Office for National Statistics

Article

Volume index of capital services: Estimates to 2013

This article presents new estimates of capital services, which are the preferred measure of capital input into production and for use in analysing and modelling productivity, as well as growth accounting analyses.

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1. Abstract

This article presents new estimates of capital services, which are the preferred measure of capital input into production and for use in analysing and modelling productivity, as well as growth accounting analyses. New estimates are provided up to 2013 and previous estimates have been revised, reflecting revisions to source data and methodological changes. Estimates of capital services now include services flowing from newly capitalised assets including R&D and weapons systems, and source data are more closely aligned with those used in ONS estimates of net capital stocks. Capital services estimates in this article are incorporated in growth accounting estimates in an accompanying article (Connors and Franklin, 2015). Estimates for 2013 show that capital services grew at the fastest rate since 2008, but still well below rates of growth prior to the economic downturn of that year. Average growth of capital services has been revised sharply downwards compared with previous estimates; this may account for some of the observed weakness in labour productivity.

2. Acknowledgements

The authors would like to thank Emily Connors of ONS for research and analytical support in preparing this article, and Gavin Wallis of the Bank of England for providing Tax Adjustment Factors used in the underlying calculations.

3. Introduction

About this release

This article represents reinstatement of a series of articles on capital services that was last published on a stand-alone basis in 2011. This follows reinstatement of ONS estimates of capital stocks and consumption of fixed capital in July 2014 and November 2014, which in turn reflects quality improvements in the underlying asset accumulation estimates that are the principal source for both sets of estimates.

Estimates of capital services are presented for the whole economy, the market sector and ten industry groups. The time series properties of these series differ from the evolution of capital stocks which are compiled and aggregated differently. Conceptually, capital services measure flows of capital into production, whereas capital stocks measure wealth embodied in capital assets.

Capital services are informative in their own right, not least in terms of differences in time series properties compared with the widely used conventional measures of capital stocks [1]. However, the main motivation for their estimation is as an input to multi-factor productivity, within a growth accounting framework. This provides a decomposition of movements of growth of economic output and labour productivity into contributions due to changes in inputs of factors of production (labour and capital) and a residual component described as multi-factor productivity (MFP). Movements in capital services rather than movements in the National Accounts estimates of capital stocks are the preferred measure of changes in capital inputs in this framework (Harris and Drinkwater, 2000). MFP estimates using the capital services estimates in this article are presented in an accompanying article (Connors and Franklin, 2015).

Layout of article

The rest of this article is structured as follows. The flowing section describes what is new in this edition, summarising the main changes to sources and to the methodology. More information is provided in Appendix 1.

The next section provides some context by drawing comparisons between movements in capital as measured by capital services and those implied from the ONS capital stock estimates. This section also provides some technical material on differences in compilation between the two sets of estimates. Next, three results sections present results at the aggregate level, industry level, and asset level. Results are presented as cumulative contributions to percentage growth by the components of each index. These provide a convenient arithmetic decomposition of where growth is coming from, but should not be confused with indices, and cumulative percentage changes will not be equal to index changes. A full set of underlying estimates of growth rates and weights for all component industries and assets in the capital services system can be found in the reference table (256 Kb Excel sheet) component of this release.

Following on from results, the article examines revisions from previous estimates. As noted above, stand-alone estimates of capital services were last published in 2011 but indicative estimates were compiled for the purpose of estimating MFP in September 2012 and most recently in January 2014. It is the latter estimates that are the comparator for the revisions section, which examines revisions to source data and how these have impacted on estimates of capital services.

The last section in the main article is a short section on next steps. As always, feedback from users is welcome. Contact details are provided in the Background Notes. Appendix 1 provides detailed notes on the methods and sources used in producing the estimates in this article.

Notes for introduction

1. Capital stocks are presented in monetary units, in current prices and chained volume measures (CVMs), and gross and net of depreciation. Capital services are unit-less volume estimates and are presented as indices and changes in indices. The relevant comparison, as discussed further below, is between changes in capital services and changes in net CVM capital stocks.

4. What's new?

This article embodies important changes to sources as well as one noteworthy change to the methodology.

The main changes to sources are twofold. First, subject to some caveats noted in the following section, detailed gross fixed capital formation (GFCF) estimates by industry and asset have been aligned with those used in the November 2014 edition of the ONS capital stocks and consumption of fixed capital release. This provides long time series of GFCF estimates on a SIC07 industry breakdown. Previously, such estimates were not available prior to 1997, and the post-1997 estimates were of poor quality.

Secondly, in accordance with ESA2010 accounting standards, BB14 recognises new forms of assets, of which the most important are research and development (R&D) and weapons systems. Additionally, in this release cultivated assets have been identified as a separate asset, having previously been incorporated within Other machinery and equipment. The impact of the latter change is trivial, but the impact of the former produces considerably different results in certain industries. Further information is provided in the Revisions section below.

It should be noted that in some cases the new source data display radically different industry allocations of GFCF from earlier estimates. The extent of these revisions is discussed further in the Revisions section below. It should also be noted that the source data on GFCF by industry and asset used here and in the ONS capital stocks release differ in some instances from the industry by asset breakdown published in the Business Investment release on 30 September 2014.

Turning to methodology, the only material change is that we have used asset-specific tax adjustment factors produced by Gavin Wallis of the Bank of England. These adjust user costs of capital, which enter as weights in the capital services system, for tax incentives or disincentives for investing in certain assets.

5. Comparing capital services and capital stocks

The conceptual difference between capital service estimates and net capital stocks is that the former aims to directly identify the flow of services into production from capital goods, while the latter is primarily a wealth measure of the value or volume of capital goods, and does not attempt to measure how they are used in productive activity. As a simple example, a building purchased for £1m would be expected to contribute less to production over a single time period than £1m of ICT equipment over the same period, because the ICT equipment will use its productive potential up much more quickly, and because its purchase price will likely fall dramatically.

These factors (as well as the estimated rate of return on the asset) combine to represent the cost of owning the computer to the user, and because we assume that the costs of employing factors of production are equal to their marginal products (their contribution to production, or more simply, what they give back in profits) over the time period.

Differences in sources

The principal differences between the source data used for ONS capital stocks estimates and those used in this release are:

- The capital stocks source data employs a common asset deflator across industries, whereas the capital services system employs differential deflators across industries for the principal tangible assets. Differential deflators are taken from ONS legacy systems and benchmarked to BB14 aggregate asset deflators. Legacy estimates are available up to 2009. Beyond 2009, industry deflator movements are assumed to evolve towards the movement of the aggregate asset deflator.

- As noted above there are some differences in asset composition between the two systems. In particular, the capital services system excludes dwellings, treats ICT equipment as a separate asset class and divides software into own-account and purchased components.

- Additionally, ONS capital stocks estimates use a single deflator for software, based on price growth of computer consultancy, programming and related activities. In the capital services system, the own-account deflator is the same as the aggregate BB14 software deflator, while the purchased software deflator is a weighting of the own-account deflator and a US deflator for purchased pre-packaged software, converted to sterling using market exchange rates. One implication is that real investment in software evolves differently in the capital services source data as compared with the National Accounts. Over the period 1997-2013, real software investment grows around 1% a year faster in the capital services system than as reported in the National Accounts[1].

Differences in methodology

Conceptually, capital services estimates are flow estimates which depend upon estimates of stocks of productive capital. Stocks of productive capital are compiled by assuming that past investments follow an age efficiency profile, rather than an age price profile, as is used in the ONS capital stocks framework. This is primarily because, as noted in the OECD manual ‘Measuring Capital’:

‘A one year old truck may have lost 20 per cent of its market value, but it has not necessarily lost 20 per cent of its capacity to transport goods from one place to another’. (OECD, 2001a)

This implies that we are interested in estimating the way that accumulated investment in different assets combines over time in contributing to the production of economic output, rather than how different assets add to a measure of wealth.

Another primary difference between capital services and conventional capital stocks is that instead of simple addition of capital stocks by industry and by asset to arrive at a total, flows of capital services of different assets in different industries are weighted together according to their marginal productivity, which is determined by rental functions.

Rental functions are used to proxy marginal productivity as in efficient markets, a rational firm would be willing to rent an asset over a time period up to the cash value which it would give back in production. This is analogous to how rational firms would be willing to hire labour over a time period up to the cash value of what that labour would contribute to production. Actual rental markets for the assets in question are scarce, so rental prices have to be imputed. The approach used to impute rental prices requires three main departures from the method used to compute national accounts net capital stock estimates.

Firstly, in computing the net stocks used in the capital services system, a geometric (or declining balance) depreciation is used rather than an arithmetic (straight line) depreciation rate. This causes the age-price and age-efficiency profiles to equalise. Next, a constraint is employed such that at the industry level, imputed rents are equal to national accounts measures of the return to capital (which is defined as gross operating surplus plus the capital share of self employment income). Capital services estimates also use a more detailed asset breakdown than conventional capital stock measures. The more detailed asset breakdown is desirable because of the greater granularity it provides in both growth rates and marginal productivity of different types of assets. For example, in capital services, other machinery and equipment is split to exclude ICT equipment, which is defined as a separate asset. These two asset categories behave quite differently in their growth profile, their life length, their price evolution and their imputed rental value, all of which affect their impact on capital services growth. The capital services system estimates rental functions for each asset, which give relatively more weight to short lived assets such as software and computers and relatively less weight to longer lived assets such as buildings relative to their asset prices.

Figure 1: Comparison of growth of capital services and capital stock (excl dwellings)

Whole economy

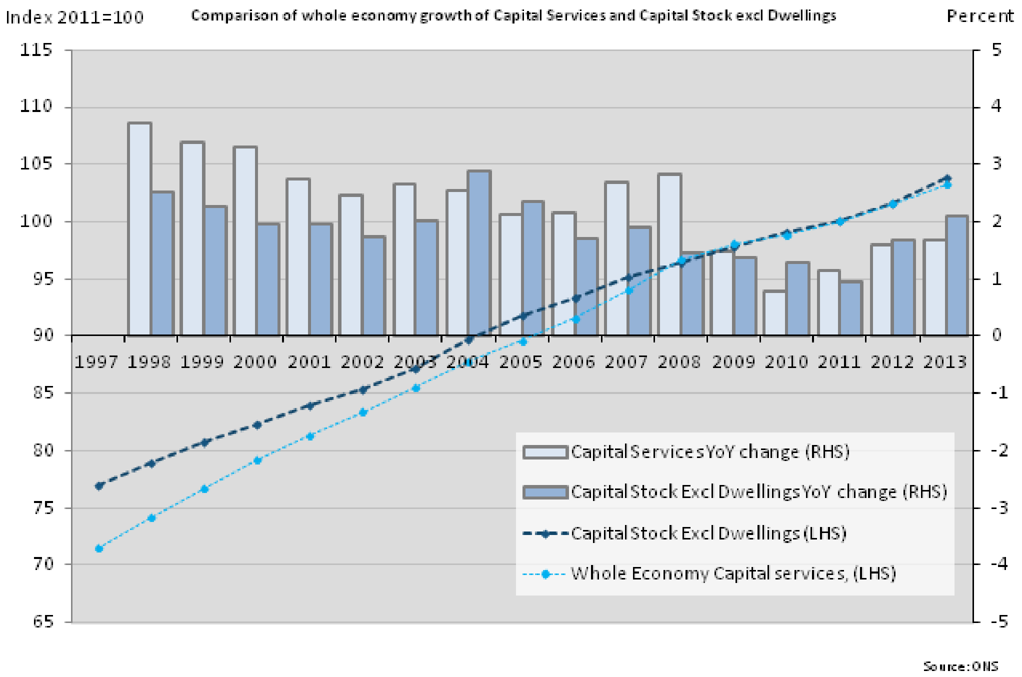
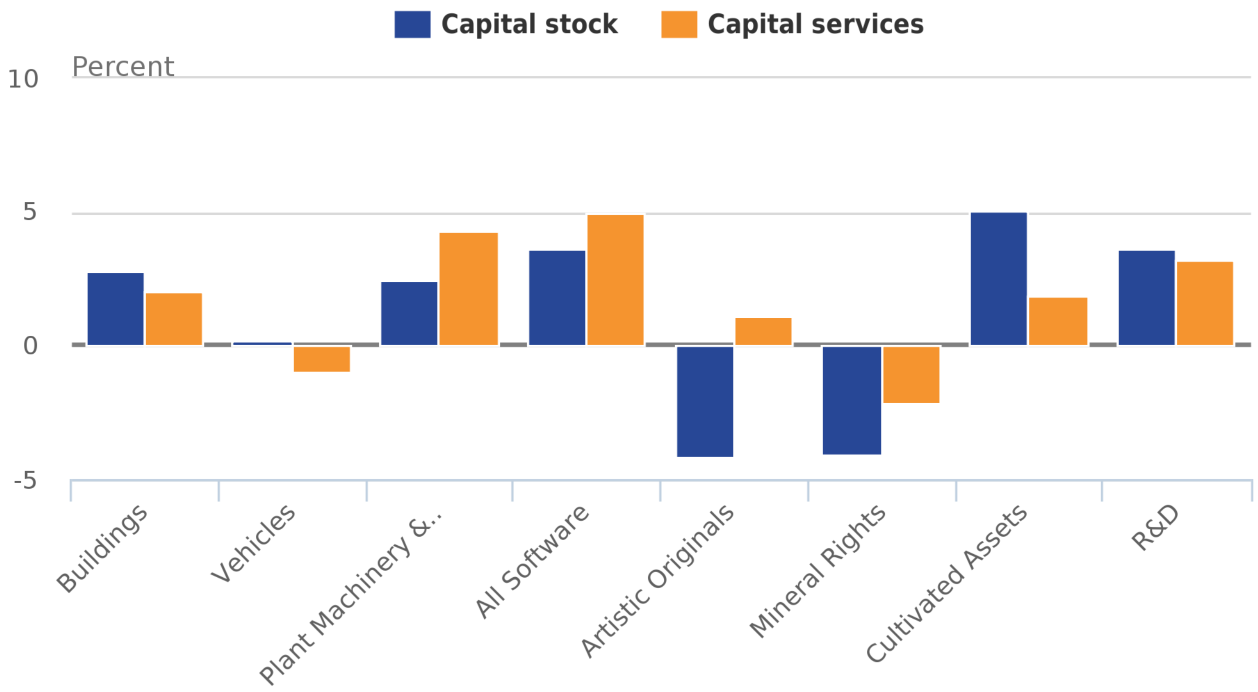


Figure 1 outlines the differences between conventional net capital stocks and capital services, showing that over the 1997-2013 period, capital services grow by more, however over the downturn period (2008-2012), the difference in growth profiles is less pronounced. Figure 2 shows how the different methods of calculation used in producing capital services estimates results in different growth rates from capital stocks by asset. In general, this shows that longer lived assets such as buildings and vehicles grow more quickly using the capital stock methodology, and plant and machinery, computers and software grow more quickly using the capital services methodology.

Figure 2: Compound average growth rate comparisons of capital stock and capital services (97-13)

By asset



Source: Office for National Statistics

The findings of Figure 2 are compounded further by the results seen in Table 1 which shows how different assets contribute to the aggregation of the different measures. The table shows the relative share in the total capital stock of assets, and total user cost share of each asset as used in capital services. These values essentially enter as aggregation weights in the two systems and show the relative importance of the different assets. The results show that in capital services, buildings comprise a much smaller share than in the capital stocks system, and software and R&D comprise a much larger share. As software is in general the fastest growing asset in volume terms over time (as well as ICT equipment, where a similarly larger weight is applied in capital services), this goes part way to explaining why capital services measures are likely to show growth outstripping that of capital stock measures.

Table 1: Comparisons of relative size of capital stock of assets and user cost shares

	Wealth share, 2011	User cost share, 2011
Asset description	%	%
Buildings, excluding dwellings	60%	56%
Vehicles	4%	4%
Plant, machinery and computers	27%	20%
Software	3%	12%
Artistic originals	2%	2%
Mineral extraction rights	0%	0%
Cultivated assets	0%	-0%
Research and development	3%	7%

Source: Office for National Statistics

Notes for comparing capital services and capital stocks

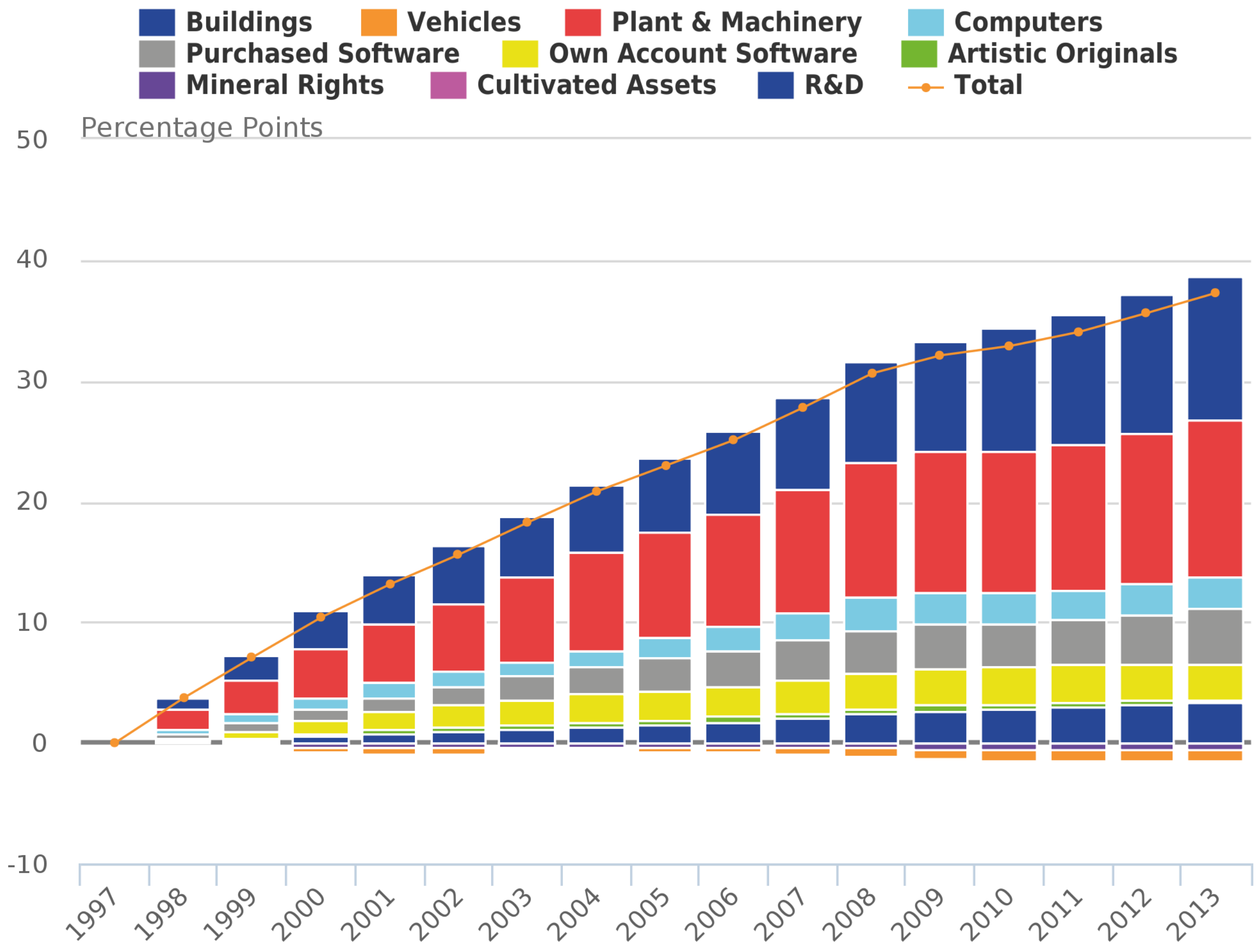
1. A further implication is that, to the extent that real GDP is compiled from the expenditure side, faster growth of software investment would feed into faster GDP growth. This could affect estimates of MFP, although since the weight of software in overall GDP is less than 2%, any such impact on MFP would be very small.

6. Results: whole economy and market sector

Figure 3 shows how different assets have contributed to whole economy growth in capital services. The two largest contributions over time are from buildings and plant and machinery, but the two different types of software and computers, together comprising of IT capital also contribute a significant amount over the time series. R&D has been included in these measures of capital services for the first time, and its inclusion provides a substantial boost to growth over time. The largest negative contribution to growth comes from vehicles, but this does not significantly affect the aggregate over the whole time series. Negative contributions also come from both mineral rights and cultivated assets, however these are very small over time.

Figure 3: Cumulative contributions to growth in capital services by asset

Whole economy

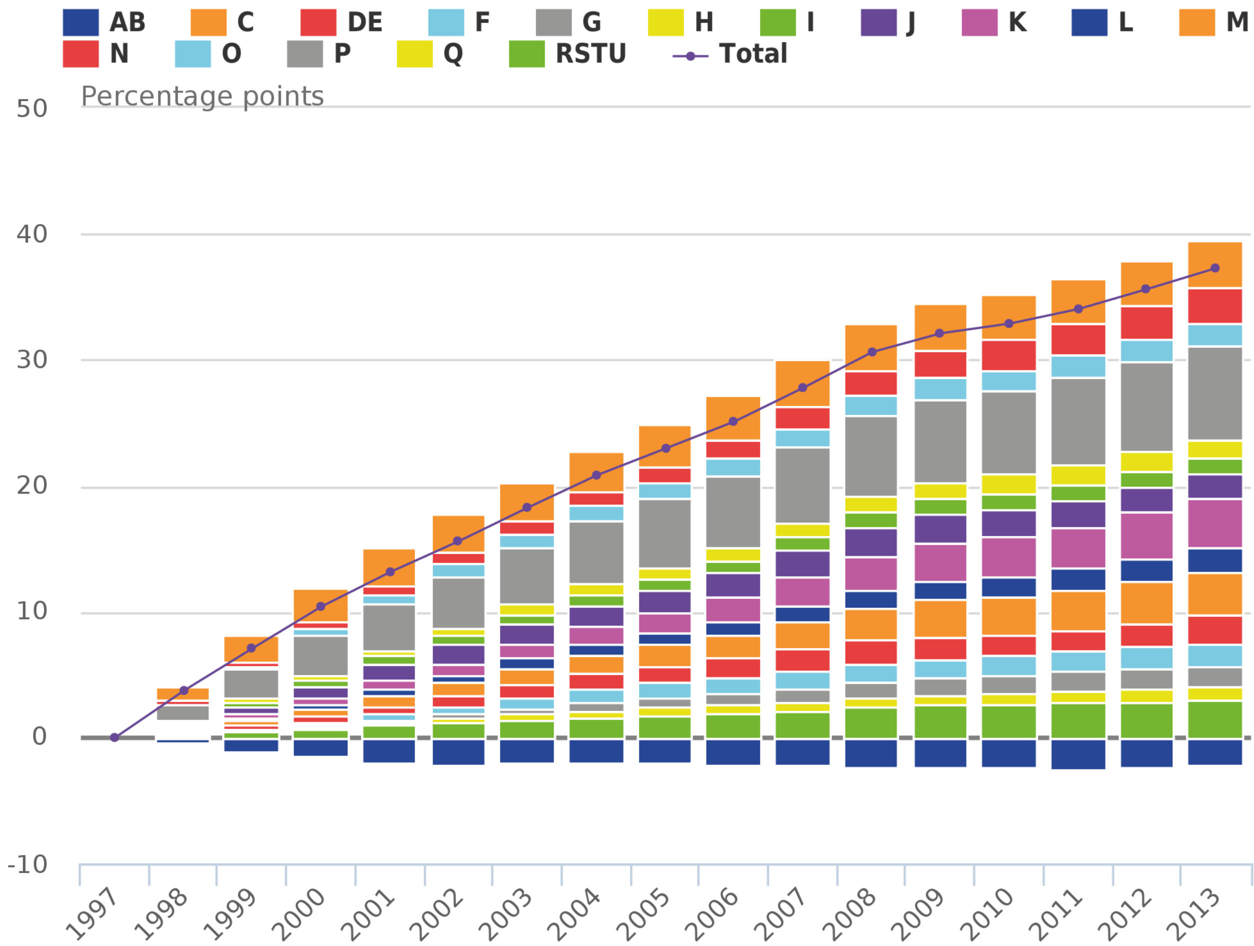


Source: Office for National Statistics

Capital services growth contributions from different industries are shown in Figure 4. These figures show that all industry groupings with the exception of the "other production" ABDE aggregate provide positive contributions over the whole period. The negative contribution of ABDE may be largely driven by industry B, where declining north sea oil stocks have led to a substantial fall in services from machinery and equipment.

Figure 4: Cumulative contributions to growth of capital services by industry

Whole economy

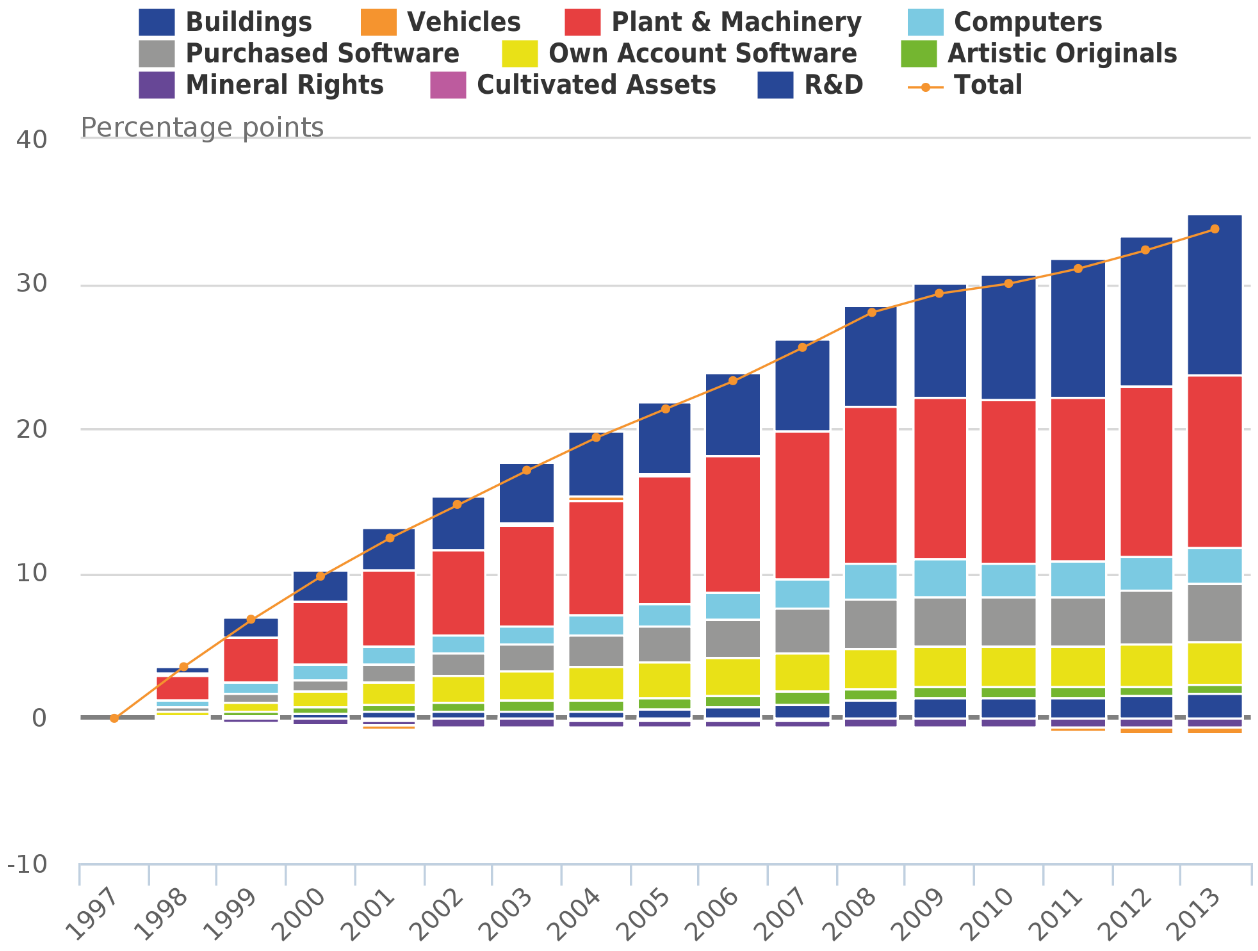


Source: Office for National Statistics

Figure 5 shows contributions to Market Sector capital services growth, which is notably more muted than for whole economy capital services. This is likely to be a result of a few factors. Firstly, R&D expenditure is more intensive in the non-market sector than in the market sector, resulting in smaller effects on growth from R&D in the market sector. The market sector also appears to be less software intensive than the whole economy, particularly in the own-account component. Measurement of market sector also goes part way to explaining the differences. Market sector capital services are calculated at the whole market sector level, rather than the aggregate of capital services from the market sector component of each industry, as these data are not currently available. This results in lost industry granularity from the index, which is likely to mute growth rates.

Figure 5: Cumulative contributions to growth of capital services by asset

Market sector



Source: Office for National Statistics

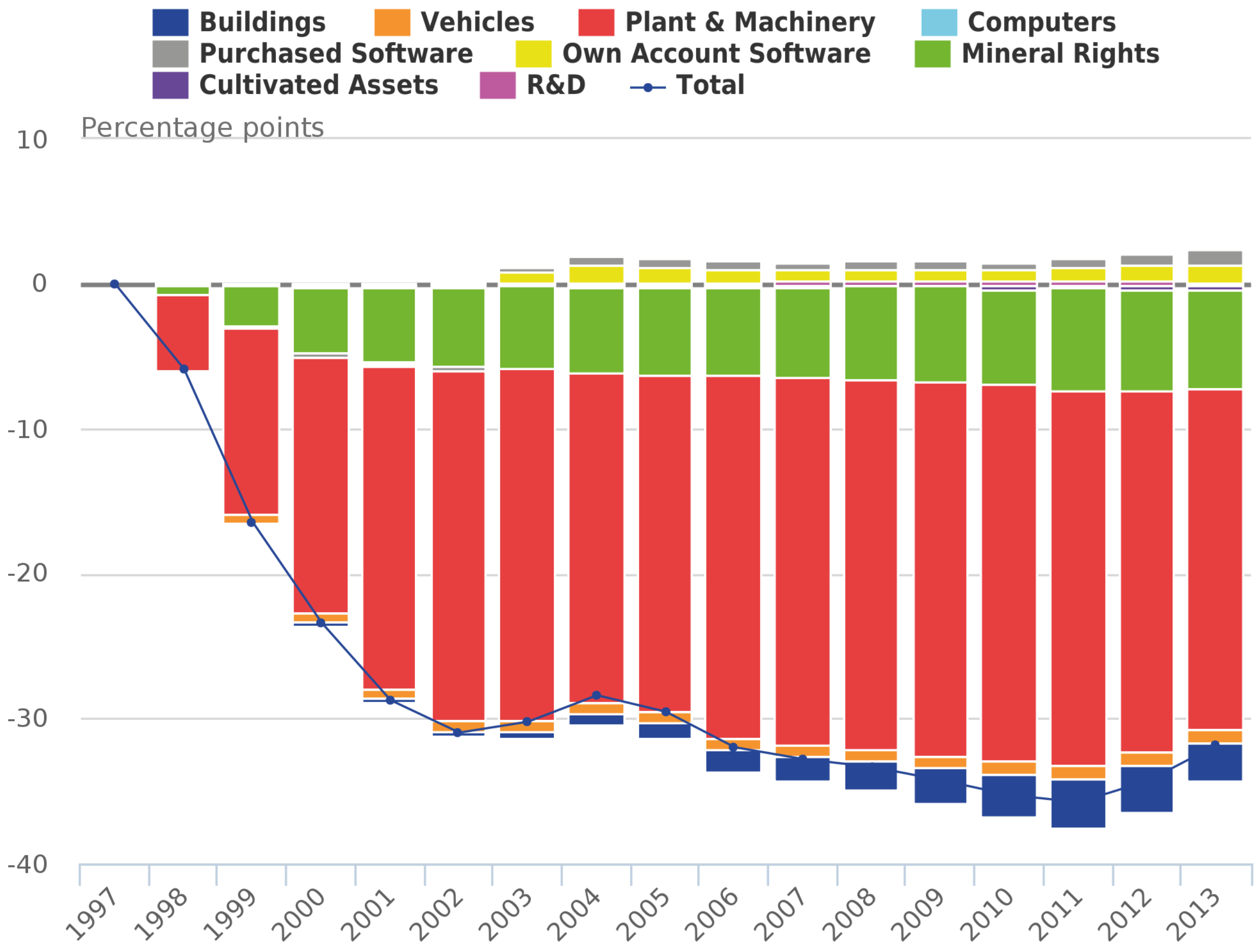
7. Results by industry

This section explores how different assets contribute to the capital services from each industry or industry group. The results broadly show that there is a great deal of difference in the asset composition of each industries capital input, and that in many of the larger industries, computers, software and R&D are major contributors to the growth of capital services, despite comprising only a relatively small share of the capital stock of each industry.

Figure 6 shows contributions to growth in capital services of industry aggregate AB, which comprises of the agriculture, forestry and fishing industry and the mining and quarrying industry. Most notable here are the large negative contributions from most assets, in particular from plant and machinery. As noted earlier, this is likely to represent the large falls in north sea oil and gas reserves from the mining and quarrying industry, as extracting these resources is a machinery intensive activity, and falling reserves may have encouraged companies to not replace machinery and scale back activities. This view is supported by the negative contribution of mineral extraction rights to capital services growth, which occur over the whole period 1997-2013, which accumulate to more than a 5 percentage point negative contribution. The only two assets providing non-trivial positive contributions are both types of software. Very little software investment occurs in agriculture forestry and fishing, so this is likely to be a result of software activity in the mining and quarrying industry.

Figure 6: Cumulative contributions to growth of capital services by industry

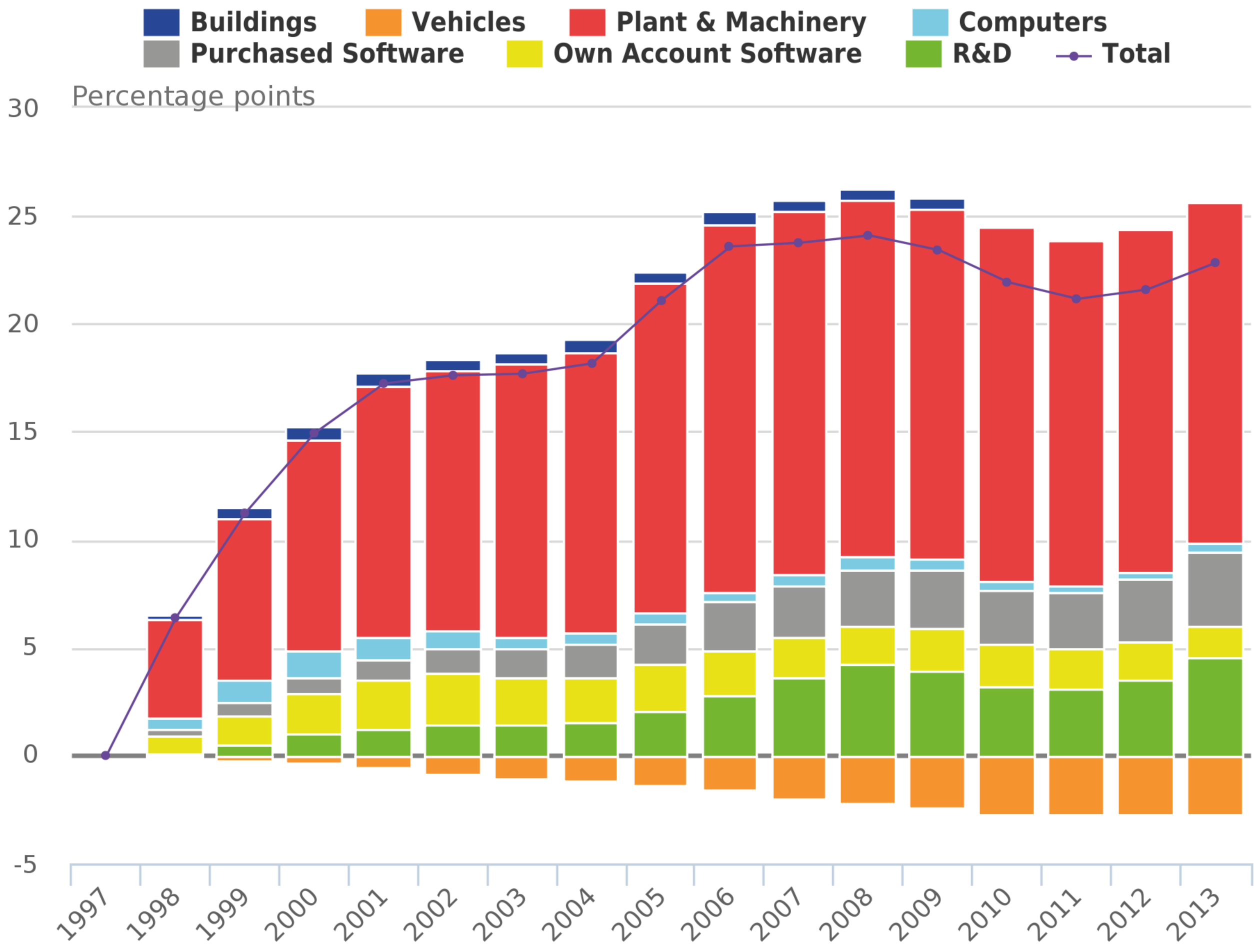
Agriculture, forestry and Fishing; Mining and quarrying



Source: Office for National Statistics

Figure 7: Cumulative contributions to growth of capital services by industry

Manufacturing



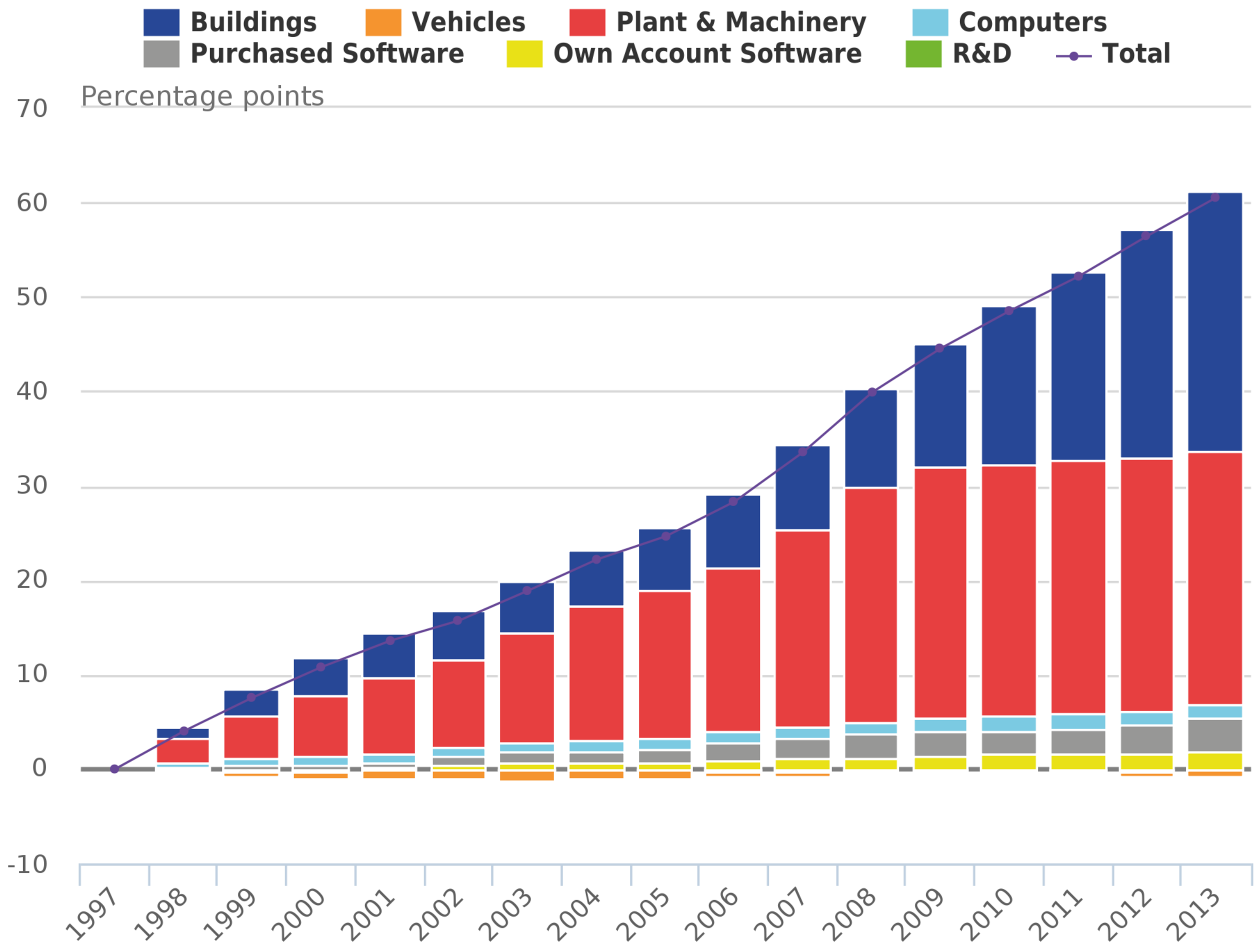
Source: Office for National Statistics

Figure 7 shows that manufacturing capital services grew strongly until around 2001, when growth continued, albeit muted until the 2008 downturn, when they fell until 2011 and have shown muted growth since. Interestingly for this relatively large industry, buildings have contributed a trivial amount to aggregate capital services, and vehicles constitute a significant negative contribution. The largest contributor has been plant and machinery, which meets a priori expectations about the structure of the manufacturing industry, however the three intangible assets used in manufacturing; R&D, and the two types of software, all make substantial contributions to growth.

Figure 8 shows that capital services in the energy, water and sewerage industries have grown steadily and uninterrupted since 1997. In this industry, growth is dominated by contributions from the traditional productive assets; buildings and plant and machinery. Despite this, software and R&D provide non-trivial positive contributions which have grown from very little in the back series, suggesting that the industry has become more dependent on high-tech procedures since the late 1990s.

Figure 8: Cumulative contributions to growth of capital services by industry

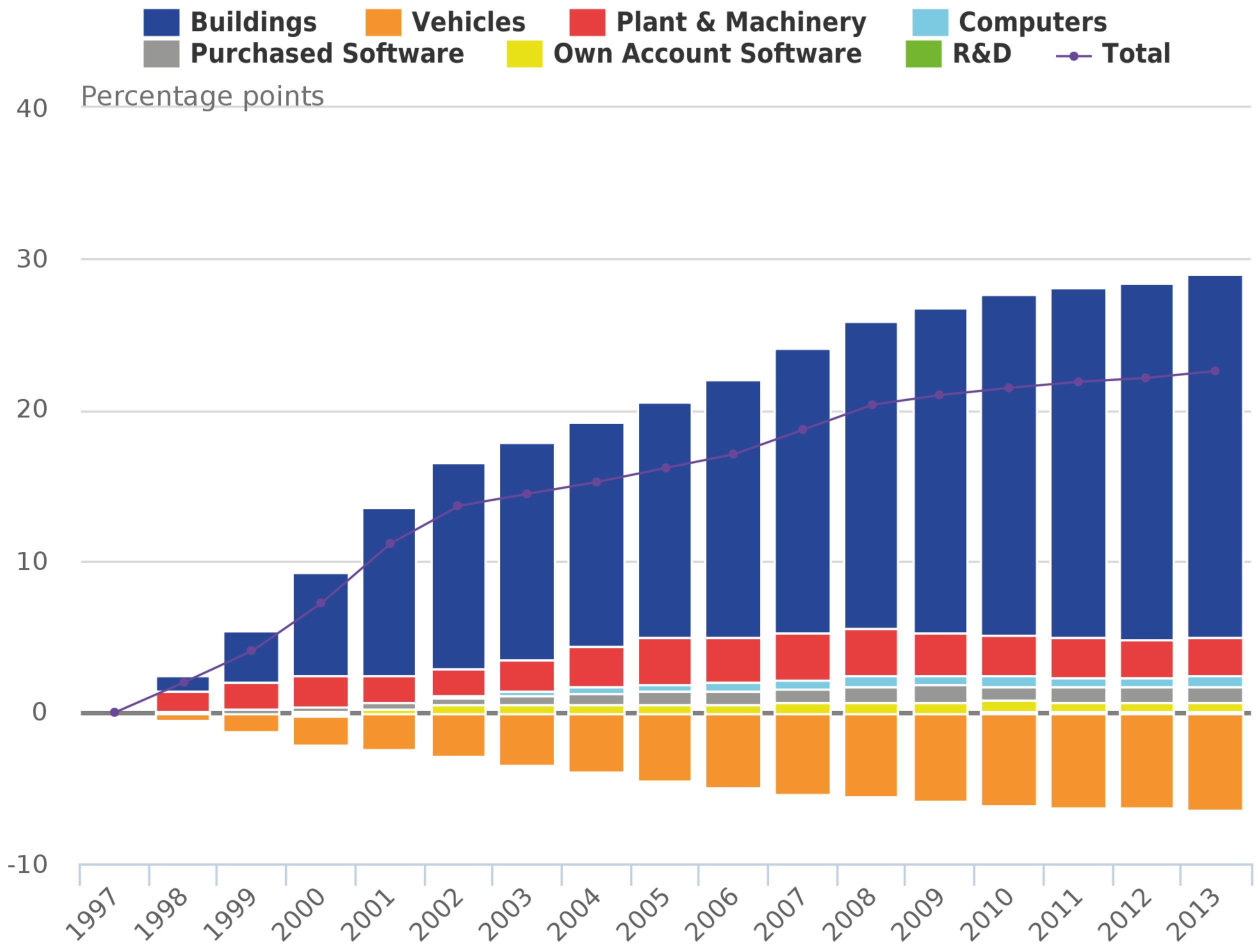
Electricity, gas, steam and air conditioning supply; Water supply, sewerage, waste management and remediation activities



Source: Office for National Statistics

Figure 9: Cumulative contributions to growth of capital services by industry

Construction



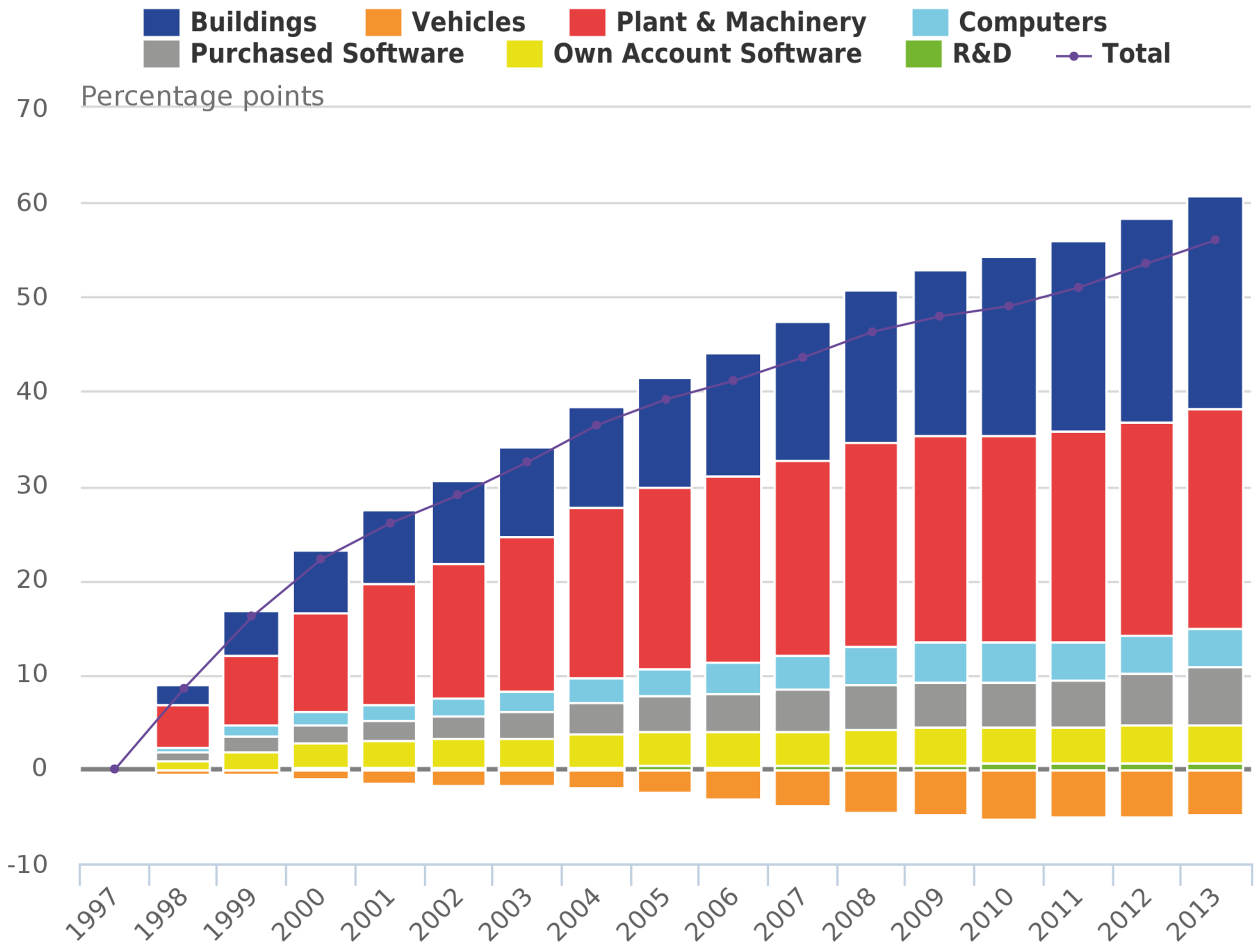
Source: Office for National Statistics

Figure 9 shows that capital services in the construction industry have grown over the whole period 1997-2013, but that growth became muted after 2002. Growth is dominated by buildings as a result of large observed investment from the industry, the rationale is that this comes from investment in storage facilities for construction equipment. The aggregate for construction closely tracks the buildings contribution. Other positive contributions are made by both types of software and computers, suggesting that the construction industry may have become more dependent on computer aided techniques.

Contributions to capital services growth of the retail and wholesale industry are fairly balanced, and are shown in Figure 10. Unsurprisingly for an industry heavily dependent on showrooms and warehouses, plant and machinery and buildings constitute the largest contributions, however computers and software have also made substantial contributions. Negative contributions are observed for only vehicles, and this cumulates to a significant drag on the total over the time series.

Figure 10: Cumulative contributions to growth of capital services by industry

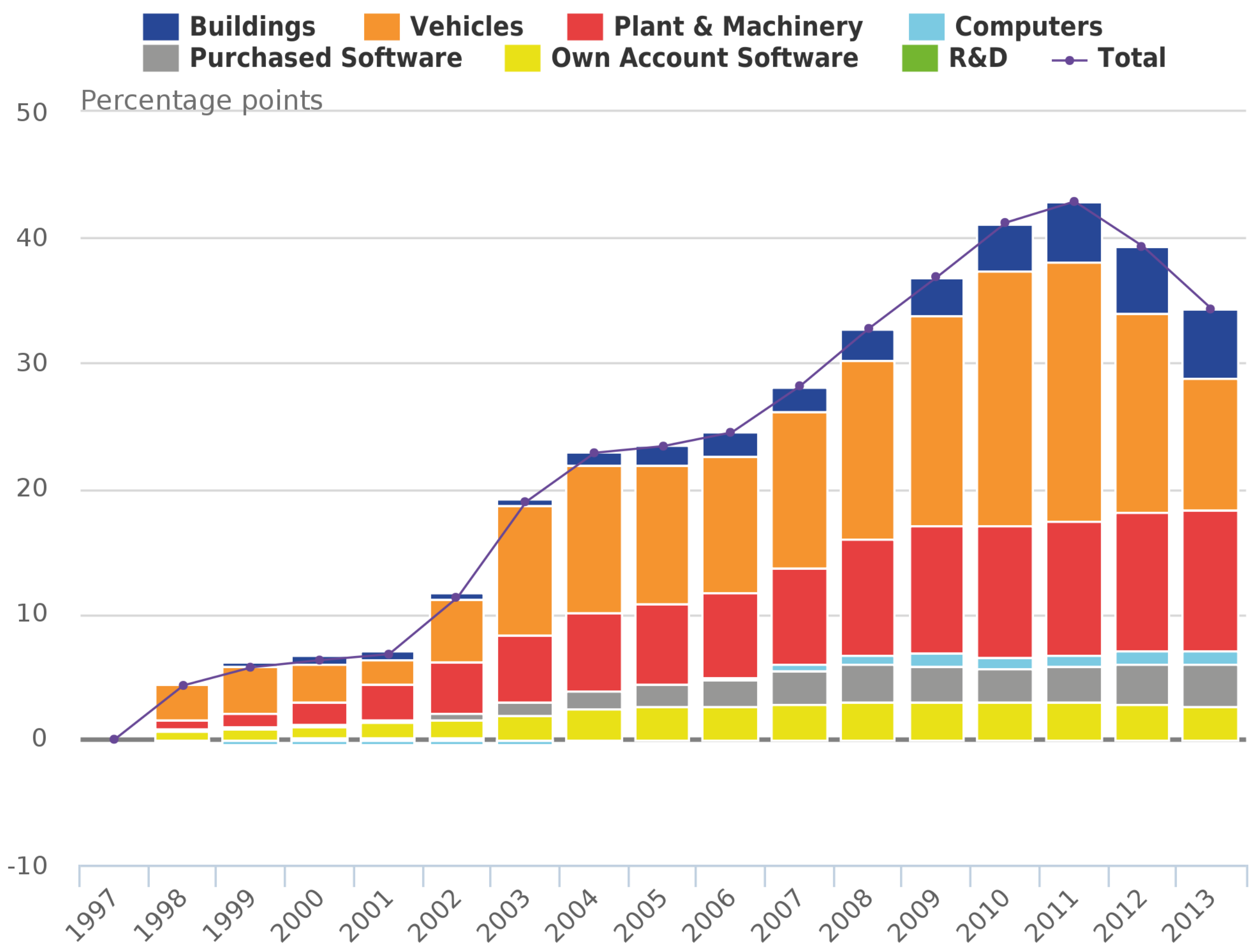
Wholesale and retail trade; repair of motor vehicles and motorcycles



Source: Office for National Statistics

Figure 11: Cumulative contributions to growth of capital services by industry

Transportation and storage



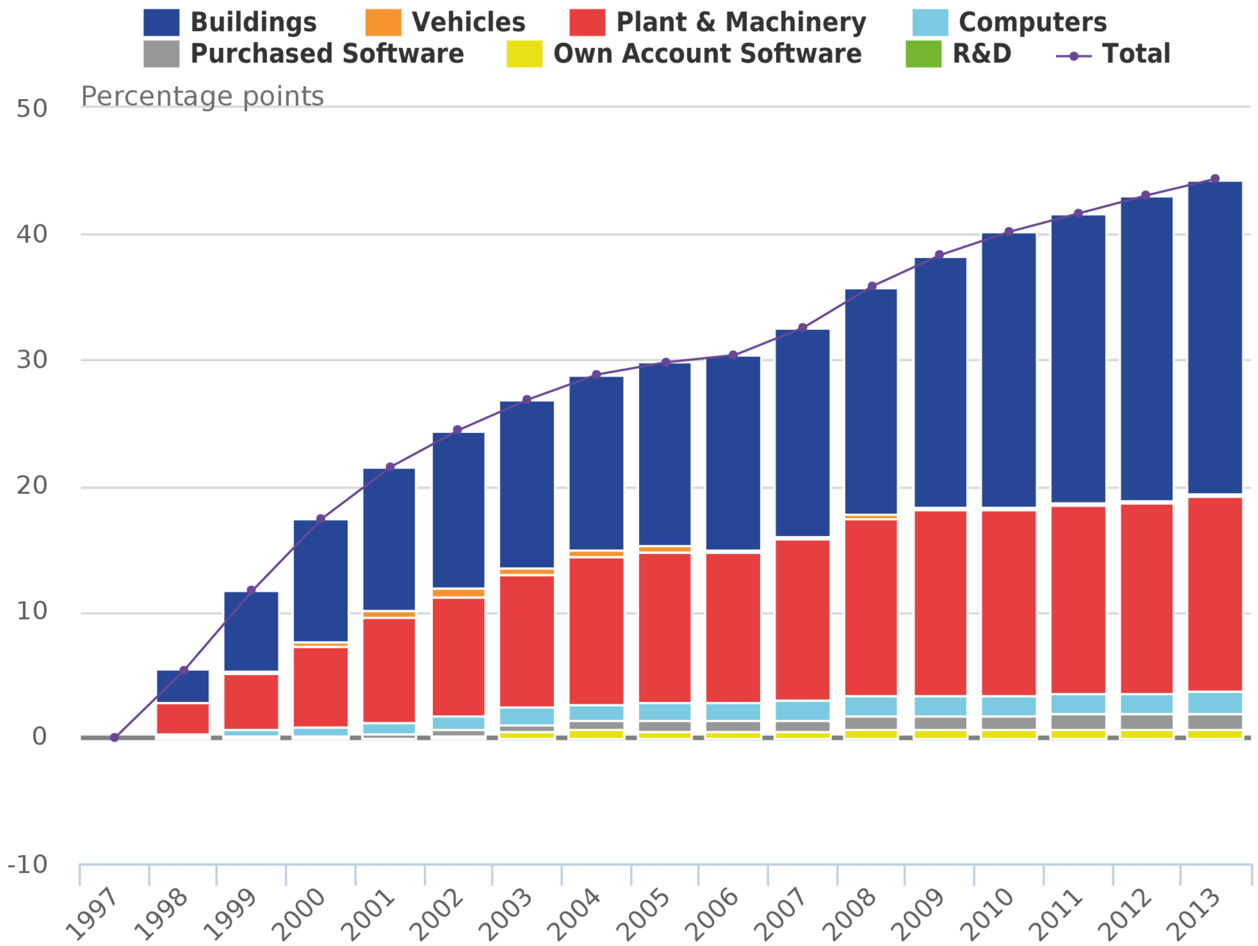
Source: Office for National Statistics

For the transport and storage industry, Figure 11 shows little contribution from buildings. This is likely to reflect the relative shares of the transport components compared to the storage components, with buildings likely to embody a much larger share of capital services growth in the storage industry. This view is compounded by the large positive contribution made by vehicles, which likely dominate capital services in the larger transportation industry. Contributions from vehicles also explain most of the downward movement since 2011 in the aggregate, as well as remaining flat during the mid 2000s. The large fall in contribution from vehicles reflects a large fall in vehicles investment over this time, and as vehicles have a relatively short asset life, this quickly translates into a fall in the productive stock. Plant and machinery provides a steady and significant contribution and computers and software make up the other non-trivial contributions.

Figure 12 shows that contributions from plant and machinery and buildings explain the majority of the growth in the aggregate for the accommodation and food services industry. This is unsurprising given the nature of production processes used in the industry; however a small amount of cumulative growth occurs due to computers and software, likely reflecting increased use of automated booking and ordering systems.

Figure 12: Cumulative contributions to growth of capital services by industry

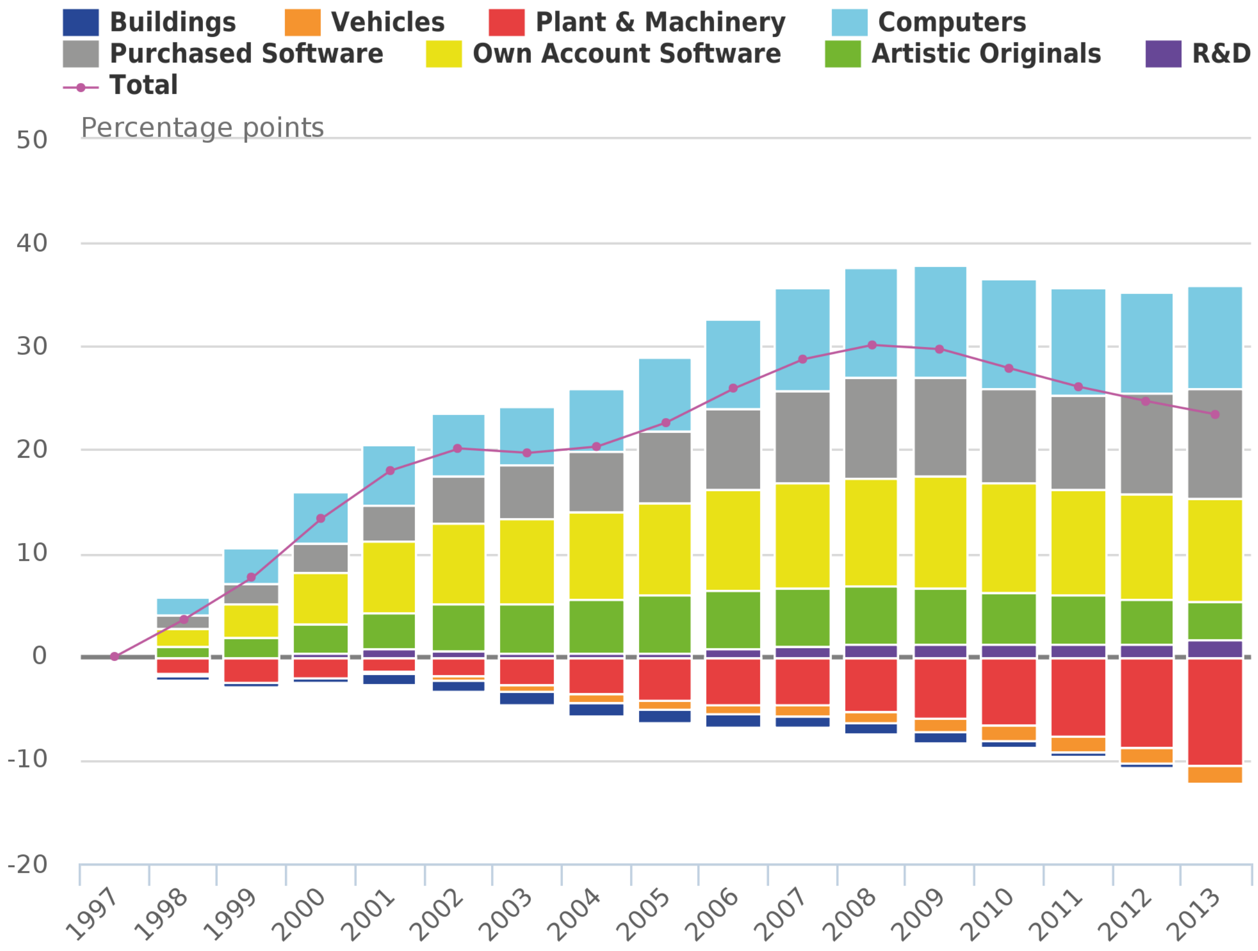
Accommodation and food service activities



Source: Office for National Statistics

Figure 13: Cumulative contributions to growth of capital services by industry

Information and communication



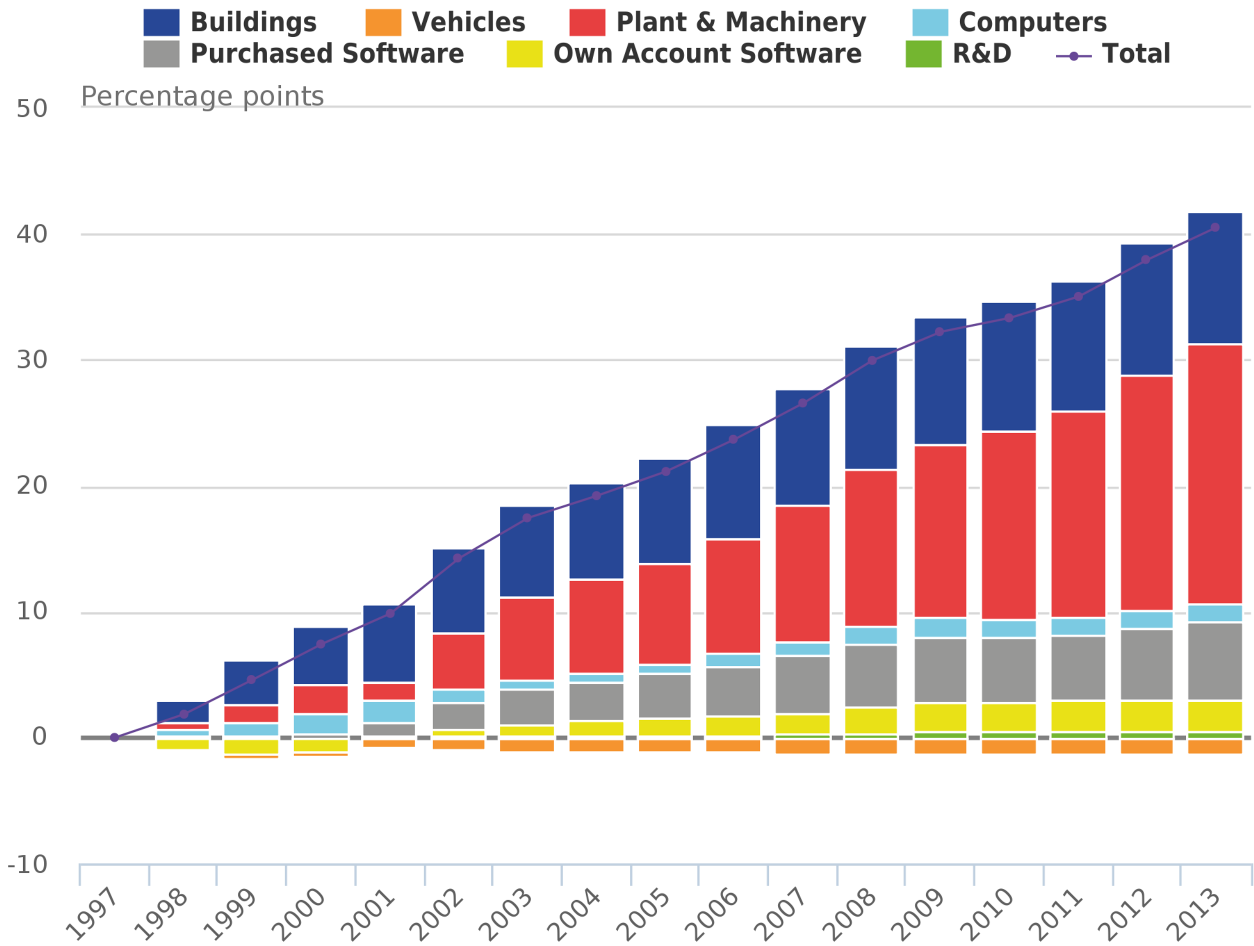
Source: Office for National Statistics

The information and communication industry, shown in Figure 13 is one of few industries where investment in artistic original assets occurs, and so it is capitalised in the productive capital stock and therefore has an impact on capital services. Artistic originals includes investment in producing recorded music, television and film, and the rights to these products are in principle, used to produce output in the same way as any intangible asset. Artistic originals provide a substantial contribution to capital services, however the main positive contributions come from computers, purchased software and most of all, own account software. With the exception of computers, all tangible assets provide negative contributions to the total. This industry illustrates the importance of correctly incorporating intangible assets into any capital input or growth accounting model. Without the contribution of the intangibles, growth of capital services over the period would be little different from zero, and all the contribution from intangible assets would be incorrectly captured as multi-factor productivity growth.

In the finance and insurance industry, shown in Figure 14, buildings and plant and machinery provide the largest contributions to growth. However since around 2001, software of both types have grown substantially, suggesting that the finance industry has become much more reliant on automated systems over the period.

Figure 14: Cumulative contributions to growth of capital services by industry

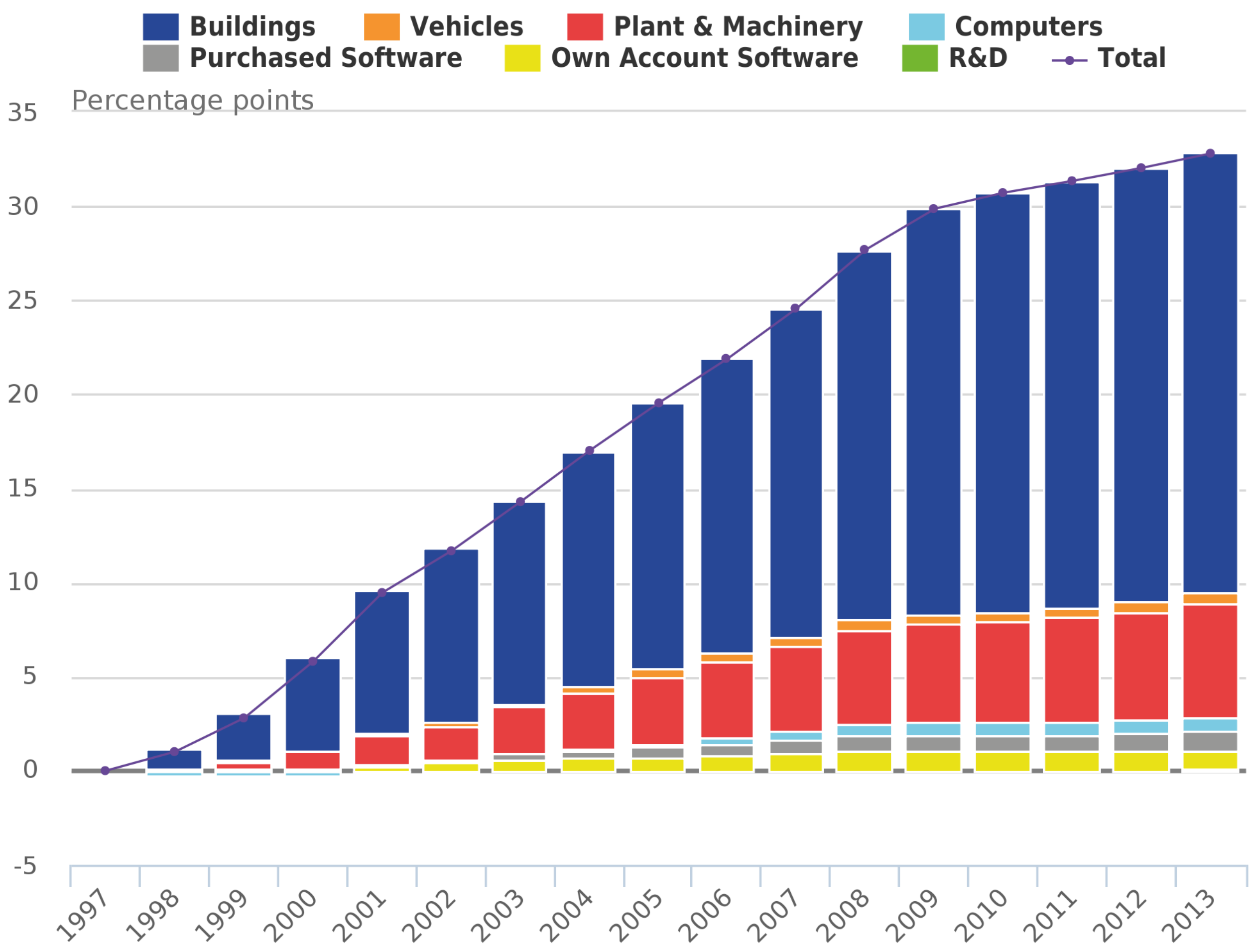
Finance and insurance activities



Source: Office for National Statistics

Figure 15: Cumulative contributions to growth of capital services by industry

Real estate activities



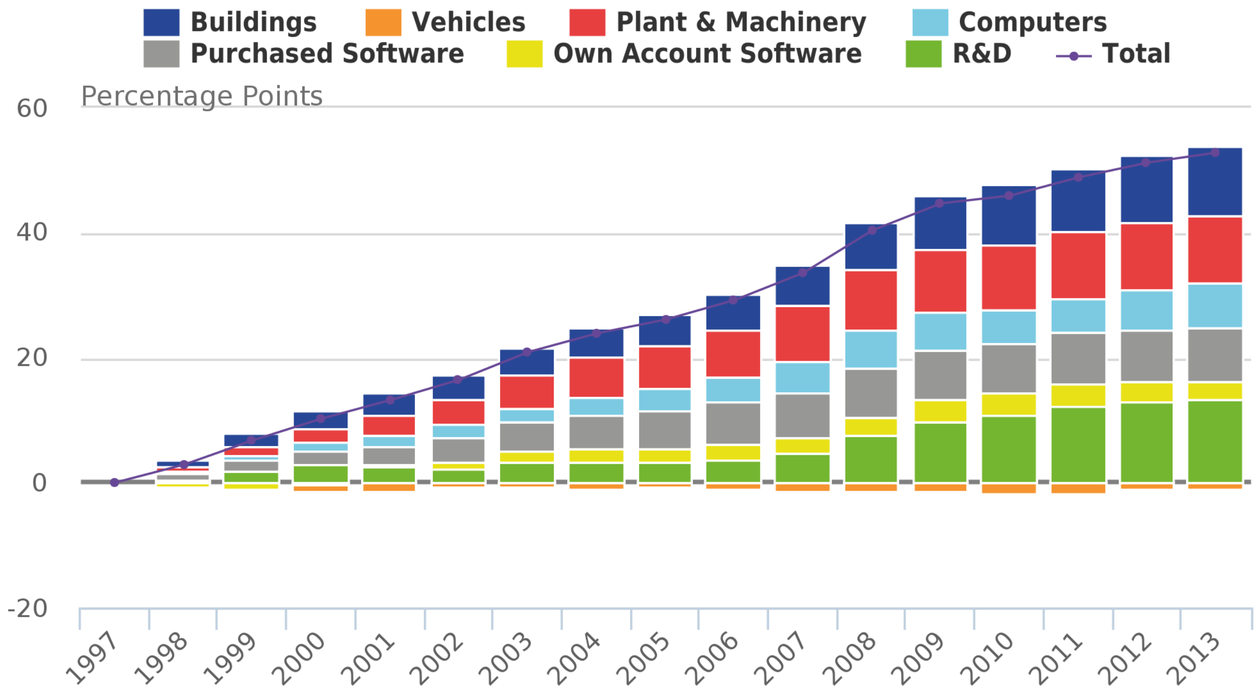
Source: Office for National Statistics

Figure 15 shows that for the real estate industry, the majority of capital services growth is due to investment in buildings, which meets a priori expectations about the nature of the industry. Plant and machinery also contributes a significant share of the increase in capital services, and other small but non-trivial contributions are made by computers and software.

The inclusion of R&D as investment and part of the capital stock is demonstrated to be important in the professional, scientific and technical activities industry (Figure 16), which itself includes the R&D industry (industry 72). R&D accumulates to the largest industry contribution to capital services growth by 2013, with the three ICT assets also making substantial contributions. The traditional assets; plant and machinery and buildings, also make substantial positive contributions, while vehicles has made a small negative contribution.

Figure 16: Cumulative contributions to growth of capital services by industry

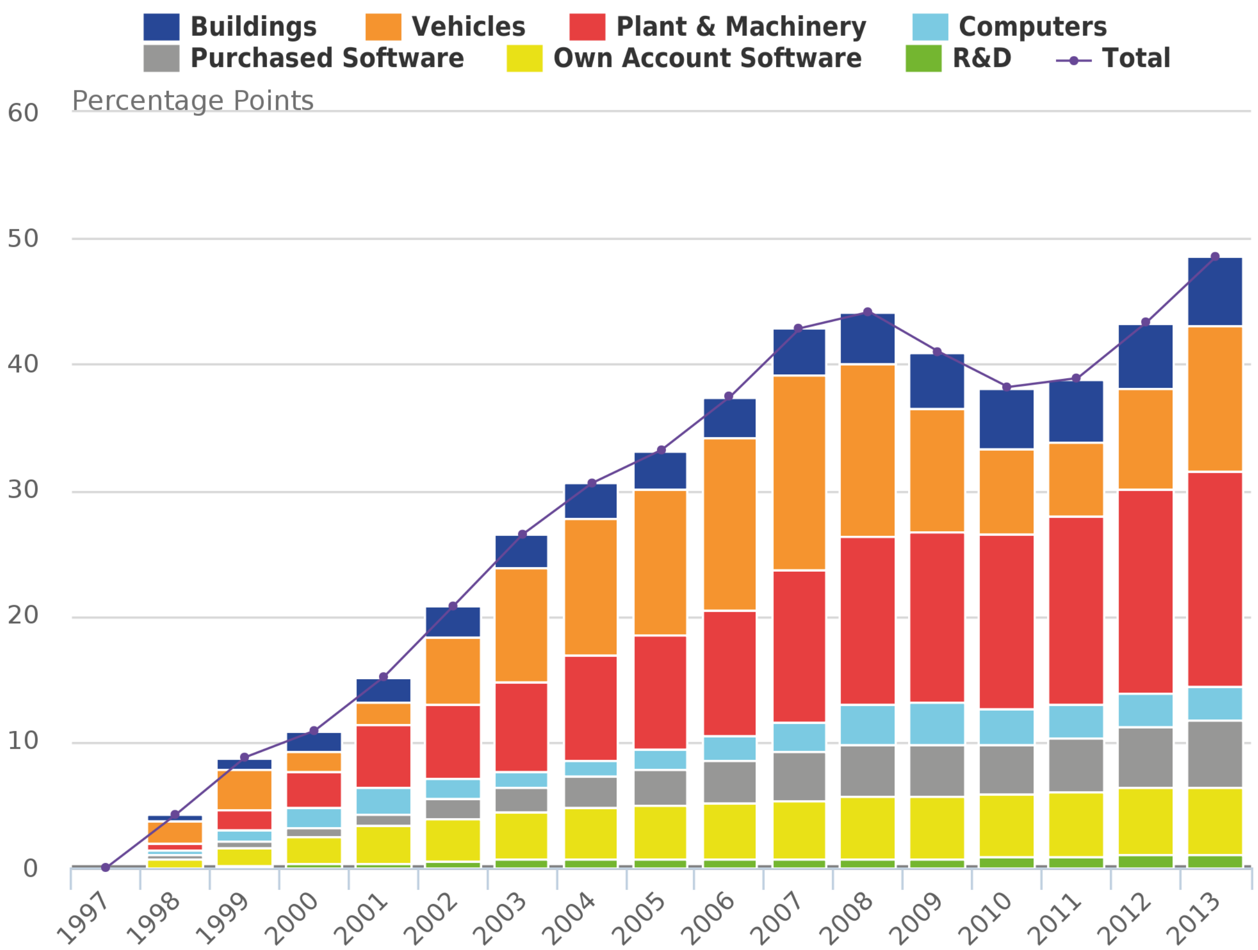
Professional, scientific and technical activities



Source: Office for National Statistics

Figure 17: Cumulative contributions to growth of capital services by industry

Administrative and support service activities



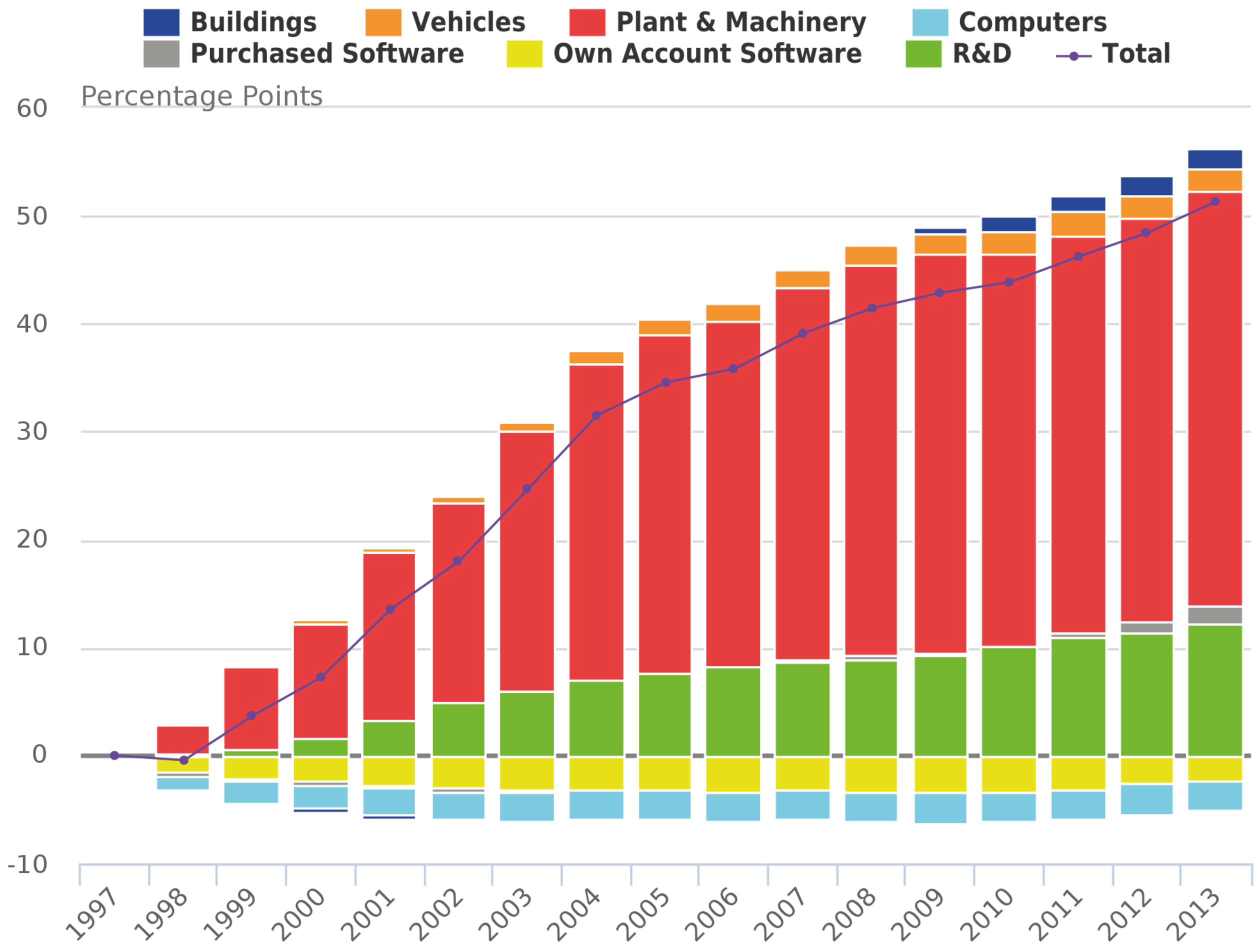
Source: Office for National Statistics

Figure 17 shows strong growth in capital services for the administrative and support services industry until the 2008 downturn, followed by two years of contraction and a recovery. This contraction is almost fully explained by a fall in services from vehicles, as most assets continue to grow in contribution over the period. Plant and machinery provides the largest contribution over the period, and substantial contributions are made from computers and software. Buildings provide a muted but still significant contribution, growing gently over the period.

Figure 18 shows that for the public administration and defence industry, the largest contribution comes from plant and machinery, which grows strongly to 2004 before showing more nuanced growth. Other assets show relatively stable growth in contribution. R&D comprises of the next largest contribution, and grows substantially over the period. Vehicles and buildings provide small contributions over the period, and computers and software provide negative contributions.

Figure 18: Cumulative contributions to growth of capital services by industry

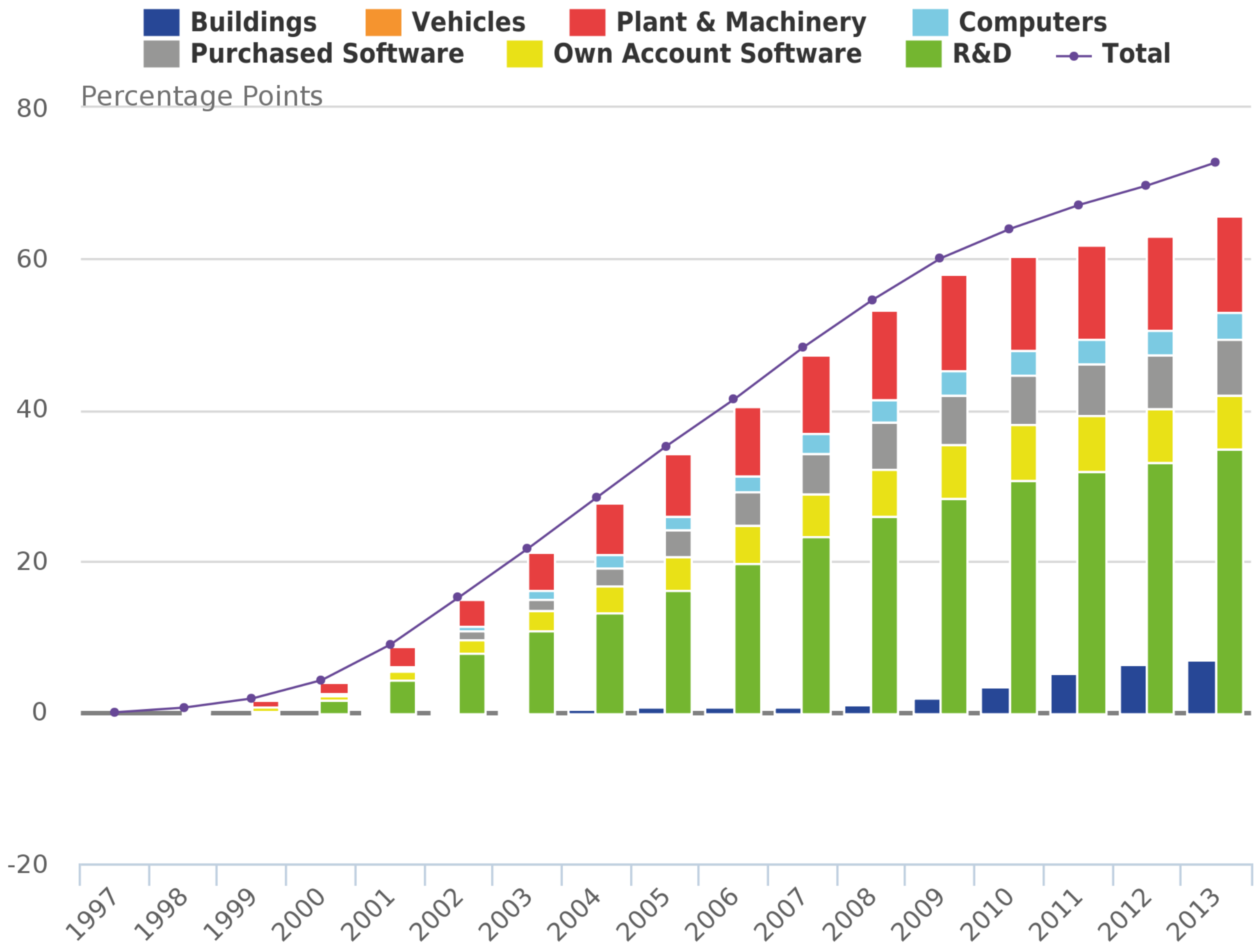
Public administration and defence; compulsory social security



Source: Office for National Statistics

Figure 19: Cumulative contributions to growth of capital services by industry

Education



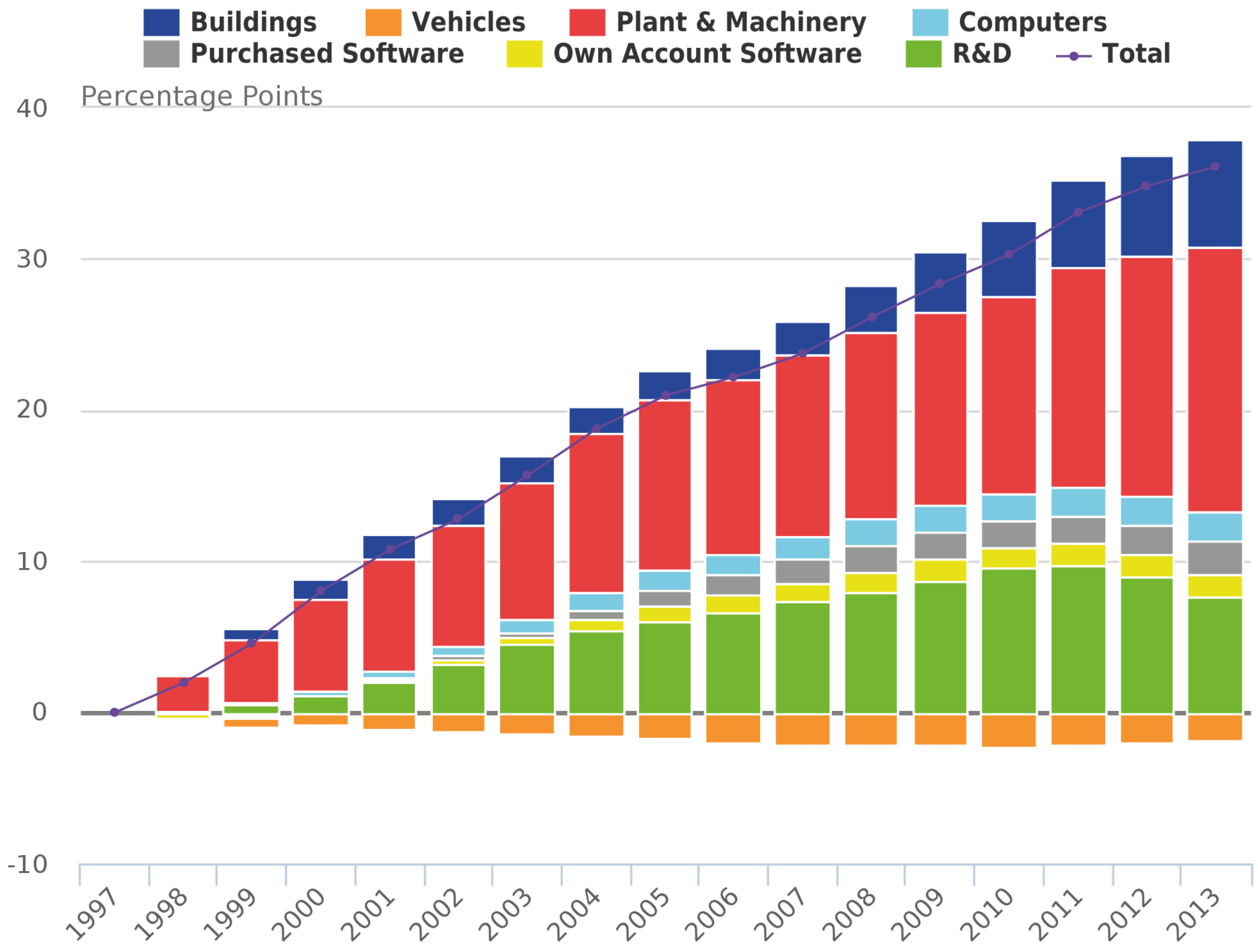
Source: Office for National Statistics

The education industry (Figure 19) shows a substantial increase in capital services over the period 1997-2013, and this is driven by R&D, which contributes more than half of total growth by the end of the series. Growth accelerates after 2000 and slows from 2009, but remains robustly positive. Software and computers constitute a large contribution to growth, as well as plant and machinery. Buildings contribution remained relatively muted until around 2008, and has increase more rapidly since.

Figure 20 shows that in the human health and social work industry, all assets except vehicles have provided positive contribution over most of the period 1997-2013. The largest contribution comes from plant and machinery, which is likely to embody high-tech medical equipment containing microprocessors. This gives rise to the measurement issue where it is not clear what constitutes plant and machinery and what constitutes a computer. Computers and software constitute a non-trivial but still muted contribution to capital services growth, and R&D provides the second largest contribution, likely reflecting medical research embodied in the industry.

Figure 20: Cumulative contributions to growth of capital services by industry

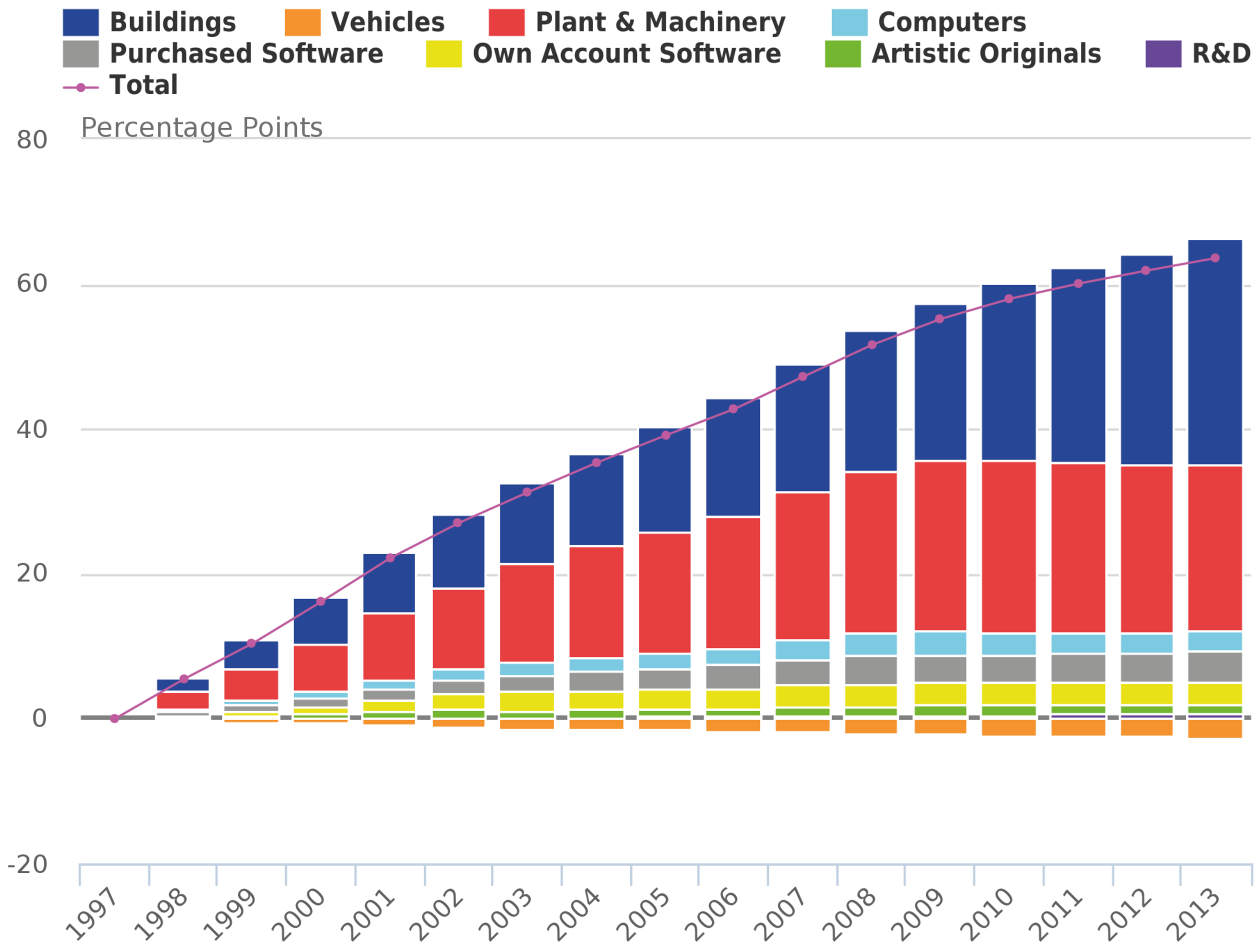
Human health and social work activities



Source: Office for National Statistics

Figure 21: Cumulative contributions to growth of capital services by industry

Arts, entertainment and recreation; Other service activities; Activities of households as employers; Activities of extraterritorials



Source: Office for National Statistics

The aggregate shown in Figure 21, comprises of the arts, entertainment and recreation, other services, activities of households, and activities of extraterritorial organisations industries (RSTU). Of these, the arts, entertainment and recreation industry embodies investment in artistic original assets, which results in a muted, but non-trivial positive contribution to growth. The majority of the remaining contributions come from buildings and plant and machinery, however computers and software also provide a considerable positive contribution.

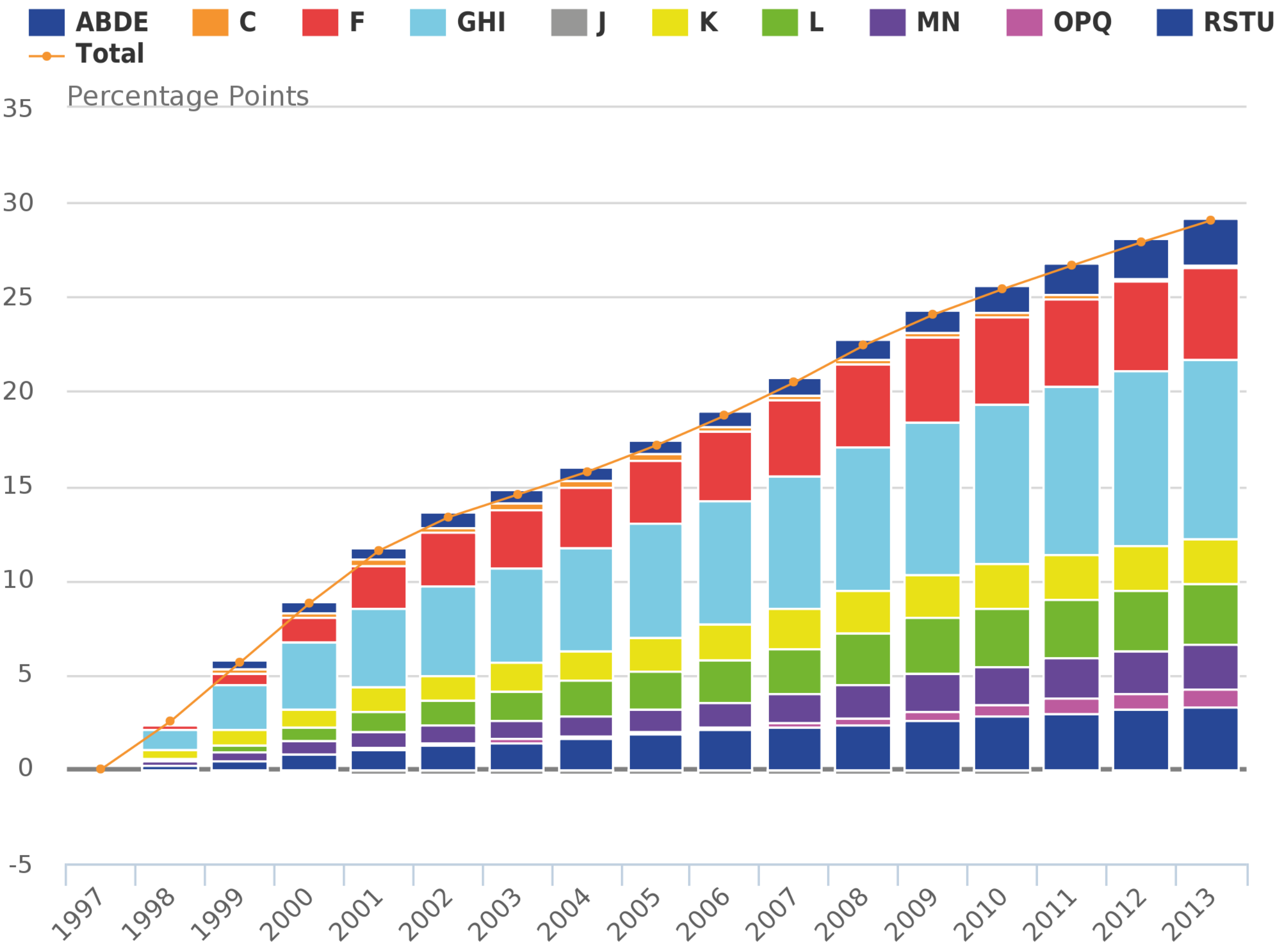
8. Results by asset

Results in this section show how different industries contribute to the aggregate capital services estimate for each asset. Differences in contributions reflect both differing volumes of accumulated investment, as well as the different marginal products of the same asset across different industries. These are themselves driven by different deflator movements and industry rates of return (user costs are also influenced by different deterioration profiles, which are themselves determined by asset lives and declining balance rates, however in most cases, these are assumed to be the same across industries).

Figure 22 shows contributions to capital services from buildings from different industries, shows that they are in general, roughly proportional to industry sizes in terms of employment or GVA. The notable exceptions to this are the manufacturing industry and government services (OPQ), where capital services from buildings cumulate to a trivially small contribution. This is consistent with Figures 7, 17, 18 and 19, which show small contributions by buildings to these industries.

Figure 22: Cumulative contributions to growth of capital services by asset

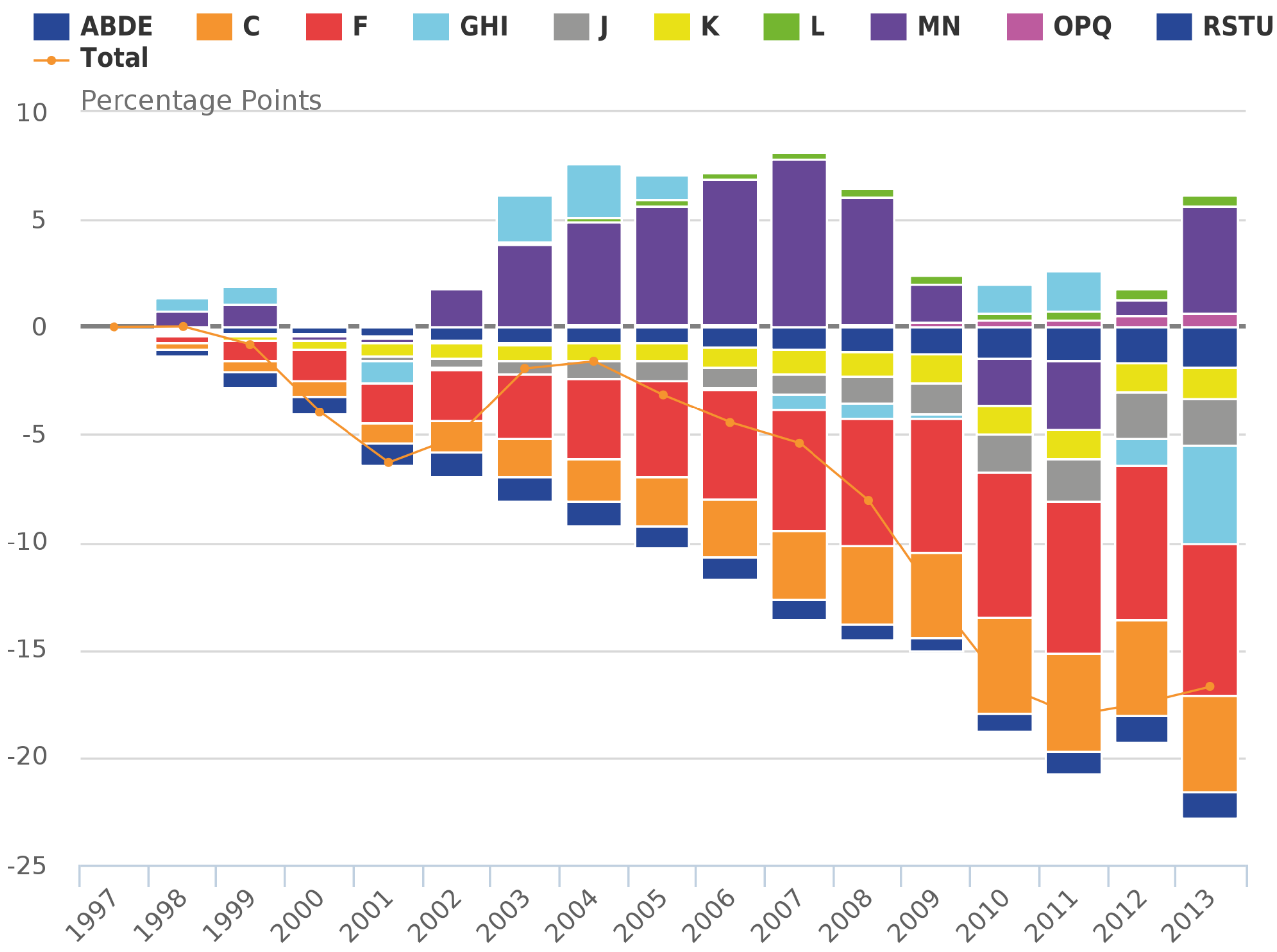
Buildings



Source: Office for National Statistics

Figure 23: Cumulative contributions to growth of capital services by asset

Vehicles



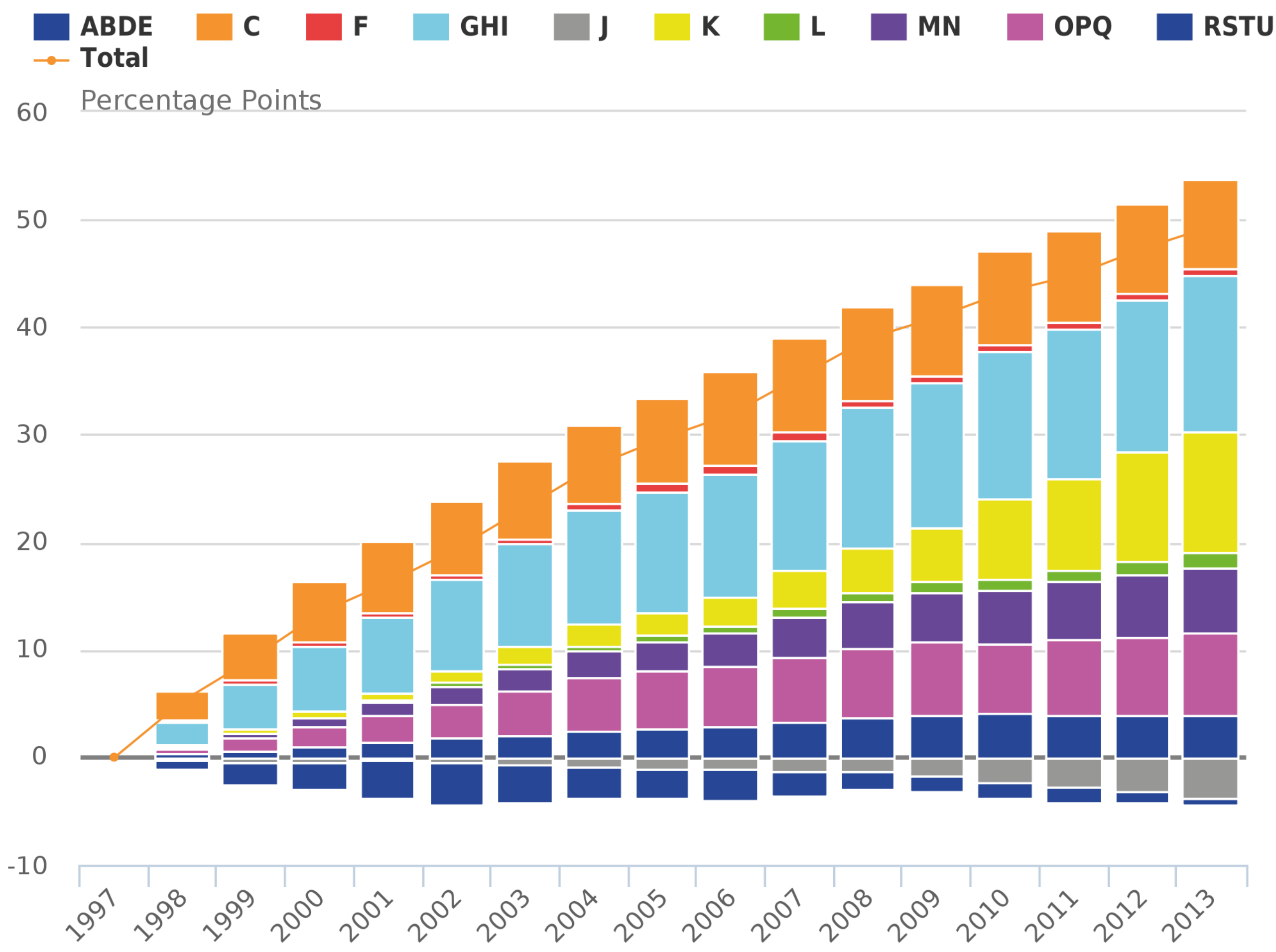
Source: Office for National Statistics

Figure 23 shows a highly varied picture for contributions to capital services from vehicles. Most industries produce negative contributions to vehicles, as the productive stock of vehicles follows a negative trend for all industries except the transport and storage and administrative and support industries. These both start to fall around 2007, and this is reflected in the steepening downward trend in the aggregate. Large negative contributions come from construction, compounding the results seen in Figure 9.

Figure 24 shows a stable picture for capital services from plant and machinery. The only two industry groups which show negative contributions are production other than manufacturing (ABDE) and information and communication, the former almost certainly reflecting declining investment in the North Sea oil and gas industry in the early 2000s. These do not significantly affect the growth profile; however growth does flatten to a degree after 2008, influenced by the flattening of growth from the other services industries (RSTU).

Figure 24: Cumulative contributions to growth of capital services by asset

Plant and Machinery, excluding computers

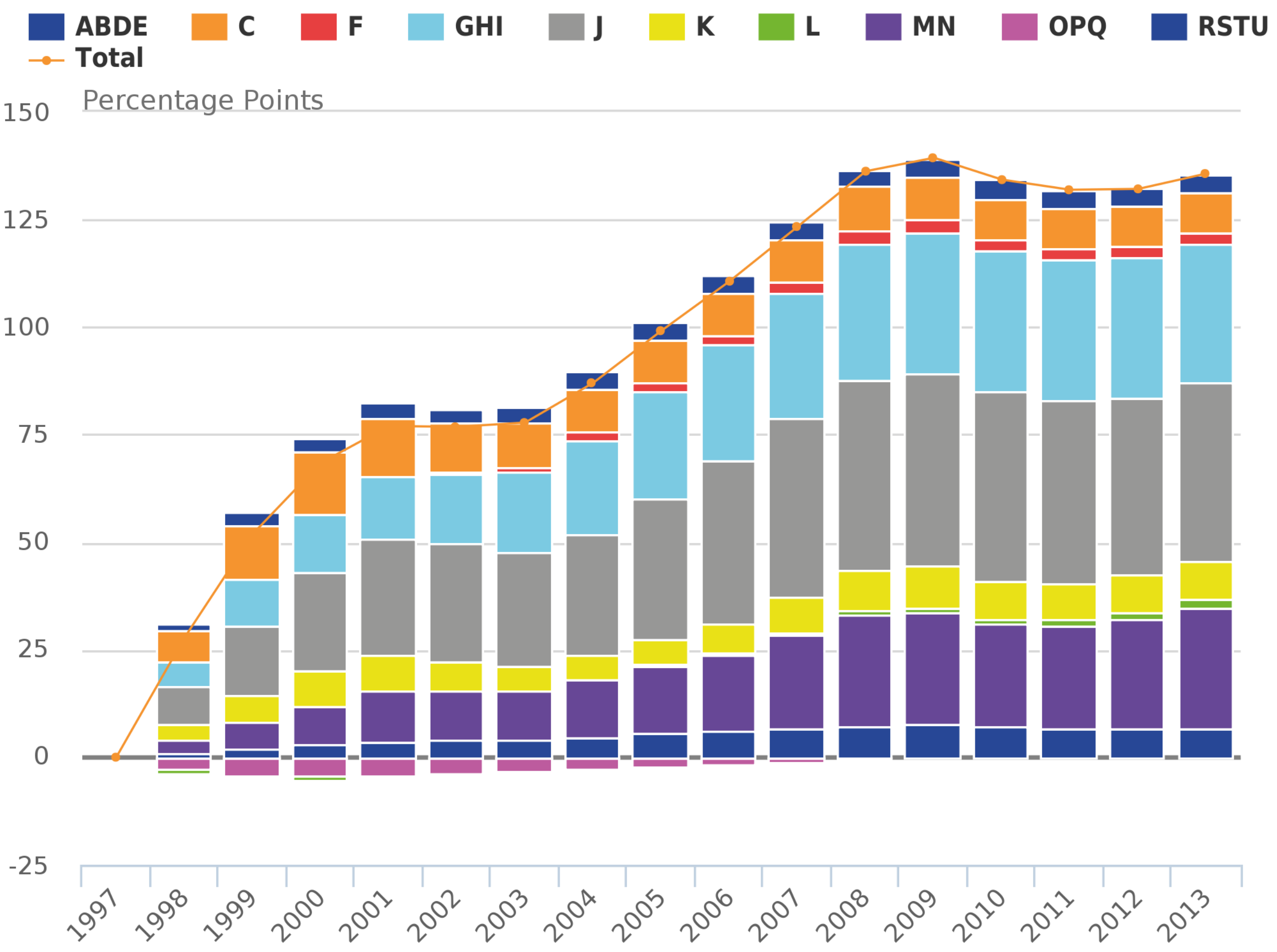


Source: Office for National Statistics

Figure 25 shows contributions to capital services growth from computers, which have seen growth of an order of magnitude higher than other tangible assets over the period 1997-2013. With the exception of the government services aggregate, all industries show positive contributions to growth over the whole period. Growth slowed during the 2001-2003 period, likely a consequence of the collapse of the IT bubble around 2000. Growth then picked up until around the 2008 downturn, when a contraction occurred largely due to the industry grouping professional and scientific and administrative and support (MN).

Figure 25: Cumulative contributions to growth of capital services by asset

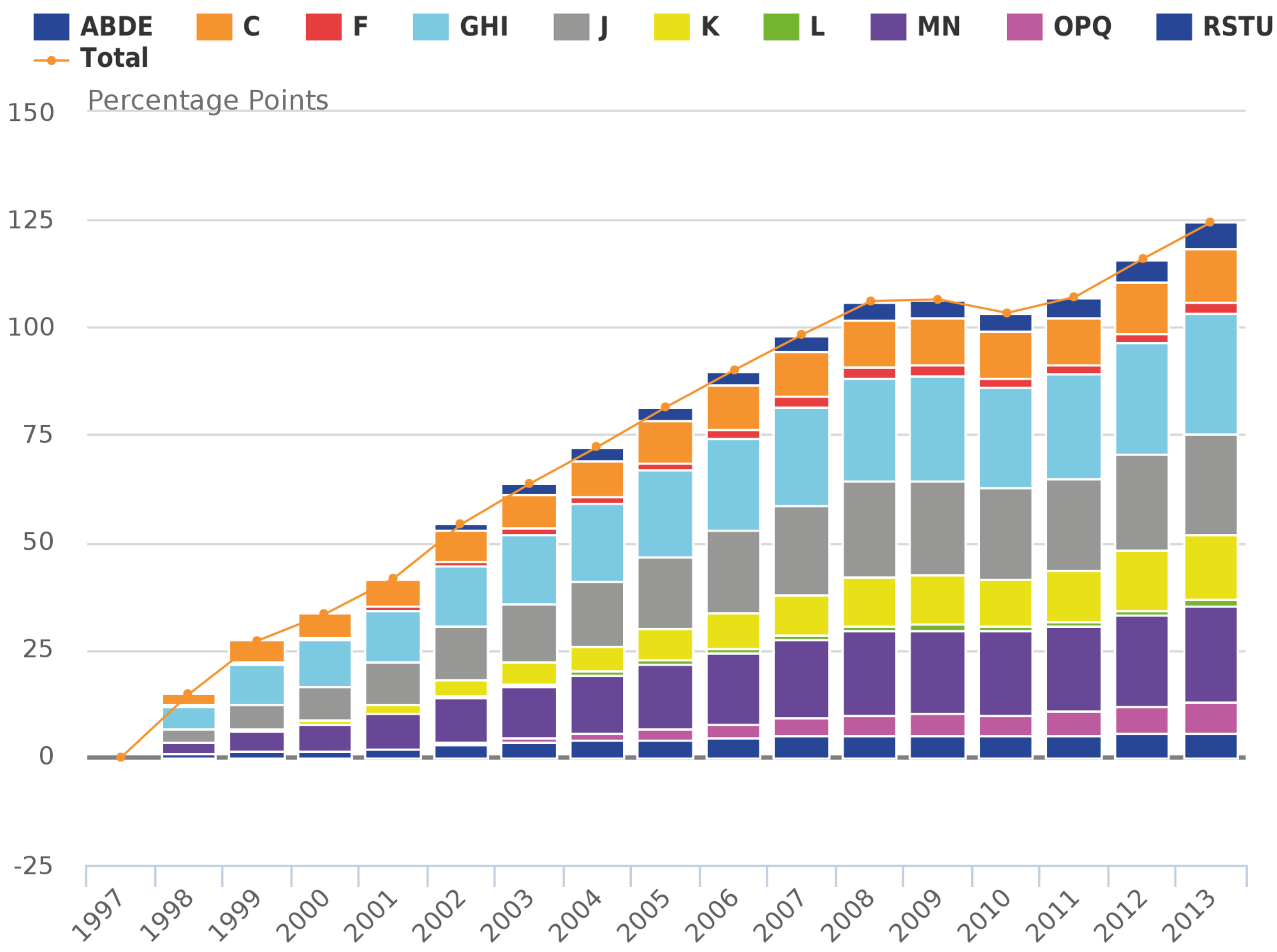
Computers



Source: Office for National Statistics

Figure 26: Cumulative contributions to growth of capital services by asset

Purchased software

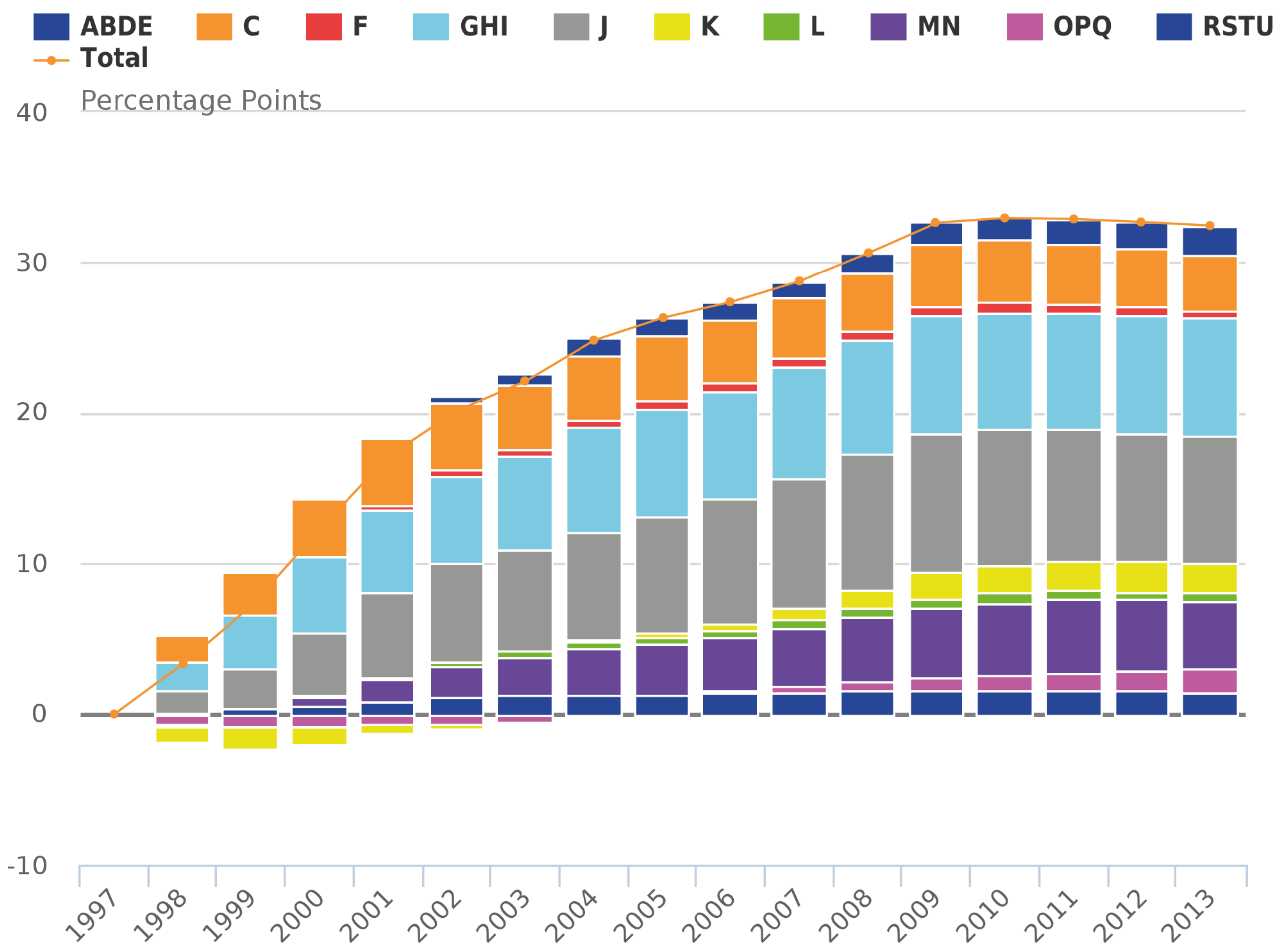


Source: Office for National Statistics

Figures 26 and 27 show contributions to capital services from the two different types of software; purchased and own account respectively. Contributions to the total are roughly proportional in both cases, except that the information and communication industry contributes substantially more to own account and the finance and insurance industry less so. Services from purchased software have grown by an order of magnitude faster than those of own account software, and this is largely due to the different deflation methods employed. As noted in the methodology section of this article, Capital Services estimates use a purchased software deflator which is an exchange rate adjusted version of the American BEA hedonic software deflator, which records large price falls in software, once improving characteristics are taken into account. This results in high growth in the volumes of purchased software investment, and as falling asset prices tend to increase user costs, a relatively large weight in capital services aggregates. Own-account software is deflated using a weighting of the purchased software deflator and the UK software deflator, which is largely composed of the wage costs of people working in the computer programming industry. This is done to reflect that own account software will likely be built on purchased platforms, but its creation will embody work done by programming experts, and that these costs should be included in the price of producing it.

Figure 27: Cumulative contributions to growth of capital services by asset

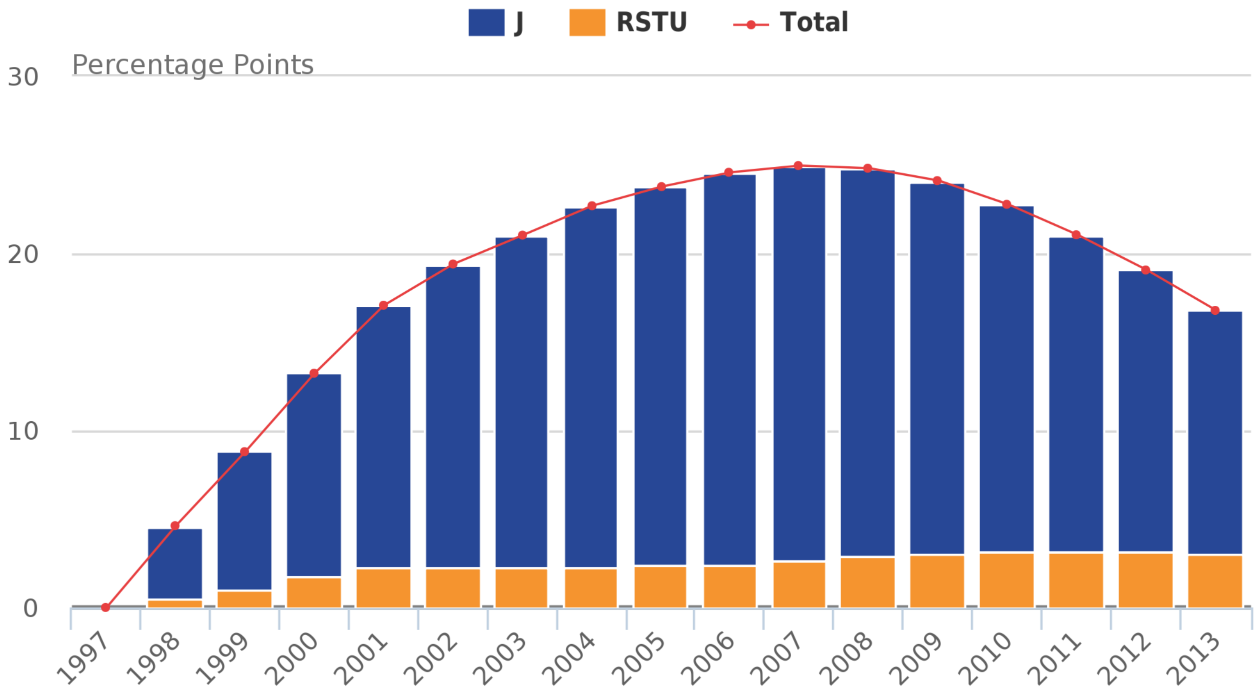
Own account software



Source: Office for National Statistics

Figure 28: Cumulative contributions to growth of capital services by asset

Artistic originals

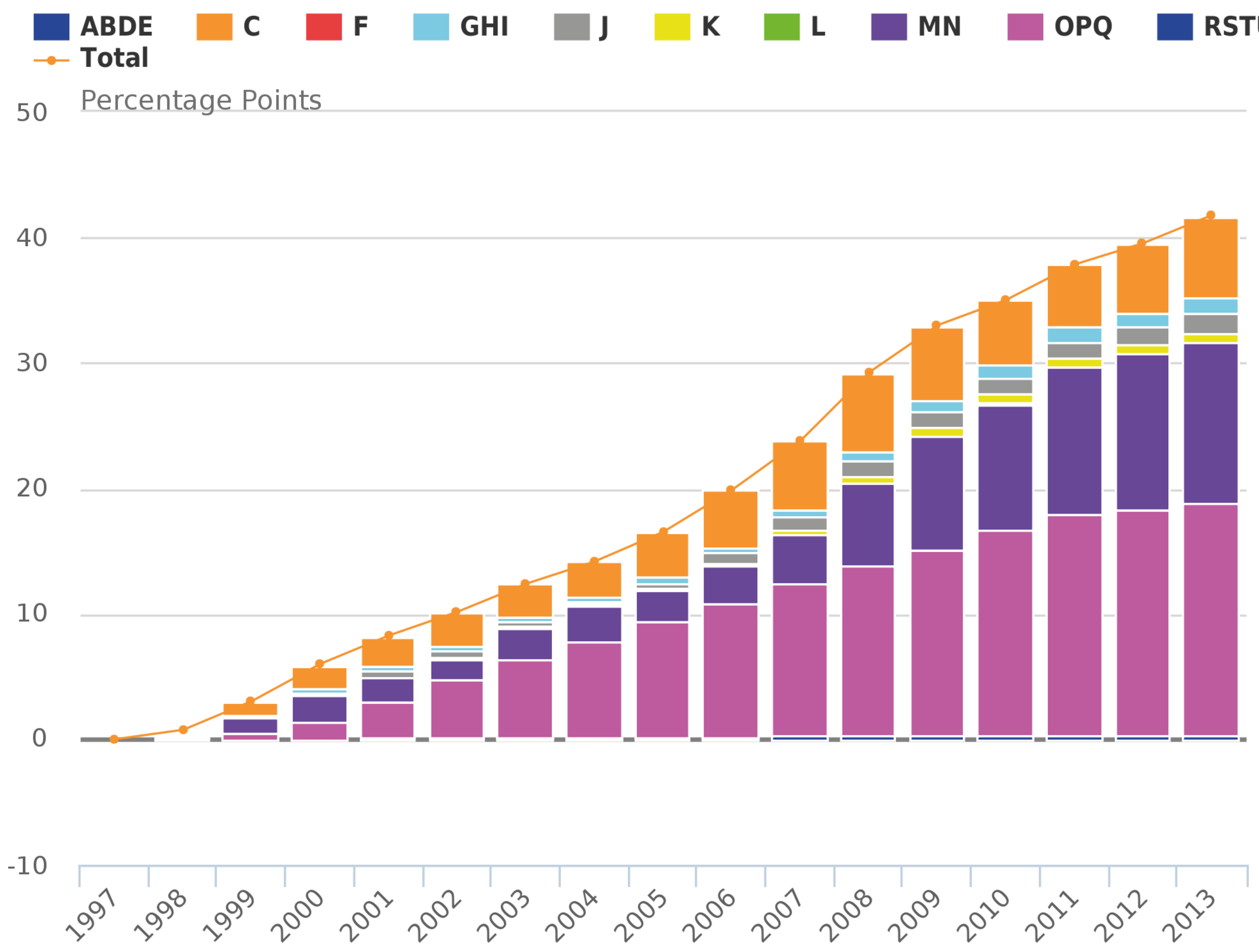


Source: Office for National Statistics

Capital services from both cultivated assets and mineral extraction rights are assets which only appear in the agriculture, forestry and fishing, and mining and quarrying industries respectively. In general, movements in these assets do not follow the growth trend of the whole economy, and are influenced by other factors. The latter of these assets, mineral extraction rights, falls steeply until around 2009, likely a result of falling stocks of North Sea oil and gas. The growth after this period could be a result of increased investment in exploration itself resulting from the sharp increase in oil prices from 2009.

Figure 29: Cumulative contributions to growth of capital services by asset

Research & development



Source: Office for National Statistics

Figure 29 shows contributions to growth in capital services from R&D. It is clear that the largest contributor to growth is the government services aggregate (OPQ), followed by industry group professional and scientific and administrative and support (MN, which includes the R&D industry), and manufacturing also makes a large contribution. The growth profile accelerates during the mid 2000s, before slowing but not declining after the 2008 downturn.

9. Revisions

(i) Revisions to GFCF asset aggregates

Revisions to GFCF estimates within the framework of the UK National Accounts are described in a series of articles published by ONS prior to publication of Blue Book 2014 (BB14), including ONS (2014a), ONS (2014b), ONS (2014c) and ONS (2014d).

The main revisions are inclusion of R&D and military weapons systems as new forms of assets. Within the capital services system, R&D is treated as a new class of intangible asset, and weapons systems are included within other machinery and equipment (OME)[1]. Additionally, in this edition, cultivated assets are incorporated as a separate tangible asset, having previously been included within OME.

R&D investment is about 40% of all intangible investment. Weapons systems investment is around 4% of tangible investment and cultivated asset investment is less than 1% of tangible investment.

Between 1997 and 2012, the level of current price (CP) GFCF for the combined assets that feed into estimates of capital services[2] has been revised up by around a fifth on average. The smallest percentage revision is in 2005 (+15%) and the largest revision is in 2012 (+27%). Average growth of CP total asset accumulation over this period has been revised from 2.8% per year to 3.0% per year, and the volatility of CP annual growth rates is now significantly lower.

Unsurprisingly, revisions to intangible investment are larger than revisions to tangible investment. CP intangible investment has been revised upwards by almost 60% on average between 1997 and 2012, and by as much as 75% in 1997 and 2009, reflecting the addition of R&D asset formation. However, growth of current price intangible investment has been revised down, from 4.4% per year to 4.0% per year. Despite the large revisions to levels of current price intangible investment, volatility of estimates has fallen[3].

Apart from the addition of R&D as a new class of intangible assets, investment in other intangible assets including purchased software and mineral exploration rights has been revised downwards in CP terms over the period 1997 to 2012.

Total tangible CP investment has also been revised upwards between BB13 and BB14 but not as markedly as intangibles. The average upward revision between 1997 and 2012 is 9%. At the BB aggregate asset level, the main revisions are to OME which, as noted above, includes weapons systems from BB14. The level of investment in OME assets in CP terms is approximately 29% higher, on average, over 1997-2012 in BB14 than in the previous dataset. Elsewhere among tangible assets, there are large upward revisions to CP estimate of investment in transport equipment in 2011 (+100%) and 2012 (+74%). Investment in buildings and structures (other than dwellings) has been revised down a little, and the profile is considerably smoother than in BB13.

Revisions to the chained volume investment series in BB14 broadly echo the revisions to the CP series. Overall investment in the capital services system has been revised upwards by around one-fifth in volume terms (after adjustment to a common price base) over the period 1997 to 2012, and the volatility of CVM annual growth rates has reduced. Real tangible investment has been revised up by around 10% on average, and real intangible investment has been revised up by around three-fifths.

Average growth of real tangible investment is virtually unchanged in the latest dataset compared with the previous dataset. However, there are some significant differences in growth profiles at the individual asset category: growth of real investment in other buildings and structures is now a little slower, and growth of investment in ICT equipment has roughly halved from around 10% per year to around 5% per year. The largest upward revision is to growth of real investment in transport equipment, which is now estimated at -1% per year over the period 1997 to 2012, compared with around -4% in the previous dataset.

Average growth of real investment in OME has been revised up by around half a percentage point per annum over the period 1997 to 2012, while growth of the implied deflator is little changed. In fact a striking feature of the GFCF asset breakdowns is that deflators for both OME and transport equipment exhibit a shallow U-shape over the period since 1997. Average growth of the OME implied deflator has been negative in every Blue Book since 2010. Deflator growth in BB13 was a little less negative than in previous editions, and deflator growth in BB14 (when weapons systems were added to this asset category) is less negative still. Deflator growth for transport equipment was positive up to BB12 but has turned negative in each of BB13 and BB14. By contrast, deflator growth for other buildings and structures has tended to be revised upwards over successive Blue Books, and this pattern continued in BB14, when average deflator growth over the period 1997 to 2012 was revised up from 2.9% to 3.2%.

Aggregate intangible investment also grows more slowly in real terms in the current dataset compared with the previous dataset. This reflects the addition of investment in R&D which, although estimated to have grown by some 2.8% per year since 1997, pulls down the overall growth of intangibles from around 4% to around 3% per year.

(ii) Revisions to GFCF by industry

As noted above, as well as large revisions in aggregate GFCF asset series and deflators, this edition incorporates revised estimates of shares of investment across industries, in line with industry shares used in the ONS Capital Stock release of 14 November 2014. In some cases, these shares are radically different from the industry shares used in Field and Franklin (2014) to derive capital services estimates for the purpose of computing indicative estimates of MFP.

For other buildings and structures, there has been a marked shift in investment from service industries to production and construction industries. In our previous estimates, service industries accounted for around 80% of CP investment in this asset category on average over 1997-2012, with around 18% in the production industries and around 2% in construction. In the GFCF dataset used for estimates in this article, the respective shares of investment in other buildings and services are roughly 68% for service industries, 26% for production industries and 6% for construction. Most of the increased weight of the production industries is outside manufacturing.

For transport equipment, overall CP shares are similar between the overall production and service industries, although there is more volatility in industry shares in the latest GFCF estimates, and there are large changes in the shares of some individual industries. For example, the combined share of industries H (transportation and storage) and N (administrative and support services) has increased from around 40% of total investment in transport equipment in the previous edition to over 70% in the latest dataset, while the share of industry J (information and communication) has collapsed.

Turning to shares of OME there has also been a significant shift from service industries to production industries in the latest GFCF estimates. This is true over the whole period 1997-2012, although it is especially pronounced in 2005. Within the service industries, the share of government services has increased significantly, reflecting the addition of weapons systems in BB14. Shares of investment in computers are broadly similar across the overall production and service industries. However, there are some large re-allocations among individual service industries: the share of government services is sharply lower in the latest source data (from around 12% to around 4%) while the share of information and communication has tripled from around 9% to around 27%.

Looking at investment in tangible assets as a whole, the share of production industries has increased from around 21% in the previous vintage to around 31% in the latest vintage. The corollary is that the share of service industries has fallen (from around 76% to around 65%) and the share of the construction industries has risen from roughly 3% to roughly 4%.

There are no material revisions in industry allocations of investment in intangible assets in the source data used for this release. However, the inclusion of R&D investment, around one-third of which is conducted by manufacturing industry, means that there is a shift in the overall balance of intangibles from service industries to production industries. In the previous vintage, around 80% of intangible investment was conducted by service industries. This share has now fallen to around 75%.

(iii) Impact of revisions on Capital Services estimates

Revisions to levels, growth rates and industry distributions of GFCF, and revisions to GFCF deflator growth rates drive revisions to estimates of capital services. Overall growth of capital services across the whole economy has been revised downwards between 1997 and 2012, from 3.6% per year to 2.3% per year. However, much of this reflects relatively large downward revisions to capital services growth in the first half of this period; the average downward revision to growth since 2006 has been just 0.2% per year, helped by a large upward revision to growth of capital services in 2012 which reflects, inter alia, a large upward revision to investment in transport equipment.

Revisions to growth of capital services across different industries reflects the pattern of revisions to asset accumulation noted above. Thus, growth of capital services has been revised upwards for the production industries, and especially for manufacturing. This likely reflects the impact of capitalisation of R&D, which is disproportionately concentrated in manufacturing. All service industries exhibit slower growth of capital services in these estimates compared with the previous vintage, with notably large downward revisions in information and communication but only marginally lower growth in government services.

Turning to revisions to growth of capital services by asset, there are comparatively large and persistent downward revisions to capital services of other buildings and structures. This is consistent with downward revisions to growth of real investment in this asset class in the current dataset. Moreover, although the capital services methodology gives a lower weight to this asset class than the National Accounts capital stock methodology, the combination of long asset lives and low rates of deterioration implies that this asset still has the largest absolute weight in overall capital services.

There are also large downward revisions to growth of capital services of ICT equipment and –counter-intuitively – transport equipment. The former reflects the large downward revisions to real investment growth for ICT equipment noted above. The latter occurs despite less negative investment growth over the whole period. But much of this is due to large upward revisions at the very end of the comparison period.

Lastly, growth of capital services of OME has been revised upwards in the latest dataset. Again this is consistent with the direction of revisions to real investment growth, as well as the addition of weapons systems to this asset class.

Notes for revisions

1. In the capital services framework, OME excludes transport equipment and ICT equipment, both of which are stand-alone asset categories.

2. That is, total GFCF less investment in dwellings and transfer costs.

3. There were also large upward revisions to intangible investment in Blue Book 2013, reflecting improvements to the estimation of artistic originals and changes to the estimation of own-account software. For further information see ONS (2013). The combined impact is that intangible investment is around three times larger in CP terms in BB14 than in Blue Book 2012 and earlier estimates.

10. Next steps

Capital stock utilisation

Capital services estimates make the implicit assumption that each component (industry by asset) productive capital stock is directly proportional to its capital services, or in other words, that if the volume of ICT equipment in an industry doubles, then capital services from ICT equipment in that industry will double. This may not be the case, particularly in economic downturn periods, or even across economic cycles more generally. Ideally, this could be accounted for by adjusting capital stocks by machine hours, however these are not measured. A simpler approach is taken in the seminal work in growth accounting, Solow (1957), where the whole economy capital stock is simply adjusted by the employment rate, but this makes strong assumptions about the underlying production processes. One approach could be to model deviations from trend rates of weekly working hours by industry, however this has an end-point problem, in that falling working hours may be a rational choice made by workers in light of increasing productivity, or it could be involuntary lower working hours in response to poor demand conditions. In either case, there is less justification in adjusting user costs for capacity utilisation, as the main costs to the user of holding the asset will still occur regardless of whether the asset is in full use.

Progress in this area would likely involve analysis at the firm level in order to analyse the relationships between labour input, capital input, and multi-factor productivity. From this, if a firm had high capital input, but relatively low output and low multi-factor productivity compared to similar firms (as determined by employment), we could deduce that the observed low multi-factor productivity was due to low stock utilisation, and this could be used to derive industry level capital stock adjustment factors.

Another approach is to assume a significant negative supply shock, such as premature scrapping of capital. HM Treasury (2009) assumes that there was a 5% once for all negative impact from the financial crisis on trend output resulting from firms becoming insolvent and their capital goods being scrapped, rather than sold to other firms. In principle, this would be reflected by a proportional downwards adjustment to the productive capital stock. It is likely that the effect of this would not be uniform across assets, and would be a function of the asset composition of the industries more or less heavily affected. Deriving factors to adjust for this would involve research at the micro level on firm insolvency by industry over the downturn period.

Quarterly growth accounting

The main purpose of the production of capital services estimates is for their use in a growth accounting framework, such as multi-factor productivity estimates. ONS is keen to hear user feedback on the usefulness of these multi-factor productivity estimates, and whether users would benefit from the production of quarterly growth accounting estimates. The approach used in Appleton & Wallis (2011) to generate a quarterly profile of capital services estimates was to generate all industry estimates of capital stocks at the level of asset detail available in the quarterly business investment release (buildings, transport equipment and intangibles), the latest of which is to Q3 2014, and to weight these together by whole economy asset level user costs, and then constrained such that the quarterly growth rates equal those of the annual capital services estimates. A similar approach would allow a whole economy estimate of capital services to be produced, and multi-factor productivity to be estimated alongside or shortly after the production of the quarterly national accounts.

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12. Appendix 1: methodology and sources

Data sources

The main sources required to produce capital services estimates are the same as those underpinning the national accounts estimates of capital stocks. The dataset consists of long annual time series of investment flow data, stratified by industry and by asset. The average life lengths of different assets are also required for calculation of deterioration rates. In addition to these, capital services estimates also require corresponding investment price deflators by industry and asset, a goods basket inflation benchmark (required to construct indices of GFCF prices changes relative to the general price level), and declining balance rates for different assets. Finally, national accounts measures of profits (Gross operating surplus (GOS)), and an estimated capital share of mixed (self-employment) income and taxes less subsidies on production are required by industry to act as constraints for the user costs of capital at the industry level. These income measures are all sourced from underlying data from the ONS supply-use tables, which currently cover 1997-2012. We extend the series to 2013 by using whole economy GOS from Blue Book 2014, holding industry shares from 2012 constant, and extend the series back between 1997 to 1948 using shares of total GFCF by industry to apportion whole economy GOS, the capital shares of mixed income, and taxes less subsidies on production.

Investment data are available in some cases as very long time series. For example, records of investment in buildings begin in 1828, and plant and machinery before the beginning of the 20th century. In other cases, investment values exist for periods much closer to the present. Software and computer investment are two examples of this, as investment records begin in the 1970s for these assets. Computers existed before this period, but not in a way which was particularly meaningful in a productive context. For this reason, capital services estimates include computers and software from 1984, as this is the period for which the source data allow a stabilised productive stock to be computed.

Computation of productive stocks

As noted in the introduction to this article, in deriving the net and productive capital stocks required to produce capital services estimates, we use geometric depreciation, which is widely used in empirical estimations of capital services, such as Jorgenson (1989). The key advantage of this approach is that the distinction between the age-price and age-efficiency profile disappears, and this greatly facilitates the computation of depreciation, and by extension, the user costs of capital, and does so in a single, consistent framework.

All intangible assets use a widely used declining balance rate of two, with tangible assets generally lower. The capital stock of each asset is taken as the sum (in constant prices) of the investment flow of each asset within each industry, where each industry follows a deterioration pattern determined by its declining balance rate and life-length mean. The net stock is therefore an end-period concept. For modelling inputs against output, we would like the stock average over the period in question. For this reason, the productive stock is approximated as the net stock at the end of the previous period added to half of the investment in the current period.

Derivation of user costs of capital

The derivation of user costs of capital requires three main components, each of which embodies a cost incurred in holding an asset.

Firstly, a 'real' price index of the investment in question, used to show how much the asset price has changed in comparison to the general price level. If the price of investment has grown by more than the general price level, this represents a gain to the asset holder, and is reflected by this component being negative. If the price of the investment has grown by less than the general price level, this represents a loss to the holder, which is reflected by this component being a positive cost to the user. In the former case, using the example of buildings, there are examples of where prices grow so strongly that the whole user cost function becomes negative, implying that the rental price of a building should be negative. In reality, it is unlikely that that would happen, but in a capital services context, it is perfectly plausible that in some extreme cases, buildings are held by firms simply because they rise in price relative to the general level of prices, and not because they are expected to add to productive potential.

Asset deterioration is also included in the user cost function, and this component covers the loss in productive potential incurred over the time period, taken as asset deterioration. This, as discussed earlier, is a function of the declining balance rate, and the life length mean of the asset. For example, a building will last for decades, so its deterioration in a year will be a relatively small proportion of its total usable life. Computers on the other hand will be expected to last around five years, so will be expected to use a significant proportion of their usable life in a single year.

Finally, the cost of financing an asset is included, which is modelled in the user cost formula as the internal rate of return, as in efficient markets, these should be equal. A full description of the derivation of this part of the function can be found in the OECD measuring productivity manual (OECD, 2001b).

Inclusion of asset specific tax adjustment factors

This year we have included updates tax adjustment factors by asset, produced and provided by Gavin Wallis from the Bank of England. The methodology used in producing these can be found in Appleton & Wallis (2011), or in more detail in Wallis (2012), but in principle, they are multiplicative factors relative to one, where if there is a tax incentive to invest in an asset, the factor is less than one, thereby reducing the weight of that asset in the capital services framework. The rationale for this is that if firms are enticed to invest in assets because of an attractive tax regime, rather than because they believe that the asset will earn a return, then estimated user costs will overestimate the contribution to production of an asset. If there is a tax disincentive to invest in a certain type of asset, then the opposite is true; estimates of user costs will be lower than the contribution of an asset to production, so the adjustment factor will be more than one.

Different index numbers

The results presented in the charts in this article are based on chained Laspeyres type volume indices, where weights are from the previous year and enter arithmetically. This provides computational simplicity and reduces the requirement for estimation of current period information from the ONS supply use tables, but it has the disadvantage that production theory strongly supports the use of index numbers which use flexible weights, and in principle, formulas which provide a good approximation of the continuous time 'Divisia' index. The OCED measuring productivity manual recommends using the Tornqvist index for measuring all inputs and output in the multi-factor productivity framework, including estimates of capital services. More information can be found on this topic in Diewert (1976).

The reference table component of this release shows results produced by both the Laspeyres and Tornqvist index formula, however the difference in growth rates is small, at an average of the Laspeyres growing 0.1% faster a year than the Tornqvist over the period 1990-2008. Though international guidance recommends using Tornqvist indices for measuring all components of a growth accounting framework, it is important for users to note that in the UK national accounts, chained Laspeyres indices are used to measure output, where weights are fixed for years which have not been fully balanced through the supply-use process.

13. Background notes

1. Capital services calculations are based on the methodology recommended in The OECD Measuring Productivity manual and the OECD Measuring Capital manual. The OECD produces a spreadsheet which outlines the data sources and an example of how they combine to produce capital services estimates.

2. ONS is keen to develop a greater understanding of the use of productivity statistics. If you have any feedback, please get in touch via productivity@ons.gsi.gov.uk

3. This publication will be discussed at a productivity statistics user group workshop in London on 4th February 2015. For more information email us at productivity@ons.gsi.gov.uk

4. ONS publishes a quarterly Labour Productivity statistical bulletin. This provides more timely and periodic information on UK labour productivity, and is accredited as a national statistic.

5. ONS publishes international comparisons of labour productivity in levels and growth rates for the G7 countries. More international data on productivity are available from the OECD, Eurostat, and the Conference Board.

6. ONS also publishes a range of public sector productivity measures and related articles. These measures define productivity differently from that employed in the ONS Labour Productivity and MFP estimates. Further information can be found in Phelps (2010).

   More information on the range of ONS productivity estimates can be found in the ONS productivity handbook.

7. Details of the policy governing the release of new data are available by visiting www.statisticsauthority.gov.uk/assessment/code-of-practice/index.html or from the Media Relations Office email: media.relations@ons.gsi.gov.uk