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# The Impact of Digitalisation on Danish Companies and Workers

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## Abstract

- Using micro-level data from the period 2001-2018, we document the increased digitalisation of the Danish economy and analyse the effect of digitalisation on sectoral and firm performance measured by sales. We introduce two concepts to measure digitalisation. We approximate the degree to which firms *use* digital goods with their holdings of intangible assets (*input-based digitalisation)*, and the extent to which they *produce* digital goods with the number of programmers that they employ (*output-based digitalisation*).
- Within sectors, large firms that increased their usage of digital goods on average grew faster in terms of sales. Across sectors, we do not find a strong relationship between the degree of digitalisation and performance.
- We examine the evolution of the workforce in the IT sector and we find that workers have become more specialised over the last decade. The data are consistent with the hypothesis that this higher specialisation is associated with higher productivity; however, it might reduce the resilience of the IT labour market against economic shocks.


Digitalisation can be understood as the process of controlling, connecting and planning processes digitally. Digital tools can render firms more profitable: a firm might reach more customers using an online presence, and the digital management of its supply chain might be more cost-effective. It is notoriously difficult to measure the extent to which firms embrace digital technologies in detail: previous studies rely on international comparisons[1] or surveys of very large firms[2].

In this memo we use Danish microdata to investigate how digitalisation affected firms and workers between 2001 and 2018. We first provide two metrics that allow us to capture digitalisation in the Danish economy. We then use these to measure the effects of digitalisation on firms and workers.

A firm that aims to increase its utilisation of digitalisation has two avenues available: it can purchase services from third parties specialised in producing digital goods, or use an in-house workforce. We discuss two digitalisation measures corresponding to these concepts: *input-based digitalisation*, which aims to sort firms based on how many digital goods they use as inputs; and *output-based digitalisation*, which tries to measure the degree to which firms produce digital goods. The two measures are correlated and the IT sector is a clear outlier in both.

We explore the effects of digitalisation on different measures of performance (number of firms, sales, value added and number of workers) at the sector level using our first, input-based measure. We do not find that more digitalised sectors outperform less digitalised sectors. In contrast, when we look at firm-level changes within each sector, we find that growing firms are also increasing their degree of

[1] For an overview of developments in digitalisation in European countries, see Anderton, Jarvis, Labhard, Morgan, Petroulakis and Vivian (2020), Virtually everywhere? Digitalisation and the euro area and EU economies, ECB Occasional Paper No. 244

[2] For a detailed survey of large firms, see Elding and Morris (2018), Digitalisation and its impact on the economy: insights from a survey of large companies, ECB Economic Bulletin, Issue 7.

digitalisation. Our interpretation of these findings is that digitalisation helps firms to outperform their competitors, who are likely in the same sector. Because the degree of competition is lower across sectors, the relative benefits of becoming more digitalised are smaller and more likely to be overshadowed by other shocks that hit different sectors differently.

Next, we investigate the impact of digitalisation on the workforce that is key in producing it: the information technology (IT) sector. The Danish IT sector ranks highest according to both of our digitalisation measures, and its employment has grown by over 30 per cent over the past decade. We first present two findings that show ongoing specialisation in the IT sector's labour market.

First, *the composition of employment in* the IT *sector has been increasingly specialised*: the share of workers with both a higher educational attainment and IT-related college degree has been increasing. Second, *wage-age profiles in* the IT *sector are much steeper* than in the rest of the economy: workers' wages increase faster with age than in other sectors. This second observation is consistent with higher build-up of human capital in the IT sector over time: as workers' skill levels rise, so do their wages.

We then conclude by discussing the potential implication of this higher specialisation for the fluidity of the Danish labour market.

## Measuring digitalisation in the Danish economy

There are many different channels through which a firm may use digital goods in order to ultimately increase its productivity. It may, for example, internally develop communication technologies to improve in-house information flows, it can purchase digital services (e.g. online marketing) from other companies to reach more customers, or it might hire a social media manager to leverage online websites developed by other companies. The challenge for the empirical research is to capture these channels using available data.

We use two concepts to assess the firm-level digitalisation in the Danish economy. First, the *input*-based approach uses intangible assets to measure the extent to which firms *use* digital goods in their production. Second, the *output*-based approach instead calculates the share of employed programmers to measure the extent to which a firm *produces* digital goods – irrespective of whether these goods are then used by the firm itself, or sold to other firms. Box 1 provides more background and reviews other approaches to measuring digitalisation.

**Alternative measures of digitalisation** Box 1

We measure the extent to which firms *use* digital goods with the share of intangible *assets* (for example software and R&D) in total fixed assets using the firm-level balance sheet information. Unfortunately, accounting standards are not identical across countries and across time, so any conclusions need to be taken with a grain of salt. For example, an update to the Danish Financial Statements Act in the year 2016 changed, among other things, the rules on amortisation of intangible assets.[3] Given the aforementioned challenges with balance sheet definition, refining the measurement of intangible assets that firms use has been the focus of several research efforts worldwide.[4]

One thematically related yet different approach is to use the investment in information and communication technologies (ICT), which we do not observe in our data. Such measures also sometimes combine both intangible and tangible capital (such as computer hardware). In future research it would be worthwhile to study ICT in the Danish context more as they have been found to be a significant contributor to growth in value added on a sectoral level.[5]

Further approaches infer the degree of digitalisation from various aspects of consumer behaviour. For example a recent Danmarks Nationalbank memo[6] explores the measures of digitalisation using the fraction of people with internet access or the number of people who shopped online. Such measures are often available only at the country level and cannot be used to provide insights about sectoral or firm-level effects of digitalisation, which is the focus of this memo. In the Danish context, Statistics Denmark conducts the survey "*It-anvendelse i virksomheder* " (IT use by firms). This survey follows many markers of digitalisation such as the use of 3D printing, e-commerce, artificial intelligence or utilisation of robots. The authors find that the use of e-commerce has been steadily increasing over the last 12 years, and that larger firms are more prone to engage in online sales.

An increasing number of studies use micro-level data to estimate effects related to digitalisation: Dhyne et al. (2018) study the effects of IT capital, and Roth et al. (2021) find sectoral differences in the role of intangible capital.

Intangible assets cover the usage of digital goods in a wide number of categories, from software solutions to patents. As such, they provide a proxy for the *usage* of digitalisation. Our first measure corresponds to the *input*-based approach and is defined as the share of fixed intangible assets to all fixed assets at firm-level. This measure can be interpreted as the proportion of intangibles in firm capital, and hence it is not directly affected by firm size *per se*. For additional discussion of our intangible share measure, see chart 1. The main advantage of the intangible share is that it is based on balance sheet information and its definition is consistent over the universe of Danish firms. It comes with two disadvantages. First, it includes some intangible assets that we do not consider digital inputs, such as trademarks, licences or exclusive distribution rights. Second, it excludes some digital inputs that are not captured by fixed capital, for example intermediate goods and services.[7] Finally, some software and services are being offered for free and as such do not do not enter the balance sheet and will be missed by our measure. These might matter relatively more for the smallest companies that do not require professional grade IT solutions. The intangible share hence provides only an imperfect measure of input digitalisation.

For our second measure of digitalisation we turn to the number of programmers within firms. These are the workers that are most directly occupied with the creation of digital goods. For each firm, we use the share of *programmers* in its total employment as a proxy for the extent to which it *produces* digital goods. Firms that *ceteris paribus* employ a larger share of programmers are thus more likely to produce digital output.

[3] Larsen, M. S. and Møllmann. J. T. (2016) "Overview of significant differences between the current Danish Financial Statements Act, the new Danish Financial Statements Act and IFRS", KPMG

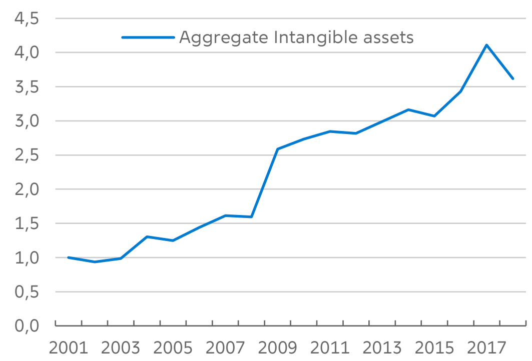
[4] See Corrado C, Haskel J.,Jona-Lasinio C, Iommi M., Mas M. and O'Mahony M., (2017), "Advancements in measuring intangibles for European economies, in Eurona – Eurostat Review on National Accounts and Macroeconomics indicators (Issue No 2/2017) or Knud G.F., (2017) It-anvendelse i virksomheder 2016, DST

[5] Spiezia, Vincenzo (2012), "ICT investments and productivity: Measuring the contribution of ICTS to growth", OECD Journal: Economic Studies, Vol. 2012/1.

[6] Amy Yuan Zhuang (2021), "*Digitaliserede økonomier har klaret sig bedre gennem pandemien*", Danmarks Nationalbank Memo NR 6

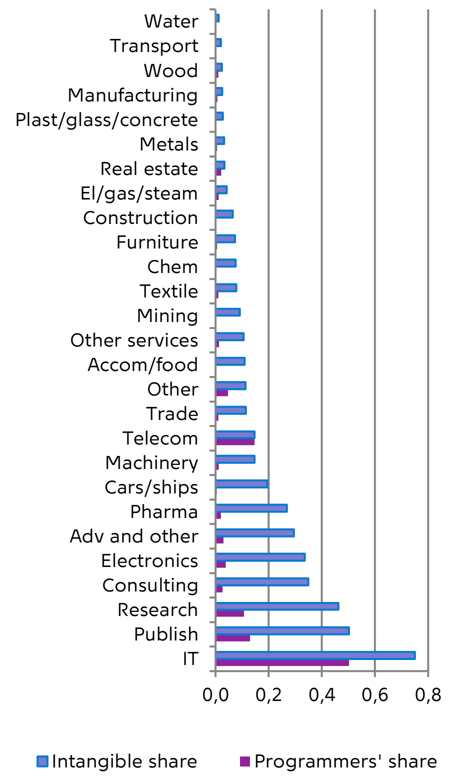
[7] For instance, the intangible share would miss a firm that starts *renting* new digital services, since these would not appear on the balance sheet as intangible capital.

**Steady growth of intangible assets** Chart 1




Note: This chart depicts the normalised (2001=1) evolution of aggregated intangible assets in Denmark. The intangible assets were growing along a stable positive trend throughout the sample.
Source: Statistics Denmark and own calculations.

**Sectors with high intangible share also tend to employ more programmers** Chart 2




Note: The Intangible share is defined as the median of firm level share of intangibles to total assets in a given sector. Programmers' share is the average share of programmers among firms' employment. The measures are computed over the period 2010-2018. The sectors are defined according to Danish Industrial Classification 2007 (36 groupings).
Source: Statistics Denmark and own computations

Programming is an occupation covering several categories of tasks that produce digital goods by producing computer code, including, for example, web designers. A high share of programmers thus indicates that the firm is developing software technologies, either for its own use or for sale to other firms. The downside of this measure is that it misses other occupations that also contribute to digital output, such as social media managers. Overall, the two measures offer complementary perspectives on firms' digitalisation. While the intangible assets measure provides information about the usage of digitalisation, the employment share of programmers is correlated with the *production of* digital goods.

**Digitalisation across Danish sectors**

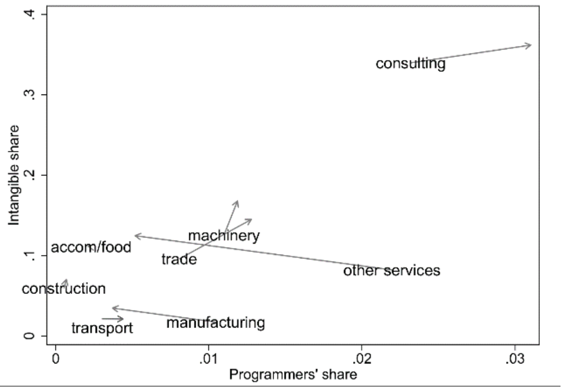
In what follows, we describe differences in digitalisation across Danish sectors. For this, we aggregate our firm-level measures of digitalisation to the sectoral level. Chart 2 plots both measures.

The IT sector is a clear outlier: it is the only sector where firms on average use more intangible than tangible assets. The dispersion of our input-based measure is high across all sectors: the least digitalised sectors (such as various utilities, transport or manufacturing sectors) categorise less than 5 per cent of their assets as intangible, whereas for the most digitalised sectors (even after excluding IT) this measure is over 30 per cent.

Next, we turn to the output-based programmer share metric. We find that firms in the IT sector – due to their sectoral assignment – score highest on our ranking. Sectors that attain high values in the input-based definition also tend to rank high based on the output-based definition. The telecommunications sector is an exception as it employs a much higher share of programmers what its intangible share would predict. The positive correlation between the two measures suggests that many firms produce digital goods in-house to serve as inputs for their own production.

**Evolution over time**
Sectoral changes have been very heterogeneous: some sectors experienced increases in both digitalisation measures, while others increased in one but decreased in the other and one sector even decreased in both (manufacturing of plastics, glass and concrete). The evolution of digitalisation for a selected set of sectors that employ the majority of workers is captured by chart 3.

**The sectoral evolution of digitalisation does not have a uniform pattern** Chart 3



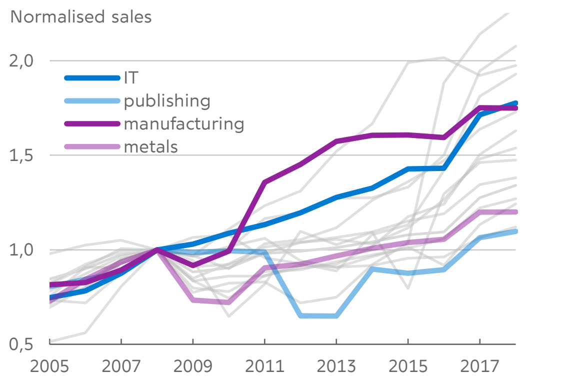

Note: The values are computed over the period 2010-2018. The selected sectors correspond to about 75 per cent of aggregate private employment. The arrow starts at the values for the early period (2010-2014) and points toward the value for the late period (2015-2018). The lack of any uniform direction of the arrows indicates that there is no uniform pattern in the evolution of digitalisation over time.
Source: Statistics Denmark and own computations

## Digitalisation and economic performance

After having described the evolution of digitalisation in the Danish economy, we now turn towards its implications for economic performance. We do not find evidence that digitalisation is a determinant of the relative performance at the sectoral level. Within sectors, however, firms that are increasing in their digitalisation grow faster than firms that do not. We interpret these findings as a sign of the importance of competition within narrowly defined markets: becoming more digitalised helps firms to outperform their closest peers who, by definition, also happen to operate in the same sector. Across sectors, however, goods are not (close) substitutes, which limits the degree to which firms can increase their sales at the expense of firms from different sectors.

**Intangible capital and sectoral performance**
Do more digitalised sectors perform better? We use employment and value added as firm-level performance indicators. We then compute sectoral averages to study whether more digitalised sectors on average perform better.
We do not observe any uniform pattern that would rank the outcomes of sectors according to their degree of digitalisation over the past 15 years. The IT sector has performed exceptionally well and it experienced some of the highest increases in number of firms, number of workers as well as increases in sales and value added. In contrast, "Publishing", also a highly digitalised sector, was among the sectors that performed the worst in terms of sales and value added growth. The outcomes are just as diverse for the least digitalised sectors. On the one hand, "Manufacturing" was among the best performing sectors in terms of growth of sales and value added, whereas firms in the "Metals" sector were among the slowest growing firms. Chart 4 displays the relative performance of Danish sectors in our two performance metrics with the four aforementioned sectors highlighted to visualise the high diversity of outcomes among the most and the least digitalised sectors.

**Sales performance of selected sectors** Chart 4




Note: The graphs show the evolution of value added and employment aggregated at the sectoral level for 17 selected sectors based on data availability. All series are normalised relative to 2008. We highlight two highly digitalised sectors (IT and Publishing) and two highly non-digitalised sectors (Manufacturing and Metals) according to the input-based measure of digitalisation.
Source: Statistics Denmark and own calculations

It is likely that different sectors experience many different sector-specific shocks that contribute to the overall performance. Consistent with this hypothesis, we find that sectoral performance in our sample appears to not be primarily driven by the degree of digitalisation. We interpret this finding in the following way: sector-level outcomes are driven by many factors, such as long-term changes in consumer taste, cyclicality of demand for output of different sectors or fluctuations in the exchange rate. These effects are sufficiently large to dominate the potential impact of digitalisation. There is ongoing research[8] refining the measures of use of intangible assets and that way addressing some of the data issues that we discussed earlier. Some studies that are based on this alternative measure of intangibles find more positive effects of digitalisation even at the sectoral level.[9]

**Intangible capital and within sector performance**

Even if digitalisation is not powerful enough to create meaningful shifts in demand from one sector to another, the data show that it still plays an important role for firm outcomes via competition *within sectors*. We run a regression analysis where we decompose the economic performance of firms into the contributions stemming from changes in capital and labour and those stemming from shifts in the intangible share. This specification allows us to analyse the relevance of changes in the intangible share independently of the total level of assets.
We use two metrics to evaluate the economic performance: *sales* and market share (defined as the firm's share of total sales of all firms in a given sector). The technical details of the econometric analysis are provided in box 2.

**Estimating the firm level effects of adopting more digitalisation** Box 2

To explore the effect of digitalisation on the firm level, we estimate the following equation:

$$\Delta x_{i,t} = \alpha \Delta n_{i,t} + \beta \Delta k_{i,t} + \gamma \Delta \sigma_{i,t} + \sum_{\tau=1}^{T} \delta_\tau 1_{\tau=t} + \varepsilon_{i,t}, \qquad (1)$$

where $\Delta$ is the first difference operator, $x_{i,t}$ is the variable measuring the sales of firm i, $n$ is the number of workers, $k$ total number of assets and $\sigma$ is the intangible share defined as $\sigma_{i,t} = \frac{intangible\ assets}{tangible\ assets+intangible\ assets}$ and $\delta_\tau$ are the year fixed effects. The operator $\Delta$ is the normalised growth rate defined as

$$\Delta z_{i,t} = \frac{z_{i,t} - z_{i,t-1}}{\frac{1}{2} z_{i,t} + \frac{1}{2} z_{i,t-1}}$$

for any variable $z_{i,t}$. The positive coefficient $\gamma$ shows that firms that are shifting their capital towards using relatively more intangibles on average grow faster in terms of sales.[10]

The two metrics exhibit almost identical behaviour.[11] Compared to the effects of increasing the number of

[8] C. Corrado, J. Haskel, C. Jona-Lasinio , M. Iommi (2016). "Intangible investment in the EU and US before and since the Great Recession and its contribution to productivity growth," in "Investment and Investment Finance in Europe" , Chapter 2, p. 73-102, European Investment Bank Report, November 2016.

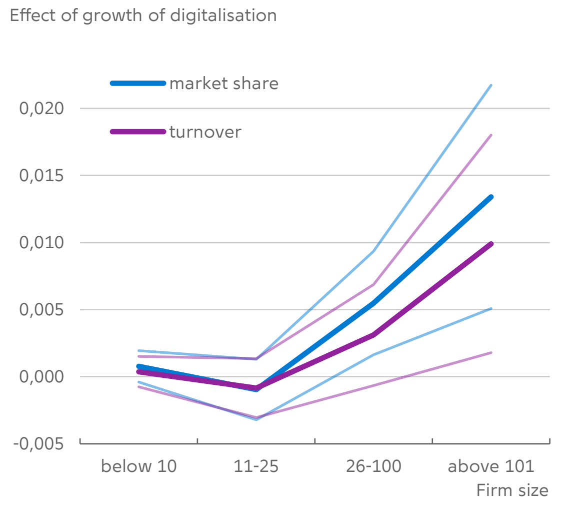
[9] Eric Hazan, Sven Smit, Jonathan Woetzel, Biljana Cvetanovski, Mekala Krishnan, Brian Gregg, Jesko Perrey, and Klemens Hjartar (2021). Getting tangible about intangibles, discussion paper McKinsey Global Institute

[10] When interpreting this effect as causal, one has to be aware of plausible endogeneity concerns. As in any production estimation exercise, the issue is that some part of the error term $\varepsilon_{i,t}$ might be observed by the firms when making their input choices,in which case the regressors would be correlated with the eror term resulting in biased estimates of the coefficients $\alpha, \beta$ and $\gamma$. Estimating the relationship in differences removes the fixed firm-level differences.

[11] We find similar patterns when exploring other measures of firm outcomes such as firm value added (or sectoral share of value added), but the results are more noisy and hence less statistically significant. In contrast, we do not find any statistically significant results or

workers or increasing the total stock of capital, the effect of increasing the intangible share is small -- in line with the aforementioned literature. This is not surprising, as adding new workers or increasing the total capital stock adds additional resources to the firm, whereas changing the intangible share is in principle free, because it entails reducing tangible capital investment by a given amount while increasing the investment in intangible capital by the same magnitude.

**Effect of an increase in digitalisation on growth of sales or market share** Chart 5




Note: The graphs visualise the effect of increasing the degree of digitalisation (measured by the intangible share) on either sectoral market share (measured by the firms' share of sector-level sales) or sales. The solid lines plot the coefficient $\gamma$ from equation (1) when splitting the sample by firm size (defined by the number of workers), the dashed lines denote the 95 per cent confidence interval. While small, this effect is economically significant.
Source: Statistics Denmark and own calculations

While across all firms, the effect of increasing the intangible share is small or not statistically significant, there is considerable heterogeneity in the size of the effect by firm size (measured by the number of workers); the effect is stronger for larger firms (as depicted in chart 4).

Econometric considerations suggest caution in considering the empirical relationship between the growth rate of digitalisation and firms' sales as causal (see footnote 10). Subject to this caveat, we can consider the following thought experiment. Assume that a firm is endowed with the population median value of intangible share (8 per cent), and is also growing its sales at the rate that corresponds to the median growth rate in the firm population (1 per cent per year). If this firm were to replace just 1 per centof its tangible capital with intangible capital, the change would lead to a noticeable shift in the growth rate in the intangible share (the term $\Delta\sigma_{i,t}$ in equation (1)). As chart 4 shows, the ultimate effect of the increase in the intangible share on the growth of turnover is different for firms of different sizes. If the hypothetical firm in our thought experiment came from the largest firm size group, the 1 per cent increase in digitalisation would lead to a very sizable increase in the adjusted growth rate of sales $\Delta x_{i,t}$ – about 5 per cent. If the firm came from the second largest group, the increase in the sales growth rate would be around 2 per cent. The increase would be close to zero for firms from the two smallest groups, since in the latter two cases the regressions coefficients are not statistically distinguishable from zero for standard confidence levels.

We have a twofold explanation of this finding. First, digitalisation solutions typically aim to reduce marginal costs of operation but require large upfront investment. Digitalisation thus favours large firms that can afford the fixed investment and drive out smaller firms that do not operate at a large enough scale to justify the upfront costs. Indeed, there is some evidence that digitalisation might be leading to increases in market power of already large firms.[12] Second, all firms, large and small, can grow by introducing new products and by becoming more efficient at selling their existing products. The larger firms are also more likely to be older and so is their product portfolio. Our finding that the effect of digitalisation is stronger for larger firms can thus be explained by the fact that these firms have already

qualitatively similar patterns when using the growth in programmer share as a measure of digitalisation. It is worth noting that the number of firms that have any programmers is much lower than the number of firms that use at least some intangible assets so the size of the sample is reduced significantly.

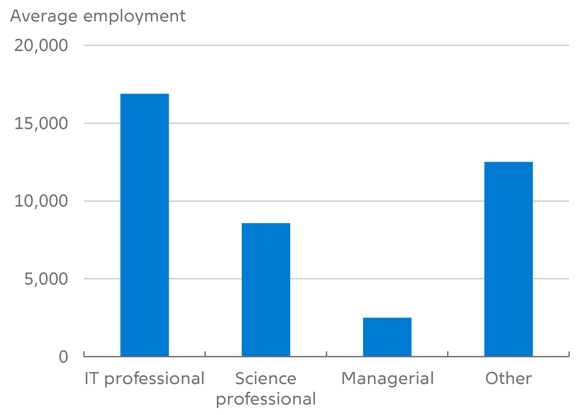
[12] McMahon, M., et al. (2021), "Scale, market power and competition in a digital world: Is bigger better?", OECD Science, Technology and Industry Working Papers, No. 2021/01, OECD

reached a stable customer base, and becoming more digitalised is one possible way to grow. In contrast, the young firms are also small on average and have newer products that will be finding new customers regardless of their investment into digitalisation. While these explanations are speculative and more investigation is needed, the heterogeneity of the effect of digitalisation along the size dimension highlights the importance of studying the whole firm population in order to draw aggregate conclusions, rather than relying on a particular subset of firms.
To summarise, the firm-level evidence suggests that digitalisation is useful for gaining market share *relative to* other competitors that produce similar types of goods.

## The transformation of the Danish labour market

The increased uptake of digital goods -- software -- as part of firms' production processes and as final goods has led to a booming IT sector: employment in that sector increased by about 30 per cent over the past decade. As we have seen in chart 2, firms in this sector drive the production of digital goods. We can therefore learn about the impact of digitalisation on the Danish labour market by studying employment trends in the IT sector.
In this section, we present two distinct findings. First, we show that the employment growth in the IT sector has come with compositional changes in its labour force: workers with a more general education have been replaced by IT specialists who have been trained to work in this sector. Second, we show that the wages of workers in the IT sector increase much more with age than in the rest of the economy. At the cross-sectoral level, this also implies that the pay gap between the IT sector and the rest of the economy is higher for workers of older age.
We suggest that a higher build-up of human capital in the IT sector can explain these findings: workers in the IT sector earn more as their human capital rises. These facts indicate a higher degree of specialisation in this sector. We finally discuss what these insights

**Employment by occupation in the IT sector in 2010** Chart 6

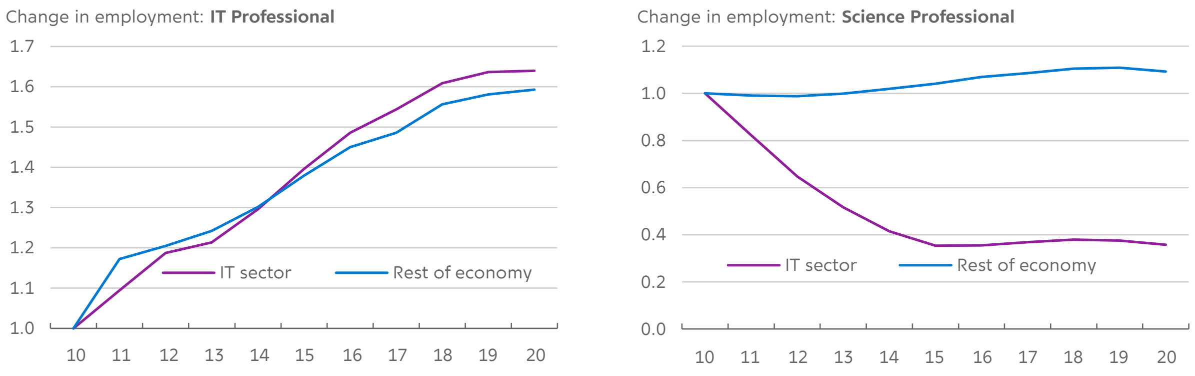



Note: Workers that have some university education in information technologies and that provide IT-related services are classified as *IT professionals*. *Science professionals* are similar workers that instead come from a general science background. The third largest occupational group is *managers*. *Other* contains a large variety of occupations such as business professionals, salesmen and caretakers.
Source: Statistics Denmark and own calculations.

suggest about the potential impact of this higher degree of specialisation on the resilience of Danish labour markets to macroeconomic shocks.

**Employment trends in the IT sector**
We split the workers in the IT sector into four groups according to their occupation: IT professionals, Science professionals, Managerial and Other. Chart 6 shows the distribution of employment across these four groups at the beginning of our sample in 2010: more than half of employment in that sector is in two occupational groups, "IT professionals" and "Science professionals". It is reasonable to believe that IT professionals and Science professionals are the core occupations that produce the output of firms in that sector. The remainder of employment in that sector is in occupations supportive of the core ones, "Managerial" and "Other".

**Core occupations: IT Professionals replace Science Professionals in the IT sector** Chart 7



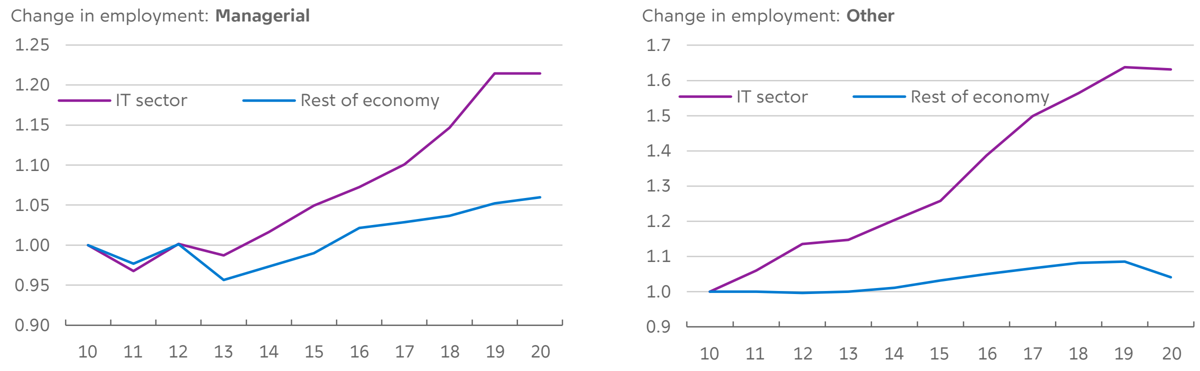

Note: The classification of occupations described in chart 5. Changes in employment relative to 2010.
Source: Statistics Denmark and own computations.

Charts 7 and 8 describe the different employment trends that these four groups have been experiencing during the past decade. We also show the trends in the rest of the economy to provide a benchmark. We find the following. The number of IT professionals increased by 60 per cent both in the IT sector and the rest of the economy between 2010 and 2020. The employment of Science professionals remained constant in the rest of the economy, but strongly decreased in the IT sector. The number of workers in managerial occupations increased by 20 per cent in the IT sector, and remained roughly constant in the rest of the economy. The employment of workers in other occupations has been growing in the IT sector proportionally to the number of IT professionals, while it remained constant in the rest of the economy.

Together, these trends suggest that two phenomena have been happening simultaneously. First, as the IT sector has been growing, employment has been growing in most occupation groups. Second, the more general-purpose science professionals have been continuously substituted by more specialised IT professionals. This latter trend is specific to the IT sector and it is not a general phenomenon in the economy at large. These two patterns together – the growth in employment and the substitution of science professionals with programmers – can simultaneously account for the medium growth in supportive occupations, the strong growth in IT professionals and the decrease in science professionals.

**Supportive occupations: growth in the IT sector relative to economy-wide average**

Chart 8




Note: Changes in employment relative to the level in 2010. The classification of occupations described in chart 5.
Source: Statistics Denmark and own computations.

There are two potential explanations for the substitution of science professionals with IT professionals in the IT sector. First, the individual workers' type might change: workers that have previously been classified as Science professionals might have taken up additional education or changed their tasks to be reclassified as IT professionals. Second, the composition of workers across sectors might have changed: science professionals could have left the IT sector and been replaced by new incoming IT professionals.

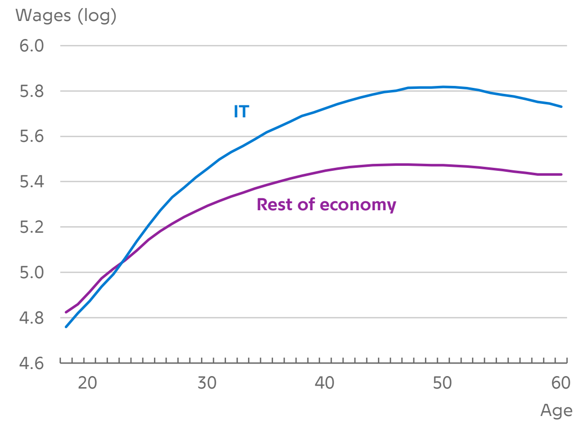
In the data, we do not find a dominant explanation: transitions of workers across industries and occupations suggest that both channels have been reducing the share of science engineers. We also examined the evolution over time of workers' educational attainment. We find a continuous increase in the education levels of both IT professionals and science professionals throughout that period.

This is in line with the idea that the skill requirements in many jobs accessible to IT professionals are relatively new, and so university-level education targeted towards these skills was rare at the beginning of this century. Consequently, many IT professionals were self-taught programmers that only had a high school degree. Nowadays, higher education has adapted to the situation and many young workers that enter the IT sector come with university-level education, increasing average education in that sector.

**Wage-age profiles in the IT sector**

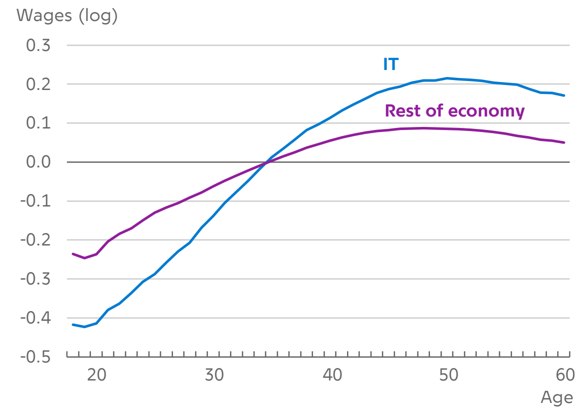
Other things being equal, workers should earn higher wages as they learn more valuable skills throughout their careers. We use the development in wages throughout workers' careers to assess the evidence on whether workers in the IT sector learn more skills throughout their careers. Our empirical specification can answer the question: how do hourly wages vary with the worker's age both inside and outside of the IT sector?

**Wage profiles are steeper in IT…** Chart 9




Note: Average log hourly wages in the IT sector and the rest of the economy, by age..
Source: Statistic Denmark and own computations.

**… even for similar workers** Chart 10




Note: We remove the variation in log hourly wages that can be predicted by occupation, education and gender. We then plot the remaining variation in wages against the worker's age.
Source: Statistic Denmark and own computations..

Chart 8 displays earnings profiles over the life cycle: it correlates the logarithm of wages with age. Small differences in the logarithm approximate percentage changes in wages: an increase in the logarithm of wages from 5 to 5.2 corresponds to a 20 per cent increase in average wages. Similarly, the slope of the two lines depicting the logarithm of wages approximates the growth rates of the corresponding wages: workers in the IT sector enjoy a much steeper relative increase in wages over their life cycle. It is natural to ask how much of this difference is due to compositional differences between the IT sector and other sectors. We have already documented that the occupational composition of the IT sector is largely skewed towards IT professionals, particularly programmers. To what extent do these and other observable differences between workers inside and outside of the IT sector account for the differences in the life cycle profiles of hourly earnings?

To address this question, we repeat the previous exercise for workers with similar characteristics. Chart 10 explains the approach in more detail and displays the variation of wages with the life cycle that cannot be explained by these characteristics.
As we can see, the life cycle of workers' earnings in the digital economy remains steeper relative to other sectors in the Danish economy, even after accounting for workers' observable characteristics that may explain wage differences. Candidate explanations for this steeper wage curve over the life cycle are either institutional settings that ensure a better bargaining position for workers in the IT sector, or higher labour productivity growth.

**Estimation of wage profiles** Boksx 2

We estimate wage profiles using administrative data on monthly wage payments that we enrich with information on socioeconomic background of the agents. We compute unconditional wage profiles by computing the unconditional average of log wages by sector and age groups. These unconditional wage profiles are displayed in chart 8.We compute the wage profiles for "similar workers" by removing the variation in wages that are due to observable differences across workers. To do this, we estimate the effect of a set of observable characteristics $X_{i,t}$ on the logarithm of workers' monthly wages $w_{i,t}$:

$$w_{i,t} = X_{i,t} + \varepsilon_{i,t},$$

where $X_{i,t}$ contains occupation at the two digit level, seven groups of educational attainment, and the worker's gender. The residual $\varepsilon_{i,t}$ contains variations in wages that are not explained by these observable characteristics. We compute averages of this residual by sector and age and plot these in chart 9.

The origin of the steepness of the gradient is relevant for the effect of labour market shocks on productivity and worker mobility. Consider the case in which the steepness of the gradient reflects knowledge build-up of the workers that is specific to their current jobs. In that case, an economic shock that forces workers to relocate to different employers reduces or possibly eliminates the return to the firm-specific human capital accumulated in the IT sector. It reduces the productivity of these workers and consequently their wages. Consequently, this shock would lead to a larger decline in total factor productivity across the economy. If the wage-age gradient instead reflects different wage setting institutions, this shock would still require some workers to relocate, but these relocations would not lead to loss of specific knowledge that cannot be used in other sectors. As a consequence, the decline in total factor productivity would be smaller than in the previous case.

## Concluding remarks

We have studied two measures of digitalisation in this memo, one based on the use of intangible assets as inputs and one based on the number of programmers employed. The two measures are positively correlated, but there is large dispersion in their levels across the sectors and there is no uniform trend over time in how digitalisation evolved over time within each sector.

Using the input measure of digitalisation, we find that sectors that score higher do not experience faster growth in terms of employment, sales or value added. In contrast, at the firm level, growing digitalisation is associated with faster growth of sales. The data thus suggest that becoming "more digitalised" is at least correlated with firm-level growth within a sector where firms compete against other firms producing similar goods. However, there is considerable heterogeneity in the effect: small firms see no impact whereas large firm see statistically significant and economically meaningful effects. Meanwhile, we find no evidence that would support the claim that digitalisation provides an advantage for firms competing across sectors. The degree of substitutability across sectors is lower than within sectors, and thus gaining additional customers from firms from diffirent sectors is consequently more difficult.

Turning to the labour market, our data analysis leads to two results. First, a large and increasing share of the worker pool in the IT sector comes with a specialised background and education. Second, workers in the IT sector start on average with lower earnings, but enjoy a steeper rise in their earnings over time. These facts suggest that the IT sector employs an increasingly specialised labour force that – throughout their careers – becomes more specialised. The IT sector's employment has been growing significantly throughout the past decade. Moreover, the employment of programmers has been increasing steadily also in the rest of the economy. Should this pattern in the IT sector be representative of future shifts across other sectors, we would expect that a rising share of the Danish labour market would become more and more specialised.

Higher human capital and specialisation have historically led to large productivity gains. The data support the hypothesis that the increased specialisation in the IT sector comes with a gain in total factor productivity and can potentially explain the large rise of employment in that sector over the past decade. However, higher specialisation also comes with less flexibility: changes in careers are more costly to workers that have built up human capital that is more specific to their current firms and career. Large shocks to the IT sector have been historically rare, but workers in this sector would possibly suffer from larger earnings losses should an economic shock require substantial reallocation to other sectors. We emphasise that these predictions for labour market dynamics represent initial evidence from the empirical analysis of the microdata. Further research is required to provide a complete and definitive picture of the higher specialisation in the IT sector and its implications on labour market mobility in the face of rising digitalisation throughout the Danish economy.

**Data** Box 3

The information about firm assets (both tangible and intangible), sales and employment comes from FIRE register. For the firm-level regressions we use the sample 2001-2019. Due to limited sector information in the early years of the sample, we start with the sectoral analysis only in 2005. We also focus on private firms and so we do not consider sectors that are dominated by public enterprises (such as hospitals, libraries or educational institutions). Furthermore, we ignore firms that never reach more than two employees and do not survive at least another two years. In the regression analysis we only consider firms older than five years, so the results are not driven by the fast growth in the first couple of years after entry.

To provide some basic overview of the distribution of intangible share in the population of firms, we also compute the average intangible share over firms' age and size. Younger firms are also on average more digitalised (firms below the age of 10 have approximately intangible shares of around 18 per cent, compared to below 15 per cent for firms above the age of 10), so they might find it difficult to further increase their degree of digitalisation. We find that the intangible share is smaller (15 per cent) in smaller firms (measured by the number of employees below 25) than in larger firms (19 per cent).

Our source on wages and employment is the BFL register. We extend this with worker characteristics from BEF and UDDA. The BFL provides information from 2008 onwards. However, we exclude data prior to 2010 due to the change in occupational codes in 2010: the old DISCO-88 codes that were used up to 2010 do not allow us to isolate "programmers" from a larger engineering-based occupational group.

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# Digitalisation

The digital transformation is progressing rapidly in these years, and Denmark and the other Nordic countries are currently among the most digitalised countries in the world.

Digitalisation brings changes. Obvious changes are in the way we purchase and pay for goods and the way we transfer funds to each other. But increased digitalisation and new digital technologies may also affect the growth potential of the economy and labour market developments. Prices of goods, trade, financial sector stability and the way we calculate the digital economy are also impacted by digitalisation.

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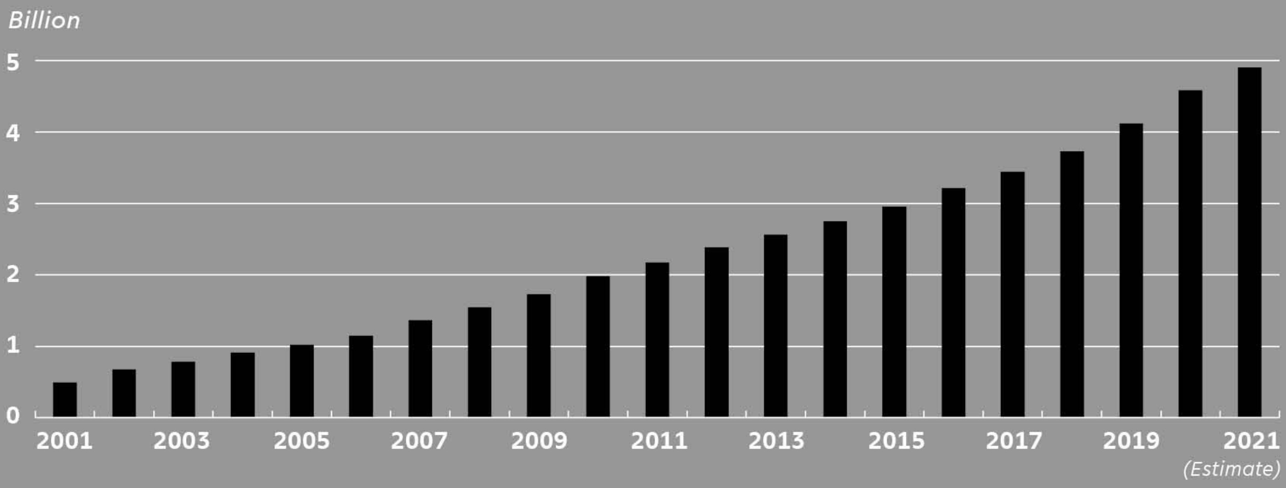


Source: ITU World Telecommunication /ICT Indicators database.

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