Measures of Real Output

| | 1300 | 1500 | 1700 | 1750 | 1800 | 1850 |
|---|---|---|---|---|---|---|
| prices of: | | | | | | |
| 1300 | .95 | 1.00 | 1.90 | 2.37 | 2.50 | 4.20 |
| 1500 | .95 | 1.00 | 1.80 | 2.30 | 2.47 | 4.28 |
| 1700 | .92 | 1.00 | 1.72 | 2.24 | 2.41 | 4.07 |
| 1750 | .90 | 1.00 | 1.76 | 2.31 | 2.45 | 4.06 |
| 1800 | .89 | 1.00 | 1.73 | 2.25 | 2.36 | 3.90 |
| 1850 | .90 | 1.00 | 1.79 | 2.32 | 2.45 | 3.95 |
| square root of | | | | | | |
| 1300 & 1850 | .93 | 1.00 | 1.85 | 2.34 | 2.47 | 4.08 |
| production estimated from: | | | | | | |
| demand curve | 1.65 | 1.00 | 1.78 | 2.25 | 2.47 | 3.99 |
| population | 2.00 | 1.00 | 2.00 | 2.36 | 2.99 | 5.15 |

notes:
population estimate equals an index of the population of England and Wales multiplied by the ratio of calories produced to calories consumed to account for the changing net import position.

Table 9

Current Value of Agricultural Output and Incomes
(Millions of pounds)

| | 1300 | 1500 | 1700 | 1750 | 1800 | 1850 |
|---|---|---|---|---|---|---|
| <u>Allen estimates</u> | | | | | | |
| production | 3.1 | 3.1 | 28.3 | 34.1 | 77.2 | 103.1 |
| income | 3.0 | 3.2 | 27.4 | 34.5 | 77.3 | 103.1 |
| Of which (in millions of shillings)-- | | | | | | |
| wages | 30.6 | 44.3 | 210.0 | 272.5 | 551.9 | 713.2 |
| animal costs | 3.5 | 5.6 | 52.6 | 63.3 | 120.2 | 200.2 |
| implements | 2.8 | 1.5 | 5.0 | 20.7 | 93.0 | 154.2 |
| rent | 13.8 | 8.1 | 238.0 | 284.6 | 669.5 | 918.0 |
| tithes | 8.7 | 4.0 | 37.4 | 36.4 | 44.6 | 12.9 |
| taxes | 0.7 | 0.1 | 5.2 | 12.8 | 67.0 | 64.3 |
| Total | 60.1 | 63.6 | 548.2 | 690.3 | 1546.2 | 2062.8 |
| <u>Previous estimates</u> | | | | | | |
| Deane & Cole | | | | | 75.5 | 106.5 |
| Contemporary | | | 27.33 | 33.85 | 78.68 | - |
| Clark | | 4.7 | 32.2 | 40.1 | 78.3 | 103.1 |
| <u>Implicit index of agricultural prices</u> | | | | | | |
| index | 1.06 | 1.00 | 4.91 | 4.66 | 10.01 | 8.11 |

Sources:

Deane and Cole (1969, p. 166) for 1801 and 1851.
Crafts (1985a, p. 13).
Turner, Beckett, and Afton (1997, p. 60).

Table 10
Rent (shillings) per acre

| | 1300 | 1500 | 1700 | 1750 | 1800 | 1850 |
|---|---|---|---|---|---|---|
| arable | .77 | .52 | 8 | 8 | 20 | 30.6 |
| pasture | .77 | .52 | 15 | 15 | 25 | 30.6 |
| meadow | 3.80 | 1.42 | 15 | 15 | 25 | 30.6 |

Sources:
1300 and 1500-Clark, 'Microbes and Markets,' p. 25, for 1300 and 1490.

Table 11
Values assumed for daily male wage (pence)

| | 1300 | 1500 | 1700 | 1750 | 1800 | 1850 |
|---|---|---|---|---|---|---|
| wage per day | 1.6 | 2.8 | 10 | 11 | 19 | 20 |

Sources:

Table 12
Daily calorie production and consumption per person

| | 1300 | 1500 | 1700 | 1750 | 1800 | 1850 |
|---|---|---|---|---|---|---|
| production: | | | | | | |
| vegetable | 1502 | 2733 | 2624 | 3157 | 2018 | 1559 |
| animal | 289 | 664 | 616 | 752 | 532 | 411 |
| total | 1791 | 3397 | 3240 | 3909 | 2550 | 1970 |
| consumption: | | | | | | |
| vegetable | 1502 | 2733 | 2601 | 2962 | 2248 | 2019 |
| animal | 289 | 664 | 654 | 841 | 690 | 506 |
| total | 1791 | 3397 | 3255 | 3803 | 2938 | 2525 |

Table 13
Distribution of Agricultural Income: Price Movements

| | 1300 | 1500 | 1700 | 1750 | 1800 | 1850 |
|---|---|---|---|---|---|---|
| real rent | 1.00 | .42 | 2.02 | 2.53 | 3.26 | 4.49 |
| real wage | 1.00 | 1.38 | 1.04 | 1.21 | 1.15 | 1.31 |
| real price | 1.00 | .74 | .82 | .80 | .93 | .79 |

Table 14
Distribution of Agricultural Income
(Fraction going to each group)

| | 1300 | 1500 | 1700 | 1750 | 1800 | 1850 |
|---|---|---|---|---|---|---|
| labour | 51.0 | 69.6 | 38.3 | 39.5 | 35.7 | 34.6 |
| capital | 10.5 | 11.1 | 10.5 | 12.2 | 13.8 | 17.2 |
| land | 38.5 | 19.2 | 51.2 | 48.4 | 50.5 | 48.2 |
| land consists of: | | | | | | |
| rent | 22.9 | 12.8 | 43.4 | 41.2 | 43.3 | 44.5 |
| tithes | 14.4 | 6.3 | 6.8 | 5.3 | 2.9 | .6 |
| rates | 1.2 | .1 | 1.0 | 1.9 | 4.3 | 3.1 |

Table 15
Output per worker in English agriculture

| | 1300 | 1500 | 1700 | 1750 | 1800 | 1850 |
|---|---|---|---|---|---|---|
| Wrigley (1985) | - | 1.00 | 1.41 | 1.69 | 2.13 | - |
| Allen (2000) | .80 | 1.00 | 1.15 | 1.54 | 1.43 | - |
| Karakacili-type | .69 | 1.00 | 1.29 | 1.25 | 1.18 | 1.19 |
| output/family | .45 | 1.00 | 1.11 | 1.54 | 1.38 | 1.93 |
| output/day | .76 | 1.00 | 1.39 | 1.50 | 1.35 | 1.81 |

Sources:
Wrigley (1985, 1987, p. 170)
Allen (2000, p. 20)

Notes:
Wrigley gives a figure for 1520 rather than 1500. I have projected his 1520 back to 1500 assuming the growth rate for 1520-1600 applied to 1500-1600.
output per day is (a) sq rt of 1300 and 1850 output indices divided by (b) male equivalent days.

Table 16
TFP calculations for English agriculture:
Alternative Formulae

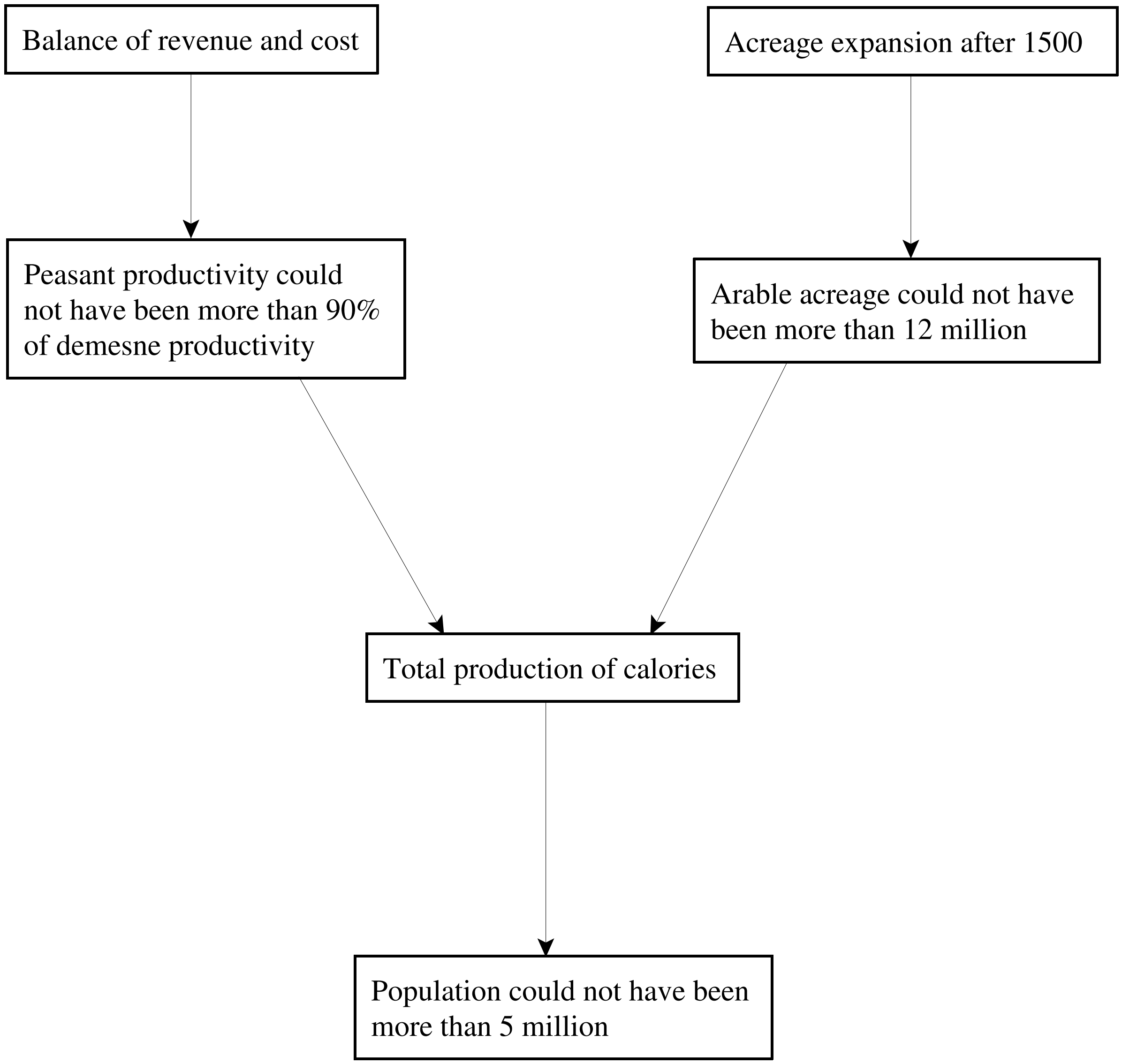
| | 1300 | 1500 | 1700 | 1750 | 1800 | 1850 |
|---|---|---|---|---|---|---|
| primal indices (quantities of inputs and outputs) | | | | | | |
| average shares | .62 | 1.00 | 1.43 | 1.88 | 1.79 | 2.62 |
| Divisia chain | .57 | 1.00 | 1.41 | 1.83 | 1.78 | 2.67 |
| dual indices (prices of inputs and outputs) | | | | | | |
| average shares | .66 | 1.00 | 1.46 | 2.01 | 1.86 | 2.71 |
| Divisia chain | .56 | 1.00 | 1.36 | 1.85 | 1.78 | 2.66 |

Table 17
TFP calculations for English agriculture:
Alternative Measures of Inputs

| | 1300 | 1500 | 1700 | 1750 | 1800 | 1850 |
|---|---|---|---|---|---|---|
| 1. natural units | .62 | 1.00 | 1.43 | 1.88 | 1.79 | 2.62 |
| 2. labour in days | .81 | 1.00 | 1.53 | 1.81 | 1.77 | 2.57 |
| 3. labour in med | .81 | 1.00 | 1.55 | 1.81 | 1.74 | 2.54 |
| 4. Land in eff | .83 | 1.00 | 1.38 | 1.54 | 1.40 | 2.03 |
| 5. capital in eff | .84 | 1.00 | 1.31 | 1.43 | 1.29 | 1.82 |
| 6. elim arable rev | .82 | 1.00 | 1.13 | 1.18 | 1.01 | 1.47 |

Figure 1

Arguments relating to Output and Population in 1300



References

Allen, Robert C. (1982). "The Efficiency and Distributional Consequences of Eighteenth Century Enclosures," Economic Journal, Vol. 92, December, 1982, pp. 937-953.

Allen, Robert C. (1988a). "The Growth of Labour Productivity in Early Modern English Agriculture," Explorations in Economic History, vol. 25, pp. 117-146.

Allen, Robert C. (1988b). "The Price of Freehold Land and the Interest Rate in the Seventeenth and Eighteenth Centuries," Economic History Review, 2nd series, vol. 41, pp. 33-50.

Allen, Robert C. (1988c). "Inferring Yields from Probate Inventories," Journal of Economic History, Vol. 38, pp. 117-25.

Allen, Robert C. (1989). "Enclosure, Farming Methods, and the Growth of Productivity in the South Midlands," in Agrarian Organization in the Century of Industrialization: Europe, Russia, and North America, ed. by George Grantham and Carol S. Leonard, Research in Economic History, Supplement 5, Part A, pp. 69-88.

Allen, Robert C. (1991). "Labor Productivity and Farm Size in English Agriculture Before Mechanization: Reply to Clark," Explorations in Economic History, forthcoming.

Allen, Robert C. (1992). Enclosure and the Yeoman, Oxford, Oxford University Press.

Allen, Robert C. (1994). 'Agriculture During the Industrial Revolution,' in The Economic History of Britain since 1700, Vol. I: 1700-1860, ed. by Roderick Floud and Donald McCloskey, Cambridge, Cambridge University Press, 2nd edition, pp. 96-122.

Allen, Robert C. (1999). "Tracking the Agricultural Revolution," Economic History Review, 2nd series, Vol. 52, pp. 209-235.

Allen, Robert C. (2000). "Economic Structure and Agricultural Productivity in Europe, 1300-1800," European Review of Economic History, Vol. 3, pp. 1-25.

Allen, Robert C. (2001). "The Great Divergence in European Wages and Prices from the Middle Ages to the First World War," Explorations in Economic History, Vol. 38, pp 411-447.

Allen, Robert C. (2003). "Poverty and Progress in Early Modern Europe," Economic History Review, Vol. LVI, No. 3, pp. 403-443.

Allen, Robert C. (2004). "The Nitrogen Hypothesis and the English Agricultural Revolution: A Biological Analysis."

Allen, Robert C. and O Grada, Cormac (1988). "On the Road Again with Arthur Young: English, Irish, and French Agriculture during the Industrial Revolution," Journal of Economic History, Vol. 48, pp. 93-116.

Batchelor, T. (1808). General View of the Agriculture of the County of Bedford, R. Phillips.

Bowden, Peter (1967). "Agricultural Prices, Farm Profits, and Rents," in Joan Thirsk, ed., The Agrarian History of England and Wales, 1500-1640, Vol. IV, Cambridge, Cambridge University Press, pp. 593-695.

Bowden, Peter J. (1985). "Agriculture prices, wages, farm profits, and rents," The Agrarian History of England and Wales, Vol. V, 1640-1750, II. Agrarian Change, ed. By Joan Thirsk, Cambridge, Cambridge University Press, pp. 1-118.

Brunt, Liam (2002). "New Technology and Labour Productivity in English and French Agriculture, 1770-1850," European Review of Economic History, Vol. 6, pp. 263-7.

Brunt, Liam (2004). 'Nature or Nurture? Explaining English Wheat Yields in the Agricultural Revolution, c. 1770,'Journal of Economic History, Vol. 64, pp. 193-225.

Brunt, Liam (2000). ''Where There's Muck, There's Brass': The Market for Manure in the Industrial Revolution,' University of Oxford, Discussion Papers in Economic and Social History, Number 35.

Caird, James (1852). English Agriculture in 1850-1, second edition, ed. by G.E. Mingay, London, Frank Cass and Company Limited, 1967.

Campbell, Bruce M.S. (1983). 'Arable Productivity in Medieval England: Some Evidence from Norfolk,' Journal of Economic History, Vol. 43, pp. 379-404.

Campbell, Bruce M.S. (2000). English Seigniorial Agriculture 1250-1450, Cambridge, Cambridge University Press.

Campbell, Bruce M.S. (2002). "The Sources of Tradeable Surpluses: English Agricultural Exports, 250-1350," in Lars Berggren, Nils Hybel, and Annette Landen, eds., Cogs, Cargoes, and Commerce: Maritime Bulk Tradein Northern Europe, Toronto, Pontifical Institute of Medieval Studies.

Campbell, Bruce M.S. and Overton, Mark. (1991). "A New Perspective on Medieval and Early Modern Agriculture: Six Centuries of Norfolk Farming c. 1250-1850," Past & Present, 141, pp. 38-105.

Campbell, Bruce M.S. and Overton, Mark (1992). "Norfolk Livestock Farming 1250-1740: a

Comparative Study of Manorial Accounts and Probate Inventories," Journal of Historical Geography, Vol. 18, pp. 377-96.

Chambers, J.D. (1953). "Enclosure and Labour Supply in the Industrial Revolution," Economic History Review, 2nd series, Vol. V, pp. 319-343.

Chartres, J.A. (1985). "The Marketing of Agricultural Produce," in Joan Thirsk, ed., The Agrarian History of England and Wales, Vol. V, 1640-1750, II. Agrarian Change, Cambridge, Cambridge University Press, pp. 406-502.

Chorley, P. (1981). "The Agricultural Revolution in Northern Europe, 1750-1880, Nitrogen, Legumes, and Crop Productivity," Economic History Review, second series, Vol. 34, pp. 71-93.

Clark, Gregory (1991a). 'Yields per Acre in English Agriculture, 1250-1860: Evidence from Labour Inputs,' Economic History Review, 2nd series, Vol. 44, No. 3, pp. 445-460.

Clark, Gregory (1991b). "Labour Productivity in English Agriculture, 1300-1860," in Bruce M.S. Campbell and Mark Overton, eds., Land, Labour and Livestock: Historical Studies in European Agricultural Productivity, Manchester, Manchester University Press, pp. 211-35.

Clark, Gregory (1993) 'Agriculture and the Industrial Revolution, 1700-1850,' in J. Mokyr, ed., The British Industrial Revolution: An Economic Perspective, Boulder, Westview Press, pp. 227-66.

Clark, Gregory (1998a). 'Commons Sense: Common Property Rights, Efficiency, and Institutional Change,' Journal of Economic History, Vol. 58, Number 1, pp. 73-102.

Clark, Gregory (1998b). 'Renting the Revolution,' Journal of Economic History, Vol. 58, No. 1, pp. 206-210.

Clark, Gregory (1999). "The Long March of History: Farm Laborers' Wages in England, 1208-1850."

Clark, Gregory (2001). "Farm Wages and Living Standards in the Industrial Revolution: England, 1670-1850," Economic History Review, 2nd series, Vol. 54, pp. 477-505.

Clark, Gregory (2002a). "Farmland Rental Values and Agrarian History: England and Wales, 1500-1912," European Review of Economic History, Vol. 6, pp. 281-308.

Clark, Gregory (2002b). "The Agricultural Revolution and the Industrial Revolution: England, 1500-1912".

Clark, Gregory (n.d.) "Microbes and Markets: Was the Black Death an Economic Revolution?"

Clark, Gregory, Huberman, Michael, and Lindert, Peter H. (1995). 'A British Food Puzzle, 1770-1850,' Economic History Review, 2nd series, Vol. 48, No. 2, pp. 215-37.

Clarkson, L.A. (1989). "The Manufacture of Leather," in G.E. Mingay, ed., The Agrarian History of England and Wales, Vol. VI, 1750-1850, Cambridge, Cambridge University Press, pp. 466-483.

Cooper, J.P. (1967). "The Social Distribution of Land and Men in England, 1436-1700," Economic History Review, 2nd series, Vol. 20, pp. 419-440.

Crafts, N.F.R. (1976). "English Economic Growth in the Eighteenth Century: A Re-Examination of Deane and Cole's Estimates," Economic History Review, second series, Vol. 29, pp. 226-235.

Crafts, N.F.R. (1985a). British Economic Growth during the Industrial Revolution, Oxford, Clarendon Press.

Crafts, N.F.R. (1985b). "Income Elasticities of Demand and the Release of Labor by Agriculture during the British Industrial Revolution: A Further Appraisal," in J. Mokyr, ed., The Economics of the Industrial Revolution, Totowa, N.J., Rowman and Allanheld, pp. 151-63.

Deane, Phyllis (1957). "The Output of the British Wool Industry in the Eighteenth Century," Journal of Economic History, Vol. 17, pp. 207-223.

Deane, Phyllis, and W.A. Cole (1969). British Economic Growth: 1688-1959, Cambridge, Cambridge University Press.

Dyer, C.C. (1989). Standards of Living in the Later Middle Ages: Social Change in England, c. 1200 - 1520, Cambridge, Cambridge University Press.

Ernle, Lord (1961). English Farming: Past and Present, London, Heinemann Educational Books Ltd and Frank Cass and Company Ltd.

Feinstein, Charles (1978). "Capital Formation in Britain," in Peter Mathias and M.M. Postan, eds., The Cambridge Economic History of Europe, Vol. VII, The Industrial Economies: Capital Labour, and Enterprise, Part I Britain, France, Germany, and Scandinavia, Cambridge, Cambridge University Press, pp. 28-96.

Feinstein, Charles (1988). "National Statistics, 1760-1920," in Charles H. Feinstein and Sidney Pollard, eds., Studies in Capital Formation in the United Kingdom, 1750-1920, Oxford, Clarendon Press, pp. 258-471.

Floud, R., Wachter, K.W., and Gregory, A. (1990). Height, Health, and History: Nutritional

Status in the United Kingdom, 1750-1980, Cambridge, Cambridge University Press.

Floud, R., Wachter, K.W., and Gregory, A. (1993). "Measuring Historical Heights–Short Cuts or the Long Way Round: A Reply to Komlos," Economic History Review, 2nd series, Vol. 46, pp. 145-54.

Fox, H.S.A. (1996). "Exploitation of the Landless by Lords and Tenants in Early Medieveal England," in Zvi Razi and Richard Smith, eds., Medieval Society and the Manor Court, Oxford, Clarendon Press, pp. 518-68.

Glennie, Paul (1991). "Measuring crop yields in early modern England," in Bruce M.S. Campbell and Mark Overton, eds., Land, Labour and Livestock: Historical Studies in European Agricultural Productivity, Manchester, Manchester University Press, pp. 255-283.

Grubb, Farley (1999). "Withering Heights: Did indentured Servants Shrink from an Encounter with Malthus? A Comment on Komlos," Economic History Review, 2nd series, Vol. 52, pp. 714-29.

Hatcher, J. (1981). "English serfdom and villeinage: towards a reassessment," Past & Present, 90, 3-39.

Holderness, B.A. (1988). "Agriculture, 1770-1860," in Charles H. Feinstein and Sidney Pollard, eds., Studies in Capital Formation in the United Kingdom, Oxford, Clarendon Press, pp. 9-34.

Holderness, B.A. (1989). "Prices, Productivity, and Output," The Agrarian History of England and Wales, Vol. VI, 1750-1850, ed. By G.E. Mingay, Cambridge, Cambridge University Press, pp. 1-118.

Holmes, G.S. (1977), "Gregory King and the Social Structure of Preindustrial England." Transactions of the Royal Historical Society 5th series, 27, 41-68.

Jackson, R.V. (1985). "Growth and Deceleration in English Agriculture, 1660-1790," Economic History Review, 2nd series, Vol. 36, pp. 333-351.

John, A.H. (1989). "Statistical Appendix," in G.E. Mingay, ed., The Agrarian History of England and Wales, Vol. VI, 1750-1850, Cambridge, Cambridge University Press, pp. 972-1155.

Jorgenson, Dale W. and Griliches, Zvi (1967). "The Explanation of Productivity Change," Review of Economic Studies, Vol. 34, No.99, pp. 249-283.

Kanzaka, Junichi (2002). "Villein rents in thirteenth-century England: an analysis of the Hundred Rolls of 1279-1280," Economic History Review, Vol. 55, No. 4, pp. 640-56.

Karakacili, Eona (2004). "English Agrarian Labor Productivity Rates Before the Black Death: A Case Study," Journal of Economic History, Vol. 64, Number 1, March, pp. 24-60.

King, Gregory (1696). "Natural and Political Observations and Conclusions upon the State and Condition of England," in George Chalmers, An Estimate of the Comparative Stength of Great Britain, London, J. Stockdale, 1802, pp. 405-449.

Kitsikopoulos, Harry (2000). "Standards of Living and Capital Formation in pre-plageue England: a Peasant budget Model," Economic History Review, 2nd series, Vol. 53, No. 2, pp. 237-61.

Komlos, J. "The Secular Trend in the Biological Standard of Living in the United Kingdom, 1730-1860," Economic History Review, 2nd series, Vol. 46, pp. 115-44.

Langdon, John (1982). "The Economics of Horses and Oxen in Medieval England," Agricultural History Review, Vol. 30, pp. 31-40.

Langdon, John (1986). Horses, Oxen and Technological Innovation: the use of draught animals in English farming from 1066 to 1500, Cambridge, Cambridge University Press.

Lindert, Peter H. (1980). "English Occupations, 1670-1811," Journal of Economic History, Vol. 40, pp. 685-712.

Lindert, Peter H., and Williamson, Jeffrey G. (1982). "Revising England's Social Tables, 1688-1812," Explorations in Economic History, Vol. 19, pp. 385-408.

Luccock, John (1805). The Nature and Properties of Wool, Leeds, Edward Barnes.

McCloskey, Donald (1972). "The Enclosure of Open Fields: Preface to a Study of Its Impact on the Efficiency of English Agriculture in the Eighteenth Century," Journal of Economic History, Vol. 32, pp. 15-35.

Nicholas, S., and Steckel, R.H. (1991). "Heights and Health of English Workers during the Early Years of Industrialization, 1770-1815," Journal of Economic History, Vol. 51, pp. 937-57.

Norton, Trist, and Gilbert (1891). "A Century of Land Values: England and Wales," Journal of the Royal Statistical Society, Vol. 54, pp. 128-31.

O'Brien, Patrick K. "Path Dependency, or why Britain became an industrialized and urbanized economy long before France," Economic History Review, Vol. 49, pp. 213-49.

Oschinsky, D. (1971). Walter of Henley and Other Treatises on Estate Management and Accounting, Oxford, Clarendon Press.

Overton, Mark (1979). "Estimating crop yields from probate inventories: an example from East Anglia, 1585-1735," Journal of Economic History, Vol. 39, pp. 363-78.

Overton, Mark (1991). "The determinants of crop yields in early modern England," in Bruce M.S. Campbell and Mark Overton, eds., Land, Labour and Livestock: Historical Studies in European Agricultural Productivity, Manchester, Manchester University Press, pp. 284-322.

Overton, Mark (1996). The Agricultural Revolution: The Transformation of the Agrarian Economy: 1500-1850, Cambridge, Cambridge University Press.

Phelps Brown, E.H., and Hopkins, Sheila V. (1956). "Seven Centuries of the Prices of Consumables, Compared with Builders' Wage-rates," Economica, new series, Vol. 23, pp. 296-314.

Smith, Richard M. (1991). "Demographic Developments in Rural England, 1300-1348: A Survey," in Bruce M.S. Campbell, ed., Before the Black Death: Studies in the "Crisis" of the Early Fourteenth Century, Manchester, Manchester University Press, pp. 25-77.

Solar, Peter M. (2004). "Land Values, Rents, Tenures and the Distribution of Income in English Agriculture during the Eighteenth and Nineteenth Centuries."

Stone, David (1997). "The Productivity of Hired and Customary Labour: evidence from Wisbech Barton in the fourteenth century," Economic History Review, Vol. 50, No. 4, pp. 640-56.

Tan, Elaine (2002). "'The bull is half the herd': property rights and enclosures in England, 1750-1850," Explorations in Economic History, Vol. 39, pp. 470-89.

Thompson, F.M.L. (1983). "Horses and Hay in Britain, 1830-1918," in F.M.L. Thompson, ed., Horses in European Economic History: A Preliminary Canter, Reading, British Agricultural History Society, pp. 50-72.

Thornton, Christopher (1991). "The determinants of land productivity on the Bishop of Winchester's demesne of Rimpton, 1208 to 1403," in Bruce M.S. Campbell and Mark Overton, eds., Land, Labour and Livestock: Historical Studies in European Agricultural Productivity, Manchester, Manchester University Press, pp. 183-210.

Trow-Smith, Robert (1957). A History of British Livestock Husbandry to 1700, London, Routledge and Kegan Paul.

Turner, M. (1981). "Arable in England and Wales: Estimates from the 1801 Crop Returns," Journal of Historical Geography, Vol.7, pp. 291-302.

Turner, M. (1986). "English Open Fields and Enclosures: Retardation or Productivity

Improvements," Journal of Economic History, Vol. 46, pp. 669-692.

Turner, M.E., Beckett, J.V., and Afton, B. (1997). Agricultural Rent in England, 1690-1914, Cambridge, Cambridge Univerity Press.

Turner, M.E., Beckett, J.V., and Afton, B. (1998). "Renting the Revolution: A Reply to Clark," Journal of Economic History, Vol. 58, pp. 211-19.

Turner, M.E., Beckett, J.V. and Afton, B. (2001). Farm Production in England, 1700-1914, Oxford, Oxford University Press.

Wrigley, E.A. and Schofield, R.S. (1981). The Population History of England, 1541-1871: A Reconstruction, London, Edward Arnold.

Wrigley, E.A. (1985). "Urban Growth and Agricultural Change: England and the Continent in the Early Modern Period," Journal of Interdisciplinary History, Vol. 15, pp. 683-728.

Wrigley, E.A. (1986). "Men on the Land and Men in the Countryside: Employment in Agriculture in Early-Ninteenth-Century England," in Lloyd bonfield, Richard M. Smith, and Keith Wrigtson, the World We Have Gained, Oxford, Basil Blackwell Ltd, pp. 295-336.

Young, Arthur (1770). A Six Month’s Tour through the North of England, London, W. Strahan.