Are Intangibles Running out of Steam?

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Abstract

This article looks at the role of intangibles in explaining the slowdown in productivity growth for (the average of) nine EU countries, the United Kingdom and the United States from 2011 to 2019 compared to the period before the Global Financial Crisis (GFC). Using the 2023 version of the EUKLEMS-INTANProd industry-level database, we find that while intangible investment continues to increase as a share of nominal GDP, the growth rate of the intangibles capital stock has moderately slowed in real terms. The contribution of intangible capital deepening to labour productivity growth has remained positive though not strong enough to offset the effects of the large decline in tangible capital deepening. We also find a relatively strong slowdown in labour productivity growth for the most intangible-intensive industries, especially in the United Kingdom and the United States. Preliminary econometric analysis suggests little evidence of strong TFP spillovers from intangible capital deepening, there is mixed evidence of interaction effects for business innovation-related intangibles and ICT and non-ICT tangibles. While intangibles have not run out of steam, we conclude that the impact of intangibles on productivity growth has become more complex, especially as business innovation-related investments seem highly complimentary with other types of capital. We advocate for policies focused on broad-based investment in both tangible and intangible assets to facilitate the diffusion of new technologies and knowledge.

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We are living in a world of rapid technological change and slowing productivity growth. While a new generation of technologies is emerging, ranging from new information and communication technologies (ICT), artificial intelligence (AI) and robots to nano- and biotechnologies, productivity growth has not responded to the changes in the way one might have expected - at least not at the macroeconomic level. Over the past two decades average productivity growth for advanced economies has slowed to the lowest rate since World War Two (van Ark, de Vries and Pilat, 2024).

There are many potential explanations for the productivity slowdown, including the drag from the Global Financial Crisis (GFC) because of low demand, weak investment, resource misallocation, an erosion in catch-up growth in emerging markets which has also affected advanced economies, and the mismeasurement of outputs and inputs in an increasingly digital and intangible economy (Goldin *et al*,, 2024).

In earlier work, we have stressed the importance of time lags in the adoption of new technologies and the increased complexity in generating productivity growth from the latest round of new digital technologies since the early 2010s. These new technologies include the transition toward mobile, ubiquitous access to broadband, the rise of cloud technologies and advances in AI and robotics (van Ark, 2016; van Ark, de Vries and Erumban, 2021). We have argued that the "new digital economy" might still be its "installation phase" and that broad-based productivity effects will only occur once the technology enters the "deployment phase" (Perez, 2002). Brynjolfsson, Rock and Syverson (2019) have formalised this idea by way of their "Productivity J-curve" which describes how initial investments in intangible assets (such as data, skills, management, and organisational improvements) which are complementary to new digital technologies, do not show productivity effects until later.

Indeed, the rise in intangible investment has played an important role in facilitating the transition to those new technologies. There is widespread evidence that investment in intangible assets, as conceptualized by Corrado, Hulten and Sichel (2005) has outpaced tangible investment as a share of GDP in the United States (since the 1990s), the United Kingdom (since the early 2000s) and the EU (since the 2010s) (van Ark *et al.*, 2009; Corrado *et al.*, 2016). There is also ample evidence that intangible capital has contributed positively to productivity growth (Corrado *et al.*, 2022).

However, there are some reasons to be concerned about the changing role of investment in intangibles as a contributor to productivity growth in recent times. First, in some countries, the growth rates of intangible investment have begun to slow down since the 2010s, potentially reducing the contribution of intangibles to productivity growth compared to previous decades (Haskel and Westlake, 2022; Goldin *et al.*, 2024).

Second, in addition to the possibility of a weaker direct contribution of intangibles to labour productivity growth, the productivity spillovers from intangibles, measured by their impact on total factor productivity (TFP) growth, may also have begun to lose steam (Bloom *et al.*, 2020; Goldin *et* *al.*, 2024; Bontandini *et al.* 2024).

Third, a specific reason for the weakening of spillovers may be the increased complexity in combining different types of intangible investment, pointing at the sensitivity of TFP growth to the complementarity of intangibles (Brynjolfsson, Rock and Syverson, 2019; Coyle, 2023). In addition to different mechanisms through which the impact of intangibles on productivity may have changed, there may also be different experiences between countries, and – as we will investigate in this article – between different types of intangible capital.

In this article, we aim to contribute to answering the question to what extent the slowdown in market-sector productivity growth may be attributed to a weakened performance of intangible capital.[2] Using the 2023 version of the EUKLEMS & INTANProd database, we look at the performance of intangibles for 11 advanced economies (nine member states of the European Union, the United Kingdom and the United States) before and after the GFC (1996-2007 and 2011-2019). We are using the Global Financial Crisis (2008-2010) as a proxy for the segmentation between the rapid productivity growth period of the 1990s and early 2000s and the slower growth period since.[3] However, this does not imply that we see the GFC as the main reason for the productivity slowdown, acknowledging the evidence suggesting that the slowdown in many countries seems to have begun before the start of the GFC (Fernald, Inklaar and Ruzic, 2023).

We build on the earlier literature, referred to above, by adding some new elements to the discussion.

First, we compare the evidence for three different measures of intangibles, namely intangibles as a share of value added (measured in nominal and gross terms), the growth rate of real intangible capital investment, and the growth rate the intangibles capital stock.

Second, as EUKLEMS & INTANProd provide data for different types of intangible, we distinguish between those which are included in current measures of GDP and those which are not. We suggest that the intangibles which are included in GDP (such as R&D, software and databases) can be marked as directly related to the production and use of new technologies. Those which are not part of GDP (including market research and branding, operating models, and employer-provided training) are especially important for the broader organisation's business innovation process. We also look separately at ICT-related and other tangible capital in relation to intangibles.

Third, we add an industry dimension to the analysis by dividing the market sec-

2 Throughout this article we focus on the market economy, excluding public administration (NACE Sector O), education (P), health care (Q), activities of households (T) and extra-territorial organization (U), as well as real estate (L).

3 We do not think that there are that many conclusions to draw on the long-term trend of intangibles and productivity from the volatile movements in economic indicators during the GFC or the disruption in the trend when COVID-19 pandemic emerged in 2020. When including the crisis, the breakpoint in the series is rather sensitive to the choice of year impacting the comparisons of the pre- and post GFC trends. The data for 2008-2010 period are provided in the online Appendix (https://csls.ca/ipm/46/vanArk_Appendix.pdf).

tor up into two groups of industries. The first group is classified as the above-median ("intensive") users of intangible capital and the second group as below-median ("less intensive") users of intangible capital.

Fourth, we undertake a preliminary econometric analysis of the relationship between the growth in capital deepening and TFP before and after the GFC to look for pointers indicating changes in spillover effects from different types of tangible and intangible capital on TFP as well as the effects from interactions between different types of capital.

Our main findings can be summarized as follows. First, even though the share of intangible investment in nominal value added in the market-sector has continued to increase since the GFC, the growth of real investment for "technology-related" intangibles slowed, whereas that for "business innovation-related" intangibles picked up. There is a more consistent albeit still modest slowdown visible in the growth rate of the intangible capital stock between the pre- and post GFC periods.

Second, even though the slowdown in TFP growth has been the main culprit of the productivity problem since the GFC, weaker capital deepening has also played a large role. While the contribution of intangible capital deepening has remained positive during the post-GFC period, it has not been strong enough to offset the large decline in the contribution of tangible capital deepening to productivity growth.

Third, industries which are relatively intangible-intensive (that is, those with intangible investment shares above the median of all industries) contributed more to the slowdown in productivity growth than those that are less intangible-intensive, most strongly so in the United Kingdom and to a lesser extent in the United States.

Fourth, we find rather mixed and weak evidence of spillover effects from intangible capital deepening on TFP growth. However, there are some signs of positive effects from combining different types of capital, perhaps mostly so between business innovation-related intangibles and ICT or non-ICT tangibles. This evidence hints at the importance of a broad-based investment strategy focused on tangibles and intangibles.

Taken together, we find that even though intangibles have not run out of steam in terms of growth, the rates of growth of the intangible stock and the contribution of intangible capital deepening to productivity growth have slowed somewhat, especially in countries (like the United Kingdom and the United States) that were the most intangible-intensive early on. The impact of intangibles on productivity growth seems to have become more complex, especially as the importance of business innovation-related intangibles tends to be increasingly dependent on other types, including tangible capital.

The article proceeds as follows. In the first section we review the evidence on the changing shares of tangible and intangible investment in market sector value added, the growth trends in real investment and those of the stock of tangible and intangible capital. Next, we use the data from the extended growth accounting framework as presented in EUKLEMS & INTANProd to look at the extent to which intangible capital contributed to the slowdown in labour productivity growth at the aggregate level. The third section provides an industry perspective by comparing the growth accounts between intangible- and less intangible-intensive industries. In the fourth part of the article, we investigate the spillover effects from intangible and tangible capital deepening on TFP growth and the extent to which interactions different types of intangibles and tangibles also play a role. The concluding section makes a number of suggestions for policy directions that may help in strengthening the role of intangibles for productivity growth.

Pre- and Post-GFC Trends in Intangible Investment and Capital

In recent decades the importance of intangible capital in advanced economies has increased strongly, but there are some signs of a moderation in the growth rate of intangibles. For example, comparing recent intangible investment data up to 2017 against the pre-2007 trend, Haskel and Westlake (2022:51-52) see "a decline in the growth of 'intangible' capital services, including and excluding software. The pace of growth slowed in the 2010s onwards, particularly excluding software." Goldin *et al.* (2024) also find a large slowdown in the growth of capital services from intangibles in the United States and in Germany, but a stable picture for the United Kingdom and a moderate improvement in France.

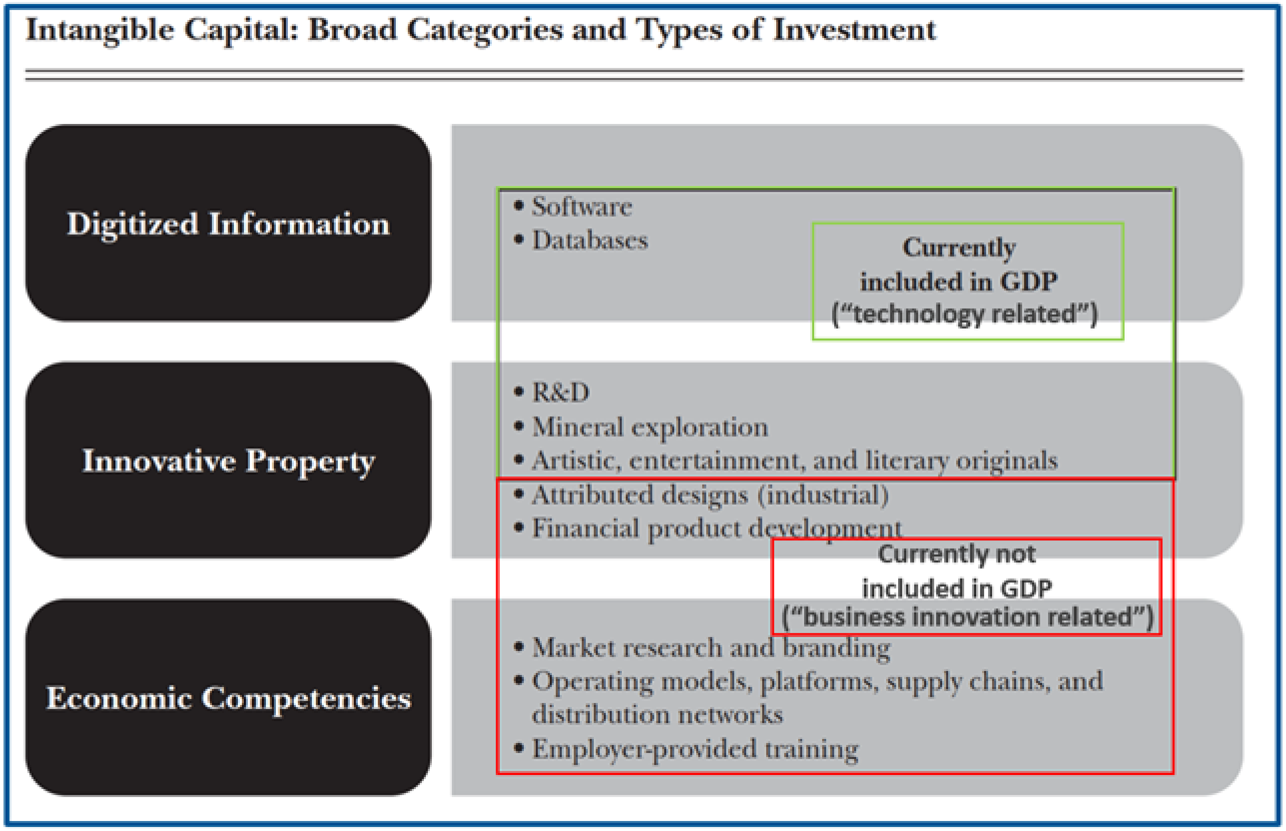
To investigate the recent trends in more detail, we make a distinction between different components of tangible and intangible capital. With regard to tangible capital, we separate ICT capital, including computer hardware and telecommunication equipment, which grew rapidly before the GFC (though from a low base) from other tangibles, such as non-ICT machinery and equipment and non-residential structures, which have grown much more slowly.[4]

Regarding intangibles, we distinguish between intangibles which are included in current measures of GDP and those that are not (Figure 1). Investments in the first group (including software, databases, R&D, etc.), which are fully capitalized in the national accounts, are mainly intangibles directly related to the creation and use of technology. We will therefore refer to those as "technology-related" intangibles. The second group of intangibles, which are currently expensed as intermediate inputs in the national accounts, are more broadly related to an organization's business process. These include activities which, on the whole, are not of a technological nature, such as financial product development, market research and branding and organizational capital. However, they add important value to the innovation capabilities of the organization.

Our data are obtained from the latest version of the EUKLEMS & INTANProd – Release 2023 database by the LUISS Lab of European Economics. It merges the original EUKLEMS Growth and Productivity Accounts with the latest estimates on in-

4 Residential structures are not included as the EUKLEMS-INTANProd database allocates all investment in dwellings to the Real Estate industry (NACE L), which we exclude from our figures for the market sector.

Figure 1



Source: based on Corrado *et al.* (2022).

tangible capital. The database includes 30 countries for 38 industries.[5]

In this article, we base our analysis on 11 of the 30 countries included in EU-KLEMS & INTANProd, namely those for which we could obtain complete data series for the period 1996-2019.[6] Nine countries are member states of the European Union (Austria, Germany, Denmark, Finland, France, Italy, Netherlands, Spain and Sweden), which we present here as a single group using GDP-weighted country averages (results of individual countries are presented in an on-line Appendix).[7] We also look separately at the data for the United Kingdom and the United States as both

5 Bontandini *et al.* (2024), who have produced the latest EUKLEMS-INTANProd Database, provides an extensive description of the features of the intangible capital measures included in EUKLEMS-INTANProd. They also present a useful framework for addressing how innovation, intangibles and TFP growth relate, including their own analysis of how intangibles relate to labour productivity.

6 We are not using the 2020 data as these are not available in full for all countries. In addition, 2020 represents the first year of the COVID-19 pandemic, which would seriously distort the long-term trend analysis in this article.

7 In an earlier version of this article, presented at the 7th World KLEMS conference in 2022, we looked at data for six countries (France, Germany, Italy, Spain, the United Kingdom and the United States). Here we use a later vintage of the data, released in 2023, allowing us to cover nine EU economies. The number of countries is too small, however, to divide up into sub-regions like North and Southern Europe, although we do provide analysis of individual countries where significant for the average of the EU average.

economies have exhibited a relatively rapid growth in intangibles.[8]

Table 1 presents the summary results for the investment shares of tangibles and intangibles in nominal gross value added (GVA), the growth rates of real investment and of the capital stock for the market sector for the periods 1996-2007 and 2011-2019. Columns (1)-(3) show that intangible investment shares have continued to increase for all three areas. During the 2011-2019 period, the value-added share of intangibles exceeded that of tangibles for all three areas, even though tangible investment still accounted for a larger share than intangibles in three EU economies (Austria, Italy and Spain).[9]

The United Kingdom and the United States clearly exhibited higher GVA shares for intangibles than the EU, even though there has been a narrowing of the gap between the EU and the United Kingdom, which was largely driven by an increase in the share of "technology-related" intangibles (R&D and software) in the EU. Technology-related intangibles in the United Kingdom account for one of the lowest shares in value added (around 4 per cent), comparable to Germany, Italy and Spain, but much lower than for France and the United States (around 7 per cent). In contrast, the United Kingdom accounts for the highest GVA share of all eleven countries in "business innovation-related" intangibles (11.9 per cent).

The increase in the investment shares in columns (1)-(3) are, in part, due to the slower growth of the denominator (nominal GDP in the market-sector), which has increased more slowly from 2011-2019 compared to 1996-2007. Focusing on the numerator only, and adjusting investment for investment prices, columns (4)-(6) in Table 1 show that the real growth rate of technology-related intangible investment slowed in the United Kingdom and the United States while it substantially accelerated for business innovation-related intangibles. In contrast, the growth of intangible investment showed no acceleration in Europe across either category.[10]

The picture becomes somewhat more sobering, when moving from the growth in investment to that of stock of capital, reflecting the accumulated investments in net terms over time (columns (7)-(9) in Table 1). The growth of the intangible capital stock weakened across all three areas between 1997-2007 and 2011-2019. For the United States and the United Kingdom, we find a comparatively strong slowdown in "technology-related" intangible capital stocks (as we did for investment). A deeper analysis of the data (not shown here) sug-

8 For the United Kingdom we have also access to intangibles data with greater industry detail from Goodridge and Haskel (2023), but for the sake of comparability, we use the EUKLEMS-INTANProd version for the United Kingdom here. The online Appendix provides a comparison between the two datasets for the United Kingdom.

9 See Appendix Table 1 in the online Appendix. This table shows that tangible investment was also more important as a share of GVA in Germany from 1996-2007. However, the share of intangibles has overtaken that of tangibles since, possibly reflecting the growth of intangible-intensive service industries relative to the manufacturing sector, which has traditionally been quite strong in Germany.

10 This result is caused to a large extent by large a slowdown in Spain and Italy since the GFC (see Appendix Table 1).

Table 1: Nominal Investment Share in Value Added, Real Investment and Capital Stock Growth, Tangible and Intangibles, Market Economy, 1996-2007 and 2011-2019

	1996 -2007 (1)	2011 -2019 (2)	change: 2011 -2019 less 1996-2007 (3)	1996 -2007 (4)	2011 -2019 (5)	slowdown: 2011-2019 less 1996-2007 (6)	1996 -2007 (7)	2011 -2019 (8)	slowdown: 2011-2019 less 1996-2007 (9)
European Union (9)	Investment value added/ share (%)			Real Investment (average annual % growth)			Real Capital Stocks(average annual% growth)		
Tangibles	13.5	11.9	-1.6	3.2	2.3	-0.9	1.7	0.4	-1.3
Non-ICT tangibles	12.3	11.0	-1.2	2.6	2.2	-0.4	1.5	0.4	-1.1
ICT tangibles	1.2	0.8	-0.4	7.2	3.8	-3.4	6.3	2.8	-3.5
Intangibles	11.4	13.6	2.2	3.0	3.0	0.0	2.6	2.4	-0.2
Technology-related	4.1	5.2	1.1	3.7	3.5	-0.1	3.0	2.8	-0.2
Business innovation-related	7.3	8.3	1.0	2.6	2.6	0.0	2.6	2.3	-0.3
TOTAL	24.8	25.4	0.6	3.1	2.6	-0.5	1.9	0.9	-1.0
United Kingdom	Investment value added/ share (%)			Real Investment (average annual % growth)			Real Capital Stocks(average annual% growth)		
Tangibles	11.7	9.9	-1.8	3.0	2.9	-0.1	2.7	1.1	-1.6
Non-ICT tangibles	10.1	9.1	-1.1	1.7	3.8	2.1	2.2	1.2	-1.0
ICT tangibles	1.5	0.8	-0.8	10.4	-0.5	-10.8	11.8	-0.1	-11.9
Intangibles	14.9	16.2	1.3	3.8	4.3	0.5	3.7	3.5	-0.2
Technology-related	4.2	4.3	0.1	3.0	2.7	-0.2	3.8	3.1	-0.7
Business innovation-related	10.8	11.9	1.1	4.0	4.8	0.8	3.7	3.4	-0.3
TOTAL	26.6	26.1	-0.6	3.4	3.8	0.3	3.0	1.8	-1.2
United States	Real Investment (average annual % growth)			Real Investment (average annual % growth)			Real Capital Stocks(average annual% growth)		
Tangibles	11.2	10.1	-1.1	5.0	5.0	0.0	2.7	1.8	-0.9
Non-ICT tangibles	9.0	8.5	-0.5	2.3	4.6	2.3	2.0	1.5	-0.5
ICT tangibles	2.3	1.6	-0.6	13.8	7.1	-6.7	11.7	8.8	-2.9
Intangibles	15.1	17.7	2.6	4.3	5.0	0.7	3.5	3.2	-0.3
Technology-related	5.6	7.1	1.5	6.5	5.1	-1.4	4.0	2.9	-1.1
Business innovation-related	9.5	10.6	1.1	3.1	5.0	1.9	4.0	4.1	0.1
TOTAL	26.3	27.8	1.5	4.6	5.0	0.4	2.9	2.3	-0.6

Notes: European Union (9) includes Austria, Germany, Denmark, Finland, France, Italy, Netherlands, Spain and Sweden and are weighted by their GDP. Market economy definition: see footnote 1. Growth rates are averages of annual log changes, and the difference between periods is expressed in percentage points. Technology-related intangibles are measured as part of GDP in the national accounts; business-innovation intangibles are not included in GDP, and value added is therefore adjusted to include the output contribution from the latter (see Figure 1). The volume changes in investment for tangible ICT assets for the UK for the period 2011-2019 have been recalculated by the authors using the ICT investment price index for the aggregate economy rather than for individual industries, due to some irregularities in the industry-level source data.

Source: EUKLEMS-INTANProd, 2023 (https://euklems-intanprod-llee.luiss.it/). For EU country detail see Appendix Table 1.)

gests this was especially driven by a softer growth of software. However, even the growth of "business innovation-related" intangible stocks did not hold up in the United Kingdom during the post-GFC period due to a decline in financial product development.

The reason for the slowdown in the stock compared to any modest growth in intangible investment is due to the compounding effects of the latest additions to the stock, especially from assets for which depreciation rates are relatively high, as is the case for many intangibles compared to most tangible assets. Even if the investment growth rates of intangibles increase more rapidly than for tangibles, intangibles also drop out of the stock more quickly, which affects the growth rate of the capital stock negatively when they are not replenished at a faster pace than tangibles.

In sum, while the choice of metric and the type of intangible matters, we conclude that on balance there has been a modest weakening in the growth of intangibles. However, when looking beyond intangible capital, Table 1 clearly points out that the big story for the slowdown in capital stock growth is related to tangible assets.

The slowdown in growth in tangible assets, which on average dropped much more sharply across the EU, the United Kingdom and the United States than intangibles, is especially large for ICT-tangibles (such as computer hardware and telecom equipment). The latter has of course been growing from a much lower base than non-ICT tangible capital during the pre-GFC period and the growth rate therefore often exhibits a trend towards levelling off. However, the slowdown may also reflect a shift from ICT hardware towards intangible ICT assets such as big data and AI tools. Indeed, the reader is reminded here that our sample period ends in 2019, whereas some of the larger impacts of those recent technologies may only have begun to appear since 2020, on which we comment in the concluding section of the article.

Intangibles, Tangibles and Productivity Trends

During the aftermath of the GFC, advanced countries have widely experienced a slowdown in productivity growth which, according to several studies, already began a few years before the GFC (Fernald and Inklaar, 2022). Table 2 shows that annual labour productivity growth slowed by 0.5 percentage points in the EU, more than triple that in the United States (1.7 points) and quadruple that in the United Kingdom (2 points).[11] The latter two countries experienced significantly faster productivity growth than the EU during the pre-GFC period. During the post-GFC period, EU and US labour productivity annual growth rates were about the same (1.1 and 1.2 per cent respectively). At 0.7 per cent, the UK productivity growth rate fell well below that of the EU and the United States.[12]

Table 2 provides the results from the standard Jorgensonian growth accounting framework extended with intangibles includes, as explained by Bontandini *et al.* (2024). Before discussing the direct contributions of capital deepening to labour productivity group, we note that weaker TFP growth accounted for the bulk of the labour productivity slowdown after the GFC, that is, half in the United Kingdom (52 per cent) and the United States (50 per cent) to three-quarters in the EU (73 per cent) (column 6). However, in absolute terms the TFP growth was much bigger in

11 Note that labour productivity growth rates have been adjusted to reflect the inclusion of the business-innovation intangibles which are not measured as part of GDP according to the System of National Accounts. According to EUKLEMS-INTANProd, the slowndown in labour productivity without the intangibles not in the SNA would have been slightly larger at 0.6 points in the EU, 2 points in the US, and 2.3 points in the UK. See EUKLEMS-INTANProd, 2023 (https://euklems-intanprod-llee.luiss.it/)

12 Only Finland (which also had high productivity growth rates from 1996-2007) was at par with the UK post-GFC growth rate while Italy and the Netherlands showed even slower productivity growth rates than the United Kingdom (0.5 per cent) (see Appendix Table 2).

Table 2: Growth Accounting Decomposition of Labour Productivity into Contributions of Tangible and Intangible Capital and Total Factor Productivity, Market Economy, 1996-2007 and 2011-2019

	1996 -2007	2011 -2019	slowdown: 2011-2019 less 1996-2007	1996 -2007	2011 -2019	contribution to the slowdown: 2011-2019 less 1996-2007
	(1)	(2)	(3)	(4)	(5)	(6)
European Union (9)	Absolute Contributions to Labour Productivity Growth (%)			Relative Contributions to Labour Productivity Growth (%)		
Labour productivity growth	1.6	1.1	-0.5	100	100	100
Labour composition	0.2	0.4	0.2	11	38	-44
Tangible capital deepening	0.6	0.2	-0.4	36	14	81
Non-ICT	0.4	0.1	-0.3	24	10	52
ICT	0.2	0.1	-0.2	13	5	29
Intangible capital deepening	0.3	0.4	0.1	21	36	-10
Technology-related	0.2	0.2	0.0	13	20	-2
Business innovation-related	0.1	0.2	0.0	8	16	-8
Total Factor Productivity	0.5	0.1	-0.4	32	11	73
United Kingdom	Absolute Contributions to Labour Productivity Growth (%)			Relative Contributions to Labour Productivity Growth (%)		
Labour productivity growth	2.7	0.7	-2.0	100	100	100
Labour composition	0.3	0.2	-0.2	13	29	7
Tangible capital deepening	0.7	0.1	-0.6	25	11	29
Non-ICT	0.4	0.1	-0.3	13	8	15
ICT	0.3	0.0	-0.3	12	3	15
Intangible capital deepening	0.5	0.3	-0.2	19	46	11
Technology-related	0.1	0.0	-0.1	4	0	5
Business innovation-related	0.4	0.3	-0.1	15	46	5
Total Factor Productivity	1.2	0.1	-1.1	43	14	52
United States	Absolute Contributions to Labour Productivity Growth (%)			Relative Contributions to Labour Productivity Growth (%)		
Labour productivity growth	2.8	1.2	-1.7	100	100	100
Labour composition	0.4	0.2	-0.2	13	15	11
Tangible capital deepening	0.8	0.2	-0.6	27	15	34
Non-ICT	0.3	0.0	-0.2	9	3	13
ICT	0.5	0.2	-0.4	18	14	21
Intangible capital deepening	0.7	0.6	-0.1	24	52	4
Technology-related	0.4	0.3	-0.1	15	25	8
Business innovation-related	0.3	0.3	0.1	9	26	-3
Total Factor Productivity	1.0	0.2	-0.8	36	17	50

Note: European Union includes Austria, Germany, Denmark, Finland, France, Italy, Netherlands, Spain and Sweden (see Appendix Table 2). Growth are averages of annual log changes. Market economy definition: see footnote 1."Intangibles –technology-related" are measured as part of GDP and included in the national accounts; "intangibles – business-innovation related" are not included in GDP in the national accounts (see Figure 1). Value added is adjusted to include the output contribution from intangibles not included in the System of National Accounts. Source: EUKLEMS-INTANProd, 2023 (https://euklems-intanprod-llee.luiss.it/). For EU country detail see online Appendix Table 2 to this paper.

the United Kingdom (1.1 points) and the United States (0.8 points) than in the EU (0.4 points) (column 3).[13]

Despite the modest slowdown in the growth of the intangible capital stock, discussed in the previous section, intangible capital deepening (measured as the capital services from intangibles per hour worked) accounted for a small part of the aggregate labour productivity slowdown between the pre- and post-GFC periods. In the United States, intangibles only contributed 0.1 points to the 1.7 points slowdown in labour productivity, and in the United Kingdom it accounted for 0.2 points of the 2 points slowdown in labour productivity growth. In the EU, the contribution of intangible capital deepening even strengthened modestly by 0.1 points hence partly offsetting the 0.5 points slowdown in labour productivity growth.[14]

Compared to intangibles, the slowdown of the growth in tangible investment and capital has contributed much more to the slowdown in labour productivity growth. Column (6) in Table 2 shows that tangible capital deepening accounted for 34 per cent of the productivity slowdown in the United States (compared to 4 per cent for intangible capital), and for 29 per cent in the United Kingdom (compared to 11 per cent for tangible capital). While intangible capital had somewhat come to the rescue in the EU, tangible capital deepening accounted for four fifths (81 per cent) of the EU's slowdown in labour productivity growth.[15]

The weakening in the contribution of tangible capital deepening to productivity is not only driven by ICT hardware, but is also reflected in the decline in other machinery, equipment and structures. Hence this is not just an ICT story in terms of a shift away from computers and telecommunication equipment to the greater use of ICT software and data during the most recent period.

In summary, compared to the slowdown in TFP growth across all three areas, the slowdown in capital deepening across the three areas has played a small role in explaining the slowdown in labour productivity growth during the post-GFC period. The latter is primarily driven by the decline in tangible capital deepening. Despite its positive contribution to labour productivity growth, intangible capital deepening has not been strong enough to offset the negative contribution from tangible capital to the labour productivity slowdown. We will return to this observation later in the article.

Productivity in Intangible-intensive Industries

In our earlier work (van Ark, de Vries and Erumban, 2021), we have stressed the

13 Within the EU, Finland (2.4 points) and the Netherlands (1.6 points) exhibited the largest TFP slowdowns as both countries – like the United Kingdom and the United States – benefited rather strongly from the deployment of digital technology during the 1990s and early 2000s (see Appendix Table 2).

14 Only Denmark, Finland, Sweden and Italy saw a modest weakening in the contribution of intangible capital in the EU (see Appendix Table 2).

15 Only Finland saw a small positive contribution from tangible capital deepening, which arose from a recovery in non-ICT capital (see Appendix Table 2).

importance of time lags in the adoption of new technologies. Based on Perez (2002), we have argued the "new digital economy" might still be in its "installation phase" with broad-based productivity effects occurring only once the technology enters the "deployment phase".

One way to test the time lag hypothesis is by making a distinction between industries which are characterized as early or late adopters of technology. Here we replicate our earlier analysis by, which was based on an OECD industry taxonomy for digital intensity, but by applying a slightly different taxonomy based on intangible investment intensity. We based the industry taxonomy on the intangible investment shares in value added (in nominal terms) by industry in the market-sector for six of the eleven economies in our study (France, Germany, Italy, Spain, the United Kingdom and the United States). Industries above the median intangible investment share, which is 12.7 per cent of value added, are called "intangible-intensive industries" whereas those below are called "less intangible-intensive" industries.

Table 3 provides an overview of the industries in each group. Many manufacturing industries are classified as intangible-intensive mainly because of their relatively high R&D intensity.[16] In contrast only three, albeit quite large, services industries are identified as intangible-intensive: information and communication services (J), financial and insurance activities (K) and profession, scientific and technical activities (M-N).[17]

Next, we exploit the industry detail in the EUKLEMS-INTANProd database by comparing the performance of industries that are intensive users of intangible capital vis-à-vis industries which are less intensive users. Table 4 explores some of the key metrics for each group, including their share in nominal value added and total hours worked, the relative nominal level of labour productivity and the contribution of each industry group to the average growth rate of labour productivity.

Even though the share in value added is fairly equally between the two industry groups, the less-intangible-intensive industries dominate in terms of the share in working hours. The implication is that productivity levels in the intangible-intensive industry group are much higher than in the less intangible-intensive industry group, that is, about 65 per cent higher in the EU, 63 per cent in the United Kingdom and 89 per cent in the United States.

The last few rows of Table 4 show

16 Van Ark, de Vries and Erumban (2021) investigate the comparative performance of industries characterised as early adopters of digital technologies vis-à-vis industries that are less intensive digital users, based on an industry taxonomy for digital intensity by industry from the OECD (Calvino *et al.*, 2018). Our intangibles taxonomy is largely comparable to the OECD digital intensity taxonomy, but there are also some differences. In manufacturing several industries which are intangible-intensive are not digital intensive, such as petroleum products (C19), chemicals and pharmaceuticals (C20-21), rubber and plastic products (C22-23). In contrast, retail and wholesale Trade (G), arts, entertainment and recreation (R) and other service activities (S) were classified as digital intensive industries but not as intangible-intensive industries.

17 The median value is affected by the number of industries (some of which are much larger than others) we were able to look at which was constrained by data availability. However, the manufacturing industries,which are mostly smaller in size than the larger service sector, show more hetoregeneity with regard to their investment/value added shares.

Table 3: Industry Taxonomy for Intangible-Intensive and Less Intangible-Intensive Industries

NACE	INTANGIBLE -INTENSIVE INDUSTRIES	NACE	LESS INTANGIBLE-INTENSIVE INDUSTRIES
B	Mining and quarrying	A	Agriculture, forestry and fishing
C10-C12	Manufacture of food products, beverages and tobacco products	C13-C15	Manufacture of textiles, wearing apparel, leather and related products
C19	Manufacture of coke and refined petroleum products	C16-C18	Manufacture of wood, paper, printing and reproduction
C20-C21	Manufacture of Chemicals and basic pharmaceutical products	C24-C25	Manufacture of basic metals and fabricated metal products, except for machinery and equipment
C22-C23	Manufacture of rubber and plastic products and other non-metallic mineral products	D	Electricity, gas, steam and air conditioning supply
C26-C27	Manufacture of computer, electronic, optical products; electrical equipment	E	Water supply; sewerage, waste management and remediation activities
C28	Manufacture of machinery and equipment n.e.c.	F	Construction
C29-C30	Manufacture of motor vehicles, trailers, semi-trailers and of other transport equipment	G	Wholesale and retail trade; repair of motor vehicles and motorcycles
C31-C33	Manufacture of furniture; jewellery, musical instruments, toys; repair and installation of machinery and equipment	H	Transportation and storage
J	Information and communication	I	Accommodation and food service activities
K	Financial and insurance activities	R	Arts, entertainment and recreation
M-N	Professional, scientific and technical activities; administrative and support service activities	S	Other service activities

Note: "intangible-intensive industries" refers to the top-half of industries with the highest investment/nominal value added shares the market economy.

that labour productivity growth in the intangible-intensive industry group contributed substantially more to aggregate productivity growth than the less intangible-intensive industry group. This was true by a large margin in the United Kingdom and the United States, though less in the EU (and only for the period 1996-2007).[18] However, strikingly, industries which are relatively intangible-intensive also contributed more to the slowdown in productivity growth since the GFC than those that are less intangible-intensive. In the EU-9 the difference is relatively small, namely a slowdown of 0.3 points in the intangible-intensive group versus 0.1 points in the less intangible-intensive group. However, in the United States the slowdown was 1 point in the intensive group versus 0.6 points in the less intensive group, and the gap was even larger in the United Kingdom at 1.5 points in the intensive group and 0.5 points in the less intensive group.

Table 5 presents a growth accounting decomposition for the two industry groups. It shows that most of the change in the contributions of capital deepening is con-

18 In particular, Germany and Spain contributed to the relatively weak performance of intangible-intensive industry group.

Table 4: Value Added and Total Hours Worked Shares, Labour Productivity Levels and Average Growth Rates, Intangible-Intensive and Less Intangible Intensive Industry Groups, Market Economy, 1996-2007 and 2011-2019

	1996 -2007	2011 -2019	difference: 2011 -2019 less 1996 -2007	1996 -2007	2011 -2019	difference: 2011 -2019 less 1996-2007	1996 -2007	2011 -2019	difference: 2011 -2019 less 1996-2007
	European Union (9)			United Kingdom			United States		
Share in total value added (%)									
Intangible intensive industries	48.2	48.5	0.3	52.4	52.7	0.3	55.3	55.8	0.6
Less Intangible intensive industries	51.8	51.5	-0.3	47.6	47.3	-0.3	44.7	44.2	-0.6
Share in total hours worked (%)									
Intangible intensive industries	35.9	36.4	0.5	40.3	40.5	0.2	40.0	40.0	0.0
Less Intangible intensive industries	64.1	63.6	-0.5	59.7	59.5	-0.2	60.0	60.0	0.0
Relative level of labour prod.									
Intangible intensive industries	166	165	-1.2	163	163	0.7	185	189	4.2
Less Intangible intensive industries (=100%)	100	100	0.0	100	100	0.0	100	100	0.0
Agg. labour prod growth (%)	1.5	1.1	-0.4	2.7	0.7	-2.0	2.8	1.2	-1.7
Labour productivity growth, of which:	1.4	1.0	-0.4	2.7	0.7	-2.0	2.9	1.2	-1.6
Intangible intensive industries (%-point)	0.8	0.5	-0.3	2.0	0.6	-1.5	2.0	1.0	-1.0
Less Intangible intensive industries (%-point)	0.6	0.5	-0.1	0.6	0.2	-0.5	0.9	0.2	-0.6

Notes: European Union (9) includes Austria, Germany, Denmark, Finland, France, Italy, Netherlands, Spain and Sweden and are weighted by their GDP. Market economy definition: see footnote 1. See Table 3 for the taxonomy of intangible-intensive and less intangible-intensive industries. Average of relative level of labour productivity calculated on the basis of current prices. Growth rates are averages of annual log changes. The small differences between "aggregate labour productivity growth" and "labour productivity growth" is due to industry reallocation effects. Value added and labour productivity growth are adjusted to include the output contribution from intangibles not included in the System of National Accounts.
Source: EUKLEMS-INTANProd, 2023 (https://euklems-intanprod-llee.luiss.it/). For EU country detail see on-line Appendix Table 2.

centrated in the intangible-intensive industry group. While TFP growth was the main source of the slowdown in this industry group, we find that for the United States the weakening in tangible capital deepening (and especially in that of ICT tangibles) played a larger role than intangible capital deepening, whereas the opposite was the case for the United Kingdom. For the EU, we do not find very large differences between the two groups in the contributions of either capital deepening or TFP probably because productivity growth has been quite weak all along.

While a more detailed industry analysis is beyond the scope of this article, the source data from EUKLEMS & INTANProd actually suggest the slowdown to be quite broad-based, though some sectors shows a disproportionally large slowdown in TFP. In the EU and the United States TFP growth in the electronics/computer

Table 5: Decomposition of Labour Productivity Growth into Contributions of Capital and TFP, Intangible-Intensive and Less Intangible Intensive Industry Groups (average annual % growth), 1996-2007 and 2011-2019.

	Intangible-intensive industries			Less intangible-intensive industries			Total		
	1996 -2007	2011 -2019	slowdown: 2011-2019 less 1996-2007	1996 -2007	2011 -2019	slowdown: 2011-2019 less 1996 -2007	1996 -2007	2011 -2019	slowdown: 2011 -2019 less 1996-2007
European Union (9)									
Labour prod. growth	0.8	0.5	-0.3	0.6	0.5	-0.1	1.4	1.0	-0.4
Labour composition	0.0	0.2	0.1	0.1	0.2	0.1	0.1	0.3	0.2
Tangible capital deepening	0.3	0.1	-0.2	0.3	0.1	-0.2	0.6	0.2	-0.4
Non-ICT	0.2	0.0	-0.1	0.2	0.1	-0.2	0.4	0.1	-0.3
ICT	0.1	0.0	-0.1	0.1	0.0	-0.1	0.2	0.1	-0.1
Intangible capital deepening	0.3	0.3	0.0	0.1	0.1	0.0	0.3	0.4	0.1
Technology-related	0.2	0.2	0.0	0.0	0.1	0.0	0.2	0.2	0.0
Business innovation-related	0.1	0.1	0.0	0.1	0.1	0.0	0.1	0.2	0.0
Total Factor Prod.	0.2	0.0	-0.2	0.1	0.1	-0.1	0.4	0.1	-0.3
United Kingdom									
Labour prod. growth	2.0	0.6	-1.5	0.6	0.2	-0.5	2.7	0.7	-2.0
Labour composition	0.3	0.1	-0.2	0.1	0.1	0.0	0.3	0.1	-0.2
Tangible capital deepening	0.3	0.2	-0.1	0.4	0.0	-0.3	0.6	0.2	-0.4
Non-ICT	0.1	0.0	0.0	0.2	0.0	-0.2	0.3	0.1	-0.3
ICT	0.2	0.1	-0.1	0.1	0.0	-0.1	0.3	0.1	-0.2
Intangible capital deepening	0.4	0.2	-0.2	0.2	0.2	0.0	0.6	0.4	-0.2
Technology-related	0.1	0.0	-0.1	0.0	0.0	0.0	0.1	0.1	-0.1
Business innovation-related	0.3	0.2	-0.1	0.2	0.1	0.0	0.5	0.4	-0.1
Total Factor Prod.	1.0	0.1	-0.9	0.0	-0.2	-0.2	1.1	0.0	-1.1
United States									
Labour prod. growth	2.0	1.0	-1.0	0.9	0.2	-0.6	2.9	1.2	-1.6
Labour composition	0.2	0.1	-0.1	0.1	0.1	-0.1	0.3	0.2	-0.2
Tangible capital deepening	0.6	0.2	-0.4	0.3	0.0	-0.2	0.9	0.2	-0.7
Non-ICT	0.2	0.0	-0.2	0.2	0.0	-0.1	0.4	0.0	-0.3
ICT	0.4	0.1	-0.3	0.1	0.0	-0.1	0.5	0.2	-0.3
Intangible capital deepening	0.5	0.5	-0.1	0.2	0.2	0.1	0.7	0.7	0.0
Technology-related	0.4	0.3	-0.1	0.1	0.1	0.0	0.4	0.3	-0.1
Business innovation-related	0.2	0.2	0.0	0.1	0.2	0.1	0.3	0.4	0.1
Total Factor Prod.	0.6	0.2	-0.4	0.3	-0.1	-0.4	1.0	0.2	-0.8

Notes: European Union (9) includes Austria, Germany, Denmark, Finland, France, Italy, Netherlands, Spain and Sweden and are weighted by their GDP. Market economy definition: see footnote 1. See Table 3 for the taxonomy of intangible-intensive and less intangible-intensive industries. Growth rates are averages of annual log changes, and the difference between periods is expressed in percentage points. "Intangibles –technology-related" are measured as part of GDP in the national accounts; "intangibles – business-innovation related" are not included in GDP, and productivity growth rates are therefore adjusted to include the output contribution from the latter (see Figure 1).
Source: EUKLEMS-INTANProd, 2023 (https://euklems-intanprod-llee.luiss.it/). For EU country detail see Appendix Table 3.

manufacturing industry has slowed dramatically, but several other manufacturing industries (which are mostly part of the intangible-intensive group) have also weakened. The information and communication sector saw stronger TPF growth in the United States, but a weakening in the EU and the United Kingdom. In the United Kingdom, financial and business services experienced negative TFP growth during the post-GFC period, contributing to the TFP slowdown in the intangible-intensive group. In contrast, the retail and wholesale trade sector contributed to the slowdown in the less intangible industry group in the United States. The latter results also suggest that there may be other structural reasons unrelated to adoption effects that could explain differences in productivity growth between industries.

Taken together, the results suggest that the slowdown in productivity should not only be interpreted as a problem of low adoption of new intangible-intensive practices by lagging industries, which are concentrated in the less intangibles-intensive group. There are also clear challenges in industries at the productivity frontier, which are mostly in the intangibles-intensive group. Large requirements for upfront investment in intangibles may have caused concentration effects, slowed the diffusion of technology and weakened the overall impact of intangibles on productivity growth.

While the time lag hypothesis has been well researched for earlier technologies (David, 1990), recent evidence suggests this could also be a powerful explanation for the current productivity slowdown. For example, McElheran *et al.* (2023) show that in 2018 only 6 percent of United States firms used AI-related technologies. Recent figures from the US Census Bureau (2023) for late 2023 suggest that figure has barely moved even though there are large differences between sectors.

Building on the productivity J-curve hypothesis mentioned earlier, the upfront business investments in intangibles to adopt the latest technologies may be larger than before in particular related to skill needs, data and organisational capital (Coyle 2023). Bessen (2022) has pointed at the importance of large-scale investment in proprietary information systems, which may have increased concentration and lack of diffusion, even though this may become less of a constraint as more off-the-shelf business solution come available. Still, the complexity in combining different types of intangible investment might point at the sensitivity of TFP growth to the complementarity of intangibles – a topic we will address further in the next section.

The Role of TFP Spillovers from Intangibles

So far, this article has primarily focused on the capital contribution channel to labour productivity growth. While we have seen that the slowdown in TFP growth has been the major source of the productivity slowdown since 2011-2019, growth accounting decompositions do not allow for an adequate analysis of how investment affects TFP growth. If the true elasticity of intangible capital deepening is larger than the measured income shares (as assumed in the growth accounts), this effect is captured by measured TFP growth (Stiroh, 2002). In other words, the measured growth (or slowdown) of TFP may in part be due to spillovers from the use of intangible capital.

There is some evidence that a weakening of productivity spillovers from intangibles, captured by TFP, may have contributed to intangibles running out of steam. Corrado *et al.* (2020) find a rather sharp decline in TFP growth related to the slowdown in intangible capital services growth in the United States from 2008-2016 relative to 1999-2007. Goldin *et al.* (2024) find weakening effects from intangibles on TFP growth for France, Germany and the United Kingdom. Bontandini *et al.* (2024) show that spillover effects from intangible capital on TFP in the last five years before the pandemic (2014-2019) are positive but are still weaker than before the GFC (1996-2007).

A weakening in spillover effects from intangibles may be caused by slower technical change as postulated by the hypothesis that "ideas are getting harder to find" (Bloom *et al.*, 2020.) It also could be that, even if technological progress itself has remained strong, transmission channels of intangibles to productivity growth have been clogging up. This can be due to a variety of headwinds, ranging from a decline in the effectiveness of innovation diffusion, the lack of adequate workforce skills to adopt new technologies, or geopolitical developments reducing the incentives for firms to invest and innovate (van Ark, de Vries and Erumban, 2021; van Ark, de Vries and Pilat, 2024). Corrado, Haskel and Jona-Lasinio (2017) have provided estimates of spillover effects from intangible capital from 1998-2007 (see footnote 13 on page 19).

There may also be reasons specific to changes in how intangibles impact TFP growth. For example, the interaction between intangibles (say, different types of software applications) and tangibles (say, different types of ICT equipment) may have been changed because of the nature of the technology. For this we need a closer look at how spillover effects arise, and how it may have changed over time. We conducted econometric analysis examining the relationships between TFP growth and two types of tangibles and two types intangible capital deepening. We also include several interaction effects aiming to capture possible complementarities, which could provide additional pointers indicating changes in the strength of spillover effects.[19] The results are preliminary because an analysis of spillover effects from capital on TFP growth needs to consider a potential endogeneity bias that can downwardly bias the impact of capital deepening on TFP.

We use a simple fixed effects panel data regression analysis which exploit the EUKLEMS-INTANProd data for 24 industries over the period 1996-2019, separately for the EU, the United Kingdom and the United States:

$$\begin{aligned}
\Delta \ln TFP_{j,t} = \beta_0 + \beta_1 \Delta \ln TEC^{INT}_{j,t} \\
+\beta_2 \Delta \ln BUS^{INT}_{j,t} + \beta_3 \Delta \ln ICT^{TAN}_{j,t} \\
+\beta_4 \Delta \ln nICT^{TAN}_{j,t} \\
+\beta_5 \left(\Delta \ln TEC^{INT}_{j,t} \times \Delta \ln BUS^{INT}_{j,t} \right) \\
+\beta_6 \left(\Delta \ln ICT^{TAN}_{j,t} \times \Delta \ln TEC^{INT}_{j,t} \right) \\
+\beta_7 \left(\Delta \ln ICT^{TAN}_{j,t} \times \Delta \ln BUS^{INT}_{j,t} \right) \\
+\beta_8 \left(\Delta \ln nICT^{TAN}_{j,t} \times \Delta \ln TEC^{INT}_{j,t} \right) \\
+\beta_9 \left(\Delta \ln nICT^{TAN}_{j,t} \times \Delta \ln BUS^{INT}_{j,t} \right) \\
+\mu_j + e_{j,t}
\end{aligned}$$

Where $\Delta \ln \mathrm{TFP}_{j,t}$ is the growth rate of TFP in industry j in year t for the given country or region (the United States, the United Kingdom, and the EU.), $\Delta \ln \mathrm{TEC}^{\mathrm{INT}}_{j,t}$ and $\Delta \ln \mathrm{BUS}^{\mathrm{INT}}_{j,t}$ are respectively the growth rates of capital deepening (capital per hour worked) in technology-related intangibles and business-innovation related intangibles in industry j in year t. $\Delta \ln \mathrm{ICT}^{\mathrm{TAN}}_{j,t}$ and $\Delta \ln \mathrm{nICT}^{\mathrm{TAN}}_{j,t}$ are the

19 This approach is based on Stiroh (2002), where the difference between the observed factor share and the unobserved elasticity is used as a measure of the spillover effect. A similar estimation strategy, based on Stiroh (2002), is used by Strobel (2016), who estimated spillover effects from ICT intermediate inputs.

growth rates of capital deepening in ICT and non-ICT tangible assets. β_1 to β_4 represent the partial impact of capital deepening in individual assets on TFP growth.

A positive and significant estimate of β_1 to β_4 would indicate likely presence of positive spillover effects from capital deepening in the given asset. β_5 represents the impact of the interaction between two types of intangible assets. β_6 to β_9 represent the impact of the interaction between tangible and intangible capital deepening. Thus β_5 to β_9 are informative of whether the combined effect of these different asset combinations is synergistic or diminishing on TFP growth. Finally, μ_j is the industry fixed effects, and $e_{j,t}$ is the random error term. The regression is estimated separately for the United States, United Kingdom, and EU aggregate, both pre-and post-crisis years.

Table 6 presents the coefficients from the spillover effects for intangible capital deepening (measured as the growth of capital stock per hour worked for each capital asset) for the periods 1996-2007 and 2011-2019 for the EU (columns 1-2), the United Kingdom (columns 3-4) and the United States (columns 5-6). While the results of this analysis need to be treated with caution, they generally show mixed and rather weak spillover effects.

Two observations stand out from the table. First, the coefficients of the spillover effects of individual capital asset groups are only significant in a few cases, and in several cases even indicating negative spillovers. The EU shows strong positive and significant spillover effects for both types of intangibles during the pre-GFC period from 1996-2007 (lines 1 and 2) even though the positive effect was retained only for technology-related intangibles from 2011-2019. The only other significant positive effect from intangibles was for UK business-innovation related intangibles during the pre-crisis period, which turned weakly negative during the 2011-2019 period (line 2). In the United States, the spillover effects are generally not significant, except for a negative effect from business-innovation related intangibles in the post-crisis period (line 2). These results may suggest that when countries or regions at the lower end of the share of intangibles in value added, such as the EU, the spillover effects from either group of intangibles (technology-related or business innovation-related) are relatively important but lose that impact as the economy gets to higher levels of intangible intensity, such as for the United Kingdom and the United States.[20]

Second, the interactions between different types of capital also present mixed evidence regarding their combined impact on

20 Corrado, Haskel and Jona-Lasinio (2017) also provide estimates of spillover effects from intangible capital, which are partially consistent with our observations though not directly comparable. Their findings indicate a relatively strong positive spillover effect from total intangible assets for a sample of 10 European countries, including the United Kingdom, between 1998 and 2007. They specify TFP as a function of input growth rates, distinguishing between ICT tangible, non-ICT tangible, and intangible capital (single asset vs. distinction between two types of intangible assets). Their estimation approach utilized a difference-in-differences method, and also using lagged effects of intangibles on TFP, which are not attempted here. The difference-in-difference approach is argued to enhance the identification of causal effects and reduce the bias from omitted variables and unobserved heterogeneity.

Table 6: Regression of TFP Growth on the Growth of the Capital Stock per Hour Worked, Market Economy, 1996-2007 and 2011-2019

	European Union		United Kingdom		United States	
	(1)	(2)	(3)	(4)	(5)	(6)
	1996-2007	2011-2019	1996-2007	2011-2019	1996-2007	2011-2019
Spillover effects from individual assets						
(1) Technology Intangibles (Tech.INT)	.9569***	.911***	-.2645***	.3553	-.0422	.2112
	(.279)	(.3036)	(.077)	(.2497)	(.1038)	(.181)
(2) Business innovation intangibles (Bus.INT)	1.5028***	-.3602	.6328***	-.3952*	.1438	-.3669***
	(.398)	(.4489)	(.2094)	(.2114)	(.1109)	(.0973)
(3) ICT tangibles (ICT.tan)	.0682	-.0862	-.0376	.0199	.0354	-.0333
	(.1231)	(.2804)	(.0368)	(.0797)	(.0729)	(.1081)
(4) Non-ICT tangibles (nICT.tan)	-2.4151***	-.6463	.0771	.465*	.1989	.2676
	(.3823)	(.6124)	(.1781)	(.2454)	(.1779)	(.2248)
Interaction effects						
(5) (Tech.INT) x (Bus.INT)	-.3244***	-.0835	-.0189	.0619**	.0142*	.0038
	(.0733)	(.1043)	(.0133)	(.0285)	(.0077)	(.0236)
(6) (ICT.tan) x (Tech.INT)	-.0517*	-.1558**	.0093***	.0099	-.0019	-.0204
	(.0278)	(.0694)	(.0027)	(.0093)	(.006)	(.0203)
(7) (ICT.tan) x (Bus.INT)	.0833**	.409***	-.0106	.0039	-.0319***	.0365**
	(.0333)	(.0815)	(.0083)	(.0084)	(.0087)	(.0185)
(8) (nICT.tan) x (Tech.INT)	.1182	-.3253***	.0186	-.136***	.0062	-.0082
	(.0955)	(.1238)	(.0139)	(.0265)	(.0154)	(.0268)
(9) (nICT.tan) x (Bus.INT)	.2151***	.221*	.0304	.1078***	-.0061	-.035
	(.0805)	(.1287)	(.0281)	(.0293)	(.0254)	(.0347)
Constant	-2.3242***	-1.6012	.4232	-.4576	1.5727*	.7685
	(.8217)	(1.1543)	(.7727)	(1.1346)	(.8311)	(.5816)
Observations	276	207	276	207	276	207
R-squared	.3843	.5317	.1476	.3813	.0825	.1131

Note: *** p<.01, ** p<.05, * p<.1. Explanation of variables: see text under equation (1). European Union includes Austria, Germany, Denmark, Finland, France, Italy, Netherlands, Spain and Sweden. Market economy definition: see footnote 1.
Source: Authors' calculation using data from Source: EUKLEMS-INTANProd, 2023 (https://euklems-intanprod-llee.luiss.it/).

TFP growth. Technology-related and business innovation-related intangibles are not strongly related in a positive way in general, except for the post-crisis period in the United Kingdom and pre-crisis period in the United States (line 5). However, there seems more interaction between some of the intangibles capital assets on the one hand, and tangible assets on the other. For example, the interaction between technology-related intangibles (including software and data) and ICT tangibles (computers and equipment) is positive and significant in the United Kingdom from 1996-2007, while it is negative and weakly significant in the EU and insignificant in the United States (line 6).

In contrast, business innovation-related intangibles interact positively with ICT tangibles in the EU during both periods and in the United States during the period 2011-2019, but not in the United Kingdom (line 7). The interaction of business innovation-related intangibles with non-ICT tangibles is also significant in the EU (in both periods) as well as in the United Kingdom (positive in both periods, but only significant in the post-crisis period), but not in the United States, where it is negative and insignificant (line 9). One implication of the collapse in tangible capital deepening during the post-crisis period might therefore have been that it has become more difficult to translate intangible capital deepening into broad-based productivity growth across the economy.

However, more econometric analysis is needed to determine to what extent the importance of complementarities may have become a constraint on TFP growth.

Overall, our preliminary econometric analysis suggests that there is mixed evidence on how increases in the two types of intangible capital per worker, individually or in combination, contribute to measured TFP growth. There is some weak evidence of a greater degree of complexity on how intangibles impact on TFP growth in the later period. These results are in accordance with the possibility of an increase in non-rivalry and excludability (or appropriability) of intangibles, especially through the role of data, reducing incentives to invest in intangibles (Corrado *et al.*, 2023, Crouzet *et al.*, 2024). Others have pointed at the decline in business dynamism and increase is market power as sources of declining productivity in the intangible economy (De Ridder, 2023). Finally, as indicated in our earlier discussion, the increased complexity in combining different types of tangible and intangible investment in the process of business innovation and knowledge diffusion (Brynjolfsson, Rock and Syverson, 2019; Coyle, 2023).

Concluding Observations and Some Policy Implications

Taken together, we conclude that the evidence shows that the growth rates of the intangible stock and the contribution of intangible capital deepening to productivity growth have somewhat slowed, especially in countries (like the United Kingdom and the United States) that became the most intangible-intensive early on. However, the relative contribution to labour productivity growth has remained unmistakably positive, and from that viewpoint, intangibles have not run out of steam, at least not in terms of directly contributing to productivity growth.

Nevertheless, the positive contribution from intangible capital deepening has been insufficient to offset the strongly declining contribution of tangible capital deepening to productivity growth, especially in the United Kingdom and the United States. Given its higher rates of depreciation, intangible capital has “to work harder” than tangible capital to make a direct positive contribution to labour productivity growth.

Previous evidence has pointed at positive spillovers from intangible capital on TFP growth, but our preliminary econometric analysis of the latest data does not show much evidence of strengthening spillovers, which seems in line with evidence from other studies (e.g. Corrado *et al,*, 2022; Bontandini *et al.*, 2024; Goldin *et al.*, 2024). We find some evidence of increased interaction effects, which suggests that the impact of intangibles on productivity growth seems to have become more complex. Specifically, there is some support for the idea that business innovation-related intangibles interact with other types of capital, including ICT- and non-ICT tangible capital in creating TFP gains.

It is possible that the time lag hypothesis of technology adoption, which we tested at the industry level in the fourth section of this article, and which is temporary in its nature, will ultimately lead to a renewed strengthening of the contribution of intangibles once lagging industries are beginning to catch up in investment in intangibles.

However, we have some reasons for concern. First, the relatively large productivity slowdown in intangible-intensive industries makes it clear that the productivity slowdown is not just a matter of lagging industries, but points at problems in industries at the productivity frontier. Possibly large requirements for up-front investment in intangibles may have caused concentration effects, slowed diffusion and weakened the overall impact of intangibles on productivity growth.

Second, we find there is a slowdown in the growth rate of "technology-related" intangible capital, and not much evidence of spillovers effects from capital deepening in software and database on TFP, and mixed evidence on interactions with other tangibles and intangibles. This points at the possibility that new digital technologies, such as AI have not been producing much steam in terms of faster productivity growth at least through 2019.

In contrast, we find that "business innovation-related" intangibles are on the whole growing on a more sustained basis, and in several instances even strengthening in terms of spillovers through complementarities with tangible capital. On the one hand, this may be a sign of maturing, as technologies are increasingly commercialized, requiring more business innovation-related intangibles. On the other hand, the collapse in tangible capital deepening can indeed be one reason why it has become more difficult to translate intangible capital deepening into broad-based productivity growth across the economy.

Policies which help to strengthen broad-based investment by combining different types of capital, especially those that generate complementaries such as "business innovation-related" intangible capital, are important to realize direct (through capital deepening) and indirect (through spillovers) effects on productivity growth. Second, the need for high upfront investment in intangibles to absorb the latest technologies productivity, might cause concentration effects of productivity gains in the largest firms, requiring competition policies and market redesign that facilitate diffusion across the economy. Finally, even if the latest technologies are being available and affordable to lagging firms and industries, support through business innovation programmes can help to successfully adopt those technologies that are critical to realize the productivity gains from the intangibilisation of the economy.

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