MINISTRY OF INDUSTRY, BUSINESS
AND FINANCIAL AFFAIRS

Digitisation and productivity - Growth potential in Danish businesses

Analysis for business and growth policy

May 2017

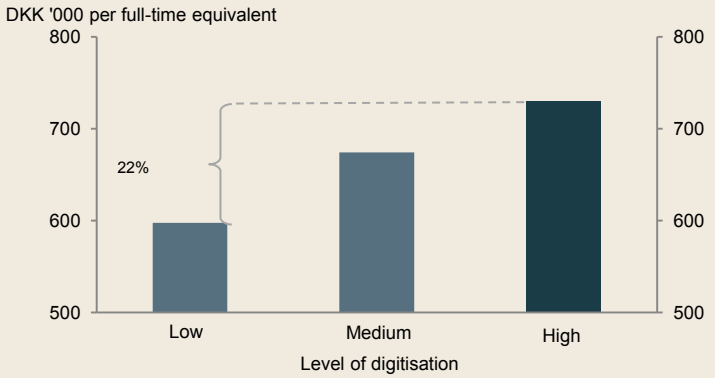
DIGITISATION AND PRODUCTIVITY - GROWTH POTENTIAL IN DANISH BUSINESSES

This analysis examines the correlation between digitisation and productivity in Danish businesses in the period 2010-2014. There is a positive correlation between digitisation and productivity.

In 2014, the most digitised businesses in Denmark had an average of more than 20% higher labour productivity than the least digitised businesses. This corresponds to every employee in highly digitised businesses contributing a value added of DKK 135,000 more than employees in less digitised businesses, see figure 1.

Differences in productivity between businesses can, among other things, be explained by the fact that the most digitised businesses have more employees, a larger capital stock and export more goods etc. When adjusted for a range of factors, highly digitised businesses have around 6 per cent higher productivity than less digitised businesses.

Figure 1: Level of digitisation and labour productivity in Denmark, 2014



Note: Calculated as value added per full-time equivalent. The figure illustrates private urban businesses. Low, medium and high refer to the level of digitisation of the businesses, see annex. Businesses with more than 10 full-time equivalents. N=3200. Average is weighted and can be listed to a population of around 17,000 businesses, corresponding to 75 percent of total revenues in Danish businesses. Size, industry, capital intensity etc. have not been taken into account in the figure. The level of digitisation has been measured from 0-6 and includes use of data analysis in business models.
Source: Statistics Denmark and own calculations

The results assume that all businesses can employ existing digital technologies at a higher level and that they have access to the right competences. Furthermore, the results assume that there are no legislative barriers preventing the businesses from implementing existing digital technology.

It is important to note that the analysis focuses on the productivity potential from increased utilisation of existing technology by less digitised businesses. Thus, no account has been taken of whether the most digitised businesses will utilise existing technology to a greater extent than they do today or whether businesses will utilise newer technology.

In addition, the results should be interpreted with caution, as there no clarification as to whether digitisation itself creates increased productivity in businesses or whether a characteristic of already highly productive businesses is that they implement new technology.

1.1 DIGITISATION CAN BE A DRIVING FORCE FOR PRODUCTIVITY

Specialist economics literature indicates that there is a positive correlation between digitisation and productivity, see box1.

Box1: The correlation between digitisation and productivity

A number of studies show positive productivity gains from various specific technologies including robots, Internet of Things, automated maintenance systems, 3D printing etc., see for example OECD (2016b), Graetz, Michaels (2015). However, estimated effects vary depending on which technologies are being considered.

Additionally, new software can improve the organisation of routine workflows, including automation, and can lead to innovation of products and business models, see for example OECD (2016a).

There are also studies indicating that productivity gains depend on whether there are additional investments in other assets and in employee competences. For example, there seems to be a relationship between digitisation and level of competences to increase productivity, see Corrado & Jäger (2014), Youssef & Aoun (2014). Similarly, there are studies indicating a correlation between digital technologies and intangible assets (for example research and development, design etc.), see for example Corrado, Haskel, Jona-Lasinio (2014).

A Danish study has also demonstrated a positive correlation between the digitisation of businesses and their productivity, see for example CEBR (2011, 2012). This study shows that a marginal change in the percentage of businesses that digitise their business processes is linked to 0.72% higher value added per employee. In another contribution to research carried out for the Danish Business Authority (CEBR, 2013), on average, productivity has increased by 2.4 percentage points faster per year in businesses that have made the most IT investments compared with businesses with the fewest IT investments.

The analysis focuses on how digitisation of internal and external processes contributes to productivity. For example, investments in software systems such as resource optimisation systems (ERP) and logistics systems (SCM) can lead to new automated workflows within procurement, bookkeeping and administration, which create cost savings for businesses. IT investments also involve better and more systematic control of production quality. In addition, use of cloud computing enables employees to share and access working documents and data in large quantities at the same time, and have access to massive computing power. These mechanisms can also reduce businesses' operating costs and generate more efficient workflows. Overall, digitisation can play a part in reducing transaction costs for businesses and consumers.

A digitisation indicator has been developed to measure utilisation of digital technology within the above processes. This indicator is a combined weighting of 10 indicators, which measure businesses' utilisation of digital technology across business areas, see box 2.

Box 2: New digitisation indicator

A new digitisation indicator has been developed to measure businesses' utilisation of existing digital solutions in order to better understand how digitisation is utilised in Danish businesses across sectors. In previous literature (CEBR 2012), digitisation was measured on the basis of utilisation by businesses of IT machines, where focus was primarily on digitisation in production, and therefore to a larger extent on the manufacturing sector. The new indicator covers five business activities, including administration and operation, production, supply chain, marketing, and sales. Thus, the indicator is assessed as useable for all businesses in the Danish business community, since these five business activities are fixed components in the majority of Danish businesses.

The indicator ranges from 0 to 5 with the following groupings: low digitisation [0-2], medium digitisation [3-4] and high digitisation [5]. In this way, it is possible to examine the correlation effects in differences between the least digital and the most digital businesses. Please refer to annex 3.2 for further information.

Are more digital businesses also more productive?

The new digitisation indicator makes it possible to estimate the correlation between businesses' utilisation of digital technologies and their productivity.

A simple measurement of productivity is labour productivity in terms of gross value added (GVA) relative to the number of full-time equivalents. A disadvantage with this measurement is that it does take into account that the use of resources can vary across sectors. In particular, capital intensity can have great significance for man-hour productivity. Another measurement of productivity, called total factor productivity (TFP), takes this into consideration.

TFP constitutes the part of productivity growth that cannot be explained by changes in capital stock and work capacity (including human capital). This means that there are implicit reservations regarding capital intensity and the direct effect from employees' level of education. TFP typically increases through more efficient workflows and good management practices as well as through innovation, where new technology for instance makes it possible to produce more for the same resources. However, TFP is harder to calculate than labour productivity and is subject to greater uncertainty.

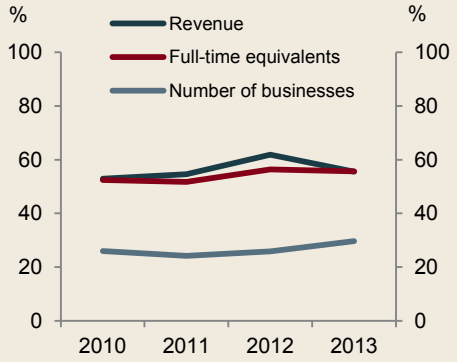
Both measurements are employed in the analysis to provide a broad insight into the correlation between digitisation and productivity. This also means that different groups of businesses are included in the analysis, since figures for TFP are only available until 2013, while labour productivity is available for 2014, see box 3.

Box 3: Businesses in the analyses

The analyses in this chapter are based on different time periods and business populations. This is due to the availability of data.

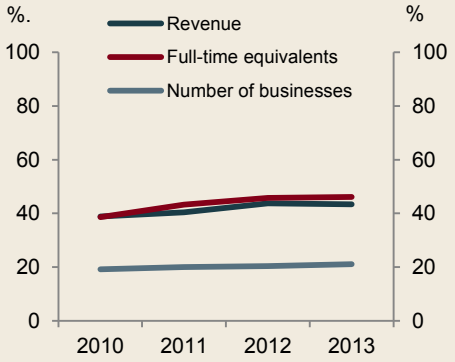
Estimating TFP places high demands on data quality. Therefore, in the analyses based on TFP, a period from 2010-2013 is considered, and this contains information on company and financial statistics as well as integrated labour force statistics and employment figures for businesses with at least 20 employees. Overall, the population of 5,865 businesses is dispersed fairly evenly over the four years in question. The sample consists of businesses in selected sectors within manufacturing and service. For both categories, around 20% of the businesses are covered in the analysis, while around half of total revenues and total full-time equivalents are covered by businesses in the sample, see figure a, and figure b. Weighting is used to extract the sample for the population consisting of businesses with at least 20 employees.

Figure a: Coverage of manufacturing, 2010-2013



Note: For businesses with at least 20 employees.
Source: Statistics Denmark and own calculations

Figure b: Coverage of service, 2010-2013



Note: For businesses with at least 20 employees.
Source: Statistics Denmark and own calculations

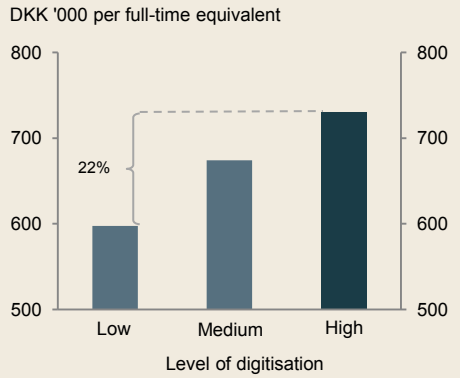
For other analyses in which it is possible to expand the business population, the most recent data basis is employed, including financial and company statistics from 2014, in which 3,206 businesses with more than 10 employees constitute the basis for the sample.

The correlation between digitisation and productivity

The most digitised businesses have an average of more than 20% higher labour productivity than the least digitised businesses, corresponding to almost DKK 135,000 per full-time equivalent (2014 level), see figure 3. Part of the difference may be explained by the fact that the most digitised businesses are large businesses with higher productivity in general.

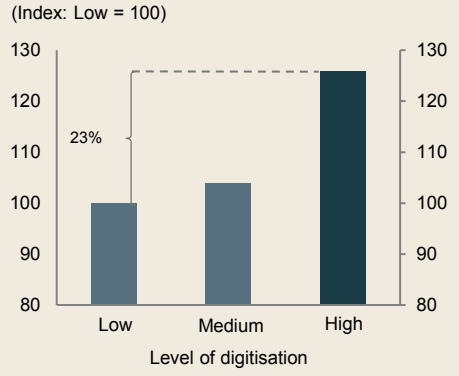
Meanwhile, the most digitised businesses have more than 20% higher total factor productivity. This indicates that productivity increases as businesses become more digitised. Productivity is particularly high in highly digitised businesses, see figure 4.

Figure 3: Level of digitisation and labour productivity in Denmark, 2014



Note: Calculated as value added per full-time equivalent. The figure illustrates private urban businesses. Sample of 3,200 businesses with more than 10 full-time equivalents. The average is weighted and can be listed to a population of around 17,000 businesses, corresponding to around 75% of total revenues in Danish businesses. Size, industry, capital intensity, etc. have not been taken into account in the figure. The level of digitisation has been measured from 0-6.
Source: Statistics Denmark and own calculations

Figure 4: Level of digitisation and total factor productivity, 2010-2013

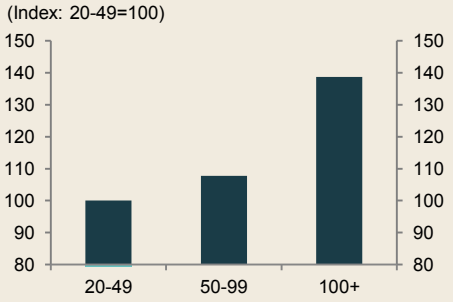


Note: The figure shows digitisation and productivity measured by TFP. Business size, industry etc. have not been eliminated in the figure, but the figures are weighted. Sample of 5,865 businesses with at least 20 full-time equivalents. The average is weighted and can be listed to a population of around 7,000 businesses, corresponding to around 50% of total revenues in Danish businesses.
Source: Statistics Denmark and own calculations

In general, larger businesses have higher productivity, see figure 5. Furthermore, significant differences in the levels of productivity can be observed across industries[1]. This indicates that it is necessary to take both business size as well as industry into account to estimate the direct correlation between digitisation and productivity.

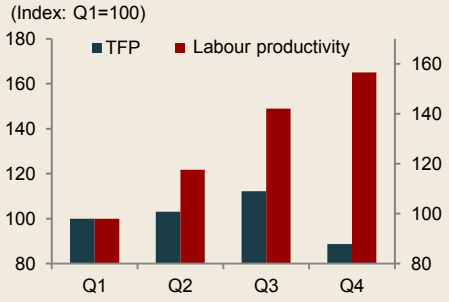
Productivity can also depend on level of education, but this seems to depend on the given productivity measurement, see figure 6. For example, labour productivity increases with level of education, but the same does not apply with regard to TFP. Therefore, education seems to be relevant in the explanation of labour productivity, but the same does not necessarily apply with regard to TFP.

Figure 5: TFP conditional on business size, 2010-2013



Note: Productivity is measured here by means of TFP. The calculation of TFP is subject to uncertainty. See annex for a description of the methods of calculation. Business size is measured as number of full-time equivalents in businesses with at least 20 employees. The average is weighted.
Source: Statistics Denmark and own calculations

Figure 6: Level of education and TFP, 2010-2013



Note: Labour productivity is measured as value added per full-time equivalent. The calculation of TFP is subject to uncertainty. Level of education is the percentage of persons in the business with relevant competences. Q denotes 1st, 2nd, 3rd, and 4th quartile for businesses with a gradually larger percentage of educated labour capacity. Only businesses with at least 20 full-time equivalents. Averages are weighted.
Source: Statistics Denmark and own calculations

[1] Ministry of Industry, Business and Financial Affairs 2017: *Redegørelse om vækst og konkurrenceevne*.

1.2 ANALYSIS & RESULTS

The analysis is based on previous analyses, see for example CEBR (2012). An indicator for digitisation is employed in the analysis, as previously described. Furthermore, TFP values are estimated by means of the Wooldridge Method, see Wooldridge (2009). See box 4 for a brief description of the applied model in the analysis.

Box 4: The model

Estimated TFP levels are inserted as a dependent variable in a log transfer function in which different levels of digitisation are included together with a number of control variables to clarify the correlation between digitisation and productivity:

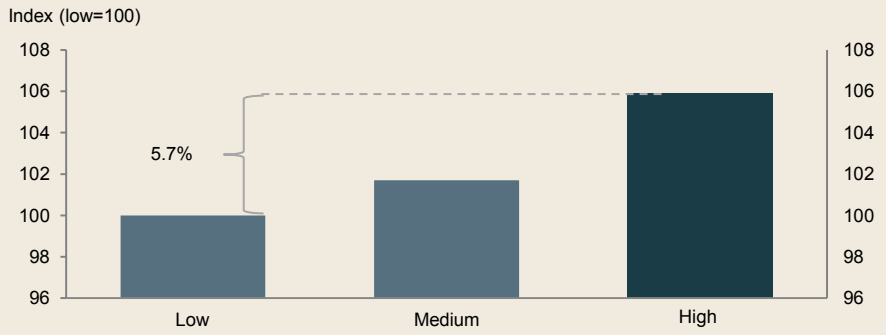
$$\widehat{TFP}_{it} = a + \theta_1 \cdot Digimedium_{it} + \theta_2 \cdot Digihigh_{it} + \delta_1 \cdot \log(FTE_{it}) + \delta_{i2} \cdot sector_{it} + \delta_{i3} \cdot reg_{it} + \delta_{4t} \cdot year_{it} + \delta_5 \cdot export_{it} + \varepsilon_{it}$$

where $Digimedium_{it}$ and $Digihigh_{it}$ are dummy variables denoting whether a business is medium or highly digitised. A dichotomous indicator for digitisation could have been employed, but the benefit of classifying into different levels is that it makes it possible to obtain a more detailed insight into the digitisation of Danish businesses. $\log(FTE_{it})$ denotes the logarithm-transformed number of full-time equivalents in the businesses that makes reservations to the fact that larger businesses are typically more productive, $sector_{it}$, reg_{it} and $year_{it}$ are categorised variables that make reservations regarding differences in productivity between businesses, differences in productivity between Denmark's five regions and annual specific shocks, respectively. Finally, $export_{it}$ is a variable that denotes the export share in a given sector in a given year, while ε_{it} is an error default for business *i* to time *t*.

The equation is estimated across years by pooled OLS, and the businesses in the analysis are weighted according to their representativeness and heteroscedastically robust standard errors are utilised. Besides the digitisation variable, a number of variables with presumed decisive significance for productivity development in businesses are included. The equation is also estimated with the between estimator.

There is a positive correlation between the utilisation of IT and productivity among businesses with at least 20 full-time equivalents. The correlation is statistically significant - also after controlling for business- specific characteristics. The estimation shows that TFP is around 5.7% higher for highly digitised businesses compared with less digitised businesses, see figure 7.

Figure 7: Level of digitisation and total factor productivity, 2010-2013



Note: Here, productivity is measured by means of TFP. The calculation of TFP is subject to uncertainty. See annex for a description of the methods of calculation. For businesses with at least 20 full-time equivalents. The analysis is based on weighted results. The figure is based on specification IV, see table 1. The number of observations is 5,865.
Source: Statistics Denmark and own calculations.

table 1 shows the coefficients in different specifications by OLS, see box 4. The coefficients from medium digitisation and high digitisation should be considered relative to less digitised businesses, which constitute the reference group. Since TFP is

logarithmically transformed, the coefficients from medium and high digitisation should be read as percentages.

Table 1: Estimates by OLS, 2010-2013

Model description	I	II	III	IV
Constant	6.23 (0.02)	6.24 (0.05)	5.59 (0.06)	5.53 (0.06)
Medium digitisation	0.037 (0.02)	0.062 (0.02)	0.022 (0.02)	0.017 (0.02)
High digitisation	**0.229** **(0.03)**	**0.174** **(0.02)**	**0.062** **(0.02)**	**0.057** **(0.02)**
Log (FTE)			0.16 (0.01)	0.15 (0.01)
Export				0.27 (0.02)
Control for sector		Yes	Yes	Yes
Control for region		Yes	Yes	Yes
Control for year		Yes	Yes	Yes
Number of observations	5,865	5,865	5,865	5,865
R^2 (adjusted)	0.02	0.40	0.47	0.49

Note: Heteroscedastically robust standard errors are shown in brackets. Businesses with at least 20 full-time equivalents. Weighting has been applied.
Source: Statistics Denmark and own calculations

More control variables are gradually included in the different specifications that can be read from the columns in table 1. The control variables are included to make reservations regarding additional factors with presumed decisive significance for productivity development in businesses. Model I describes the direct correlation, while model II includes controls for sector, region and year. Note that the degree of explanation considerably increases, and particularly the sector variable makes it possible to explain differences in productivity between businesses. Model II includes the number of full-time equivalents to take into account that large businesses are both more digital and more productive, in general.

Finally, the export share of the businesses is included in model IV to make reservations regarding two considerations. First, exports can be used as a proxy for the degree of competitiveness in a sector, including from abroad. Second, being an exporter can mean that a business has better access to the newest technology from abroad. Thus, a technological spill-over effect can exist for export businesses. However, this does not change the results with regards to the digitisation effect on productivity in model III. Overall, the analysis shows that, all things being equal, businesses with a high level of digitisation have 6% higher TFP than businesses with a low level of digitisation after controlling for business-specific characteristics, see column IV in table 1. The correlation is statistically significant.

To examine robustness in the results of the analysis and to further seek to minimise potential bias in the coefficients, another estimation method has been applied - the between estimator, see box 4. With OLS, a mixture of time and cross-section effects is achieved, while the between estimator exploits the cross-section structure in data. This further describes how digitisation affects productivity between businesses. Estimates acquired through the between estimator are similar to the estimates acquired through OLS, but are marginally lower, see table 2. This is also expected, since the sample of businesses has the characteristics of cross-section data, which is why OLS and the between estimator will resemble each another.

Table 2: Estimates by the between estimator, 2010-2013

Model description	V	VI	VII	VIII
Constant	6.27 (0.02)	6.28 (0.04)	5.60 (0.05)	5.52 (0.05)
Medium digitisation	0.02 (0.03)	0.06 (0.02)	0.01 (0.02)	0.01 (0.02)
High digitisation	**0.25** **(0.03)**	**0.19** **(0.02)**	**0.05** **(0.02)**	**0.05** **(0.02)**
Log (FTE)			0.16 (0.01)	0.15 (0.01)
Exports				0.25 (0.02)
Control for sector		Yes	Yes	Yes
Control for region		Yes	Yes	Yes
Control for year		-	-	-
Number of observations	5,865	5,865	5,865	5,865
R^2 (between)	0.02	0.45	0.52	0.51

Note: Common standard errors are shown in brackets. Businesses with at least 20 full-time equivalents. It is not possible to use weighting when the between estimator is employed.
Source: Statistics Denmark and own calculations

2. LITERATURE

2.1 LIST OF LITERATURE

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