“Depreciation and Net Capital Services: how much do Intangibles contribute to Economic Growth?”

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Paper prepared for the IARIW-ESCoE Conference
November 11-12, 2021
Session 3B
Time: Thursday, November 11, 2021 [16:00-17:30 GMT+1]

Depreciation and Net Capital Services: how much do Intangibles contribute to Economic Growth?

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20th October 2021

Abstract

We show how to decompose the contribution made by capital services to economic growth into two components, depreciation services and net capital services. We show that, for the UK and US, while capital services from intangibles as conventionally measured absorb over 40% of the total contribution of capital services, about three quarters of this is a contribution to depreciation services. In contrast more than half of the capital costs associated with the services of tangible capital is a contribution to net capital services. Thus when services are considered net of depreciation, tangible capital is around three times as important as intangible capital. Nevertheless, between 1996 and 2016 net intangible capital services have grown faster than net tangible capital services. Sectoral results for the UK suggest that there is no clear hierarchy. Intangible capital services have become relatively more important between 1996 and 2016 in manufacturing and financial services while tangible capital services have become relatively more important in information and business services.

1 Introduction

Over the last twenty years a concerted effort has been made to understand the importance of accumulation of intangible capital as a source of economic growth. Haskel & Westlake (2018) noted, that in the United Kingdom in 2014, intangible investment amounted to 11% of GDP while tangible investment was only 10% of GDP. While, looking at an average of advanced economies they find that broadening the scope of capital has little effect on GDP growth rates, the identification of intangible capital assets and gross investment in these assets certainly has the effect of raising the level of GDP and thus giving the impression that incomes are higher than previously thought. Similarly,

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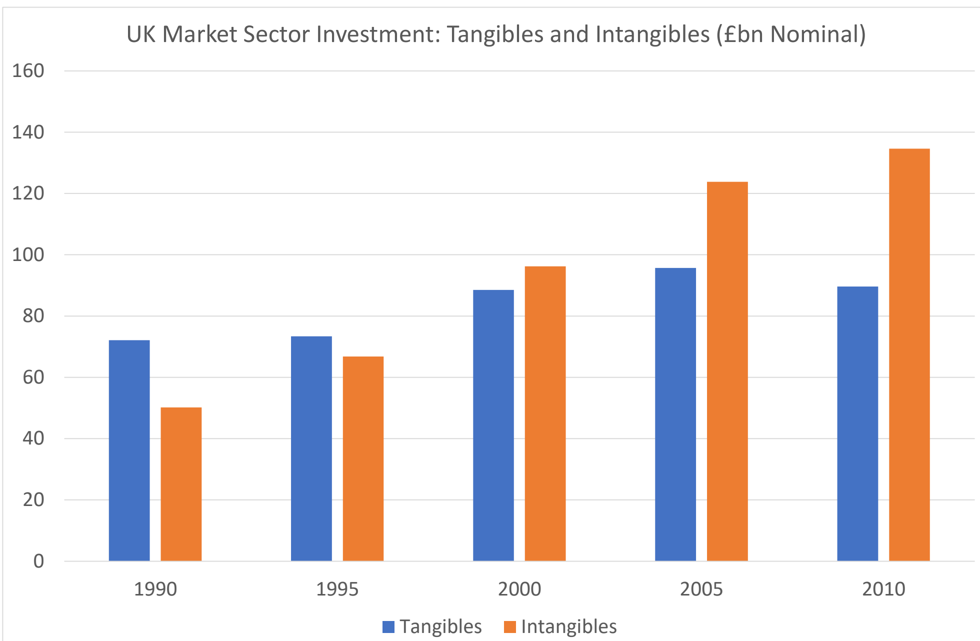
the identification of new capital assets typically increases growth accounting estimates of the contribution of capital services to GDP.

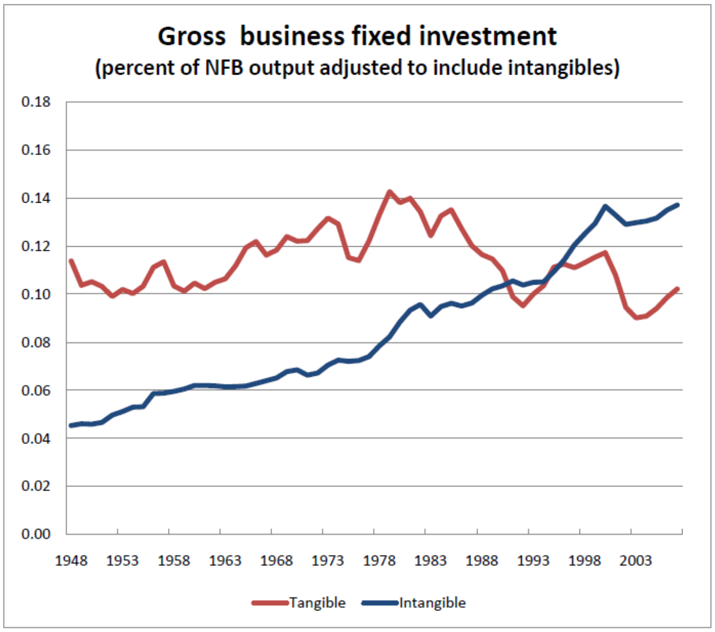
Figure 1, taken from Haskel et al. (2014) gives an indication of the importance of gross intangible and gross tangible capital formation from 1990 to 2010 in the UK, showing that by the end of last century intangible capital formation exceeded tangible capital formation. This pattern has continued in the new century, with the excess of the former over the latter increasing. Figure 2 shows the rising importance of intangible capital in the United States going back to 1948.



Source: Haskel et al. (2014)

Figure 1: Gross Fixed Intangible and Tangible Capital Formation in the UK

These calculations, while correct as far as they go, can be misleading. Intangible assets are typically thought to have rapid depreciation rates and a failure to take account of this means that the contribution of accumulation of intangible capital to growth in the net product and thus to rising real national income is likely to be exaggerated. More generally, if the national accounts show a rising share of depreciation in GDP, an increasing proportion of GDP is needed simply to maintain the capital stock so reducing



Source: Corrado & Hulten (2010)
Figure 2: Gross Fixed Intangible and Tangible Capital Formation in the US

the amount of output available to support consumption or accumulation of new capital.

Blanchard (2019) discusses the importance of intangibles with reference to the capital stock rather than the rate of gross investment, suggesting that far from being more important than tangible capital, it amounts to about 15% of the total. This measure, while it gives a satisfactory indication of the importance of intangibles, does not provide any basis for growth accounting and thus an understanding of the contribution of intangible investment to economic growth. Koh et al. (2020) shows that the capitalisation of intellectual property is entirely responsible for the observed decline in the labour share in the United States since 1929.

In growth accounting analysis the contribution of the capital stock, whether tangible or intangible, to GDP is normally measured using an index of capital services. The services provided by each type of capital are assumed to be proportional to its marginal product. This is measured by the rate of return on capital gross of depreciation and is higher for capital goods like computer software which depreciate rapidly than for those like buildings which depreciate slowly. Thus rapidly depreciating capital goods provide a relatively high volume of capital services and may appear to be an important motor behind growth in GDP.

Table 1 shows the results of a growth accounting exercise for the United States in which the contribution of capital is decomposed to show the contributions of tangible and intangible capital separately. It can be seen that if intangible capital is neglected, the resulting estimate of total factor productivity growth is materially larger than when intangible capital is included. This table therefore supports the view that a part of total factor productivity growth as conventionally measured, the unexplained component of economic growth, is partly a consequence of a failure to take account of the effects of intangible capital growth.

	1948-1973	1973-1995	1995-2007
Output per Hour	2.99	1.56	2.76
Tangible Capital	0.76	0.52	0.64
Intangible Capital	0.30	0.39	0.73
Labour Composition	0.15	0.26	0.20
TFP	1.78	0.39	1.20
Memo: TFP No intangibles	1.92	0.53	1.63

Source: Corrado & Hulten (2010)

Table 1: Growth Accounting and Intangibles in the US

In this paper, instead of constructing a single index of gross capital services, we construct distinct indices of depreciation services and net capital services. Growth in gross capital services is shown to be measured by a weighted sum of the growth in the two indices, with the weights given by the shares of depreciation and net return to capital in the overall gross return to capital. Aggregation over the two components of capital services, depreciation and net capital, is performed in exactly the same way as aggregation over the contributions made by different types of capital good.

We show that the contribution of capital to growth in gross output can be decomposed into contributions to the growth in net output and the growth in depreciation services. The weights are the shares of net output and depreciation in gross output. This makes it possible either to look at the contribution of the two forms of capital to gross output or to identify the contribution of net capital services to net output, with, by definition, depreciation services not making any contribution to the latter. This can be done for aggregate capital or for different components of capital; we focus on splitting the contributions of intangible and tangible capital in this way. We set out the theory behind this in terms of Divisia indices. As is standard in growth accounting, Törnqvist indices can be used as approximations to these, and we do that in the empirical sections of this paper.

We use the perpetual inventory method to construct estimates of the stock of each type of tangible and intangible capital. We carry out our calculations for the United Kingdom and the United States. Results for the United Kingdom and United States suggest that, over the period 1996-2015, the user cost of intangible capital amounted to just over 40% of the total user cost of capital with over three quarters of this being taken up by depreciation services. In contrast under half of the user cost of tangible capital was taken up by depreciation services. Net intangible capital services have, however, grown faster than net tangible capital services in both countries.

In the next section we set out the theoretical basis for our measures of net capital services and depreciation services. Section 3 discusses our data sources and in section 4 we provide details of the components of the user cost of capital and the growth in the different types of capital services. Section 5 sets out the contribution of these capital services to GDP growth. In section 6 we present some sectoral results for the UK before concluding in section 7.

2 Decomposition of Capital Services

We develop our framework for net income growth accounting by representing the productive structure of the economy through an implicit production function. While we do not distinguish distinct industries, it is perfectly possible to adapt this structure to do so. $\mathbf{y}^G$ represents a vector of outputs gross of depreciation and $\mathbf{k}$ a vector of capital goods. y_i^G and k_i represent the ith output and ith capital goods, respectively. The classifications of output and capital are the same but there are many output goods for which the corresponding capital stock is zero. Equally some outputs may be negative representing an open economy which imports. $\mathbf{p}$ is the price vector of output goods and $\mathbf{q}^G$ is the gross rental rate on capital; w is the wage rate. We assume a single homogeneous labour input, L, but of course the approach can easily be extended to handle heterogeneous labour. Alternatively, L can be seen as an index of labour services.

The production structure of the economy is then represented as

$$F(\mathbf{y}^G, \mathbf{k}, L, \lambda) = 0. \tag{1}$$

Here λ is a scalar which measures total factor productivity, and the function is homogeneous of degree 1 in $\mathbf{y}^G, \mathbf{k}$, and L so that, if $F(\mathbf{y}^G, \mathbf{k}, L, \lambda) = 0$, then for any scalar, $\mu, F(\mu\mathbf{y}^G, \mu\mathbf{k}, \mu L, \lambda) = 0$. In this framework GDP is given as

$$GDP = \mathbf{p}'\mathbf{y}^G \tag{2}$$

We can also write the gross output of each good as the sum of the net output and the amount needed to make good capital consumption.

$$\mathbf{y}^G = \mathbf{y}^N + \hat{\delta}\mathbf{k} \tag{3}$$

Here $\mathbf{y}^N$ is the vector of net output and $\hat{\delta}$ is a matrix with the ith element on the leading diagonal equal to the depreciation rate of capital good i and zeros off-diagonal.

The economy is competitive, so the net profit from production is maximised. Output and input use is therefore chosen, with π a Lagrange multiplier, to satisfy the following conditions

$$\underset{\mathbf{y}^G, \mathbf{k}, L}{Max} \quad \mathbf{p}'\mathbf{y}^G - \mathbf{q}^{G\prime}k - wL - \pi F(\mathbf{y}^G, \mathbf{k}, L, \lambda) \tag{4}$$

and the standard marginal conditions result

$$p_i = \pi\frac{\partial F}{\partial y_i^G};\; q_i^G = -\pi\frac{\partial F}{\partial k_i};\; w = -\pi\frac{\partial F}{\partial L} \tag{5}$$

Further we know that, with constant returns to scale, we can construct a unique (down to a constant) Divisia index of GDP as

$$d\log(GDP) = \sum_i \frac{p_i y_i^G}{\sum_i p_i y_i^G} d\log y_i^G \tag{6}$$

We can similarly construct a Divisia index of gross capital services, K^G

$$d\log(K^G) = \sum_i \frac{q_i^G k_i}{\sum q_i^G k_i} d\log(k_i) \tag{7}$$

Now putting in time subscripts, we can express the rental rate or user cost of capital as the interest charge on capital plus the depreciation charge less any increase in the price of the capital good concerned.

$$q^G_{i,t} = i_t p_{i,t} + \delta_i p_{i,t} - (p_{i,t} - p_{i,t-1}) \tag{8}$$

Here the money interest charge, i_t is calculated so that, in aggregate the return on capital is, with an appropriate treatment of mixed income which we discuss subsequently, equal to observed operating surplus in the national accounts.

The growth accounting relationship then follows by differentiating the production function

$$\sum_i \frac{\partial F}{\partial y^G_i}\Delta y^G_i + \sum_i \frac{\partial F}{\partial k_i}\Delta k_i + \frac{\partial F}{\partial L}\Delta L + \frac{\partial F}{\partial \lambda}\Delta\lambda = 0 \tag{9}$$

and then substituting using the marginal conditions.

$$\sum_i p_i \Delta y^G_i = \sum_i q^G_i \Delta k_i + w\Delta L + \frac{\partial F}{\partial \lambda}\frac{\Delta\lambda}{\pi} \tag{10}$$

Dividing by $\mathbf{p}'\mathbf{y}^G$ gives the standard growth accounting equation with the residual equal to $\frac{\partial F}{\partial \lambda}\frac{\Delta\lambda}{\pi}\frac{1}{\mathbf{p}'\mathbf{y}^G}$.

To move instead to net income accounting we note that the profit function can be written as

$$\underset{\mathbf{y}^N, \mathbf{k}, L}{Max} \quad \mathbf{p}'(\mathbf{y}^N + \hat{\delta}\mathbf{k}) - \mathbf{q}^{G\prime}k - wL - \pi F(\mathbf{y}^N + \hat{\delta}\mathbf{k}, \mathbf{k}, L, \lambda) \tag{11}$$

Further we can define the net rental rate on capital, charged to someone who makes good the depreciation from gross output, as

$$q^N_{i,t} = q^G_{i,t} - \delta_i p_{i,t} \tag{12}$$

It follows that the profit maximisation problem can equally be written as

$$\underset{\mathbf{y}^N, \mathbf{k}, L}{Max} \quad \mathbf{p}'\mathbf{y}^N - \mathbf{q}^{N\prime}\mathbf{k} - wL - \pi F(\mathbf{y}^N + \hat{\delta}\mathbf{k}, \mathbf{k}, L, \lambda) \tag{13}$$

giving, with $\frac{\partial F}{\partial y^N_i} = \frac{\partial F}{\partial y^G_i}$the marginal conditions

$$p_i = \pi\frac{\partial F}{\partial y^N_i};\; q^N_i = -\pi\frac{\partial F}{\partial k_i} - \pi\frac{\partial F}{\partial y^N_i}\delta_i = -\pi\frac{\partial F}{\partial k_i} - \pi\frac{\partial F}{\partial y^G_i}\delta_i;\; w = -\pi\frac{\partial F}{\partial L} \tag{14}$$

The net growth accounting relationship then becomes

$$\sum_i \frac{\partial F}{\partial y_i^G}(\Delta y_i^N + \delta_i \Delta k_i) + \sum_i \frac{\partial F}{\partial k_i}\Delta k_i + \frac{\partial F}{\partial L}\Delta L + \frac{\partial F}{\partial \lambda}\Delta\lambda = 0 \tag{15}$$

giving, again substituting using the marginal conditions

$$\begin{aligned} \sum_i p_i \Delta y_i^N &= \sum_i q_i^G \Delta k_i - \sum_i p_i \delta_i \Delta k_i + w\Delta L - \frac{\partial F}{\partial \lambda}\frac{\Delta\lambda}{\pi} \\ &= \sum_i q_i^N \Delta k_i + w\Delta L - \frac{\partial F}{\partial \lambda}\frac{\Delta\lambda}{\pi} \end{aligned} \tag{16}$$

Reverting to the index of gross capital services

$$d\log(K^G) = \sum_i \frac{q_i^G k_i}{\sum q_i^G k_i} d\log(k_i) \tag{17}$$

and expanding the logarithm, we can see

$$\frac{dK^G}{K^G} = \sum_i \frac{q_i^G k_i}{\sum q_i^G k_i}\frac{dk_i}{k_i} = \sum_i \frac{q_i^G dk_i}{\sum q_i^G k_i} \tag{18}$$

The contribution of growth in capital services to growth in GDP is, to the standard first-order approximation, given as

$$\frac{\sum_i q_i^G \Delta k_i}{\sum_i p_i y_i} = \frac{\sum q_i^G k_i}{\sum_i p_i y_i}\frac{dK^G}{K^G} \tag{19}$$

where $\sum q_i^G k_i / \sum_i p_i y_i$ is, as a result of the definition of q_i^G the share of gross capital income in GDP.

We can similarly define an index of net capital services as

$$d\log(K^N) = \sum_i \frac{q_i^N k_i}{\sum q_i^N k_i} d\log(k_i) \tag{20}$$

and an index of depreciation services as

$$d\log(D) = \sum_i \frac{\delta_i p_i k_i}{\sum \delta_i p_i k_i} d\log(k_i) \tag{21}$$

$$
\begin{aligned}
d\log(K^N) &= \sum_i \frac{q_i^N k_i}{\sum q_i^N k_i} d\log(k_i) = \sum_i \frac{\left(q_{i,t}^G - \delta_i p_{i,t}\right) d\log(k_i)}{\sum_i (q_{i,t}^G - \delta_i p_{i,t}) k_i} \\
&= \sum_i \frac{q_{i,t}^G d\log(k_i)}{\sum_i (q_{i,t}^G - \delta_i p_{i,t}) k_i} - \sum_i \frac{\delta_i p_{i,t} d\log(k_i)}{\sum_i (q_{i,t}^G - \delta_i p_{i,t}) k_i} \\
&= \sum_i \left(\frac{\sum_i q_{i,t}^G k_i}{\sum_i (q_{i,t}^G - \delta_i p_{i,t}) k_i} \right) \frac{q_{i,t}^G d\log(k_i)}{\sum_i q_{i,t}^G k_i} \\
&\quad - \sum_i \left(\frac{\sum_i \delta_i p_i k_i}{\sum_i (q_{i,t}^G - \delta_i p_{i,t}) k_i} \right) \frac{\delta_i p_{i,t} d\log(k_i)}{\sum_i \delta_i p_i k_i} \\
&= \left(\frac{\sum_i q_{i,t}^G k_i}{\sum_i (q_{i,t}^G - \delta_i p_{i,t}) k_i} \right) d\log\left(K^G\right) - \left(\frac{\sum_i \delta_i p_i k_i}{\sum_i (q_{i,t}^G - \delta_i p_{i,t}) k_i} \right) d\log(D)
\end{aligned} \tag{22}
$$

so we can see that the growth of the net capital services index is the weighted difference of the growth in the gross capital index and the growth in the depreciation index. The weights can be better understood by transforming the relationship into a decomposition of the gross capital index

$$
d\log\left(K^G\right) = \frac{\sum_i (q_{i,t}^G - \delta_i p_{i,t}) k_i}{\sum_i q_{i,t}^G k_i} d\log(K^N) + \left(\frac{\sum_i \delta_i p_i k_i}{\sum_i q_{i,t}^G k_i} \right) d\log(D) \tag{23}
$$

We can now see that the growth of the gross capital services index is the weighted sum of the growth of the net capital services index and the growth of the depreciation index. The weights are the shares of net capital income and depreciation in gross capital income.

This allows us to decompose the standard growth accounting relationship, with ϕ^G the share of gross capital income in GDP and ϕ^N the share of net capital income in GDP.

$$
\begin{aligned}
d\log(Y^G) &= \sum_i \frac{p_i y_i^G}{\sum_i p_i y_i^G} d\log(y_i^G) = \phi^G d\log(K^G) + (1 - \phi^G) d\log(L) + residual \\
&= \phi^N d\log(K^N) + (\phi^G - \phi^N) d\log(D) + (1 - \phi^G) d\log(L) + residual
\end{aligned} \tag{24}
$$

Just as we decomposed gross capital services into net and depreciation services, so too we can decompose growth of gross output into growth in net output and growth of depreciation, noting that the depreciation rates, δ_i are constant and therefore that

$d\log(\delta_i k_i) = d\log(k_i)$.

$$\begin{aligned} d\log(Y^N) &= \sum_i \frac{p_i y_i^N}{\sum p_i y_i^N} d\log(y_i^N) = \sum_i \frac{p_i(y_i^G - \delta_i k_i) d\log(y_i^G - \delta_i k_i)}{\sum_i p_i y_i^N} \\ &= \sum_i \frac{p_i(y_i^G - \delta_i k_i)}{\sum_i p_i y_i^N} \left\{ \frac{y_i^G}{(y_i^G - \delta_i k_i)} d\log y_i^G - \frac{\delta_i k_i}{(y_i^G - \delta_i k_i)} d\log(k_i) \right\} \\ &= \sum_i \frac{p_i}{\sum_i p_i y_i^N} \left\{ y_i^G d\log y_i^G - \delta_i k_i d\log(k_i) \right\} \\ &= \sum_i \left(\frac{\sum_i p_i y_i^G}{\sum_i p_i y_i^N} \right) \frac{p_i y_i^G}{\sum_i p_i y_i^G} d\log y_i^G - \left(\frac{\sum_i p_i \delta_i k_i}{\sum_i p_i y_i^N} \right) \frac{p_i \delta_i k_i}{\sum_i p_i \delta_i k_i} d\log k_i \\ &= \frac{1}{1 - \phi^G + \phi^N} d\log Y^G - \frac{\phi^G - \phi^N}{1 - \phi^G + \phi^N} d\log D \end{aligned} \tag{25}$$

Once again we can rearrange this to write

$$d\log Y^G = \left(1 - \phi^G + \phi^N\right) d\log Y^N + \left(\phi^G - \phi^N\right) d\log D \tag{26}$$

showing that the growth rate of the gross output index is equal to the growth rate of the net output index, weighted by the share of net output in gross output plus the growth of the depreciation index, weighted by the share of depreciation in GDP. We can now combine this with the growth accounting equation (24) to give

$$d\log Y^N = \frac{\phi^N}{(1 - \phi^G + \phi^N)} d\log(K^N) + \frac{(1 - \phi^G)}{(1 - \phi^G + \phi^N)} d\log(L) + \frac{residual}{(1 - \phi^G + \phi^N)} \tag{27}$$

showing that the growth in the net output index can be expressed as the weighted sum of the growth in the net capital services index and the growth in labour input, with the weights being given by the shares of each of these in the net product. The magnitude of the residual is increased by the ratio of gross to net output. The growth in the net capital services index can be derived using equation (22).

Thus far we have focused on setting up a growth accounting structure for net domestic product. Net national income is, however, linked to changes in welfare rather more precisely than net domestic product (Sefton & Weale 2006). There are two effects to be taken into account. First, it is necessary to take account of property income from abroad. Secondly, Sefton & Weale (2006) show that the consumption deflator rather than any product deflator should be used to deflate net national income. This means that the growth in the net output index has to be adjusted for the change in the ratio of the net output deflator to the consumption deflator. The former is most simply calculated as the nominal rate of growth of net income less the rate of growth of the net output index. In an open economy (reflected in our formulae above by some of the "outputs" being negative) this deals simply with the terms of trade effect and does so in a manner which ensures that, across the world as a whole, the terms of trade effects sum to zero, as they should. It should be noted also that this definition of real income has the implication that if the price of capital goods falls relative to that of consumption goods, the growth in real national income is weakened relative to that of real net domestic product. The logic of this is that welfare is accrued from consumption, present or future, rather than investment and if investment goods become cheaper, then, other things being equal, they should be expected to support less future consumption. In future work we will extend our analysis to provide a framework for accounting for growth in net national income.

3 Data and Data Sources

Data on intangible investment, at both current and constant prices, are taken from the INTAN-Invest platform (www.intaninvest.net), described by Corrado et al. (2016) This source combines estimates of investment in intangible assets from official sources (covering R & D, mineral exploration, computer software and databases, and entertainment, literary and artistic originals) with estimates for innovative property more broadly defined (design and financial innovation) and economic competencies (advertising, marketing research, organisational capital and firm provided training). This source also provides data on GDP and adjusted GDP that includes investment in intangibles for those assets not currently included in national accounts. These data are available from 1995 to 2017 and cover the market economy, excluding health, education, public administration and residential dwellings. Depreciation rates for intangible assets are also taken from INTAN-Invest.

Estimates for investment in tangible assets are taken from EU KLEMS, starting from the most recently available version (www.euklems.eu) produced by the Wiener Institut für Wirtschaftsvergleiche and described by Stehrer et al. (2019) following Hall & Jorgenson (1967). The tangible assets included are IT hardware, communications equipment, transport equipment, other plant and machinery, and structures excluding residential building. This gives data back to 1995 but some of these assets are long lived, especially structures, so we combined these data with earlier versions of EU KLEMS (www.euklems.net) to produce longer time series back to 1970. This ensures the capital stock estimates used in this paper are not overly dependent on starting values.

Table 2 shows the depreciation rates we use. For tangible assets these are taken from EU KLEMS while those for intangible assets are taken from INTAN-Invest. Finally, payments to labour are taken from EU KLEMS – this imputes the labour income of the self-employed with the balance of mixed income added to operating surplus. The data we use cover the market economy (all industries excluding L,O,P,Q,T and U).

For the assets in EU KLEMS we make the assumption that the stock of each type of capital in 1970 was equal to gross investment divided by the depreciation rate. We then cumulate forward the capital stock using the gross capital formation figures shown in EU KLEMS and the depreciation rates of table 2. By 1995 the influence of the initial assumption is relatively limited, although there is still some sensitivity of the stock of non-residential structures to the assumptions made for 1970, because the depreciation rate is low. In cumulating forward the capital stock we, of course, use volume indicators of capital formation; these are available in EUKLEMS with a reference year of 2010.

Since there are no data INTAN-Invest data before 1995, we make the assumption that the stock of capital at the end of 1995 is the amount of gross investment in 1995 divided by the depreciation rate shown in table 2. We then use the perpetual inventory to advance the stock of capital by adding on gross capital formation and deducting depreciation. Again we use volume data calculated with a reference year of 2010.

The INTAN-Invest data are not entirely consistent with the EU KLEMS data. There are some assets covered by both EU KLEMS and INTAN-Invest (research and development, computer software and data bases and entertainment) but with distinct figures. We use INTAN-Invest figures in such cases and assume that the counterpart of the discrepancy on the income side is reflected in operating surplus, leading to a change in the share of capital.

Asset	Depreciation Rate (%.p.a.)
INTAN-Invest	
Computer software and databases	31.5%
Entertainment, Artistic and Literary Originals + Mineral Explorations	30%
Design	20%
New Products in Financial Services	20%
Research and Development	15%
Brands	55%
Organisational Capital	40%
Training	40%
EU KLEMS	
Computing equipment	31.5%
Communications equipment	11.5%
Transport equipment	18.5%
Other machinery and equipment	12.6%
Non-residential structures	3.4%
Cultivated assets	19.3%

Table 2: Asset-specific Depreciation Rates

4 The Structure of Capital Costs and the Growth of Capital Services

The capital stock data, constructed as described above and the associated price indices available in the two data sources make it possible to produce estimates of the capital stock in current prices. We can then use the depreciation rates of table 2 to estimate the money value of depreciation of each asset or group of assets. We allocate the balance of net operating surplus between the different types of capital after making the assumption that the net returns on different types of capital, including the returns arising from holding gains, are equalised in each year (Hall & Jorgenson (1967)). Distinguishing intangible from tangible capital, these assumptions imply the allocation of capital costs between tangible and intangible assets as shown in figure 3 for the UK and figure 4 for the US.

Taking the two components for intangibles together, we can see, averaging over all years for which we have data, that these amount to around 40% of total user cost, with tangibles therefore amounting to almost 60% in both the UK and the US. Calculations of this type are the basis for many of the statements made about the importance of intangible capital in modern economies. If, however, we focus on the components of

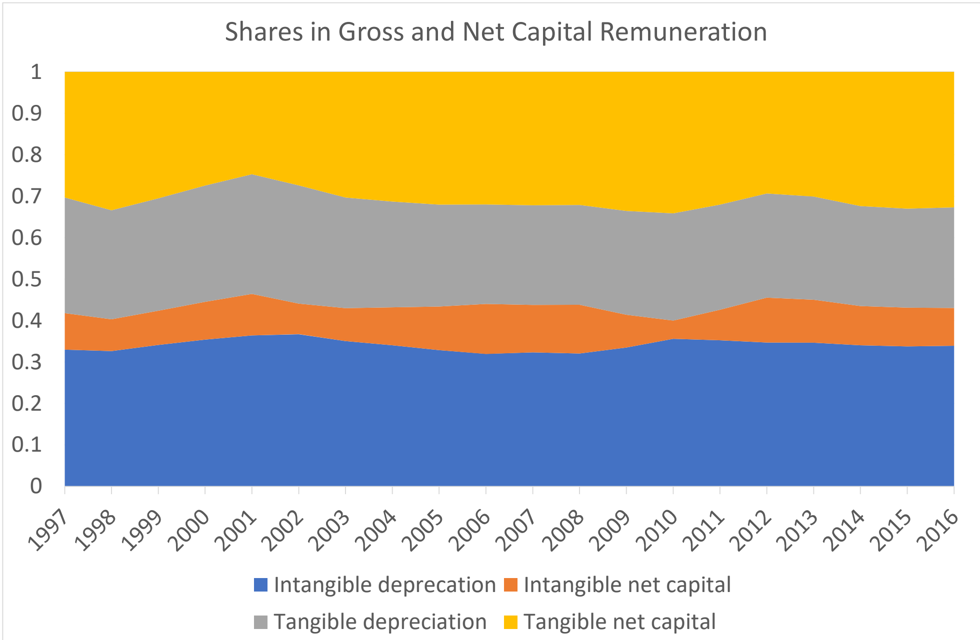


Figure 3: Shares in Capital Costs in the United Kingdom

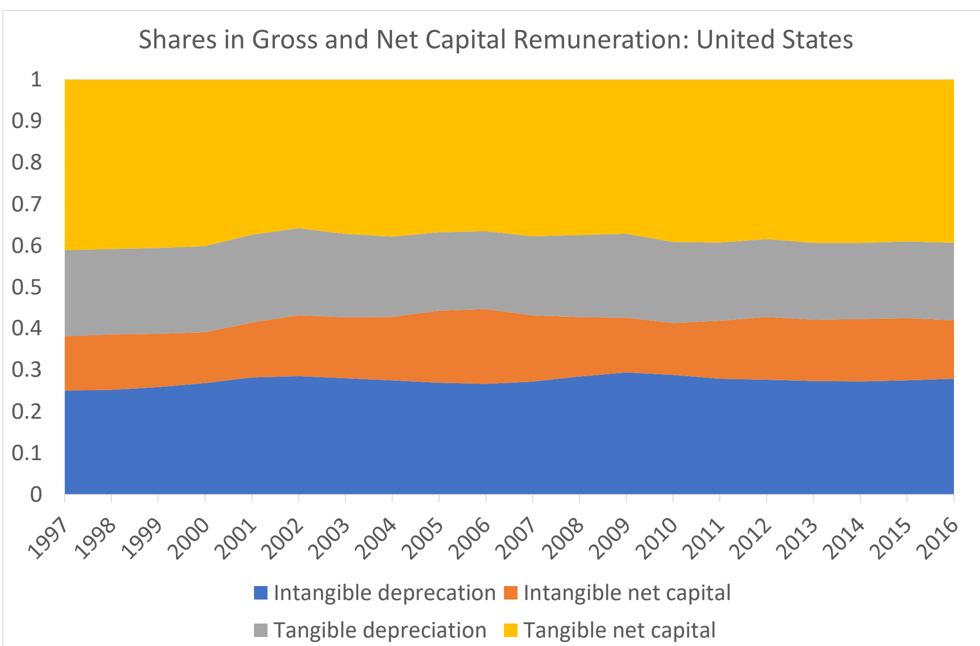


Figure 4: Shares in Capital Costs in the United States

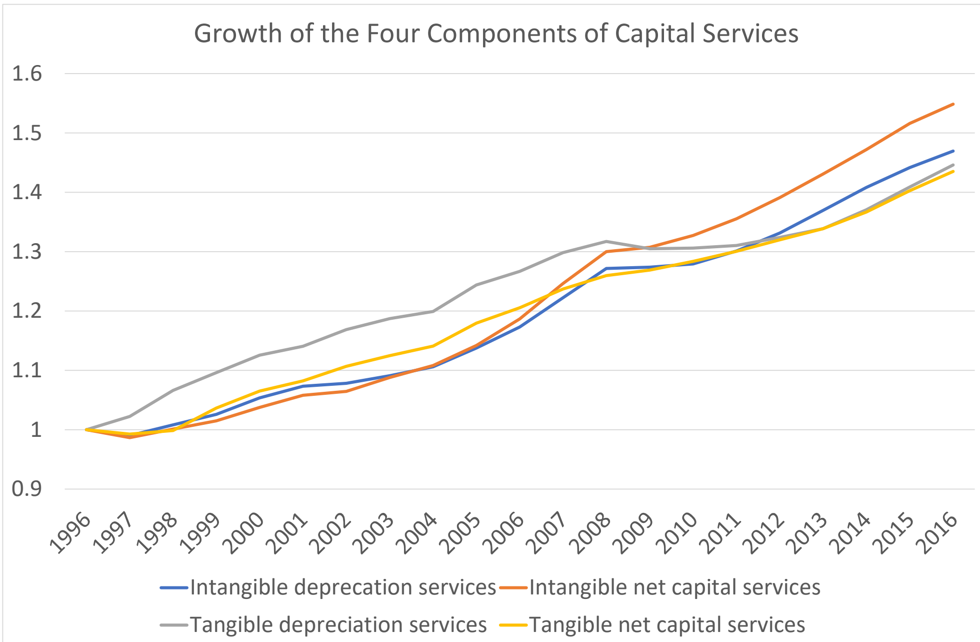


Figure 5: Growth of Components of Capital Services in the United Kingdom

user cost associated with net capital services rather than depreciation, we can see that intangible net capital accounts for about 10% of total UK user cost while tangible net capital accounts for over 30% of total UK user cost. Intangible capital contributes about 23% of total net capital services in contrast to the figure of 40% of gross capital services. In the United States intangibles account again for just over 40% of gross capital services but 27% of net capital services. In both countries intangibles, while still important, are considerably less important than the gross figures suggest.

5 Growth in Tangible and Intangible Capital Services and their Contribution to GDP Growth

Figure 5 shows the growth of volume measures of the different types of capital services in the United Kingdom derived using the approach described by Niebel et al. (2017). The graph begins in 1996 because the capital stock data relate to end years rather than the start of the year. Intangible net capital services have grown faster than intangible depreciation services, and both of these have grown faster than tangible net services,

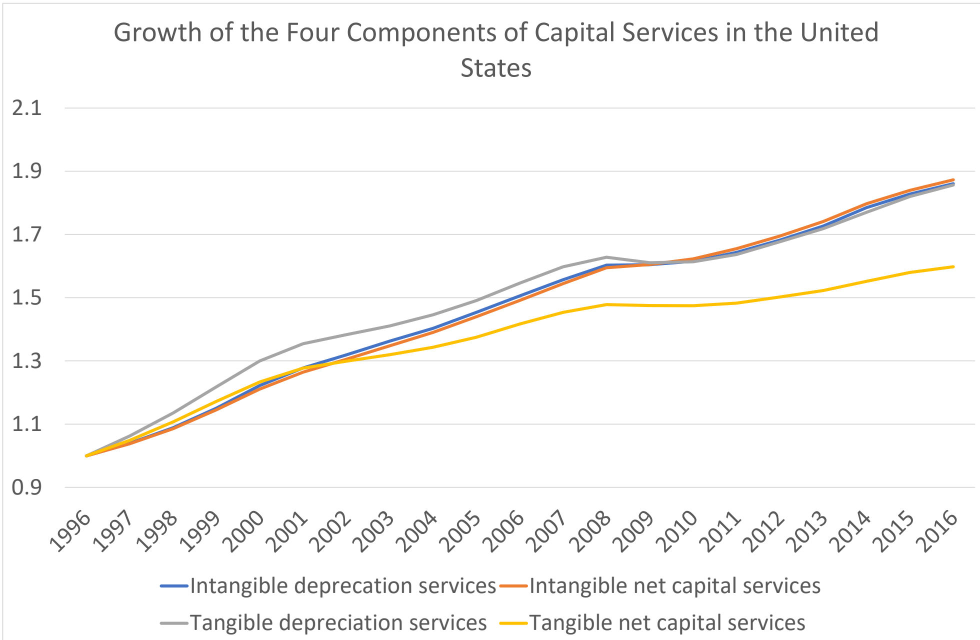


Figure 6: Growth of Components of Capital Services in the United States

which have grown largely in step with tangible depreciation services.

The results for the United States, in figure 6 also show that net intangible services have grown faster than net tangible services. Depreciation of tangibles and intangibles, and depreciation of tangibles have grown at almost exactly the same rate, while net tangible capital services have grown more slowly.

In figures 7 and 8 we show the contributions of growth in each type of capital service to growth in GDP. These bring out the importance of depreciation services as a component of the contributions of both intangible and tangible capital to economic growth. But we can see that while the contribution of net capital services from tangible capital exceeds the contribution of depreciation services, the reverse is true of intangible capital. The contribution of depreciation services for intangible capital is, in most years, well above that of net capital services.

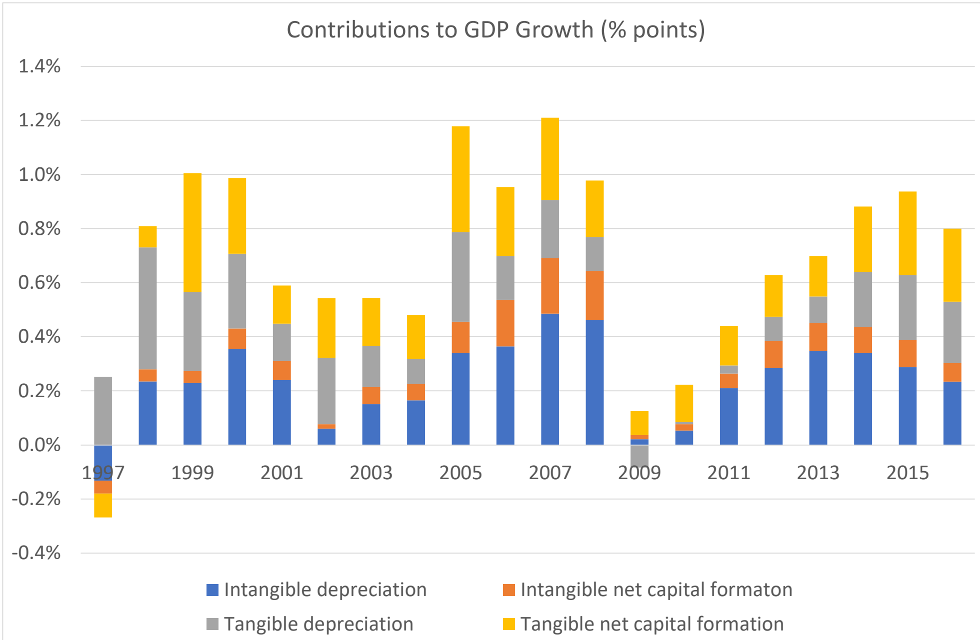


Figure 7: The Contribution of Growth in Capital Services to Growth in UK GDP

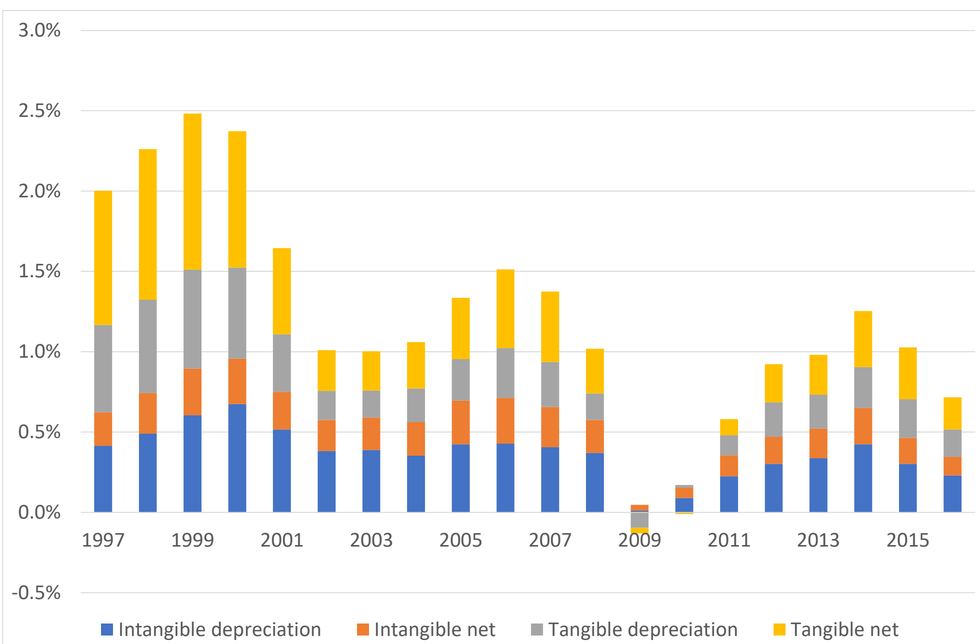


Figure 8: The Contribution of Growth in Capital Services to Growth in US GDP

6 Sectoral Results

The results so far describe what has been happening in the business sector as a whole. We now examine some of the sectoral differences in the UK, looking at selected broad sectors of manufacturing, information services, financial services and business services, We focus here on how the tangible and intangible capital stocks have grown relative to the volume index of value added and how the value of each type of capital services has developed per volume unit of value added over our data period. The indices of capital stock are calculated as Törnqvist indices combining the volume growth in each component of capital weighted by its share in the total tangible/intangible capital stock measured at current prices. When calculating the index growth between two successive years, the weights used are the averages of the shares of each type of capital in the two years in question. The overall indices are calculated by chain-linking the growth rates calculated between successive pairs of years. We also show the growth in the use of the four types of capital services (tangible and intangible depreciation and net capital services) per volume unit of value added. Thus we offer, for each sector, two different perspectives on whether production is becoming more intensive or less intensive in each type of capital.

6.1 Manufacturing

Figure 9 suggests a relatively declining role of intangible capital in manufacturing from the start of the data period until the financial crisis of 2008/9. Since then manufacturing has become more intensive in intangible capital and less intensive in tangible capital. The capital services data in figure 10 show the same broad pattern with the intensity of manufacturing in intangible services declining to the financial crisis but recovering since then. In the latter part of the period net intangible capital services have gained particularly in importance. Similarly, although both net tangible services and depreciation services from tangible capital have declined in importance since the crisis, the decline has been more pronounced in depreciation than in net services of tangible capital.

6.2 Information Services

Information services, in figure 11, show a more steady decline in the importance of both types of capital, probably reflecting pronounced capital-saving technical progress. The

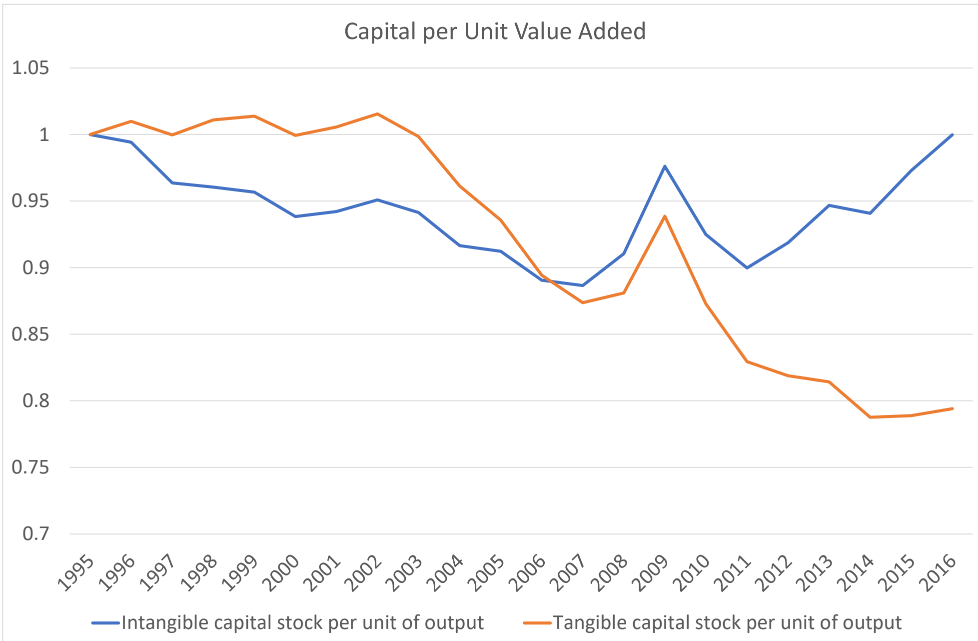


Figure 9: Evolution of the Capital/Output Ratio: Manufacturing in the UK

decline in intangible services is more pronounced. With tangible capital at least there must be a question of whether changes in the quality of the capital, as represented by the technology embodied in it, are fully reflected in the EU-KLEMS data set. The picture of capital services per unit of output in figure 12, is broadly similar for intangible capital, with depreciation services declining slightly more than net capital services. But the levels of both types of tangible capital services per unit of output are not very different in 2016 from their values in 1996.

6.3 Financial Services

Financial Services also show a reasonably stable pattern of capital usage in figure 13. Production intensity in both types of capital declined until the mid 2000s, but since then production has become more intensive in intangible capital. Looking at the roles of the different types of capital services in figure 14 we can see, however, that the sharpest increase in intensity is associated with depreciation services from tangible capital while to biggest fall in intensity is associated with the net capital services of tangible capital.

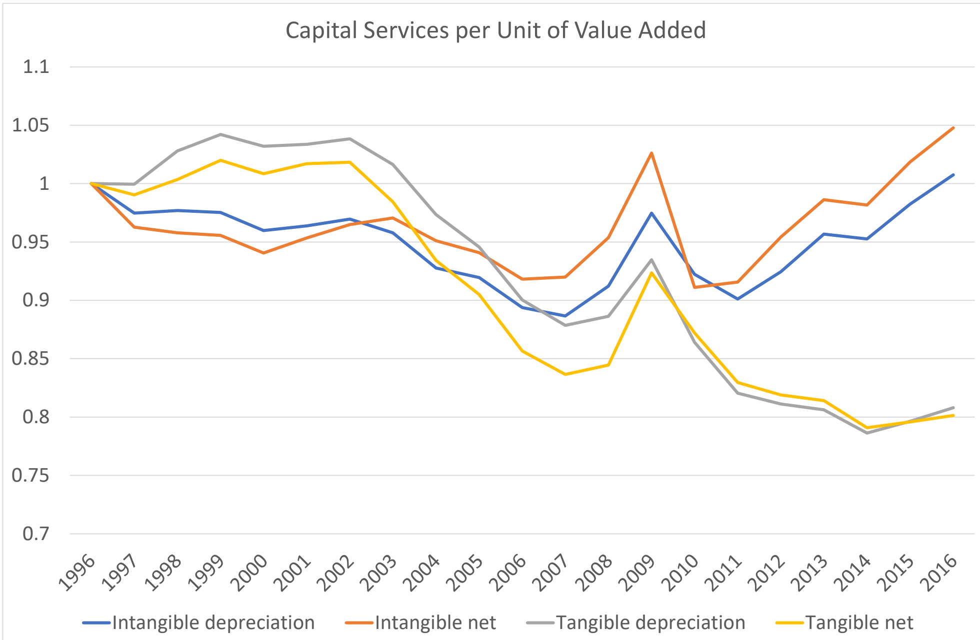


Figure 10: Evolution of Capital Services per Unit Output: Manufacturing in the UK

6.4 Business Services

Business services show, in figure 15 initially rising tangible capital and declining intangible capital per unit of output. Since the early 2000s the intensity of both has declined slightly, with the ratio of tangible capital to output in 2016 just above its 1995 value, while the ratio of intangible capital to output stands at just over 60% of its 2016 value. The pattern of capital services per unit of output in figure 16 largely reflects this, although the decline in both types of intangible capital services is less marked than that of the intangible capital to output ratio. It is also noteworthy that the depreciation services of tangible capital have grown by more than the net capital services. The industry has become disproportionately more intensive in the depreciation services of tangible capital.

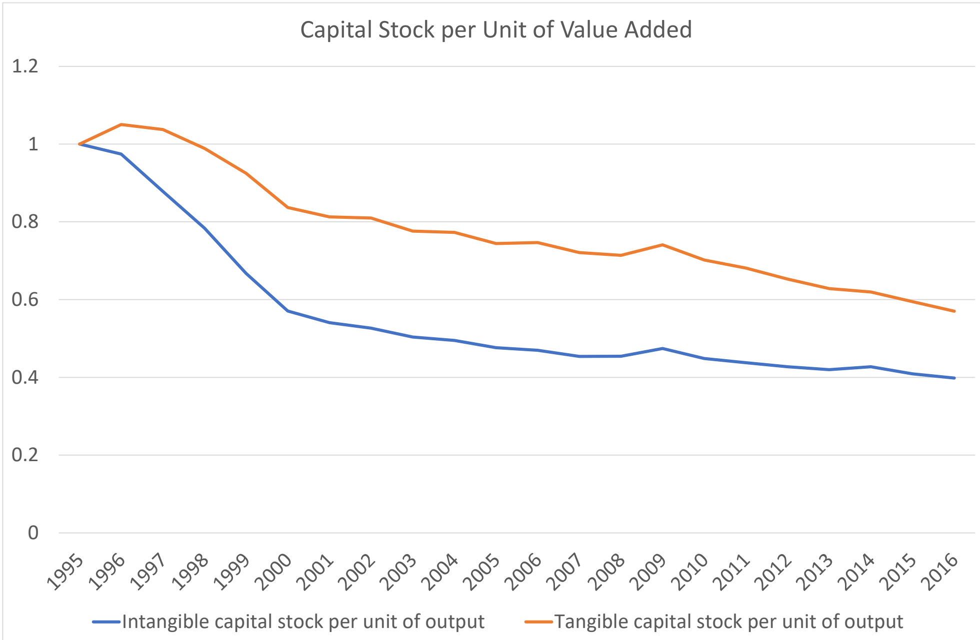


Figure 11: Evolution of the Capital/Output Ratio: Information Services in the UK

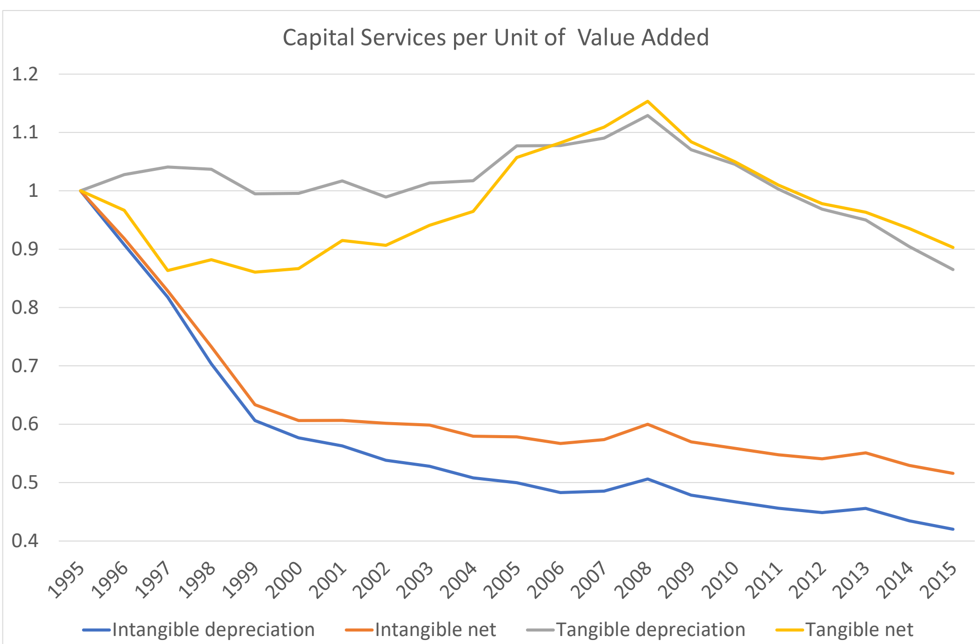


Figure 12: Evolution of Capital Services per Unit Output: Information Services in the UK

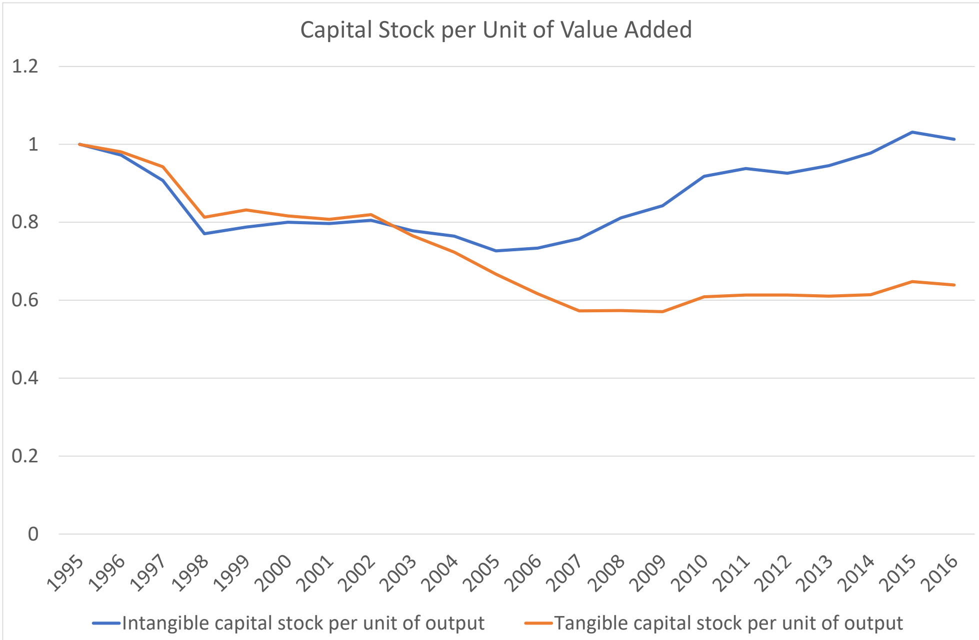


Figure 13: Evolution of the Capital/Output Ratio: Financial Services in the UK

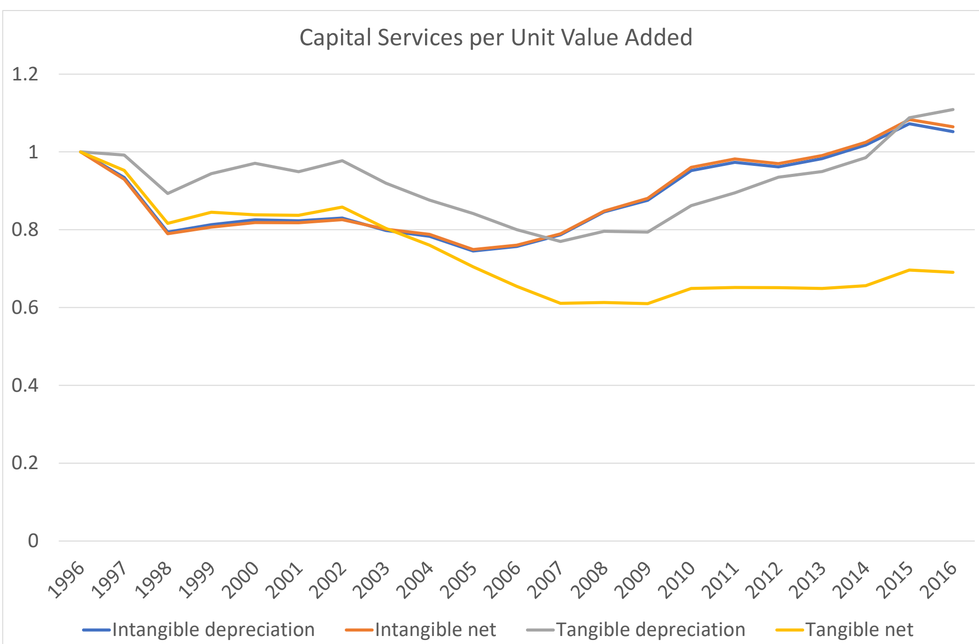


Figure 14: Evolution of Capital Services per Unit Output: Financial Services in the UK

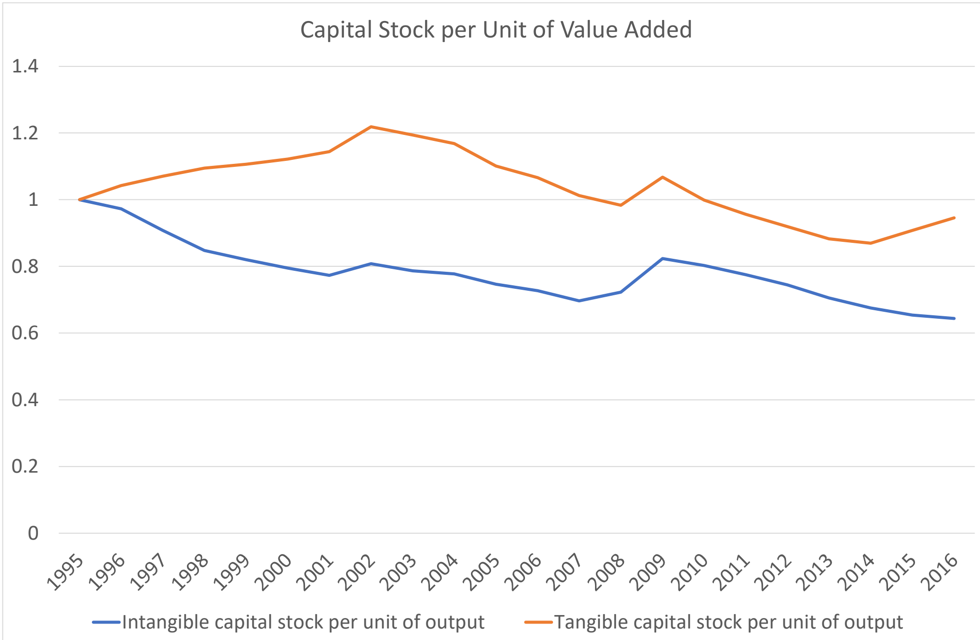


Figure 15: Evolution of the Capital/Output Ratio: Business Services in the UK

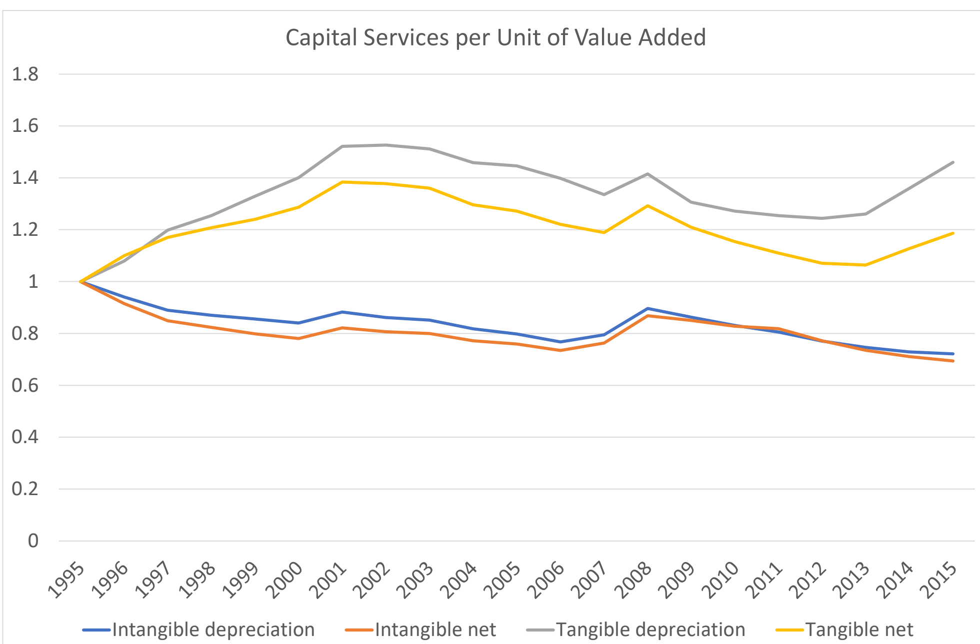


Figure 16: Evolution of Capital Services per Unit Output: Business Services in the UK

7 Conclusions

We have shown that it is possible to decompose the conventional measure of growth in capital services to show growth of those services associated with depreciation of capital (depreciation services) and those associated with a net increase in the capital stock. Growth in net services is shown to equal growth in gross capital services less growth in depreciation services, with the depreciation services growth weighted by the share of depreciation in the total return to/cost of capital. Both indices can be decomposed to show the contributions associated with individual categories of capital.

In both UK and US the volume of net intangible capital services has grown faster than the volume of net tangible capital services between 1996 and 2016. In the UK depreciation services from tangible capital have grown in line with net tangible capital services while in US they have grown faster.

The importance of each type of capital to the economy is given by its share in total user cost, or equivalently the share of the remuneration for each type of capital service in total operating surplus. The calculations needed to produce the different user cost indices allow us to identify this. We find that, in both UK and US, just over 40% of the total remuneration of capital is paid for intangible capital; three quarters of this represents depreciation. In contrast under half of the remuneration of tangible capital pays for depreciation. This means that, on a net basis, just under one quarter of net capital services are provided by intangible capital in the UK economy, with the remaining three quarters provided by tangible capital. In the United States intangibles are a slightly more important component of net capital services at just over one quarter of the total. These results follow despite the wide range of intangible services identified in the INTANINVEST data base which we use as our data source on intangible capital.

We have also been able to look at four important sectors in the UK, manufacturing, information services, financial services and business services. In manufacturing and financial services the amount of intangible capital has grown relative to that of tangible capital between 1995 and 2015, while in information and business services it has declined. The importance of tangible capital to the information services industry is easy to understand; appropriate equipment is needed to take advantage of technical progress. Capital services per unit of output show a broadly similar pattern, showing relative growth of net intangible capital services input in manufacturing and financial services, and a relative decline for information and business services. Thus the overall rise in intangible relative to tangible net capital services reflects the balance of importance of different sectors with disparate experiences.

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