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Digitalisation and Modernity of Capital Stock in Europe

Digitalisation has become one of the core concepts in European modernisation. While investment in computer hardware, telecommunications equipment, software and databases has increased over the years, the degree of modernity of the overall capital stock has not. This paper examines whether there is a relationship between digitalisation and the changes in the degree of modernity of capital stock in different sectors in 13 European countries. Our analysis shows that a higher degree of digitalisation leads to a more modern capital stock. That being said, comprehensive modernisation of capital stock will take more than an increase in the degree of digitalisation. Selective investment subsidies for digital assets, such as those provided at the EU level and in individual member states, are not enough. What Europe needs is for investment activity to be promoted across the board.

Digitalisation has become instrumental in the modernisation of developed economies. In order to remain competitive and retain technological sovereignty, the EU Commission has set out clear objectives in its Digital Decade policy programme 2030. In what is known as its Digital Compass, the Commission has laid out measurable goals for 2030 that will help translate the EU's digital objectives across four areas: population and digital skills, digital infrastructures, the digital transformation of businesses, and the digitalisation of public services (European Commission, 2021). Among other things, larger and targeted investments in multi-country projects are intended to develop and build pan-European cutting-edge capacities in strategic technology areas, and in doing so, help to increase the competitiveness and resilience of the European economy. Funding for these projects will come from member states and may be combined with funds from EU programmes. This includes contributions from the Recovery and Resilience Facility, the Digital Europe programme, the Connecting Europe Facility, the InvestEU programme, the Horizon Europe programme, as well as the European Regional Development Fund and the Cohesion Fund.

Digitalisation could also make a crucial contribution to the ecological transformation of the economy. To help achieve climate neutrality by 2050, EU member states have launched a programme of political initiatives known as the European Green Deal (Wolf et al., 2021; Tagliapietra and Veugelers, 2021). Digitalisation plays an important role in the implementation of this programme. In particular, the expansion of digital infrastructure and services is anticipated to help reduce CO_2 and other greenhouse gas emissions to an extent far exceeding the emissions produced by the information and communications industry itself. One political priority, for example, is the digitalisation of the European energy system. Investments in digital technologies such as smart IT devices, 5G and 6G connectivity, a pan-European energy data space with cloud and edge computing servers, and digital twins for energy systems are expected to facilitate the transition to clean energy.

A key instrument when it comes to stimulating additional investment in ecological and digital transformation in the EU is the Recovery and Resilience Facility (EU Commission, 2023), a temporary recovery instrument that has allowed the Commission to mobilise funds and support member states with reforms and investments from the start of the pandemic in February 2020 until 31 December

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2026. This key instrument has €800 billion to disburse in the form of grants and loans, including a significant portion for measures to help drive the digitalisation of European economies and societies. In the national recovery and resilience plans of 22 member states approved by the EU Commission, almost 40% of planned spending was allocated to climate action and more than 26% to digital transformation (European Commission, 2022).

In addition to the EU's extensive packages, there are further programmes at the national and regional levels supporting the ecological and digital transformation. One reason to get these initiatives off the ground was the hope for a boost in investment and modernisation in Europe through digitalisation that has not been fully accomplished.

While there has been an increase in investment in digital products such as computer hardware and telecommunications equipment as well as software and databases over the past 25 years or so, there has been no development in the level of modernity of capital stock. On the contrary, the capital stock is getting older on average, and its service life is increasing.[1]

Digital transformation is the incorporation of computer-based technologies (i.e. hardware and software-based control units) into an organisation's machinery and equipment. This makes equipment and systems more productive, and the improved flexibility and reliability can result in longer service life. The service life of equipment with integrated digital technologies, however, can decrease. Technological progress in this area is faster than in other technologies, meaning ICT equipment usually involves high depreciation rates and large capital losses (Stiroh, 2001). Digital assets depreciate most immediately after acquisition and at the beginning of their service life. On the one hand, this is due to the fact that they are only state-of-the-art for a comparatively short period of time. On the other hand, digital assets are often adapted to the specific requirements of the company that uses them, meaning they are barely marketable any longer (Bitkom e.V., 2020).

Given the decreasing lifetimes and increasing depreciation rates of digital technologies, as well as the fact that such technologies can be used to extend the lifespan of machinery and buildings, this paper examines whether and which connection exists between digitalisation and the modernisation of capital stock in Germany and 12 other European countries. Does digitalisation counteract the ageing of capital stock that we are seeing or do other effects crowd out any such impact?

1 For Germany, see e.g. Bardt et al. (2017); for other European countries, see e.g. Michelsen and Junker (2023).

Analytical approach and data selection

In an attempt to gain a better understanding of possible correlations, we will begin by analysing the correlation between aggregate statistical data on digital investment and the modernisation of capital stock in different sectors of the EU member states.

Eurostat provides a wealth of data on investment activity and capital stock. Aggregated indicators can be developed for industries and regions or countries. Changes in the gross fixed assets in ICT equipment (computer hardware and telecommunications equipment) as well as software and databases can be used as indicators of digitalisation. If investments in such fixed assets increase, this indicates an increase in the pace of digitalisation and vice versa.

The ratio of net to gross fixed assets can be used as an indicator of the modernity of capital stock. This expresses how much of the total assets in use have not yet depreciated. The more modern the capital stock, the higher this ratio. Modernity is also related to the service life of the capital, i.e. the shorter (longer) the service life, the higher (lower) the degree of modernity.

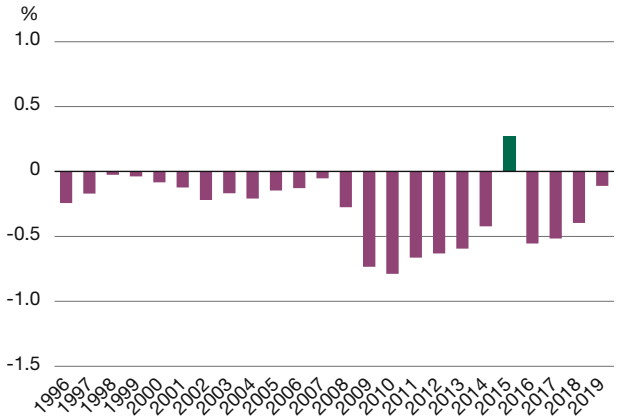
Eurostat publishes separate data on net and gross capital stock for the categories "buildings and structures", "machinery and equipment" and "intellectual property products". For the analysis in the period from 1995 to 2019, data are available from Eurostat for up to 13 different economic sectors (at the single-digit level of the NACE industry classification) in up to 13 European countries.[2]

The aim of this study is to identify an average effect of digitalisation on the modernisation of capital and thus on investment requirements as well. The goal is therefore not to prove a causal effect in individual cases, but to gain insight into the quantitative significance of the correlation. The focus is on the correlation between the change in digitalisation and the change in modernisation. The level of digitalisation achieved and the degree of modernity are not considered here.

In the following analyses, the changes in total digital assets are first compared with the changes in the degree of modernity of total assets. In this way, all possible channels of impact of digitalisation on the service life of total capital are taken into account. However, the aggregate may also reflect many changes in other underlying data. In addition, digital fixed assets are themselves part of to-

2 Austria, Belgium, Czechia, Denmark, Finland, France, Germany, Greece, Hungary, Ireland, Italy, the Netherlands and the United Kingdom.

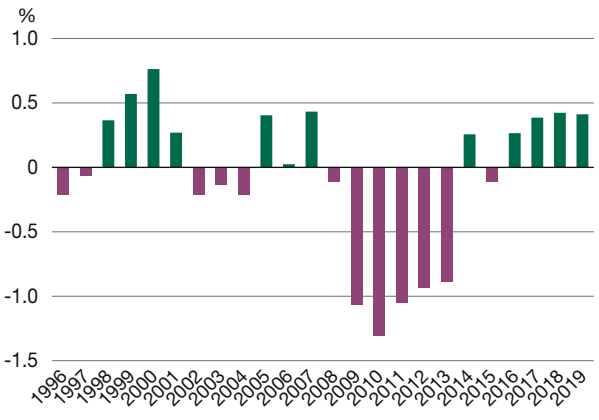
Figure 1
Average annual change in the degree of modernity of total fixed assets (1995-2019)



Note: The countries analysed are Austria, Belgium, Czechia, Denmark, Finland, France, Germany, Greece, Hungary, Ireland, Italy, the Netherlands and the UK.

Source: Eurostat; own calculations.

Figure 2
Average annual change in the degree of modernity of fixed assets in equipment (1995-2019)



Note: The countries analysed are Austria, Belgium, Czechia, Denmark, Finland, France, Germany, Greece, Hungary, Ireland, Italy, the Netherlands and the UK.

Source: Eurostat; own calculations.

tal fixed assets. For this reason, the second approach is to analyse the specific changes in the total fixed assets in software and databases with regard to changes in the degree of modernity of equipment that those digital assets are not a part of.

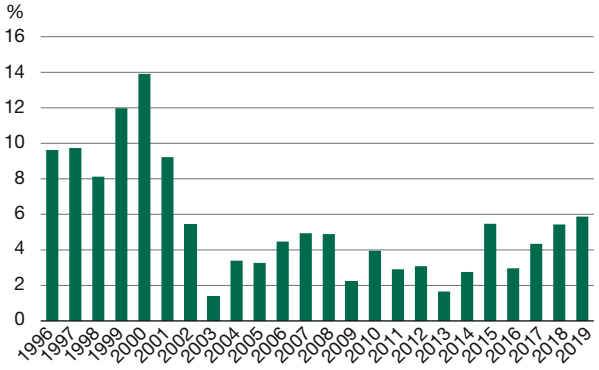
Changes in the degree of modernity and investment in digital products

In the European countries studied, the degree of modernity of total fixed assets was generally found to decline over the period 1995 to 2019 (see Figure 1), with the second half of the period studied displaying a stronger average decrease than the first.[3] The negative rates of change have, however, recently eased up, i.e. the trend towards increasing life span of fixed assets/capital has slowed.[4]

Capital stock also includes durable goods such as buildings, with residential buildings in particular, whose service life is less affected by digitalisation, playing a major role. If you look solely at the capital stock of equipment, the change in the degree of modernity paints a more nuanced picture. The rates of change in the degree of modernity are positive in half of the 24 years, but negative in the other half (see Figure 2). The global financial and economic crisis saw the onset of a six-year period of decreasing rates of change, meaning increasing service lives. From 2014 onwards, the rates of change were predominantly positive, indicating that equipment capital was once again ageing at a faster rate.

The increasing digitalisation of the economy is clearly reflected in the data. Investments are increasing from year to year (see Figure 3). The years after the dotcom crisis in 2002 and 2003 saw sharper declines in growth; a similar pattern

Figure 3
Average annual change in gross fixed assets in digital products and software (1995-2019)

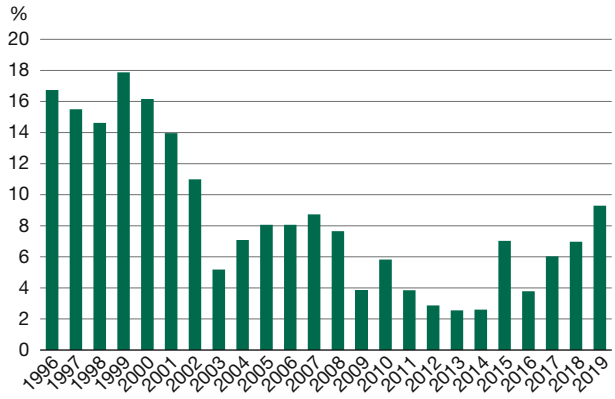


Note: The countries analysed are Austria, Belgium, Czechia, Denmark, Finland, France, Germany, Greece, Hungary, Ireland, Italy, the Netherlands and the UK.

Source: Eurostat; own calculations.

3 This is also evident when looking at individual large countries such as France and the United Kingdom (Belitz et al., 2023).
4 The positive outlier of 2015 is determined by individual values in Ireland.

Figure 4
Average annual change in fixed assets in software (1995-2019)



Note: The countries analysed are Austria, Belgium, Czechia, Denmark, Finland, France, Germany, Greece, Hungary, Ireland, Italy, the Netherlands and the UK.

Source: Eurostat; own calculations.

was observed following the global financial and economic crisis in 2009 and again in connection with the euro crisis in 2013. Investment in digital technologies increased to a far lesser degree after 2001 than before, a development that is likely to be related to the increasing digital assets.

On average, the rates of change in fixed assets in software and databases were also always positive for the countries studied (see Figure 4). Over the long term, however, these assets were found to decrease, only beginning to rise again slightly in the more recent years, similar to the growth rates of the fixed assets of all digital products taken together. Over time, the development of both the digital and software indicators has become very heterogeneous in the individual countries (Belitz et al., 2023).[5]

Correlation analysis

Correlation analysis is performed to identify indicators of the relationship between the change in digital investment and the modernisation of capital stock. Possible delayed interactions between changes in the digital fixed assets in previous years and the ageing of the capital stock must

Table 1
Correlation between the rates of change in investment and the rate of change in the degree of modernity in selected European countries (1995-2020)

	Investments in digital products and software and the degree of modernity of	
	total fixed assets[1]	equipment fixed assets[2]
Total	0.24 ***	0.25 ***
Manufacturing/production of goods	0.31 ***	0.11 *
Energy supply	0.02	-0.07
Water supply; sewerage, waste management, etc.	-0.01	0.01
Construction/building	0.25 ***	0.20 ***
Wholesale and retail trade; repair of motor vehicles and motorcycles	0.32 ***	0.33 ***
Transportation and storage	0.34 ***	0.24 ***
Hospitality/accommodation and food service activities	0.20 ***	-0.05
Information and communication	0.33 ***	0.31 ***
Financial and insurance activities	0.14 **	0.05
Professional, scientific and technical activities	0.33 ***	0.00
Other economic activities	0.37 ***	0.06
Arts, entertainment and recreation	0.19 ***	0.24 ***
Other service activities	0.41 ***	-0.06

Note: *** p<0.01, ** p<0.05, * p<0.1. [1] Austria, Belgium, Czechia, Denmark, Finland, France, Greece, Italy, the Netherlands and the UK. [2] Austria, Belgium, Czechia, Denmark, Finland, France, Germany, Greece, Hungary, Italy, the Netherlands and the UK.

Source: Eurostat; own calculations.

also be taken into account. First of all, it can be assumed that investments, whether in individual years or over several previous years, can have a delayed effect on the degree of modernity of capital stock. Indications of such time lags can only be derived from the data themselves. The Akaike information criterion was applied to determine which lag structures provide the clearest evidence of possible time-delayed effect correlations (see Cavanaugh and Neath, 2019). For the correlations between the changes in the degrees of modernity of the total assets in digital systems or equipment, and the rates of change in the digital or software indicators in the different countries and sectors, we tested up to seven time lags for the digital or software indicators in every possible combination. For both correlations, the Akaike information criterion is lowest for the model with the current values only, i.e. without

5 In Germany and the United Kingdom, for example, the rates of change in the digital indicators were also negative at times; the swings in both directions were found to be greater in the United Kingdom than in Germany. In France, on the other hand, the digital indicator grew throughout the entire period studied. This was the case for the software indicator in both Germany and France, while in the United Kingdom, negative values were also observed with greater variation in the rates of change.

Table 2
OLS estimates of the correlation between the change in the degree of modernity of total fixed assets and the changes in the digital indicator (1995-2008 and 2011-2019)

	1995-2008					2011-2019				
	(1)	(2)	(3)	(4)	(5)	(1)	(2)	(3)	(4)	(5)
Digital indicator	0.0212***	0.0200***	0.0181***	0.0180***	0.0161***	0.0403***	0.0381***	0.0374***	0.0231***	0.0343***
Total investments		0.0387***					0.0516***			
Industry-specific investments			0.0484***					0.0418***		
Country-specific investments				0.0232***					0.0503***	
Country and sector-specific investments					0.0124***					0.0117***
Constant	0.00346***	0.00499***	0.00518***	0.00462***	0.00393***	0.00497***	0.00656***	0.00649***	0.00565***	0.00550***
Observations	1,859	1,859	1,859	1,859	1,859	1,231	1,231	1,231	1,231	1,23
R^2	0.037	0.044	0.087	0.046	0.09	0.046	0.052	0.067	0.108	0.149
Adjusted R^2	0.0361	0.0429	0.0858	0.0451	0.0888	0.0447	0.0506	0.0653	0.106	0.148
F-value	70.61	42.68	88.24	44.93	91.58	58.59	33.76	43.95	74.16	107.7

Note: *** p<0.01, ** p<0.05, * p<0.1.

Source: Eurostat; own calculations.

taking lags into account. The current annual changes in the degree of modernity of total fixed capital or equipment capital are thus most closely associated with the current annual changes in fixed assets (investments) in digital technologies or software.

Looking at the current annual changes in the indicators, a positive correlation can be seen, on average. In countries and sectors with higher growth in digital investment, the degree of modernity was also found to be on an upward trend. This is true both in terms of total digital investment and total fixed capital, as well as in terms of software and equipment capital stock (see Table 1).

That being said, there are clear differences between the sectors as well. The correlation coefficients of the relationship between the change in capital stocks in ICT technologies and the change in the degree of modernity were above the average of 0.24 in the sectors of manufacturing, trade, transportation, information and communication, professional, scientific and technical services, as well as other economic services. No significant correlation was found in the energy supply and water supply, sewage, waste management and environmental pollution and remediation, i.e. areas with a lower level of digitalisation.

In the manufacturing sector, the correlation between the annual changes in software capital stock and those in the degree of modernity of equipment capital stock is only weakly significant and below average. Significantly positive correlation coefficients are found in as few as five industries: construction; transportation and warehousing; arts, entertainment and recreation; trade; and information and communication. For the latter two sectors, the correlation coefficients are above average. Overall, a stronger positive correlation between the change in digital and software investment, on the one hand, and the degree of modernity, on the other, is evident in those sectors that have already achieved a higher degree of digitalisation, as shown in various studies (Demary and Goecke, 2021; Calvina et al., 2018).

Regression analysis

Investment and thus the development of fixed assets in ICT products as well as in software and databases, however, may not only be an expression of the degree of digitalisation, but also a consequence of changing investment conditions in general. It is therefore important to separate, as far as possible, the effects of the change in investment in digitalisation on the capital stock and its degree of modernity (or remaining service life) from other factors influencing the investment cycle.

Multiple regressions were therefore used to test the correlations between changes in both investment in digital products and software and general investment activity and changes in the degree of modernity. A distinction was made between

Table 3

OLS estimates of the correlation between the change in the degree of modernity of equipment assets and the changes in the software indicator (1995-2008 and 2011-2019)

	1995-2008					2011-2019				
	(1)	(2)	(3)	(4)	(5)	(1)	(2)	(3)	(4)	(5)
Digital indicator	0.00329	0.00282	0.00272	0.000426	0.000341	0.0371***	0.0349***	0.0351***	0.0139	0.0342***
Total investments		0.0758***					0.100***			
Industry-specific investments			0.0510***					0.0593***		
Country-specific investments				0.0570***					0.0830***	
Country and sector-specific investments					0.0228***					0.0112***
Constant	0.000555	-0.00253**	-0.00143*	0.00243***	-0.000596	-0.00238**	0.00552***	0.00459***	0.00394***	0.00297***
Observations	2,176	2,176	2,176	2,176	2,176	1,460	1,460	1,460	1,460	1,460
R^2	0.001	0.008	0.015	0.016	0.042	0.011	0.017	0.021	0.045	0.030
Adjusted R^2	0.000585	0.00708	0.0141	0.0151	0.0415	0.0103	0.0154	0.0197	0.0435	0.0290
F-value	2.274	8.750	16.54	17.62	48.11	16.18	12.42	15.68	34.14	22.81

Note: *** p<0.01, ** p<0.05, * p<0.1.

Source: Eurostat; own calculations.

changes in general investment activity across all the EU countries and sectors examined and the specific investment cycles of the individual countries and sectors.

Crisis-related developments can show a significant and sudden effect on impact investment activity. Of particular relevance in the period under study is the financial and economic crisis that began at the end of 2008 and that had a particularly strong impact on the average values in 2009. Accordingly, the regressions presented here were estimated for the periods 1995 to 2008 and 2010 to 2019, i.e. not including the crisis years. Moreover, we chose not to extend the observation period to include the year 2020 due to the sharp decline in investment related to the coronavirus pandemic.

In this context, the results of the OLS estimates confirm an independent correlation between changes in the level of digital capital (ICT products and software) and the change in the degree of modernity of the total assets (see Table 2). The coefficient of the effect of the change in digitalisation was also found to decrease when the effects of the change in overall investment activity in the different countries and sectors are taken into account. The correlation with the change in digitalisation remains statistically significant even when the specific investment cycles in a given sector within a country are taken into account.

For both periods examined, increasing digitalisation was shown to have an independent effect on the increase in the degree of modernity of the entire capital stock. Based on the size of the coefficients, however, the correlation was found to be significantly stronger in the second period. Thus, in the period 1995 to 2008, the impact of the change in digitalisation and the sector- and country-specific investment cycle is approximately equal. In the period between 2010 and 2019, however, the effect of the change in digitalisation on the overall change in the degree of modernity is three times greater than that of the investment cycle.

The differences between the two periods are even more pronounced when looking at the correlations between changes in software assets and the degree of modernity for equipment assets only (see Table 3).

In the period between 1995 and 2008, the software indicator was not found to have a statistically significant effect on the degree of modernity. The only proven correlation was the one between the changes in investment activity in the individual countries and sectors on the change in the degree of modernity.

In the period 2010-2019, on the other hand, there is a statistically proven relationship between the increasing use of software and the increase in the degree of modernity of equipment. This remains true even when controlling for the effects of sector and country-specific investment cycles. The effect of the change in the use of software was once

again found to be three times as high as that of the change in investment activity in the sectors in the individual countries. The only factors that appear to mask the effect of digitalisation on the change in capital utilisation are the – in some cases – very pronounced differences in investment patterns between the individual EU countries studied.

Conclusions

Our analyses of selected EU member states for the period 1995-2019 show that in those areas where digitalisation is picking up pace, the degree of modernity of the capital stock is increasing as well. For capital stock to be comprehensively modernised, however, it will take more than increased digitalisation efforts.

As important as digitalisation is for the modernisation of European economies, without broad investment incentives, the rapid renewal of capital stock, which is crucial for this twin transition, will not succeed. Selective investment incentives for digital technologies, as seen at the EU level, are not enough. What we need in Europe is for investment to be stimulated across the board (Revoltella, 2020; Gereben and Wruuck, 2021).

On the demand side, EU infrastructure programmes such as the Green Deal or Net-Zero Industry could play a key role. On the supply side, such stimulation can be achieved with the help of tax incentives such as degressive depreciation, for example. Some countries have already put forward concrete plans for this.[6] Investment can likewise be promoted through specific measures such as those envisaged at the EU level under IPCEI (Important Projects of Common European Interest) and the EU Chips Act. The IPCEI instrument funds the transformation of large-scale investment projects into what are known as game changer technologies (e.g. microelectronics, battery cell production, hydrogen technology) in several EU member states. What is new here is that funding can be provided until right before the start of commercial use, i.e. mass production, and that European state aid regulations are relaxed for these projects. This creates new government policy coordination mechanisms that no longer separate pre-competitive technology policy and private investment activity. The IPCEI and the EU Chips Act are already demonstrating new strategies for future investment promotion that for instance could be taken as a basis for the creation of technology-oriented investment funds (Belitz and Gornig, 2021).

6 An example of a targeted investment incentive is the introduction of "super depreciation" for investment in digital assets in 2022 and 2023, as provided for in the German government's coalition agreement.

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