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Abstract

Estimates of capital formation and the stock of capital in Britain are provided for the period 1270-1870 and used to analyse economic growth. (1) We chart the growing importance of fixed relative to working capital, the declining importance of land and the growth of net overseas assets. (2) Kaldor's stylised facts of a rising capital-labour ratio and a stationary capital-output ratio are broadly confirmed, but only if attention is confined to fixed capital. (3) Extensive form growth accounts suggest that output growth was driven largely by factor input growth, while intensive form growth accounts suggest that TFP growth was more important than capital deepening in explaining the growth of output per head. (4) The investment share of GDP increased substantially during the transition from pre-industrial to modern economic growth.

JEL Classification: N13, N33, O10, O47

Keywords: Capital, economic growth, Britain, Long Run

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1. INTRODUCTION

Recent work by Broadberry et al. (2015) has provided annual estimates of GDP for Britain over the period 1270-1870, which have been combined with estimates of labour input to track labour productivity over time. Until now, however, British capital stock data have been unavailable before 1760, making it impossible to provide long run growth accounts for the first economy to achieve modern economic growth. In this paper, we present estimates of capital formation and the capital stock in Britain, reaching back to 1270 and consider the implications for economic growth as the British economy was transformed from a relatively poor, pre-industrial economy into the first modern economy.

The modern literature on capital and growth tends to focus on fixed reproducible capital, with a particular emphasis on machinery and equipment. This is understandable given the importance of machinery and equipment in modern economies. In medieval and early modern times, however, machinery and equipment was a much less important part of fixed reproducible capital than buildings, while circulating or working capital played a more important role relative to fixed capital. Furthermore, with agriculture as the dominant economic sector, land plus stocks of animals and standing crops accounted for a larger share of national wealth. In addition to providing traditional growth accounts with their focus on fixed capital, our analysis thus also examines the changing composition of capital and national wealth.

This paper proceeds as follows. Section 2 sets out the methodology for constructing the estimates of fixed investment and the stock of fixed capital using the perpetual inventory method, as well as the other components of national wealth, including working capital, land and overseas assets. This section also discusses how to adjust the series for changing prices. Section 3 describes the construction of and major trends in domestic fixed investment and the

stock of fixed capital for Britain, broken down into the three main sectors of the economy, covering agriculture, industry and services, and also providing estimates for residential dwellings. Section 4 provides estimates of working capital, land and overseas assets to complete our estimates of national wealth.

In section 5, the new estimates of national wealth are used to shed light on British economic growth over the period 1270-1870. First, there were important changes in the structure of national wealth over time, with a dramatic reduction in the importance of land relative to domestic reproducible capital, a growing importance of fixed capital relative to working capital within domestic reproducible capital, and a growing importance of net overseas assets from the eighteenth century. Second, if attention is confined to fixed capital, the capital-labour ratio grew substantially over time while the capital-output ratio exhibited no trend, consistent with Kaldor's (1963) stylised facts based on modern experience. However, using reproducible capital, the capital-labour ratio was stationary until the seventeenth century while the capital-output ratio trended downwards. Third, growth accounting in extensive form suggests that output growth was largely driven by factor input growth rather than by TFP growth, although the period between the 1640s and the 1690s provides an important exception to this. However, intensive form growth accounts suggest that TFP growth was more important than capital deepening in explaining the growth of output per worker. Fourth, the investment share of GDP increased substantially during the transition from pre-industrial to modern economic growth, but in a much more gradual way than suggested by Rostow (1960).

2. CONCEPTUAL FRAMEWORK

Tangible civilian productive wealth consists of four main components: (1) domestic reproducible fixed capital (2) stocks and work in progress (3) the unimproved value of land

and (4) overseas assets, including gold and silver. Below, we consider each of these four components in turn.

2.1 Domestic reproducible fixed capital: the perpetual inventory method

Domestic reproducible fixed capital is estimated using the perpetual inventory method (PIM), which makes use of some basic identities linking the stock of fixed capital to the flows of previous investment. Here we follow the basic procedures of Feinstein (1978: 35). When both the annual flow of investment, I_t, and the end-year gross stock of capital, K_t, are both valued in constant prices of the same year, they can be related through the basic identity:

$$K_n = \sum_{t=0}^{n}(I_t - R_t) \quad (1)$$

where R_t is the flow of assets retired at the end of their working lives. This requires taking the original costs of the retired assets and revaluing them at the prices of the year of retirement. Assuming that all assets are retired at the end of their working life of L years, we arrive at:

$$K_n = \sum_{t=0}^{n}(I_t - I_{t-L}) = \sum_{t=n-L}^{n} I_t \quad (2)$$

To measure the gross capital stock at any date, we thus need to estimate the flow of investment for L years preceding that date. Once we know the stock at any particular date, we can also calculate the stock at other dates using the basic relationship:

$$K_n = K_{n-1} + I_n - R_n \quad (3)$$

The gross capital stock at the end of year *n* is thus equal to the gross capital stock at the end of the previous year plus investment during the year, minus retirements. This is equivalent to the value of all investments that are currently available for productive use, with each year's investments revalued in prices of the same base year, thus excluding the effects of inflation in the price of investment goods.

As Feinstein (1988: 261) notes, the empirical Achilles heel of the perpetual inventory method is information on asset lives, which is very scarce. However, it should be noted that this problem is not confined to historical estimates of the capital stock, and remains a serious issue for contemporary national statistical offices, leading some authors to experiment with asset lives standardised across countries (Maddison, 1995; O'Mahony, 1996). We have followed Feinstein (1988: 261) in adopting the following asset life assumptions, also standard in the UK Statistical Office estimates for the twentieth century: 80 to 100 years for buildings and works, 20 to 40 years for equipment and machinery, and 10 to 20 years for vehicles.

In the gross capital stock approach, assets are assumed to remain equally productive while they are still in use, in contrast to the net capital stock approach, which allows additionally for depreciation of assets during use. Although Jorgenson et al. (1987) argue that the net capital stock concept is consistent with the rental price of capital, used to weight capital in growth accounting, further pursuit of this line of reasoning leads to working with capital services rather than capital stocks, which imposes further assumptions and data demands that cannot be met in a long run historical study such as this. Furthermore, the gross capital approach has been seen as particularly suitable for the analysis of production and growth by Kendrick (1993: 133), who notes that "(i)f adequately maintained, capital goods retain their output-producing capacity over their lifetimes with little diminution".

2.2 Stocks and work in progress

Fixed capital is combined with circulating or working capital, which covers stocks or inventories and work in progress. This category of capital can be broken down into farm and non-farm stocks. Here, we again follow the procedures of Feinstein (1978; 1988), adapted to fit the circumstances and data availability of earlier centuries. In agriculture, farm stocks

consist of the value of non-working animals (mainly cattle, sheep and pigs) and working animals (horses and oxen) plus harvested crops, while work in progress consists of crops in the ground. In industry and trade, stocks consist of raw materials, domestic or imported, and semi-manufactured and finished products held at every stage of the production and distribution process, while work in progress consists of unfinished items with long gestation periods, such as houses or ships.

2.3 Land

The most important part of non-reproducible tangible domestic wealth is land. This includes the unimproved value of farmland, the land beneath dwellings and other buildings and structures, together with the value of standing timber (Feinstein, 1978: 66)

2.4 Overseas assets

The final component of national wealth considered here is holdings of overseas assets by domestic residents, net of holdings of domestic assets by overseas residents. This covers both physical and financial assets. Holdings of gold and silver coin and bullion are also included (Feinstein, 1978: 66).

2.5 Adjustment for changing prices

We are interested primarily in capital stocks and investments at constant prices, but for some purposes, current price values are required. We therefore provide price indices for the most important classes of assets: houses and other buildings; agricultural works and buildings; and machinery and equipment.

Following Feinstein (1978: 37), each of the three main capital goods price indices combines a series for labour and materials used for the production of capital goods. Key sources for prices and wages include Clark (2006; 2014), Bowley and Wood (1906) and Thorold Rogers (1866-1882). Whereas Feinstein (1978) expressed his price indices at constant 1851-60 prices, we present them at constant 1700 prices to keep our estimates consistent with the latest estimates of British GDP from Broadberry et al. (2015). Detailed sources are given in the Appendix.

The three capital goods price series are shown in Figure 1. Although there were short periods when the three series diverged, over the long run they all followed a similar trajectory, fluctuating without trend until the arrival of the Black Death in 1348, then rising sharply to a new plateau which continued until the end of the fifteenth century. This was followed by another sharp increase in the mid-sixteenth century and further growth at a slower rate until the mid-seventeenth century. The price of capital goods then remained on a plateau until the late eighteenth century, when prices rose again during the French wars, before falling back after 1815.

2.6 Data presentation

We have based our estimates as far as possible on data for England only over the period 1270-1700 and the whole of Great Britain for the period 1700-1870. The data have then been spliced at 1700 to produce continuous series for Great Britain over the period 1270-1870, as in Broadberry et al. (2015),

However, whereas Broadberry et al. (2015) were able to provide output data on an annual basis, here we follow Feinstein (1988) in presenting the results for investment and the

capital stock on a decennial basis. We agree with Feinstein's (1988: 260) judgement that before the mid-nineteenth century, too few of the key variables entering into the capital stock calculations are available at an annual frequency, so that we would be relying too heavily on interpolation if we were to provide annual data. Accordingly, investment data are presented as annual averages for the whole decade while data on the capital stock are presented for the end of each decade.

3. FIXED INVESTMENT AND THE STOCK OF FIXED CAPITAL

3.1 Data sources and methods

Before analysing the results, we provide here a brief overview of the main sources and methods used to construct the estimates of fixed investment and the stock of fixed capital in Britain over the period 1270-1870, with further details available in the Appendix. Feinstein's (1988) estimates for the period 1760-1870 generally provide the starting point, but our capital stock estimates for this period sometimes differ from those of Feinstein. This is largely because a high proportion of Feinstein's fixed capital had asset lives of 80-100 years and he had no data on investment before 1760. Rather than using retirements of investments made between 1660 and 1760, therefore, Feinstein needed to make assumptions about the proportion of the 1760 stock surviving over the following century. Our approach has been to start the investment series in 1270 and provide capital stock estimates only from 1350 onwards.

3.1.1 Agriculture

Following Feinstein (1978; 1988), the gross stock of fixed reproducible capital in agriculture is derived by first estimating a series for capital formation at current prices, which is derived in turn from an annual series for total gross rent from land. The gross rent series is obtained from the total acreage of arable, pastoral and meadow land employed in agricultural production,

multiplied by the amount of rent per acre, The acreage data are taken from Broadberry et al. (2015), while the rent data are from Clark (2002; 2016) for the period 1270-1760 and Holderness (1988: 10) for the period 1760-1870. The proportion of the gross rent used by landlords and tenants for capital spending is based on Holderness's (1988: 10) estimate of the average annual investment in fixed assets for 1760-1870, rising from 7 per cent in the 1760s to 14 per cent in the 1860s.

For the period before 1760, we have assumed a slightly lower share of gross rent, but varying with well-known changes in the economic environment. Capital expenditure was assumed to be 4 per cent of gross rent before the Black Death, rising to 6 per cent thereafter, with a further increase to 7 per cent from the mid-sixteenth century. This is consistent with two main pieces of evidence. First, Clark (1988) shows that interest rates fell from around 10 per cent in 1300 to around 5 per cent after the Black Death, before drifting down further to around 4 per cent by the mid-eighteenth century, providing growing incentives to adopt more capital intensive techniques in agriculture. Second, Postan (1967) and Hilton (1975) both use evidence from manorial accounts to support an investment rate of less than 5 per cent before the Black Death. Our figure for the investment rate of 4 per cent in 1300 rising to 6 per cent after the Back Death is based on the average investment rate in the Winchester Pipe Rolls for 1301/02 and 1409/10 (Page, 1996; 1999). Further research is needed here to strengthen the evidence on investment rates both on a wider range of manors and also outside the demesne sector. The capital expenditure series is deflated using the price index for agricultural works and buildings from Figure 1 to obtain a series for gross fixed capital formation in agriculture in constant 1700 prices. This is then used to derive the capital stock series using the perpetual inventory method and an assumed average asset life of 80 years.

3.1.2 Industry

For industry, separate estimates are provided in the Appendix for manufacturing, mining & quarrying, and gas & water supply undertakings. Within manufacturing, separate estimates are provided for industrial buildings and industrial machinery & equipment. Again following the approach of Feinstein (1978: 51), investment expenditure on both buildings and machinery & equipment was assumed to be proportional to the increase in industrial production, using the industrial output series from Broadberry et al. (2015). It should be noted that this accelerator relationship, relating investment to the increase in output rather than the level of output, avoids assuming a constant capital-output ratio. Using the perpetual inventory method, an asset life of 80 years was used to estimate the gross capital stock for industrial buildings, while assets were assumed to last 40 years for machinery & equipment.

In mining and quarrying, the gross capital stock is obtained by applying a capital cost per ton figure from the work of Feinstein (1988) for the period 1760-1870, and Flinn (1984: 200-204) and Hatcher (1993: 330-339) for earlier years. Following the approach of Feinstein (1978), capital cost per ton is multiplied by the tonnage of coal mined, but adjusted to allow for other mining output. Since there are no data on coal mining available before 1508, the series is extended back further in time using tin output from Hatcher (1973). The capital stock series is deflated to constant 1700 prices using the index for houses and other buildings from Figure 1.The investment series in mining is then obtained from the capital stock series using the perpetual inventory method, with an assumed average asset life of 40 years.

Gas and water supply investment data were derived by Brian Mitchell from *Parliamentary Papers* and company reports and formed the basis of Feinstein's (1988)

estimates of gross fixed capital from 1820 onwards. Average asset lives of 60 to 80 years are assumed for buildings and works, and 40 to 50 years for plant and equipment.

3.1.3 Services

Turning to services, separate estimates are provided in the Appendix for distribution, transport, and public & social services. For distribution, Feinstein (1978: 52) assumed that capital formation in commercial buildings moved in proportion to the construction of dwellings. Here, it is assumed to move in proportion to the increase of output in commercial services, using the series from Broadberry et al. (2015). Assets are assumed to have lasted 80 years. In addition, we follow Feinstein (1988) in providing separate estimates for equipment, fittings & furnishings. Investment is estimated in the same way, but assets are assumed to have lasted 40 years.

In the transport sector, separate estimates are provided for railways, roads & bridges, carriages & coaches, canals & waterways, docks & harbours and ships. Although railways only became important in the nineteenth century, they had such an important effect on capital markets that they are treated separately. Here we follow Feinstein (1978), who used a series for fixed capital formation from Mitchell (1964) distinguishing between permanent way and rolling stock, with average asset lives of 100 years and 30 years, respectively. For roads and bridges, Feinstein's (1988) estimates of investment have been superseded by the work of Bogart (2005), who provides a series reaching back to the 1730s. For the pre-1730 period, the investment series is projected back to 1270 using estimates of the total mileage of English roads from Hindle (1976), Thrift (1990) and Albert (1972). To derive the gross stock of roads and bridges from the investment data, it is assumed that the average life of the assets was 80 years (Feinstein, 1988: 319). Since farm wagons and carts are included in the series for agriculture,

the data for carriages and wagons are restricted to vehicles used for passenger transport. The gross stock series is taken from Feinstein (1988) for the period since 1760 and used to derive an investment series on the assumption of an average asset life of 20 years. The stock of capital was already very small in 1760, and was projected back further to 1270 in proportion to the gross stock of roads and bridges.

Turning from road transport to water transport, for canals and waterways we follow the same approach as Feinstein (1988) to estimate the gross stock of capital during the period 1760-1870 and extend the estimates back to 1270 using unpublished estimates of navigable waterways provided by Max Satchell. The investment data for docks and harbours are based on Feinstein (1988) for the period 1760-1870 and extended back to 1660 using Swann (1660). The capital stock is then derived from the investment data assuming average asset lives of 100 years. The gross stock is held constant at a low level between 1270 and 1660. For ships, Feinstein (1988) provides the gross stock of capital for the period after 1760. This concerns all steam and sailing vessels for the merchant navy. Estimates of fixed capital formation in ships are derived from the stock estimates using the perpetual inventory method and assumed average asset lives of 30 years. For the period before 1760, we make use of estimates of the merchant fleet tonnage provided by Davis (1962) for benchmark years, interpolated with the index for international trade and transport from Broadberry et al. (2015) and cross-checked against Unger's (1992) estimate for 1310.

For public and social services, Feinstein (1988) provides the gross stock of capital for the period after 1760, based on the valuation of schools, hospitals & workhouses, churches and other public buildings. For the period before 1760, we assume that the value of public buildings and works moved in proportion to the value of dwellings, based on the relationship between

1760 and 1810. Since churches accounted for nearly three-quarters of the stock of public buildings as late as 1850, the resulting estimates can be cross-checked against the trend in church buildings during the medieval period from Buringh et al. (2020). Investment is derived form the stock estimates using the perpetual inventory method, with asset lives set at 80 years.

3.1.4 Dwellings

Although residential dwellings are not normally seen as contributing to factor inputs in the analysis of productivity performance, they do nevertheless account for more than 40 per cent of the fixed capital stock in the late medieval period before falling back to around a quarter by the mid-nineteenth century. They include all dwellings except farmhouses, which are treated as part of the agricultural capital stock. The number of dwellings is estimated from the population and the average household size. Population levels are taken from Broadberry et al. (2015), with household size derived from a number of sources, including Wall (1972) and Feinstein (1978: 42). The average cost of a house in 1860 is taken from Feinstein (1978: 45) in 1851-60 prices and converted to 1700 prices using the price index for houses and other buildings. We have also followed Feinstein (1988: 383) in adjusting for an increase in the quality of housing during the nineteenth century, after the introduction of building regulations.[1] The gross capital stock in 1700 prices is obtained as the product of the population, the average household size and the average cost of a house in 1700. The investment series is obtained from the capital stock data using the perpetual inventory method and assumed average asset lives of 80 years. However, the dramatic decline in the population after the Black Death requires special treatment within the perpetual inventory method. A floor of zero is set for investment, which

[1] It is possible that another increase in housing quality occurred during what Hoskins (1953) called the "Great Rebuilding" of rural England between 1570 and 1640, although Dyer (1986) cautions against exaggerating the backwardness of medieval buildings. The reduction in household size after the Black Death also represents an implicit increase in the quality of housing experienced by individual household members.

means that a period of substantial decline in the capital stock must be matched by demolition or abandonment over and above the normal retirements at the end of useful asset lives. This created the phenomenon of deserted medieval villages (Beresford, 1989).

3.2 Trends in the stock of fixed investment and the stock of fixed capital

Table 1 provides the data on fixed investment and the stock of fixed capital at constant 1700 prices. Over the period 1350-1870, the aggregate stock of fixed capital grew at an annual rate of 0.49 per cent including dwellings, or 0.56 per cent excluding dwellings. This compares with an annual population growth rate of 0.29 per cent and a real GDP growth rate of 0.58 per cent. The sector where the fixed capital stock exhibited the slowest growth was agriculture, at an average annual rate of 0.36 per cent between 1350 and 1870, while industry showed the fastest growth, at 0.93 per cent. Fixed capital in services grew at an intermediate rate of 0.60 per cent, while dwellings grew at 0.38 per cent.

4. WORKING CAPITAL, LAND AND OVERSEAS ASSETS

4.1 Data sources and methods

Working capital consists of farm stocks and non-farm stocks. Farm stocks are derived from Broadberry et al. (2015), who provide data on the value of standing crops and working and non-working animals in England. The crops covered are wheat, barley, oats, rye, potatoes, peas and beans, with an allowance for other crops, while the working animals are horses and oxen and the non-working animals are cattle, pigs and sheep. The estimates are converted to a Great Britain basis by benchmarking on Feinstein's (1988) estimates for 1850. For non-farm stocks in industry and trade, Feinstein (1988) provided evidence to show that a ratio of 30 per cent of turnover was appropriate for the period 1760-1830, falling to 25 per cent after 1830, as a result of transport improvements. We assume that the 30 per cent ratio applies also to the period

before 1760. However, we do not have data for total final expenditure before 1830, so we use the series for GDP from Broadberry et al. (2015), but we have benchmarked it on Feinstein's (1988) total final expenditure figure for 1850.

To value farmland at current prices, we capitalise the estimated annual rent of the land. Feinstein (1978) capitalised the annual values at 25 years' purchase in 1760, which is equivalent to a return of 4 per cent. For the period before 1760, we make use of Clark's (1988) estimates of the rate of return, while for the period after 1760, we work with the figures of Feinstein (1988: 400). However, the value of the land on which rental income was received includes the value of farm buildings and works and the value of equipment, which have already been included in the fixed capital stock, so these values must be deducted from the series to estimate the unimproved value of the land between 1270 and 1870. For urban land, Feinstein (1978: 73) capitalised the rent from income tax data in 1860 at 20 years' purchase, or a rate of return of 5 per cent. For other years, we follow Feinstein (1978: 73) in assuming the ratio of land to buildings and works to be the same as in 1860 for each of the four main categories (dwellings; industrial and commercial buildings; railways; mines, canals and gasworks). We have projected this series back to 1270 by means of the growth in urbanisation. The current price value of land in 1700 represents the constant price value of unimproved land for all years, apart from two adjustments. First, we follow Feinstein (1978: 73) in making an allowance for the increase in the land area brought into cultivation by enclosure and drainage. Second, we also allow for the decline in the farmed area following the population collapse after the Black Death.

Accumulated net holdings of overseas assets have been calculated from 1760 by Feinstein (1988: 397) in current prices. In addition to the accumulated holdings of physical

assets and financial claims on overseas assets by British residents net of British assets owned by foreign residents, gold and silver specie and bullion are included here, since they represent potential claims on foreign assets. The series is extended back to 1270 using data on the stock of monetary gold and silver from Palma (2018). Net investment abroad is derived from the stock data and converted to constant 1700 prices using the GDP deflator from Broadberry et al. (2015).

4.2 Trends in working capital, land and overseas assets

Data on stocks and stockbuilding are provided in Table 2. Farm stocks declined as population and output fell after the Black Death, and began to recover only from the sixteenth century. The decline in non-farm stocks was sharper than in farming, but the recovery began earlier, from the mid-fifteenth century. Over the long run, output and hence stocks grew faster in the industrial and commercial sector than in agriculture, so that non-farm stocks became more important than farm stocks in the nineteenth century, having been less than one-third as large in the pre-Black Death period.

Part A of Table 3 sets out the data on land and overseas assets, together with the other elements of national wealth in constant 1700 prices. The sum of fixed capital and working capital from columns (1) and (2) makes up domestic reproducible capital in column (3). The addition of land from column (4) creates total domestic capital in column (5), while national wealth in column (7) is the sum of total domestic capital and overseas assets, with the latter taken from column (6).

5. CAPITAL AND ECONOMIC GROWTH IN BRITAIN

5.1 The changing structure of national wealth

There were a number of very significant changes in the composition of national wealth over this long period, which can be traced in Table 3. Because of changing relative prices, it is necessary to consider shares in both constant and current prices. The changes are most dramatic when set out in constant 1700 prices in parts A and B. The biggest change was in the share of land, which declined from over 60 per cent during the medieval period to under half by 1650 before falling sharply to less than 15 per cent by 1870. These trends reflect the declining relative importance of agriculture in the economy and the accumulation of domestic reproducible capital. A second significant change was the growing importance of fixed capital within domestic reproducible capital. Whereas working capital accounted for around 11 to 12 per cent of national wealth in both the medieval period and the late nineteenth century, the share of fixed capital increased from around a quarter to more than half. A third significant change was the growing importance of overseas assets (including gold and silver bullion and specie), with the net position going from one or two per cent of national wealth in the medieval period to two to four per cent in the early modern period before growing dramatically in the nineteenth century to reach over one-fifth of national wealth by 1870.

Parts C and D of Table 3 display the composition of national wealth in current price terms. The most noticeable difference from the constant price data concerns the share of land, due to the relatively fixed amount of agricultural land. Although there was some increase due to enclosure and drainage, the increase was limited, which resulted in a substantial increase in the relative price of land. Thus the declining share of land as agriculture accounted for a smaller share of output was much more muted in current prices than in constant 1700 prices. Indeed, it was stagnant rather than declining during the medieval, and even increased during the recovery of population during the early modern period, before declining sharply only during the nineteenth century as Britain opened up to substantial food imports. As a result of the rising

relative price of land, domestic capital accounted for a larger share of national wealth during the late eighteenth and nineteenth centuries, and overseas assets for a correspondingly smaller share. The balance between fixed capital and working capital moved strongly in favour of the former in current prices as well as in constant 1700 prices.

5.2 Capital-labour and capital-output ratios

Kaldor (1963) famously set out a number of "stylised facts" about long run growth, based on his reading of the experience of rich western economies during the nineteenth and twentieth centuries. Two of his six stylised facts concerned the capital-labour and capital-output ratios, including: "a continued increase in the amount of capital per worker" and "steady capital-output ratios over long periods" (Kaldor, 1963: 178). Thus, although there is an expectation of an increasing capital-labour ratio, or capital-deepening, over time with economic growth, there is no similar presumption concerning the capital-output ratio. Indeed, since the reciprocal of the capital-output ratio is capital productivity, a rising capital-output ratio would imply declining capital productivity.

Figure 2 charts the path of aggregate capital per head of the population in constant 1700 prices, using three different measures of the capital stock: (1) fixed capital excluding dwellings, (2) fixed capital including dwellings and (3) reproducible capital, obtained as the sum of fixed capital and working capital. All series indicate a sharp rise in the capital-labour ratio after the Black Death, but this was only a short-lived effect, with the capital-labour ratio declining again during the fifteenth century. For the series based on fixed capital excluding dwellings, there was a clear upward trend in the capital-labour ratio from the beginning of the seventeenth century, but with a pause during the first half of the eighteenth century. This was followed by a renewed upward trend from the 1750s and an increase in this this trend from the 1830s. By

contrast there was little discernible increase in the capital-labour ratio based on fixed capital including dwellings or reproducible capital before the 1830s. The modernisation of the British economy thus seems to have begun already during the early modern period, but to discern this development, it is necessary to take account of the changing composition of the capital stock, with the growing importance of non-housing fixed capital.

Figure 3 charts the capital-output ratio, again distinguishing between series based on the fixed capital stock excluding and including dwellings and the reproducible capital stock. As with the capital-labour ratio, there was a sharp increase in the capital-output ratio after the Black Death, whichever series is used, but this was a short-lived effect. Thereafter, the series based on fixed capital excluding dwellings exhibits no clear trend and has a relatively low amplitude, thus conforming roughly to Kaldor's stylised facts. By contrast, the series based on fixed capital including dwellings and reproducible capital exhibit a clear downward trend, suggesting rising capital productivity as fixed capital became more important than working capital.

Overall, then, these findings suggest that Kaldor's (1963) stylised facts of a rising capital-labour ratio but a stationary capital-output ratio depend on the use of the fixed capital stock excluding dwellings. Using the reproducible capital stock, including working capital as well as fixed capital, the capital-labour ratio increased little before the nineteenth century while the capital-output ratio trended down from the fifteenth century.

5.3 Growth accounting

Growth accounting helps us to assess whether economic growth came from the use of more factor inputs or from the more effective use of existing inputs. In the simplest formulation,

aggregate output (Y) is produced using inputs of capital (K) and labour (L) and A is a measure of efficiency or total factor productivity (TFP):

$$Y = AF(K, L) \tag{4}$$

The growth rate of output (ΔY/Y) can be related to the growth rates of the inputs of capital (ΔK/K) and labour (ΔL/L) and the growth rate of TFP (ΔA/A):

$$\Delta Y/Y = \alpha\, \Delta K/K + \beta \Delta L/L + \Delta A/A \tag{5}$$

The weights α and β reflect the relative importance of inputs in the production process, measured by their shares in the costs of production. For labour this is the share of wages in the value of output, while for capital it is the share of profits. A weighted average of the growth of capital and labour gives the growth of total factor input (TFI), and TFP growth is obtained as the residual difference between the growth rates of output and TFI.

Of more interest from the viewpoint of economic development, however, is the intensive form, which relates the growth of output per head to capital deepening and improving efficiency. Dividing both sides of equation (5) by population yields the production function in intensive form:

$$y = Af(k) \tag{6}$$

where y = Y/L and k = K/L. The growth of output per head can then be related to the growth rate of capital per head and total factor productivity:

$$\Delta y/y = \alpha\, \Delta k/k + \Delta A/A \tag{7}$$

Figure 4 plots the path of output per person (Y/L) and capital per person (K/L), using the reproducible capital in part A and the fixed capital stock excluding dwellings in part B. The two charts look very different. Using reproducible capital, which includes working capital as well as fixed capital (including dwellings), the two series do not move closely together over

the long run. When fixed capital excluding dwellings is used, however, the two series move together fairly closely over the long run. It will therefore make sense to focus on fixed capital excluding dwellings when considering the relationship between capital and growth.

Table 4 presents the results of the growth accounting exercise in extensive form using equation (5) and using fixed capital excluding dwellings. As in Crafts (1995: 752), factor input weights are 0.4 for capital and 0.6 for labour. Output growth was driven predominantly by the growth of inputs. Following the Black Death, which wiped out one-third of the population within three years and more than half the population within a century of its arrival in 1348, output exhibited negative growth until the mid-fifteenth century. During this phase, the negative contributions of labour and capital growth exceeded the fall in output, so that TFP growth was positive, particularly between the 1340s and 1400s. Between the 1450s and 1640s, the positive contributions of labour and capital growth more than accounted for the growth of output, resulting in slightly negative TFP growth. From the 1690s to the 1860s, the accelerating growth of output was also driven largely by the contributions of labour and capital. The one period which does not conform to this strong dominance of factor inputs was between the 1640s and 1690s, when TFP growth made a much larger contribution to output growth than the contributions of labour and capital. Despite the weaker relationship between long run trends in output per head and reproducible capital per head, the growth accounting results for the periods considered here are very similar to the results using fixed capital (part B of Table 4).

Table 5 presents the results of growth accounting in intensive form, using equation (7) to show how the growth of output per worker can be explained by capital deepening and growing efficiency. Again fixed capital excluding dwellings is used in part A and reproducible capital in part B. With both measures of capital, the two periods of rapid pre-industrial labour

productivity growth during the second half of the fourteenth century and the second half of the seventeenth century were driven more by growing efficiency than by capital deepening, although the role of capital deepening was greater in the case of fixed capital. However, neither of these episodes can be considered modern economic growth, since population was falling. As the British economy made the transition to modern economic growth from the eighteenth century, however, the breakdown between capital deepening and growing efficiency varies depending on the measure of the capital stock used. Using fixed capital in part A of Table 5, capital deepening accounted for more of the growth of output per worker than TFP growth between the 1830s and the 1860s. However, using reproducible capital in part B of Table 5, TFP growth remained more important than capital deepening between the 1690s and the 1860s.

McCloskey (1981: 108), believing in the faster rates of output growth suggested by Deane and Cole (1967), and hence in a much larger Solow residual or TFP growth, wrote "ingenuity rather than abstention governed the industrial revolution". To some extent, that picture is confirmed here in the intensive form growth accounts, using reproducible capital, but is less clear-cut using fixed capital excluding dwellings, with capital deepening accounting for over 60 per cent of GDP per head growth between the 1830s and the 1860s. Taken together with the growth accounts in extensive form, it may therefore be more accurate to say that abstention or thrift (savings = investment) and industriousness (growth of labour supply) as well as ingenuity (growth of TFP) governed the industrial revolution.

5.4 The investment ratio

The investment ratio, or share of investment in GDP, can be seen as a measure of the savings rate, or the willingness of a society to forego current consumption for future consumption. Rostow (1960: 7-9) famously saw an increase in the investment ratio from around 5 per cent

to 10 per cent or more over a short period of around two decades as a necessary condition for the take-off to self-sustained economic growth. The model has not fared well empirically in the case of domestic investment during the British Industrial Revolution, as can be seen in Table 6. Rostow (1960: 9) himself dated the British take-off to the two decades after 1783, but the earliest systematic quantitative assessment by Feinstein (1978: 91) suggested a much more drawn-out and non-monotonic increase in the domestic investment ratio from 8 per cent in the 1760s to 13 per cent in the 1790s before falling back to 10 per cent in the 1850s. Crafts (1985: 73) used the same investment series as Feinstein but replaced Deane and Cole's (1967) GDP series with his own, more slowly-growing series. This had the effect of leaving the investment ratio the same in the 1820s, but sharply reducing it for earlier decades. Repeating the calculation, but using the capital stock data from Tables 1 to 3 and the GDP series from Broadberry et al. (2015) has the effect of producing a similar increase in the investment ratio to that suggested by Crafts (1985), but drawn out over a longer period, with much of the increase occurring only after the 1830s.[2]

Turning now to the long run evolution of the investment ratio, Figure 5 provides data on the individual components of the total investment ratio, including overseas investment as well as domestic investment. In part A, the fixed investment ratio fluctuated at a low level of one to two per cent during the medieval period, increasing to between 2 and 4 per cent during the early modern period. However, the major change was the sharp increase from the mid-eighteenth century, reaching 10 per cent by the early nineteenth century. By contrast, stockbuilding as a share of GDP fluctuated with greater amplitude, but exhibited no clear trend over the period as a whole. Overseas investment as a share of GDP increased sharply in the

[2] Due to substantial changes in the relative price of capital goods between 1700 and 1851-60, our estimates use data in current prices rather than constant 1700 prices, for comparability with the results of Feinstein (1978) and Crafts (1985), which are based on data in 1851-60 prices.

nineteenth century, so that the total investment ratio almost reached 14 per cent by the 1860s (Figure 5, part B)

6. CONCLUSION

This paper provides estimates of capital formation and the stock of capital in Britain over the period 1270-1870 and uses the resulting series to assess the role of capital in economic growth. Fixed capital stocks are estimated using the perpetual inventory method to ensure stock-flow consistency, and combined with working capital to produce domestic reproducible capital stocks. This domestic capital series is then combined with land and overseas assets to provide a series of national wealth.

The analysis of these new data on capital and investment, together with the recent estimates of GDP from Broadberry et al. (2015), sheds new light on the growth of the British economy since 1270. First, we chart the changing composition of national wealth, with a sharp decline in the share of land and a corresponding rise in the shares of domestic reproducible capital and overseas assets. The declining share of land partly reflected the growing importance of industry and services relative to agriculture as well as the increased importance of reproducible capital in all sectors, including agriculture. The growth in the share of domestic reproducible capital was driven by the growing importance of fixed capital relative to working capital, while the growing importance of overseas assets was a relatively late phenomenon, beginning in the mid-eighteenth century.

Second, we establish trends in the capital-labour and capital-output ratios, which move broadly in line with Kaldor's (1963) "stylised facts", with the capital-labour ratio trending upwards but the capital-output ratio remaining stationary. However, these trends are dependent

on the use of fixed capital. Using reproducible capital, the capital-labour ratio was stationary until the nineteenth century and the capital-output ratio trended downwards.

Third, we use the capital stock data to construct growth accounts for Britain over six centuries. Accounts are provided in both extensive and intensive form, accounting for the growth of output and output per head, respectively, using both fixed capital and reproducible capital. The extensive form accounts suggest that output growth was driven largely by the growth of factor inputs. However, the intensive form accounts show that the growth of output per head was driven more by the growth of efficiency (TFP growth) than by capital deepening.

Fourth, we examine the changing role of investment in the economy. The investment share of GDP increased substantially during the transition from pre-industrial to modern economic growth, but in a much more gradual way than suggested by Rostow (1960), with the domestic investment rate barely reaching 10 per cent by the 1860s, when the total investment rate including overseas investment was just 14 per cent.

TABLE 1: Fixed investment and the stock of fixed capital by sector, 1270-1870 (£000 at constant 1700 prices)

A. Annual gross domestic fixed capital formation

	(1) Agric	(2) Industry	(3) Services	(4) Dwellings	(5) Total incl. dwellings	(6) Total excl. dwelling
1280s	301	0	108	263	672	409
1300s	389	46	47	0	482	482
1350s	259	0	24	0	284	284
1400s	268	0	12	0	280	280
1450s	220	8	26	0	254	254
1500s	281	33	87	83	483	400
1550s	272	3	110	276	661	385
1600s	865	170	348	538	1,922	1,383
1650s	933	209	332	470	1,944	1,474
1700s	982	177	431	500	2,089	1,590
1750s	1,287	295	579	274	2,435	2,161
1800s	2,464	1,046	2,430	1,061	7,002	5,940
1850s	3,475	8,977	12,406	6,196	31,055	24,858
1860s	3,334	9,076	16,616	11,716	40,742	29,027

B. Gross stock of fixed reproducible capital

	(1) Agric	(2) Industry	(3) Services	(4) Dwellings	(5) Total	(6) Total excl. dwelling
1350	32,260	2,455	26,370	55,483	116,568	61,085
1400	30,203	2,162	18,221	33,475	84,060	50,585
1450	21,876	1,261	16,023	27,832	66,992	39,161
1500	19,349	1,530	16,176	28,104	65.159	37,055
1550	23,644	3,328	20,830	37,710	85,512	47,802
1600	28,498	6,068	27,499	51,886	113,091	61,205
1650	60,872	3,734	34,505	67,893	167,003	99,111
1700	77,256	9,250	40,406	66,372	193,284	126,913
1750	82,125	7,154	46,405	69,119	204,803	135,684
1800	105,780	24,846	91,184	90,811	312,621	221,810
1850	170,214	155,345	349,498	225,528	900,586	675,057
1870	212,537	297,028	606,204	395,561	1,511,330	1,115,769

Source: See Appendix.

TABLE 2: Working capital, 1280-1870 (£000 at constant 1700 prices)

A. Annual stockbuilding

	(1) Farm stockbuilding	(2) Non-farm stockbuilding	(3) Total stockbuilding
1280s	1	-66	-65
1300s	4	56	60
1350s	-272	-328	-599
1400s	-147	-63	-209
1450s	-55	-6	-61
1500s	241	64	305
1550s	-89	13	-76
1600s	703	304	1,007
1650s	90	238	328
1700s	-111	221	110
1750s	1,248	354	1,602
1800s	-159	1,105	946
1850s	65	3,890	3,956
1860s	242	3,662	3,905

B. Stocks

	(1) Farm stocks	(2) Non-farm stocks	(3) Total stocks
1280	38,419	11,689	50,107
1300	42,211	12,077	54,288
1350	39,465	12,390	51,854
1400	30,209	8,608	38,811
1450	28,076	7,231	35,307
1500	26,978	8,222	35,201
1550	31,644	11,260	42,903
1600	33,418	14,254	47,672
1650	37,436	18,575	56,010
1700	42,681	28,188	70,869
1750	51,233	36,240	87,473
1800	82,842	61,869	144,711
1850	103,706	132,947	236,653
1870	106,782	208,475	315,257

Source: See Appendix.

TABLE 3: National wealth, 1350-1870

A. £ million at constant 1700 prices

	(1) Fixed capital	(2) Working capital	(3) Domestic reproducible capital	(4) Land	(5) Total domestic capital	(6) Overseas assets	(7) National wealth
1350	116,568	51,854	168,423	261,830	430,253	5,890	436,143
1400	84,060	38,811	122,871	191,503	314,374	6,197	320,571
1450	66,992	35,307	102,299	180,639	282,938	3,242	286,180
1500	65,159	35,201	100,360	180,256	280,615	3,587	284,202
1550	85,512	42,903	128,415	185,015	313,430	11,659	325,089
1600	113,091	47,672	160,763	191,663	352,426	6,481	358,907
1650	167,003	56,010	223,014	209,284	432,297	10,914	443,211
1700	193,284	70,869	264,154	210,268	474,422	12,709	487,131
1750	204,803	87,473	292,276	230,479	522,755	21,140	543,897
1800	312,621	144,711	457,332	254,455	711,787	55,044	766,831
1850	900,586	236,653	1,137,238	329,777	1,467,016	204,539	1,671,555
1870	1,511,330	315,257	1,826,587	390,846	2,217,432	609,669	2,827,101

B. % of national wealth at constant 1700 prices

	(1) Fixed capital	(2) Working capital	(3) Domestic reproducible capital	(4) Land	(5) Total domestic capital	(6) Overseas assets	(7) National wealth
1350	26.7	11.9	38.6	60.0	98.6	1.4	100.0
1400	26.2	12.1	38.3	59.7	98.1	1.9	100.0
1450	23.4	12.3	35.7	63.1	98.9	1.1	100.0
1500	22.9	12.4	35.3	63.4	98.7	1.3	100.0
1550	26.3	13.2	39.5	56.9	96.4	3.6	100.0
1600	31.5	13.3	44.8	53.4	98.2	1.8	100.0
1650	37.7	12.6	50.3	47.2	97.5	2.5	100.0
1700	39.7	14.5	54.2	43.2	97.4	2.6	100.0
1750	37.7	16.1	53.7	42.4	96.1	3.9	100.0
1800	40.8	18.9	59.6	33.2	92.8	7.2	100.0
1850	53.9	14.2	68.0	19.7	87.8	12.2	100.0
1870	53.5	11.2	64.6	13.8	78.4	21.6	100.0

TABLE 3 (continued): National wealth, 1350-1870

C. £ million at current prices

	(1) Fixed capital	(2) Working capital	(3) Domestic reproducible capital	(4) Land	(5) Total domestic capital	(6) Overseas assets	(7) National wealth
1350	17,101	6,850	23,951	15,908	39,859	1,047	40,907
1400	22,791	6,050	28,841	20,382	49,223	1,262	50,485
1450	20,016	4,711	24,727	20,370	45,097	658	45,755
1500	18,608	5,417	24,025	19,637	43,662	763	44,425
1550	26,749	12,836	39,585	35,591	75,175	3,464	78,640
1600	60,410	30,541	90,951	57,905	148,856	4,229	153,085
1650	130,884	55,512	186,396	210,188	396,584	10,113	406,698
1700	179,987	71,641	251,628	199,220	450,848	12,596	463,443
1750	200,723	81,254	281,977	309,898	591,875	19,380	611,255
1800	460,118	236,201	696,319	851,332	1,547,651	75,077	1,622,728
1850	1,604,110	356,000	1,960,110	1,290,000	3,250,110	240,000	3,490,110
1870	2,969,004	502,576	3,471,580	1,370,659	4,842,238	790,000	5,632,238

D. % of national wealth at current prices

	(1) Fixed capital	(2) Working capital	(3) Domestic reproducible capital	(4) Land	(5) Total domestic capital	(6) Overseas assets	(7) National wealth
1350	41.8	16.7	58.6	38.9	97.4	2.6	100.0
1400	45.1	12.0	57.1	40.4	97.5	2.5	100.0
1450	43.7	10.3	54.0	44.5	98.6	1.4	100.0
1500	41.9	12.2	54.1	44.2	98.3	1.7	100.0
1550	34.0	16.3	50.3	45.3	95.6	4.4	100.0
1600	39.5	20.0	59.4	37.8	97.2	2.8	100.0
1650	32.2	13.6	45.8	51.7	97.5	2.5	100.0
1700	38.8	15.5	54.3	43.0	97.3	2.7	100.0
1750	32.8	13.3	46.1	50.7	96.8	3.2	100.0
1800	28.4	14.6	42.9	52.5	95.4	4.6	100.0
1850	46.0	10.2	56.2	37.0	93.1	6.9	100.0
1870	52.7	8.9	61.6	24.3	86.0	14.0	100.0

Source: See Appendix.

TABLE 4: Accounting for the growth of British GDP, 1340s to 1860s (% per annum)

A. Fixed capital excluding dwellings

	Output growth	Due to labour	Due to capital	TFP growth
1340s - 1400s	-0.73	-0.77	-0.17	0.20
1400s - 1450s	-0.21	-0.08	-0.18	0.05
1450s - 1640s	0.50	0.32	0.20	-0.02
1640s - 1690s	0.84	-0.03	0.20	0.67
1690s - 1830s	1.08	0.45	0.38	0.26
1830s - 1860s	2.28	0.70	1.15	0.43

B. Reproducible capital

	Output growth	Due to labour	Due to capital	TFP growth
1340s - 1400s	-0.73	-0.77	-0.28	0.31
1400s - 1450s	-0.21	-0.08	-0.13	0.00
1450s - 1640s	0.50	0.32	0.18	0.01
1640s - 1690s	0.84	-0.03	0.14	0.72
1690s - 1830s	1.08	0.45	0.36	0.28
1830s - 1860s	2.28	0.70	1.02	0.56

Sources and notes: Output and capital stock data are in constant 1700 prices. Weights for labour and capital are 0.6 and 0.4, respectively. See text.

TABLE 5: Accounting for the growth of British GDP per head, 1340s to 1860s (% per annum)

A**. Fixed capital excluding dwellings**

	Output per worker growth	Due to capital deepening	TFP growth
1340s - 1400s	0.54	0.34	0.20
1400s - 1450s	-0.08	-0.13	0.05
1450s - 1640s	-0.03	-0.01	-0.02
1640s - 1690s	0.88	0.22	0.67
1690s - 1830s	0.34	0.08	0.26
1830s - 1860s	1.11	0.68	0.43

B. Reproducible capital

	Output per worker growth	Due to capital deepening	TFP growth
1340s - 1400s	0.54	0.23	0.31
1400s - 1450s	-0.08	-0.08	0.00
1450s - 1640s	-0.03	-0.03	0.01
1640s - 1690s	0.88	0.16	0.72
1690s - 1830s	0.34	0.06	0.28
1830s - 1860s	1.11	0.55	0.56

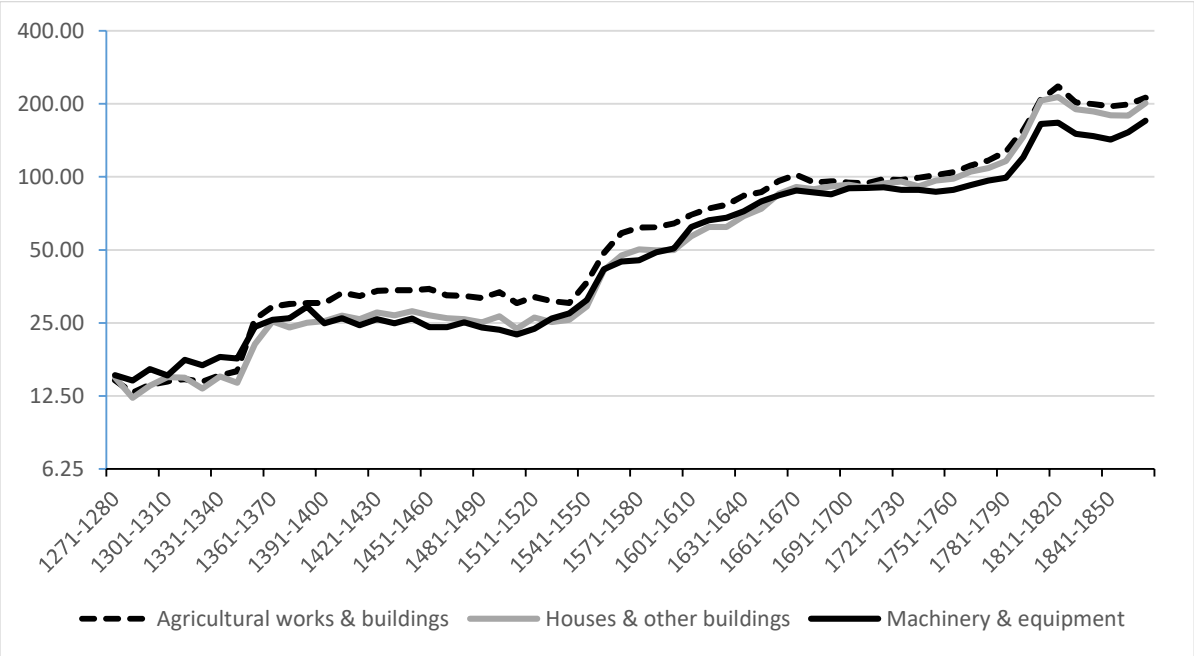
Sources and notes: Output and capital stock data are in constant 1700 prices. Weights for labour and capital are 0.6 and 0.4 respectively. See text.

TABLE 6: Domestic investment as a share of GDP during the Industrial Revolution (%)

	(1) Feinstein	(2) Crafts	(3) This study
1760s	8	4.0	3.3
1770s	9	6.0	4.9
1780s	12	7.0	4.8
1790s	13	7.9	7.0
1800s	11	8.5	6.3
1810s	11	11.2	5.7
1820s	12	11.7	4.9
1830s	12		7.5
1840s	12		10.5
1850s	10		9.7
1860s			10.2

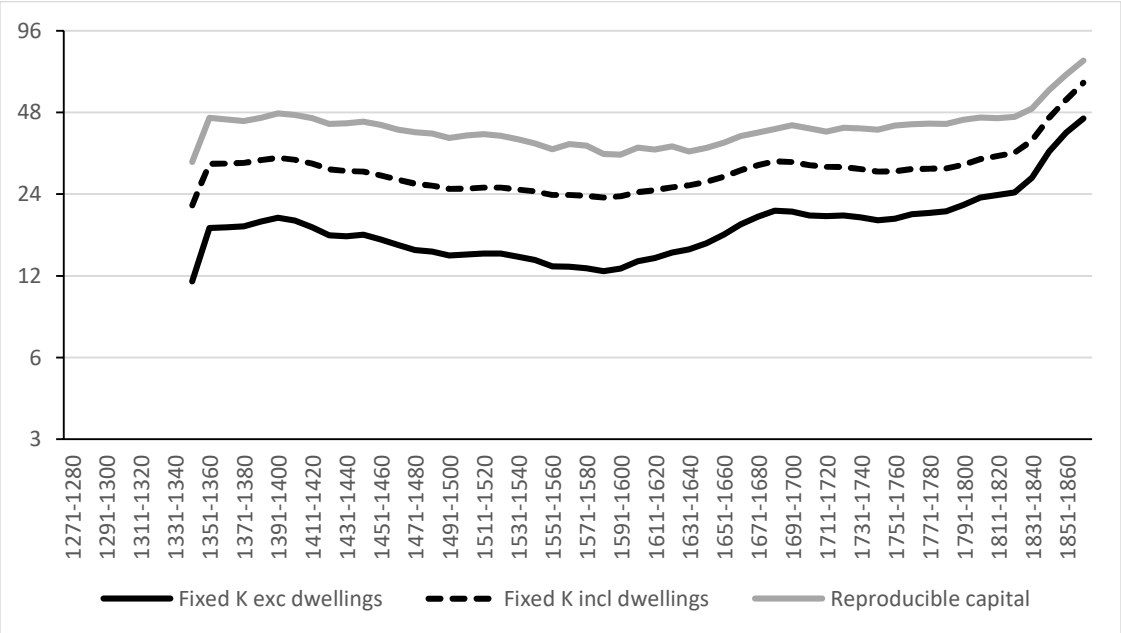
Sources and notes: Feinstein (1978); Crafts (1985); Derived from Appendix, with GDP from Broadberry et al. (2015). Feinstein and Crafts report shares at constant 1851-60 prices. Results for this study are at current prices.

FIGURE 1: Price indices for capital goods, 1270-1870 (1700=100)



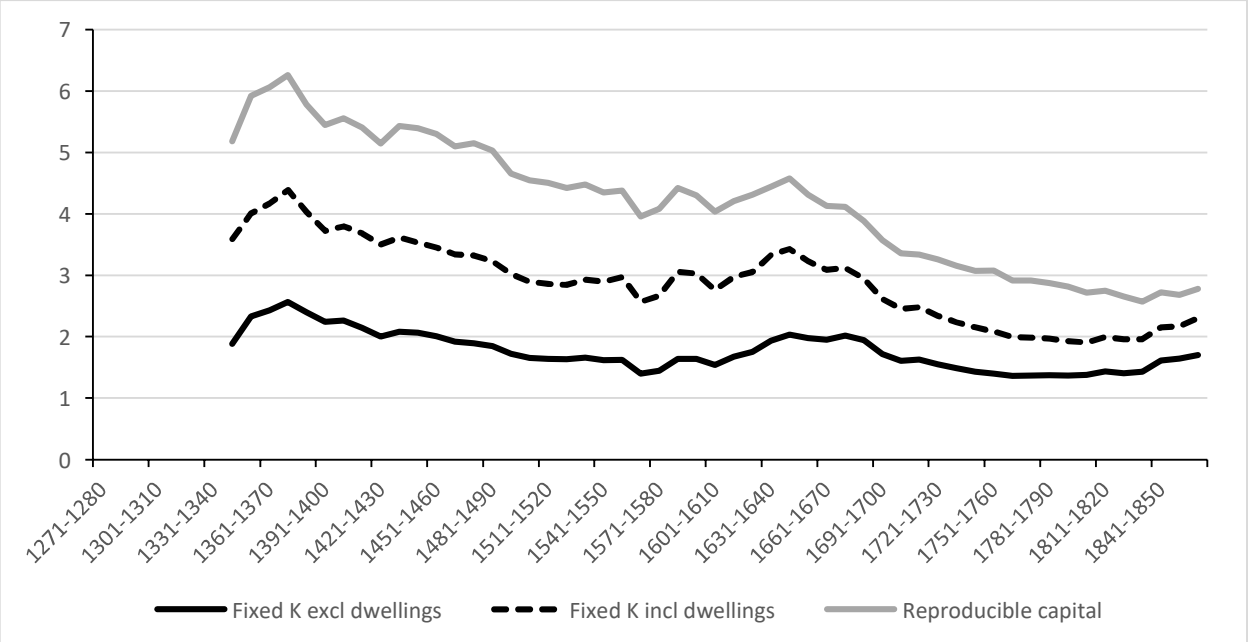
Source: See Appendix.

FIGURE 2: Capital per head of the population, 1270-1870 (£ at constant 1700 prices)



*Source*s: See text.

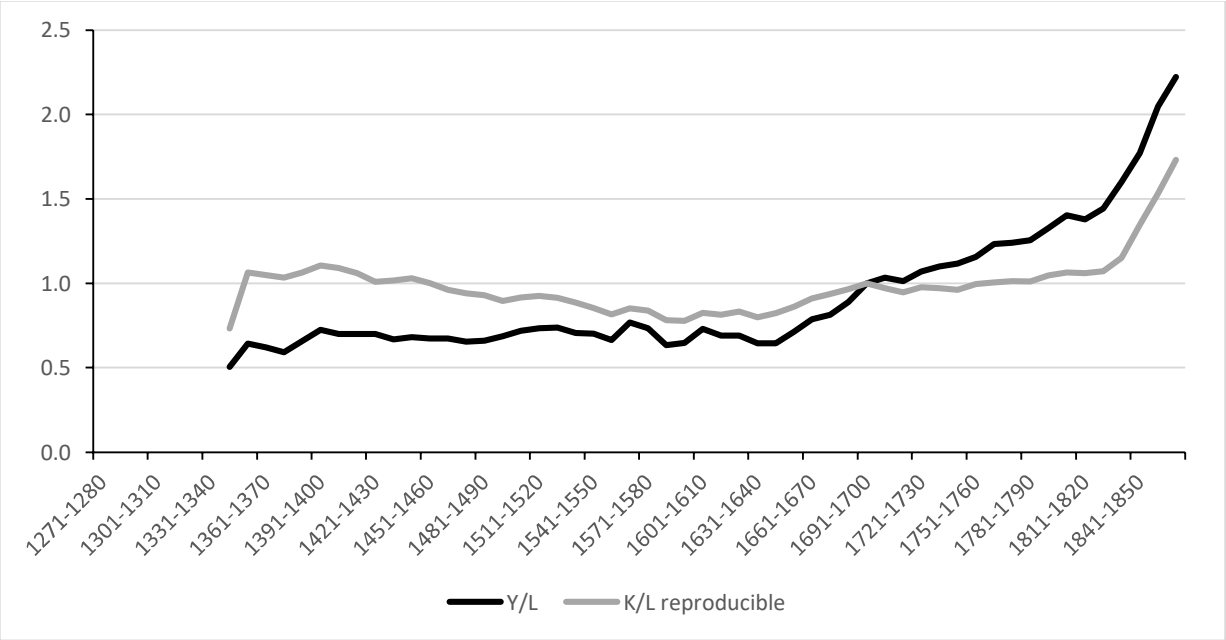
FIGURE 3: Capital-output ratio at constant 1700 prices, 1270-1870



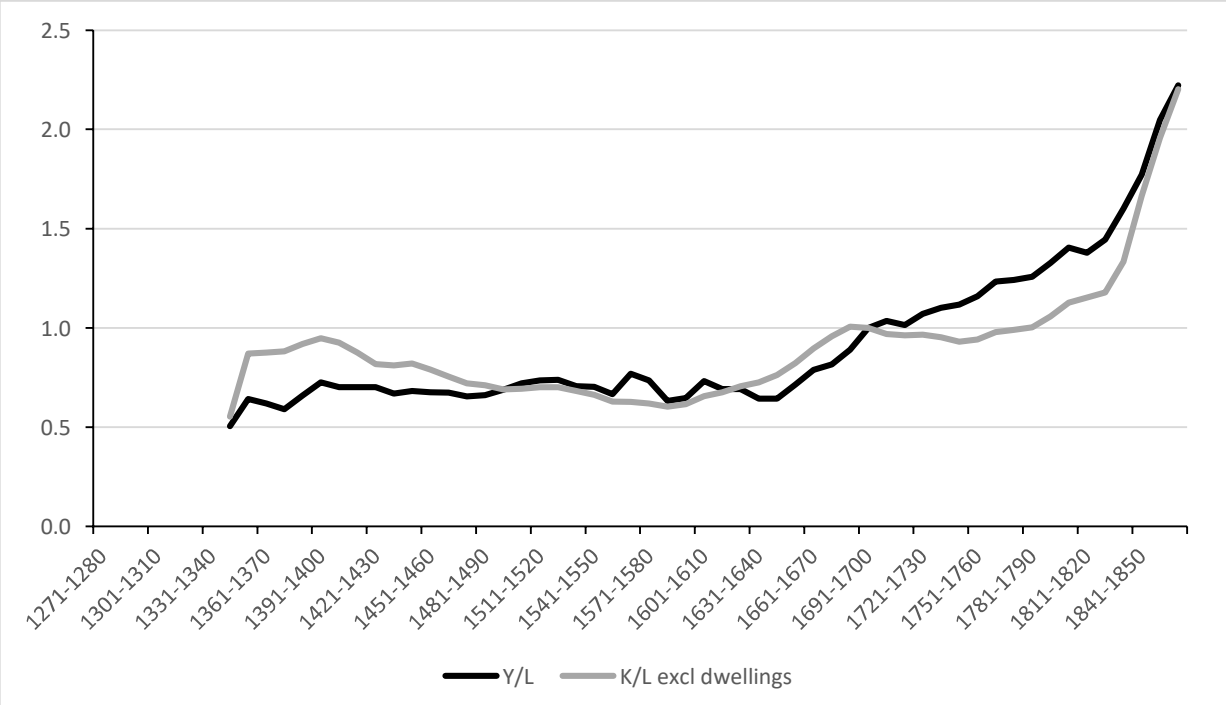
*Source*s: See text.

FIGURE 4: GDP per head and gross fixed capital per head, (1700=1.00)

A. Reproducible capital



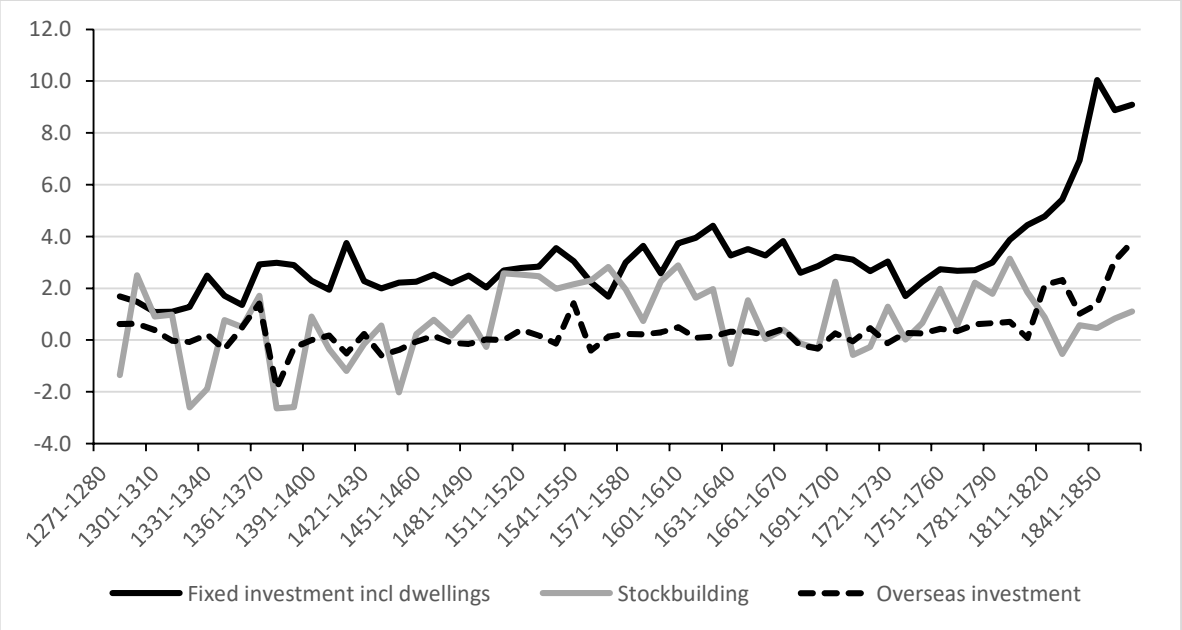
B. Fixed capital excluding dwellings



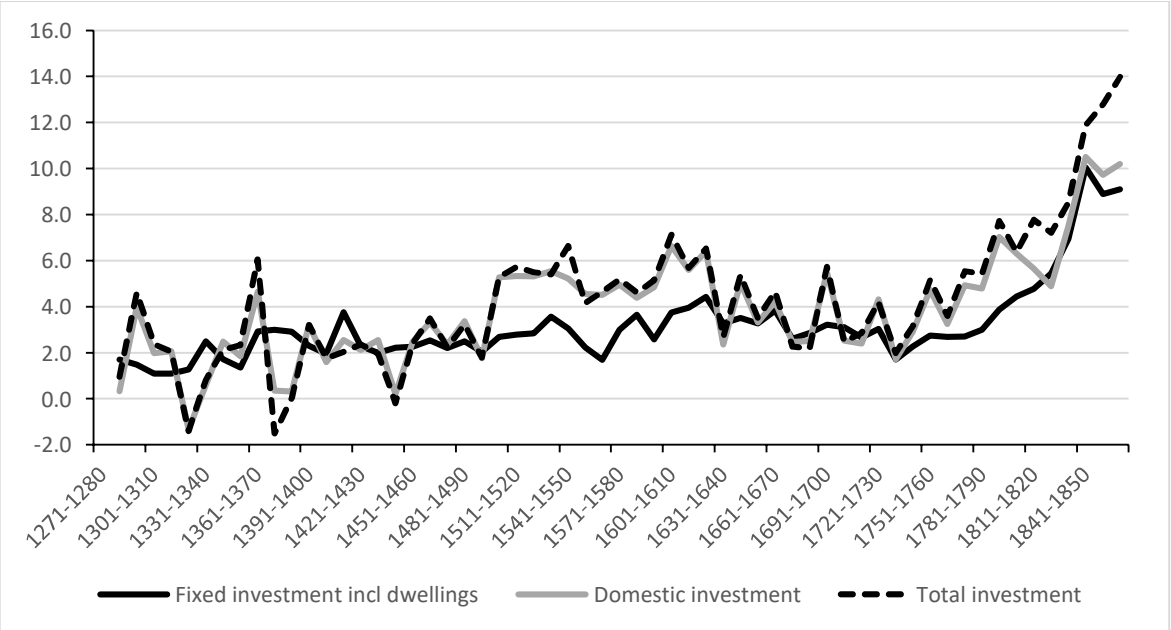
*Source*s: See text.

FIGURE 5: Fixed investment, stockbuilding and overseas investment as shares of GDP at current prices (%)

A. Individual series



B. Cumulated totals



Sources and notes: See text. Domestic investment = fixed investment + stockbuilding; total investment = domestic investment + overseas investment.

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