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DISCUSSION PAPER

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Keywords: Intangible Capital, Depreciation, Capital Services, Economic Growth, Growth Accounting

JEL classification: C43, D24, E22, O34, O47

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We show how to decompose the contribution made by capital services to economic growth into two components, depreciation services and net capital services. We apply this to examine the contributions to economic growth by depreciation and net capital services of both tangible and intangible investment. Looking at France, Germany, the UK and the US from 1997 to 2019, we find that while overall capital services contributed between 0.6 (Germany) and 1.4 (US) percentage points to growth in GVA, net of depreciation the contributions ranged from 0.1 (Germany) to 0.5 (US) percentage points. Looking only at intangibles we find gross contributions of 0.3 (Germany) to 0.8 (US) percentage points while net of depreciation the contributions of intangibles were 0.1 (Germany) to 0.2 (US) percentage points. We conclude that a focus on gross output overstates the importance of intangible capital in these economies.

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1 Introduction

We examine the importance of investment in intangible capital goods both as a share in output and as a source of underlying economic growth. Work so far has used the conventional growth accounting framework to look at this issue in terms of the services provided by different types of intangible capital and the contribution that these make to GDP growth. But at least some forms of intangible capital have, by comparison with most types of tangible capital, very high depreciation rates. This means that growth of intangible capital can be important in terms of gross domestic product (GDP), but make only a small contribution to growth of net domestic product (NDP) . It is, however, contributions to NDP rather than GDP which support growth in economic well-being on a sustainable basis. An expansion of investment which serves only to raise depreciation would make no contribution to current or future consumption.

We show that it is possible to decompose the conventional measure of capital services used in growth accounting, into two components, net capital services and depreciation services. We demonstrate that these two components can be aggregated to deliver the standard measure of capital services. The framework that we set out may be helpful to statistics offices which seek to implement the spirit of the 2025 System of National Accounts (United Nations 2025). This states, on page 8,

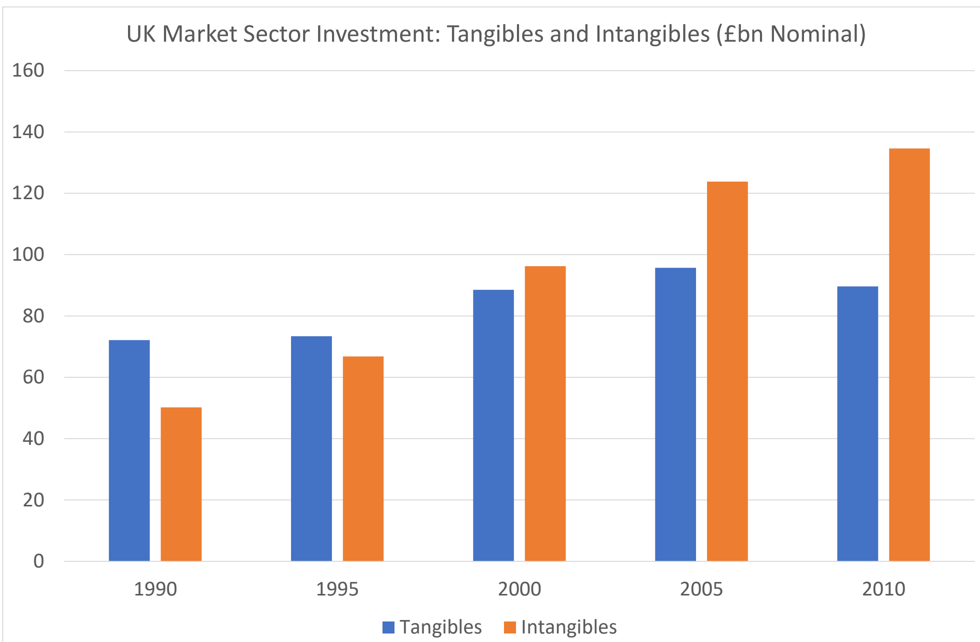
"Net income measures are given more emphasis [relative to the 2008 SNA]. *In this respect, the volume change of net domestic product (NDP) is identified as the conceptually preferred measure of economic growth... "*

We focus our attention on the market sector. We show that estimates of the importance of intangibles are much reduced when output is measured on a net basis than on the more conventional gross basis. We compare the role of intangibles using the definition of intangibles in the national accounts, with the estimates based on a wider definition. We show that widening the definition has a large impact on depreciation but little impact on both the share of intangible net investment and the share of net capital services in gross value added.

The background to this work is provided by a number of existing studies showing the importance 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.

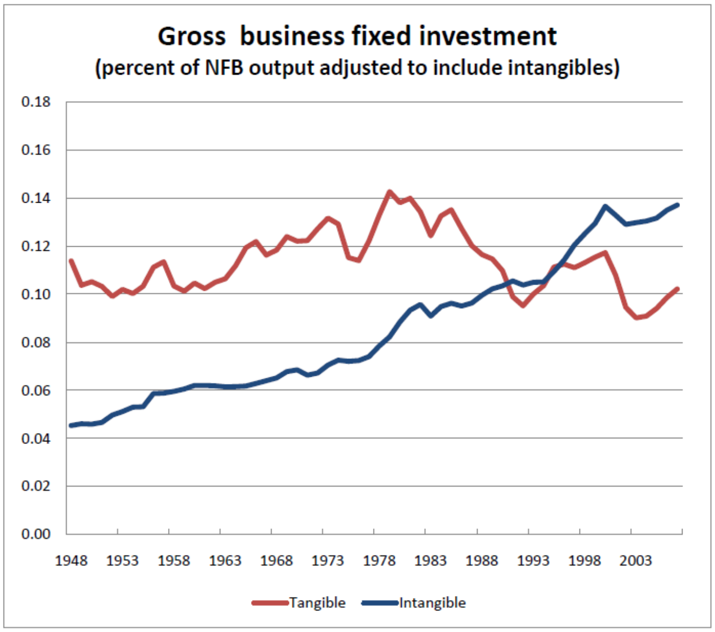
Figure 1, taken from Haskel et al. (2014) gives an indication of the importance of gross intangible and gross tangible capital formation from 1990 to 2010 in the UK, showing that by the end of last century intangible capital formation exceeded tangible capital formation. This pattern has continued in 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 importance 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 the amount of output available to support consumption or accumulation of new capital.



Source: Corrado & Hulten (2010)

Figure 2: Gross Fixed Intangible and Tangible Capital Formation in the US

As we noted above, this is implicitly recognised in the new System of National Accounts United Nations (2025).

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) show 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 or its components, whether tangible or intangible, to growth in 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 or simply distinguishing tangible from intangible capital, we construct distinct indices of depreciation services and net capital services for both tangible and intangible capital. Growth in gross capital services is shown to be measured by a weighted sum of the growth in the component indices, with the weights given by the shares of depreciation and net return to capital for each asset category in the overall gross return to capital. Aggregation over the 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 both to look at the contribution of the two forms of capital to gross output and 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 compare the importance of intangible capital formation as shown in the national accounts of France, Germany, the United Kingdom and the United States, with the pattern shown by an extended definition of intangible assets.

Looking at France, Germany, the UK and the US from 1997 to 2019, and with the extended definiton of intangible capital, we find that while overall capital services contributed 0.7, 0.6. 1.0 and 1.4 percentage points of the growth in GVA in France, Germany, the United Kingdom and the United States respectively, these contributions dropped to 0.1, 0.1, 0.4 and 0.5 percentage points when measured net of depreciation. In France which, at 54% had the highest share of intangibles in total gross capital income, the share net of depreciation in net capital income was only 27%.

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 contribution each type of capital formation (net capital formation and the capital input needed to offset depreciation for tangible and intangible capital) to GVA growth. We also show its share in GVA and its rate of growth. Section 5 concludes.

2 Decomposition of Capital Services

The general framework we use for our analysis is that developed byJorengson (1963) and used by a large number of authors such as Diewert et al. (2024), Goodridge & Haskel (2023) and Niebel et al. (2017). In common with these authors we make the assumption that each type of capital depreciates at a constant asset-specific rate and in particular, like Diewert et al. (2024) we distinguish net output from gross output[1].

We develop our framework for net product (NDP) 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 supplied to final demand gross of depreciation and $\mathbf{k}$ a vector of capital goods. y_j^G and k_j represent the gross amount of each good supplied to final demand and the stock of the jth good used as productive capital. The classifications of output and capital are the same but there are many output goods for which the corresponding capital stock is zero. $\mathbf{p}$ is the price vector of goods supplied to final demand and $\mathbf{q}^G$ is the vector of 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, with imports shown as negative output, 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 amount supplied to 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 jth element on the leading diagonal equal to the depreciation rate of capital good j and zeros off-diagonal.

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

[1] Diewert et al. (2024) provides a lengthy discussion of the concept of income. Our framework is consistent with Sefton & Weale (2006). Here, however, we focus on product rather than income.

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

$$p_j = \pi \frac{\partial F}{\partial y_j^G}; \; q_j^G = -\pi \frac{\partial F}{\partial k_j}; \; w = -\pi \frac{\partial F}{\partial L} \tag{5}$$

Here q_j^G is the user cost of capital gross of depreciation charges and w is the wage rate. Further we know that, with constant returns to scale, we can construct a unique (down to a constant) Divisia index of GDP as

$$d \log(GDP) = \sum_j \frac{p_j y_j^G}{\sum_j p_j y_j^G} d \log y_j^G \tag{6}$$

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

$$d \log(K^G) = \sum_j \frac{q_j^G k_j}{\sum q_j^G k_j} d \log(k_j) \tag{7}$$

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[2].

$$q_{j,t}^G = r_t p_{j,t} + \delta_j p_{j,t} - (p_{j,t} - p_{j,t-1}) \tag{8}$$

Here the money interest charge, r_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

$$\sum_j \frac{\partial F}{\partial y_j^G} \Delta y_j^G + \sum_j \frac{\partial F}{\partial k_j} \Delta k_j + \frac{\partial F}{\partial L} \Delta L + \frac{\partial F}{\partial \lambda} \Delta \lambda = 0 \tag{9}$$

and then substituting using the marginal conditions.

$$\sum_j p_j \Delta y_j^G = \sum_j q_j^G \Delta k_j + w \Delta L + \frac{\partial F}{\partial \lambda} \frac{\Delta \lambda}{\pi} \tag{10}$$

[2]As Diewert et al. (2024) point out, ideally the expected rather than the actual price change should be used. But data on expected price changes arenot normally available.

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 domestic product 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 capital consumption from gross output, as

$$q_{j,t}^N = q_{j,t}^G - \delta_j p_{j,t} \tag{12}$$

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 $\frac{\partial F}{\partial y_j^N} = \frac{\partial F}{\partial y_j^G}$ the marginal conditions

$$p_j = \pi \frac{\partial F}{\partial y_j^N};\ q_j^N = -\pi \frac{\partial F}{\partial k_j} - \pi \frac{\partial F}{\partial y_j^N}\delta_j = -\pi \frac{\partial F}{\partial k_j} - \pi \frac{\partial F}{\partial y_j^G}\delta_j;\ w = -\pi \frac{\partial F}{\partial L} \tag{14}$$

The net growth accounting relationship then becomes

$$\sum_j \frac{\partial F}{\partial y_j^G}(\Delta y_j^N + \delta_j \Delta k_j) + \sum_j \frac{\partial F}{\partial k_j}\Delta k_j + \frac{\partial F}{\partial L}\Delta L + \frac{\partial F}{\partial \lambda}\Delta\lambda = 0 \tag{15}$$

giving, again substituting using the marginal conditions

$$\begin{aligned} \sum_j p_j \Delta y_j^N &= \sum_j q_j^G \Delta k_j - \sum_j p_j \delta_j \Delta k_j + w\Delta L - \frac{\partial F}{\partial \lambda}\frac{\Delta\lambda}{\pi} \\ &= \sum_j q_j^N \Delta k_j + w\Delta L - \frac{\partial F}{\partial \lambda}\frac{\Delta\lambda}{\pi} \end{aligned} \tag{16}$$

Reverting to the index of gross capital services

$$d\log(K^G) = \sum_j \frac{q_j^G k_j}{\sum q_j^G k_j} d\log(k_j) \tag{17}$$

and expanding the logarithm, we can see

$$\frac{dK^G}{K^G} = \sum_j \frac{q_j^G k_j}{\sum q_j^G k_j} \frac{dk_j}{k_j} = \sum_j \frac{q_j^G dk_j}{\sum q_j^G k_j} \tag{18}$$

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

$$\frac{\sum_j q_j^G \Delta k_j}{\sum_j p_j y_j} = \frac{\sum q_j^G k_j}{\sum_j p_j y_j} \frac{dK^G}{K^G} \tag{19}$$

where $\sum q_j^G k_j / \sum_j p_j y_j$ is, as a result of the definition of q_j^G the share of gross capital income in GDP.

We can similarly define an index of net capital services as

$$d\log(K^N) = \sum_j \frac{q_j^N k_j}{\sum q_j^N k_j} d\log(k_j) \tag{20}$$

and an index of depreciation services as

$$d\log(D) = \sum_j \frac{\delta_j p_j k_j}{\sum \delta_j p_j k_j} d\log(k_j) \tag{21}$$

$$\begin{aligned} d\log(K^N) &= \sum_j \frac{q_j^N k_j}{\sum q_j^N k_j} d\log(k_j) = \sum_j \frac{\left(q_{j,t}^G - \delta_j p_{j,t}\right) d\log(k_j)}{\sum_j (q_{j,t}^G - \delta_j p_{j,t}) k_j} \\ &= \sum_j \frac{q_{j,t}^G d\log(k_j)}{\sum_j (q_{j,t}^G - \delta_j p_{j,t}) k_j} - \sum_j \frac{\delta_j p_{j,t} d\log(k_j)}{\sum_j (q_{j,t}^G - \delta_j p_{j,t}) k_j} \\ &= \sum_j \left(\frac{\sum_j q_{j,t}^G k_j}{\sum_j (q_{j,t}^G - \delta_j p_{j,t}) k_j} \right) \frac{q_{j,t}^G d\log(k_j)}{\sum_j q_{j,t}^G k_j} \\ &\quad - \sum_j \left(\frac{\sum_j \delta_j p_j k_j}{\sum_j (q_{j,t}^G - \delta_j p_{j,t}) k_j} \right) \frac{\delta_j p_{j,t} d\log(k_j)}{\sum_j \delta_j p_j k_j} \\ &= \left(\frac{\sum_j q_{j,t}^G k_j}{\sum_j (q_{j,t}^G - \delta_j p_{j,t}) k_j} \right) d\log\left(K^G\right) - \left(\frac{\sum_j \delta_j p_j k_j}{\sum_j (q_{j,t}^G - \delta_j p_{j,t}) k_j} \right) d\log(D) \end{aligned} \tag{22}$$

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

$$d\log\left(K^G\right)=\frac{\sum_j(q^G_{j,t}-\delta_j p_{j,t})k_j}{\sum_j q^G_{j,t}k_j}d\log(K^N)+\left(\frac{\sum_j \delta_j p_j k_j}{\sum_j q^G_{j,t}k_j}\right)d\log(D) \tag{23}$$

It is now obvious 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.

$$\begin{aligned}
d\log(Y^G) &= \sum_j \frac{p_j y^G_j}{\sum_j p_j y^G_j}d\log(y^G_j)=\phi^G d\log(K^G)+(1-\phi^G)d\log(L)+residual \qquad (24)\\
&= \phi^N d\log(K^N)+(\phi^G-\phi^N)d\log(D)+(1-\phi^G)d\log(L)+residual
\end{aligned}$$

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_j are constant and therefore that $d\log(\delta_j k_j)=d\log(k_j)$.

$$\begin{aligned}
d\log(Y^N) &= \sum_j \frac{p_j y^N_j}{\sum p_j y^N_j}d\log(y^N_j)=\sum_j \frac{p_j(y^G_j-\delta_j k_j)d\log(y^G_j-\delta_j k_j)}{\sum_j p_j y^N_j} \qquad (25)\\
&= \sum_j \frac{p_j(y^G_j-\delta_j k_j)}{\sum_j p_j y^N_j}\left\{\frac{y^G_j}{(y^G_j-\delta_j k_j)}d\log y^G_j-\frac{\delta_j k_j}{(y^G_j-\delta_j k_j)}d\log\left(k_j\right)\right\}\\
&= \sum_j \frac{p_j}{\sum_j p_j y^N_j}\left\{y^G_j d\log y^G_j-\delta_j k_j d\log\left(k_j\right)\right\}\\
&= \sum_j \left(\frac{\sum_j p_j y^G_j}{\sum_j p_j y^N_j}\right)\frac{p_j y^G_j}{\sum_j p_j y^G_j}d\log y^G_j-\left(\frac{\sum_j p_j\delta_j k_j}{\sum_j p_j y^N_j}\right)\frac{p_j\delta_j k_j}{\sum_j p_j\delta_j k_j}d\log k_j\\
&= \frac{1}{1-\phi^G+\phi^N}d\log Y^G-\frac{\phi^G-\phi^N}{1-\phi^G+\phi^N}d\log D
\end{aligned}$$

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

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

showing that the explained 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). In the rest of this paper we focus our attention on the impact of the different components of capital goods, looking at their contributions to capital formation, and capital services. We also show the four volume measures of capital service and the contribution that each of the four components makes to growth in GDP; simple arithmetic calculation makes it possible to convert these to contributions to the growth in NDP.

3 Data and Data Sources

Most of the data we use are taken from the EUKLEMS and INTANPROD datasets made available by LUISS at https://euklems-intanprod-llee.luiss.it/. These data are described by Corrado et al. (2016), with further details available on the platform documentation section. 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 2020. Estimates for investment in tangible assets are also taken from EUKLEMS and INTANPROD. The tangible assets included are IT hardware, communications equipment, transport equipment, other plant and machinery, and structures excluding residential building.

Finally, payments to capital are constructed in EUKLEMS after imputing the labour income of the self-employed, with the balance of mixed income added to operating surplus. Our ananlysis covers the market economy, excluding health, education, public administration and residential dwellings (all industries excluding L,O,P,Q,T and U).

The data set provided by LUISS contains data, including estimates of capital stocks, taken from the relevant national accounts for those assets[3] which appear in the national accounts. These are produced from data published by the relevant statistical offices. As noted earlier, we look at the market sector; the data set also provides estimates for the whole economy and for broad industrial categories.

There are, however, two problems with these data. First, there are some obvious inconsistencies. For example, the UK capital stock figures for information technology and communication technology imply that in some years depreciation rates were negative. More generally, the different countries have different methods of computing the capital stock and thus the data are not comparable across countries.

We therefore proceed as follows. We take the national accounting figures for gross investment by asset as given. But we compute capital stocks using the perpetual inventory method. We assume that the capital stocks at constant prices evolve in line with equation (28) and the depreciation rates are those of table 2[4] . We use these generated figures to calculate both depreciation and net capital services delivered by each type of asset.

$$k_{j,t} = (1 - \delta_j)k_{j,t-1} + i_{j,t} \tag{28}$$

We do this for two definitions of intangibles. First we use the national accounts definition, including the assets marked N in table 2. Secondly we do this for an extended definition of intangibles, including all of the assets shown in table 2. We refer to these results as produced using the extended definition. This allows us to show the effects of widening the definition on overall net capital services.

in order to apply equation (28) we need an initial value for the capital stock. For rapidly depreciating assets the capital stocks are, after a few years, insensitive to the initial stock, but for very durable assets like Other Construction, the initial capital stock casts a long shadow.

[3]Communication Technology, Information Technology, Other Construction, Other Machinery, Research and Development, Software and Databases, and Transport Equipment

[4]See Wiener Institut für Internationale Wirtschaftsvergleiche (2019) and references contained therein

Asset		Depreciation Rate (p.a.)
Brand	E	0.55
Communication Technology	N	0.115
Cultivated Assets	N	0.193
Design	E	0.2
Information Technology	N	0.315
New Financial Products	E	0.2
Other Construction	N	0.034
Other Intellectual Property Products	N	0.126
Other Machinery	N	0.126
Organisational Capital	E	0.4
Research and Development	N	0.15
Software and Databases	N	0.25
Transport Equipment	N	0.185
Training	E	0.4

E indicates extended definition
N indicates national accounts definition

Table 2: Depreciation Rates by Asset

For Information Technology, Communications Technology, Software and Databases, Transport Equipment, Other Machinery, and Other Construction we are able to draw on figures for gross investment going back to 1970 (in 1995 prices) taken from the sources listed by EUKLEMS (2007, p.40). We then calculate the growth rate of investment comparing the three year average for 1975-77 with 1970-72 and calculating an annual growth rate, g from this. Next, following Niebel et al. (2017), we set the starting value for each of these six assets indexed by j as

$$k_{j,1970} = \frac{i_{j,1970}}{g_j + \delta_j} \tag{29}$$

where investment, $i_{j,1970}$ and the capital stock, $k_{j,1970}$ are measured at 1995 prices. Finally we use the price information in the EUKLEMS/INTANPROD database to covert the capital and investment figures to 2015 prices. Equation (28) is then used to calculate the capital stock in each subsequent period in 2015 prices.

For the remaining assets[5] we do not have any estimates going back before 1995. We therefore work out a growth rate, g_j^*, for gross investment in each type of asset by

[5]Brand Value, Cultivated Assets, Design, New Financial Products, Other Intellectual Property Products, Organisational Capital, Research and Development, and Training

comparing the average for 2000-02 with 1995-1997. Thus the formula we use is

$$k_{j,1995} = \frac{i_{j,1995}}{g_j^* + \delta_j} \tag{30}$$

For the UK a value for investment in 1995 in Other Intellectual Property Products is missing. We set the 1995 figure in 2015 prices to the average of the 1996 and 1997 values and assume a value of the deflator of 70 (2015=100). Also the French data imply a very implausible figure for the price of New Financial Products. We replace this with the price index for Germany for this category of intangible investment.

There are four assets in total for which the data show negative values of g_j^*. These are Research and Development, Other Intellectual Property Products and Cultivated Assets in the United Kingdom and Training in the United States. When the negative growth rate is only just below the depreciation rate in size equation (30) generates a very large initial capital stock. This is particularly a problem for other intellectual property products in the United Kingdom where the growth rate is -8.9% and the depreciation rate is 12.6%. We set the growth rate to zero in all four cases where the calculation suggests a negative rate.

4 Results

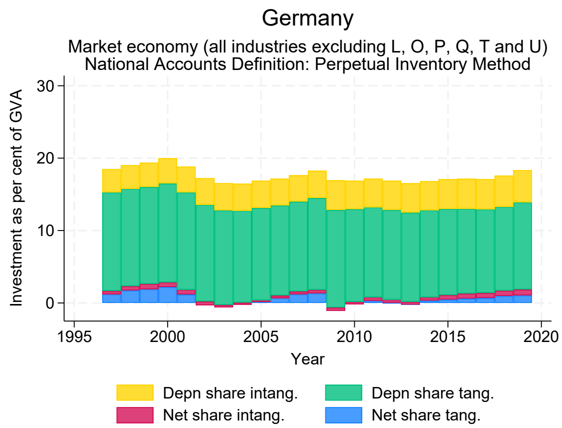
Here we present results for four advanced economies, France, Germany, the United Kingdom and the United States. We begin by showing the composition of capital formation as a share of value added, both for the definition of intangibles used in the current national accounts and the extended definition. In both cases the depreciation figures are taken from the perpetual inventory calculations. It should be noted that, because more forms of expenditure are treated as capital formation, gross value added (GVA)is higher with the extended definition than with the national accounts definition. As a result the share of tangible capital formation in GVA is lower with the extended definition than with the national accounts definition.

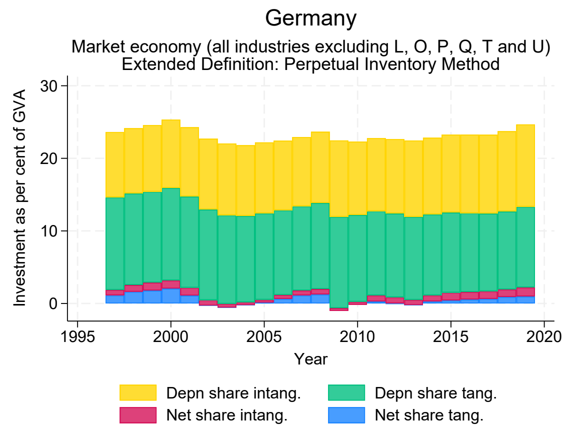
Figure 3 shows the annual data for the shares of the four different components of capital formation in GVA. We can see that depreciation takes up more than half of gross capital formation even when using national accounts definitions. The wider concept of intangible capital, reflected in the right-hand column of charts, leads to a much increased share of depreciation in GVA, but has little impact on net capital formation. This reflects the high rates of depreciation of intangible capital.

In figure 4 we show the components of capital services, again presented as a share of GVA. Here too it is striking that intangible capital services have a much larger depreciation component than do tangible capital services. And the widening of the definition of intangibles leads to a large increase in the provision of depreciation services but only a small change in the net capital services provided by intangibles.

Figure 5 shows the volume indices for each of the measures of capital services, with 2015=100. In all four countries the depreciation services and the net capital services provided by intangibles grow very closely in step. These tend, except in the United Kingdom with the national accounts definition, to grow faster than the two components of services provided by tangible capital. But it is also striking that except in the United States, the two forms of services from tangible capital grow at almost the same rates. Only in the United States do depreciation services grow materially faster than net capital services from tangibles. So in the United States the mix of tangible capital goods has shifted towards those with faster depreciation rates.

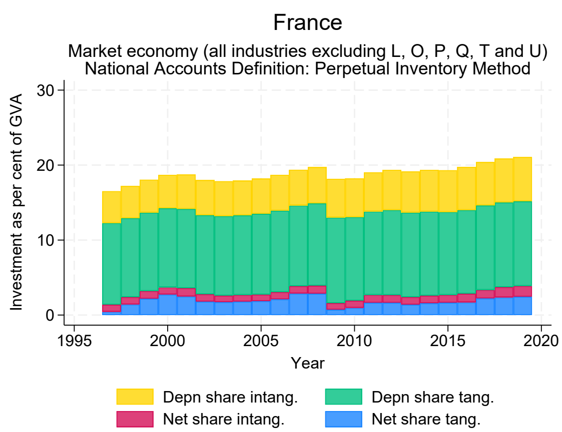
Figure 3: Capital Formation as a Share of Gross Value Added

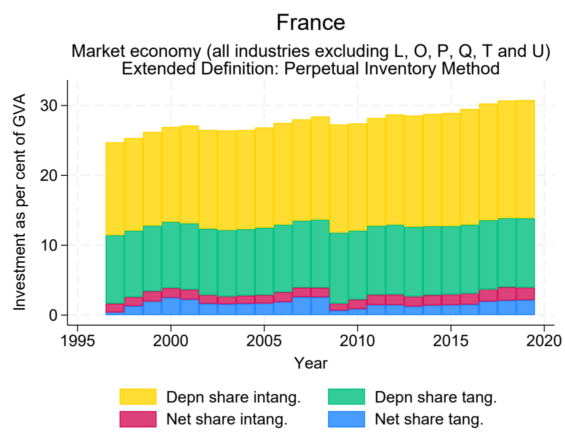




Germany: National Accounts

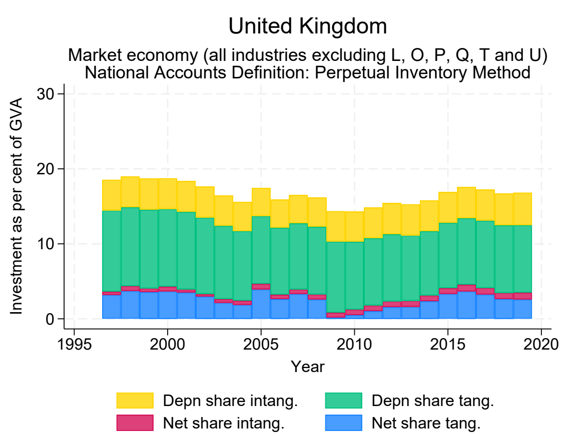
Extended Definition

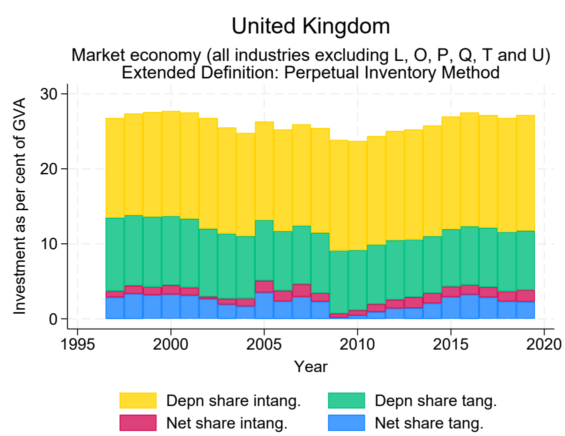




France: National Accounts

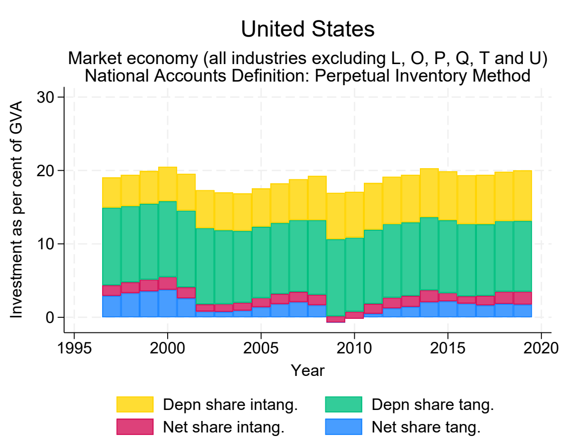
Extended Definition

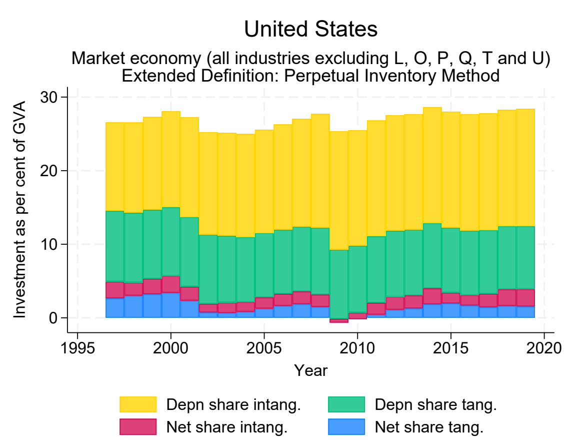




United Kingdom: National Accounts

Extended Definition

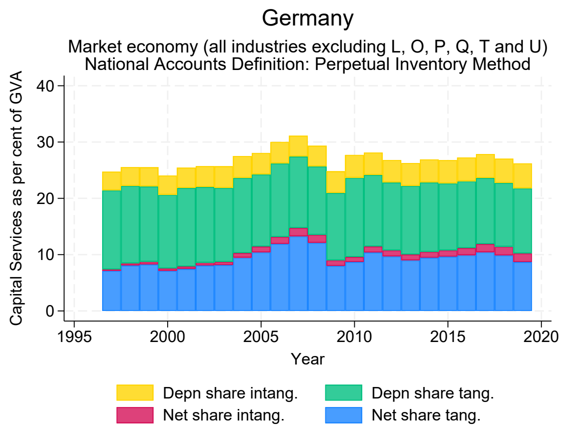




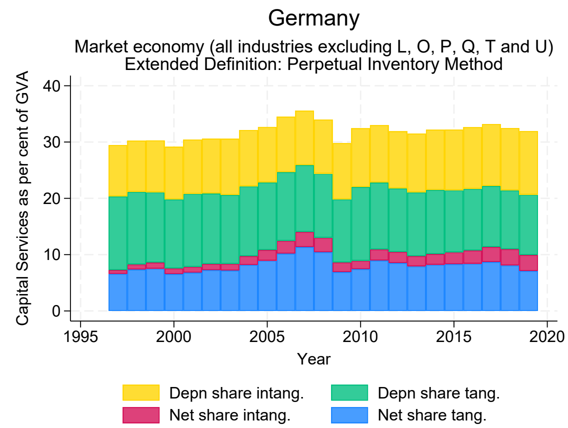
United States: National Accounts

Extended Definition

Figure 4: Capital Services as a Share of Gross Value Added



Germany: National Accounts



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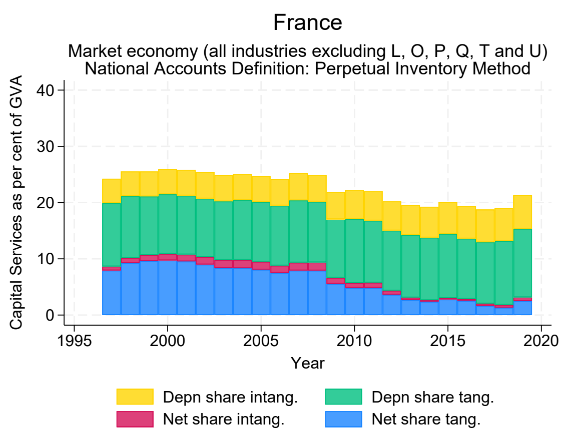
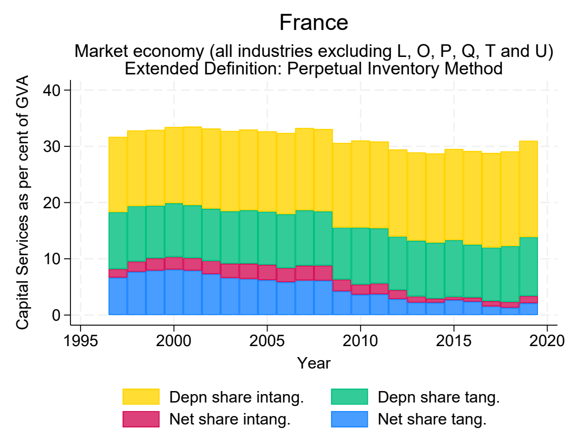


France: National Accounts



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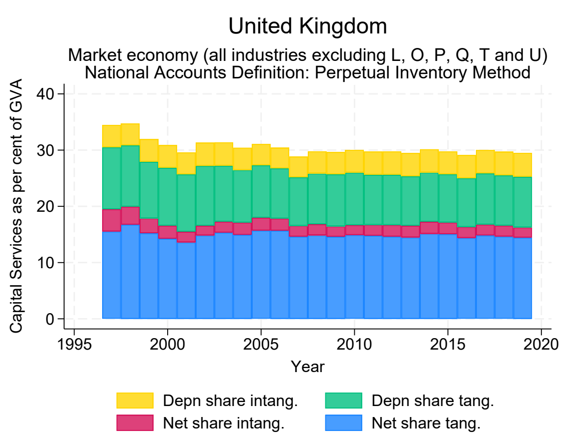
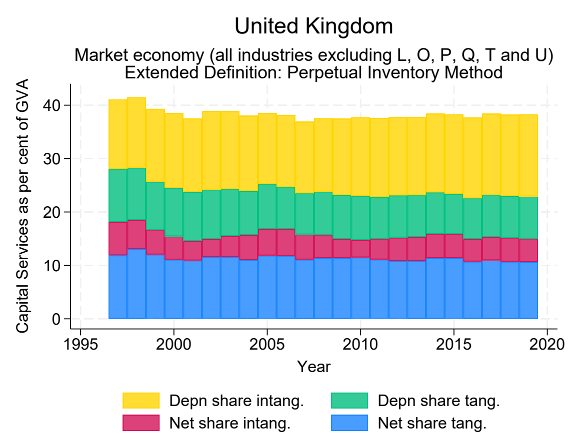


United Kingdom: National Accounts



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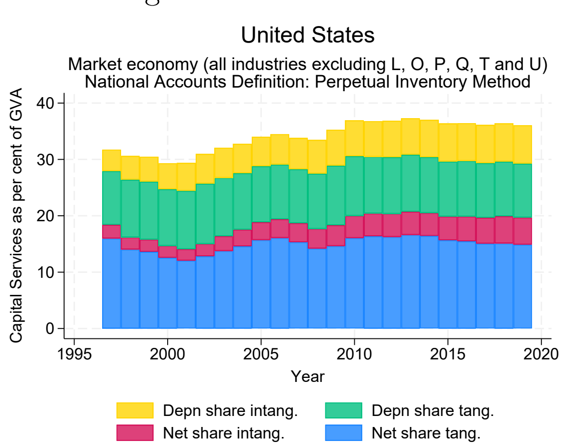
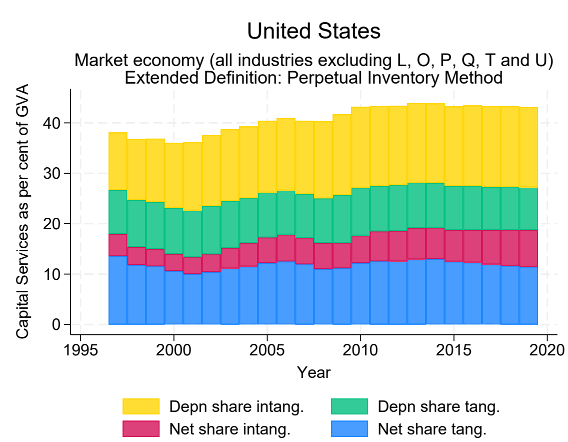
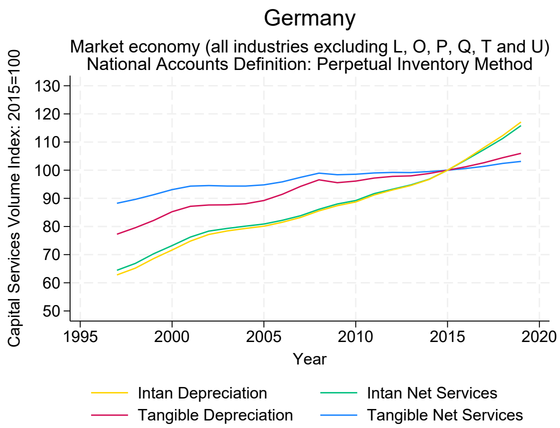


United States: National Accounts

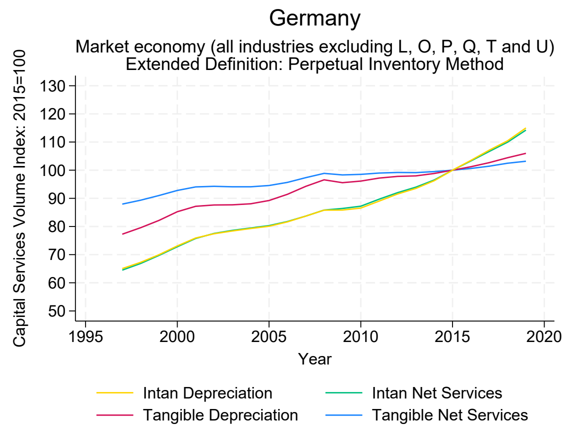


Extended Definition

Figure 5: Capital Services Volume Indices: 2015=100



Germany: National Accounts



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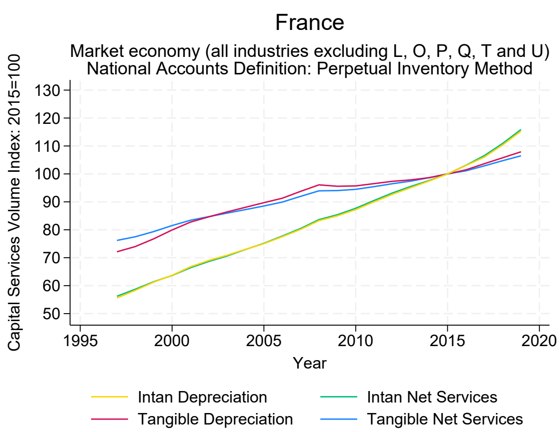
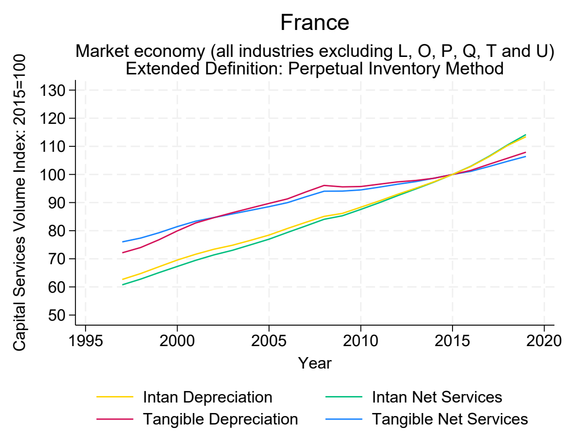


France: National Accounts



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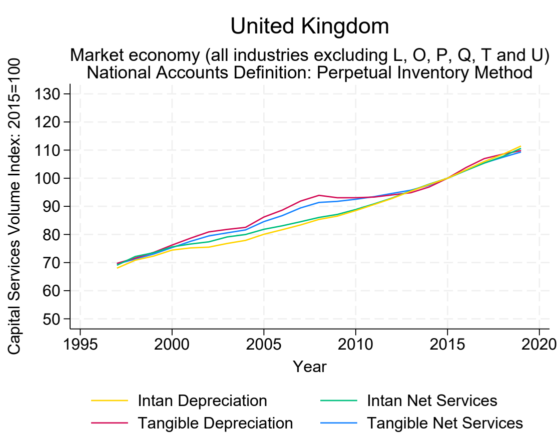
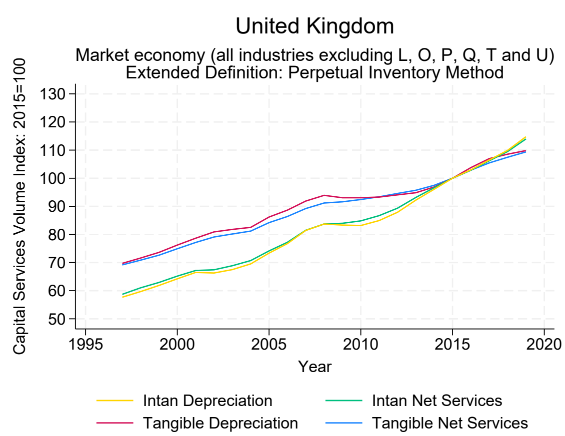


United Kingdom: National Accounts



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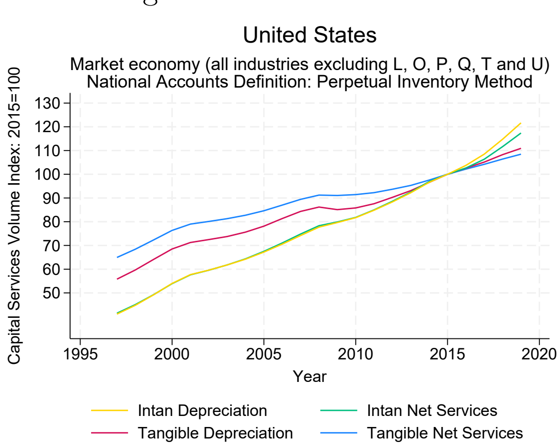
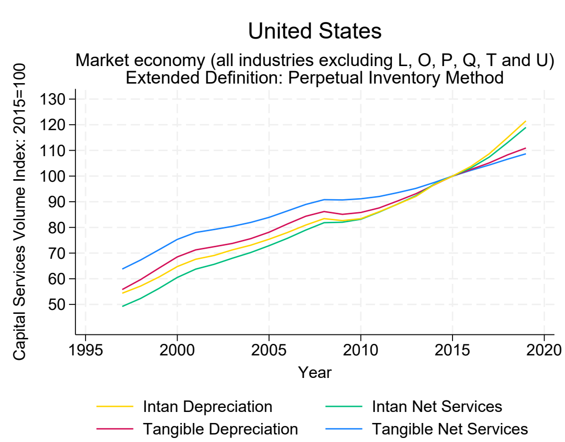


United States: National Accounts



Extended Definition

We show in tables 3 to 6, the contributions of four components of aggregate capital services, as the depreciation services and net capital services provided by both tangible and intangible assets. We show averages for the period 1997 to 2019[6] for the definition of intangible assets used in the national accounts, covering Software and Databases, Research and Development and Other Intellectual Property Products. We also show the results for the extended definition of intangible capital which also includes Brand Value, Design, New Financial Products, Organisational Capital and Training. This makes it possible to see the contributions of the four types of capital services with both definitions of intangibles.

Turning to our results, we can see, looking for example at table 3 that both depreciation and net capital services provided by intangible capital grew faster than those provided by tangible capital and that with the extended definition, the share in GVA was half as large again as that attributed to tangible capital. Similarly if we look at contributions to GVA growth, intangible capital services provided twice as much as tangible capital services. But the lion's share of this was depreciation services, and the contribution of intangible net capital services was the same as that from tangible net capital services.

Much the same is true of Germany as table 4 shows. The UK (table 5) also shows similar contributions from the two types of net capital services, while in the US (table 6), the gross contribution of intangibles is lower than that of tangibles and the net contribution, even with the extended definition, is only half as large.

Table 3: Capital Services: France 1997-2019

	National Accounts Definition			Extended Intangibles		
	Contribution to GVA gwth % pts p.a.	Share in GVA %	Growth Rate % p.a.	Contribution to GVA gwth % pts p.a.	Share in GVA %	Growth Rate % p.a.
Tangible Depreciation	0.20	10.90	1.80	0.18	9.69	1.80
Tangible Net Capital	0.10	5.99	1.49	0.08	4.86	1.49
Intangible Depreciation	0.17	5.03	3.39	0.41	15.01	2.71
Intangible Net Capital	0.03	0.93	3.34	0.05	1.82	2.88
All Depreciation	0.37	15.93	2.30	0.58	24.70	2.36
All Net Capital	0.13	6.92	1.75	0.13	6.68	1.90
Total	0.50	22.85	2.11	0.72	31.38	2.25

[6]The data run to 2021 in the vintage we used but we leave out the last year so as to avoid distortions resulting from the Covid-19 epidemic

Table 4: Capital Services: Germany 1997-2019

	National Accounts Definition			Extended Intangibles		
	Contribution to GVA gwth % pts p.a.	Share in GVA %	Growth Rate % p.a.	Contribution to GVA gwth % pts p.a.	Share in GVA %	Growth Rate % p.a.
Tangible Depreciation	0.19	12.72	1.45	0.18	11.85	1.45
Tangible Net Capital	0.07	9.36	0.71	0.06	8.13	0.73
Intangible Depreciation	0.11	3.86	2.83	0.26	10.08	2.58
Intangible Net Capital	0.02	0.95	2.66	0.05	1.81	2.61
All Depreciation	0.30	16.58	1.78	0.44	21.93	1.99
All Net Capital	0.09	10.32	0.89	0.11	9.94	1.07
Total	0.39	26.90	1.45	0.55	31.87	1.71

Table 5: Capital Services: United Kingdom, 1997-2019

	National Accounts Definition			Extended Intangibles		
	Contribution to GVA gwth % pts p.a.	Share in GVA %	Growth Rate % p.a.	Contribution to GVA gwth % pts p.a.	Share in GVA %	Growth Rate % p.a.
Tangible Depreciation	0.20	9.41	2.05	0.18	8.35	2.05
Tangible Net Capital	0.31	14.92	2.05	0.24	11.34	2.07
Intangible Depreciation	0.09	4.02	2.27	0.45	14.28	3.12
Intangible Net Capital	0.05	2.17	2.20	0.14	4.40	3.03
All Depreciation	0.29	13.43	2.12	0.63	22.63	2.74
All Net Capital	0.36	17.09	2.08	0.38	15.74	2.36
Total	0.65	30.52	2.09	1.01	38.37	2.58

Table 6: Capital Services: United States, 1997-2019

	National Accounts Definition			Extended Intangibles		
	Contribution to GVA gwth % pts p.a.	Share in GVA %	Growth Rate % p.a.	Contribution to GVA gwth % pts p.a.	Share in GVA %	Growth Rate % p.a.
Tangible Depreciation	0.33	10.01	3.25	0.30	8.99	3.25
Tangible Net Capital	0.37	14.93	2.42	0.31	11.84	2.51
Intangible Depreciation	0.28	5.75	5.10	0.56	14.69	3.84
Intangible Net Capital	0.16	3.42	4.89	0.22	5.22	4.18
All Depreciation	0.62	15.76	3.91	0.86	23.69	3.63
All Net Capital	0.53	18.35	2.86	0.53	17.05	3.02
Total	1.15	34.11	3.34	1.39	40.74	3.37

Table 7: Shares of Total Net and Gross Capital Income: Extended Definition of Intangibles, 1997-2019

	France	Germany	United Kingdom	United States
Shares of Gross Capital Income				
Tangible Depreciation	30.9%	37.2%	21.8%	22.1%
Tangible Net Capital	15.5%	25.5%	29.6%	29.1%
Intangible Depreciation	47.8%	31.6%	37.2%	36.1%
Intangible Net Capital	5.8%	5.7%	11.5%	12.8%
All Depreciation	78.7%	68.8%	59.0%	58.1%
All Net Capital	21.3%	31.2%	41.0%	41.9%
Tangible Gross Capital	46.4%	62.7%	51.3%	51.1%
Intangible Gross Capital	53.6%	37.3%	48.7%	48.9%
Shares of Net Capital Income				
Tangible Capital	72.8%	81.8%	72.0%	69.4%
Intangible Capital	27.2%	18.2%	28.0%	30.6%

Table 7 shows the importance of the different types of payments for capital services as a percentage of the total payment for capital services in the economy as a whole. We see that intangible net capital services are much less important, as a share of total net capital services, than are gross intangibles measured as a share of gross capital services.

In tables 8 to 11 we present further detail, splitting the sample into two periods, 1997-2007 and 2007 to 2019. Using the national accounts definition of intangibles, we can see that tangible net capital services contributed more to GDP growth than did intangible net capital services in the first period in all four countries. In the second period this is not true in France or Germany. Turning to the share of tangible and intangible net investment in GDP, we can see that tangible net investment exceed intangible net investment in all four countries in both periods. But the growth rates of intangible net investment exceed those of tangible net investment in both periods in all four countries. Looking now at depreciation we can see that in the second period intangible depreciation contributed more than tangible depreciation to economic growth, while in the first period tangible depreciation was more important.

Table 8: Capital Services: France National Accounts

	Contribution to GVA growth %age pts p.a.		Share in GVA %		Growth Rate % p.a.	
	1997-2007	2007-2019	1997-2007	2007-2019	1997-2007	2007-2019
Tangible Depreciation	0.27	0.13	10.69	11.09	2.48	1.17
Tangible Net Capital	0.16	0.04	8.66	3.55	1.78	1.22
Intangible Depreciation	0.17	0.17	4.59	5.44	3.78	3.03
Intangible Net Capital	0.04	0.02	1.22	0.66	3.67	3.04
All Depreciation	0.44	0.30	15.27	16.53	2.86	1.78
All Net Capital	0.20	0.06	9.88	4.21	2.00	1.53
Total	0.64	0.36	25.15	20.73	2.52	1.73

Table 9: Capital Services: Germany National Accounts

	Contribution to GVA growth %age pts p.a.		Share in GVA %		Growth Rate % p.a.	
	1997-2007	2007-2019	1997-2007	2007-2019	1997-2007	2007-2019
Tangible Depreciation	0.27	0.12	13.34	12.16	1.97	0.98
Tangible Net Capital	0.09	0.05	9.03	9.67	0.98	0.47
Intangible Depreciation	0.10	0.12	3.61	4.08	2.82	2.85
Intangible Net Capital	0.01	0.03	0.69	1.20	2.61	2.69
All Depreciation	0.37	0.24	16.95	16.24	2.14	1.46
All Net Capital	0.10	0.08	9.73	10.86	1.08	0.72
Total	0.47	0.32	26.68	27.10	1.76	1.16

Table 10: Capital Services: UK National Accounts

	Contribution to GVA growth %age pts p.a.		Share in GVA %		Growth Rate % p.a.	
	1997-2007	2007-2019	1997-2007	2007-2019	1997-2007	2007-2019
Tangible Depreciation	0.27	0.13	9.93	8.94	2.66	1.49
Tangible Net Capital	0.38	0.25	15.13	14.73	2.47	1.67
Intangible Depreciation	0.08	0.10	3.93	4.10	2.10	2.42
Intangible Net Capital	0.06	0.04	2.39	1.96	2.15	2.24
All Depreciation	0.35	0.23	13.86	13.04	2.50	1.78
All Net Capital	0.44	0.29	17.52	16.69	2.44	1.74
Total	0.79	0.53	31.38	29.73	2.47	1.75

Table 11: Capital Services: United States National Accounts

	Contribution to GVA growth %age pts p.a.		Share in GVA %		Growth Rate % p.a.	
	1997-2007	2007-2019	1997-2007	2007-2019	1997-2007	2007-2019
Tangible Depreciation	0.45	0.23	10.06	9.97	4.31	2.28
Tangible Net Capital	0.49	0.25	14.23	15.56	3.30	1.61
Intangible Depreciation	0.30	0.27	4.91	6.52	6.16	4.12
Intangible Net Capital	0.16	0.16	2.59	4.19	6.13	3.75
All Depreciation	0.74	0.50	14.97	16.49	4.90	3.01
All Net Capital	0.65	0.41	16.82	19.75	3.72	2.06
Total	1.39	0.92	31.79	36.24	4.27	2.49

Not surprisingly, the extended definition of intangibles gives a rather different picture, shown in tables 12 to 15. In the second period intangible capital dominates tangible net capital as a contribution to GVA growth more obviously. But the real change is in the importance of depreciation services. Thus in the United States broadening the definition of intangibles raises the contribution of intangible depreciation from about 0.28% pts (in both periods) to an average of 0.56% pts. In contrast, the contributions of net intangible capital services increase from 0.16% pts to 0.21% pts in the first period with a slightly larger increase in the second period.

Looking at the four types of investment as fractions of GVA we similarly find that the biggest impact of extending the scope of intangibles has been to give intangible depreciation the largest share in GVA

Table 12: Capital Services: France, Extended Definition of Intangibles PI Method

	Contribution to GVA growth %age pts p.a.		Share in GVA %		Growth Rate % p.a.	
	1997-2007	2007-2019	1997-2007	2007-2019	1997-2007	2007-2019
Tangible Depreciation	0.24	0.12	9.57	9.80	2.48	1.17
Tangible Net Capital	0.13	0.04	6.99	2.91	1.81	1.21
Intangible Depreciation	0.40	0.42	14.00	15.93	2.83	2.60
Intangible Net Capital	0.07	0.04	2.31	1.37	2.98	2.79
All Depreciation	0.64	0.54	23.57	25.73	2.68	2.06
All Net Capital	0.20	0.07	9.30	4.29	2.09	1.73
Total	0.84	0.61	32.87	30.02	2.51	2.02

Table 13: Capital Services: Germany, Extended Definition of Intangibles PI Method

	Contribution to GVA growth %age pts p.a.		Share in GVA %		Growth Rate % p.a.	
	1997-2007	2007-2019	1997-2007	2007-2019	1997-2007	2007-2019
Tangible Depreciation	0.25	0.11	12.45	11.29	1.97	0.98
Tangible Net Capital	0.08	0.04	8.00	8.25	1.00	0.49
Intangible Depreciation	0.24	0.29	9.58	10.54	2.51	2.65
Intangible Net Capital	0.03	0.06	1.40	2.19	2.62	2.59
All Depreciation	0.49	0.40	22.03	21.84	2.20	1.80
All Net Capital	0.11	0.10	9.40	10.44	1.22	0.94
Total	0.60	0.50	31.42	32.28	1.91	1.51

Table 14: Capital Services: United Kingdom, Extended Definition of Intangibles PI Method

	Contribution to GVA growth %age pts p.a.		Share in GVA %		Growth Rate % p.a.	
	1997-2007	2007-2019	1997-2007	2007-2019	1997-2007	2007-2019
Tangible Depreciation	0.24	0.12	8.85	7.89	2.66	1.49
Tangible Net Capital	0.29	0.19	11.64	11.07	2.48	1.70
Intangible Depreciation	0.47	0.43	13.73	14.78	3.41	2.86
Intangible Net Capital	0.16	0.12	4.61	4.20	3.29	2.79
All Depreciation	0.71	0.55	22.58	22.67	3.12	2.38
All Net Capital	0.46	0.31	16.26	15.27	2.74	2.01
Total	1.17	0.86	38.84	37.93	2.95	2.23

Table 15: Capital Services: United States, Extended Definition of Intangibles PI Method

	Contribution to GVA growth %age pts p.a.		Share in GVA %		Growth Rate % p.a.	
	1997-2007	2007-2019	1997-2007	2007-2019	1997-2007	2007-2019
Tangible Depreciation	0.40	0.21	9.09	8.91	4.31	2.28
Tangible Net Capital	0.42	0.21	11.56	12.09	3.42	1.67
Intangible Depreciation	0.58	0.55	13.46	15.82	4.33	3.39
Intangible Net Capital	0.21	0.22	4.17	6.17	5.02	3.41
All Depreciation	0.98	0.75	22.55	24.73	4.32	3.00
All Net Capital	0.64	0.43	15.73	18.26	3.84	2.27
Total	1.62	1.18	38.28	43.00	4.12	2.68

5 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. The approach we set out here should be straightforward for statistical offices to adopt and production of net capital services series forms is a natural step to take given the focus on net measures in the 2025 System of National Accounts.

In all four countries studied the the volume of net intangible capital services has grown faster than the volume of net tangible capital services between 1997 and 2019, whether one looks at the national accounts definition of intangibles or the wider definition of intangibles.

The relative 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, using the extended definition of intangibles, gross intangible capital services amount to 54% of user cost in France, 37% in Germany and 49% in the United Kingdom and United States respectively. All these shares fall if we look, instead at the share of net intangible capital services in the total share of net capital, with shares of 27% in France, 18% in Germany, 28% in the United Kingdom and 31% in the United States.

We similarly find that, while gross intangible investment contributes 0.5 pp, 0.3 pp, 0.6 pp and 0.8 percentage points to growth in each of France, Germany, the UK and the US respectively, there net contributions are only 0.1, 0.1, 0.1 and 0.2 percentage points in these countries. Thus a failure to look at the net position results in overstating the importance of the net capital stock to capital services.

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