Digitalization and Productivity

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This report presents the findings from a project carried out by CEBR for the Danish National IT and Telecom Agency on the relationship between the digitalization choices and productivity of Danish firms. The authors have full responsibility for the results and conclusions in the report. The views expressed do not necessarily reflect the views of the Danish National IT and Telecom Agency.

1 Table of Contents

The Report

Centre for Economic and Business Research (CEBR) has in the period March to July 2011 carried out a project for the Danish National IT and Telecom Agency that investigates the relationship between the digitalization choices and productivity of Danish firms. This report documents the findings from the project. A number of individuals have contributed helpful comments that have improved the report and the authors would like to use this opportunity to thank them all. A special note of gratitude goes to Professor Christian Møller Dahl (University of Southern Denmark) and Assistant Professor Battista Severgnini (Copenhagen Business School), who have followed the project, while Anja Skadkær Møller at the Danish National IT and Telecom Agency and Thomas Einfeldt also have been most helpful.

Frederiksberg, 18th August 2011

2 Danish Summary

Der er klar sammenhæng mellem danske virksomheders digitaliseringsstrategi og produktivitet. Det viser denne rapport, som CEBR har udarbejdet for IT- og Telestyrelsen på grundlag af en pålidelig stikprøve på omkring 8.500 danske virksomheder. Et af rapportens nøgleresultater er, at en 1 procent-point større andel af virksomheder, som har digitaliseret visse forretningsprocesser, er knyttet til 0,72 procent højere værditilvækst pr. medarbejder. Det svarer i et makroøkonomisk perspektiv til mellem 2,6 og 6,5 milliarder kroner i årlig bruttoværditilvækst.

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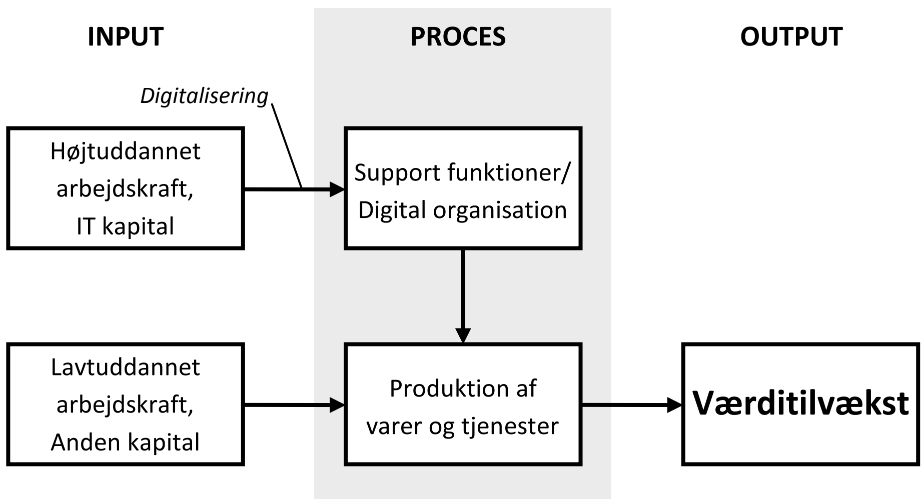
En undersøgelse af sammenhængen mellem uddannelse, digitalisering og produktivitet

Målet med denne undersøgelse er at kvantificere sammenhængen mellem på den ene side uddannelsesmønstrene i danske virksomheder og den interne digitalisering, og på den anden side sammenhængen mellem intern digitalisering og virksomhedernes produktivitet.

> ***Intern digitalisering***
>
> \- er defineret som automatiseret (dvs. IT-baseret) vidensdeling i virksomheden om modtagne og/eller afgivne ordrer i en eller flere af følgende interne funktioner: *lagerstyring*, *bogføring*, *distribution*, og *produktionskontrol*.
>
> Denne definition af intern digitalisering svarer til det EU-harmoniserede spørgsmål om "automatiseret vidensdeling i virksomheden", som Danmarks Statistik medtager i den årlige undersøgelse af danske virksomheders IT-anvendelse.

Den *mekanisme*, som knytter intern digitalisering til uddannelsesmønstre og produktivitetsudvikling, kan forklares med to hypoteser. Den *første* hypotese er, at en vellykket implementering og anvendelse af IT (herunder intern digitalisering) er relateret til veluddannede medarbejdere, for de digitaliserede funktioner i virksomheden vil først og fremmest overtage rutineopgaver, som hidtil har været udført af medarbejdere med begrænset eller ingen uddannelse. Samtidig vil de digitaliserede funktioner skabe flere data, som vil kræve analytiske kompetencer, som typisk leveres af bedre uddannede medarbejdere.

Den *anden* hypotese er, at produktiviteten er højere i virksomheder, der har implementeret intern digitalisering, end i virksomheder, der ikke har digitaliseret. Tankegangen er illustreret i Figur R1.



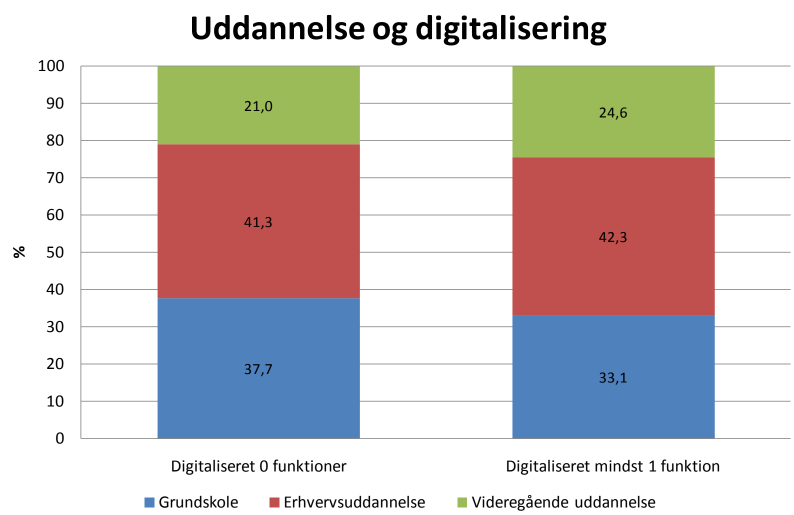
Figur R1 *– Denne rapport analyserer sammenhængen mellem uddannelsesmønstrene i danske virksomheder og intern digitalisering på den ene side, og mellem intern digitalisering og virksomhedernes produktivitet på den anden.*

Digitalisering går hånd i hånd med højere produktivitet og bedre uddannet arbejdskraft

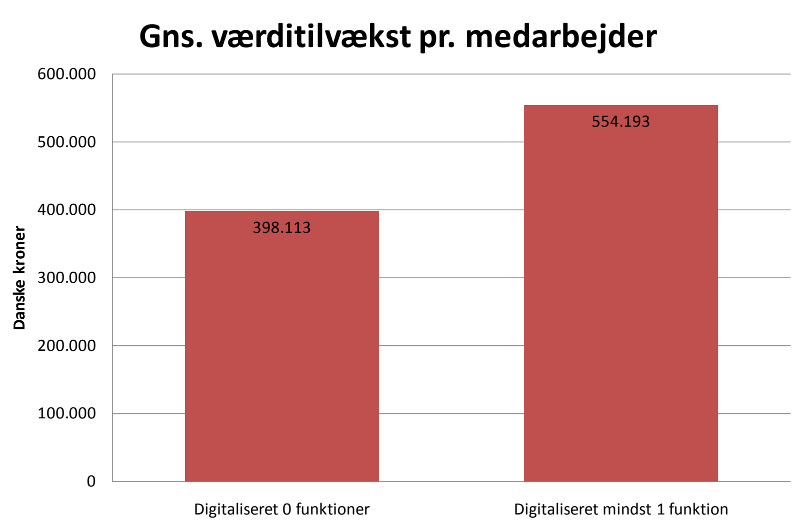
Data for virksomhedernes interne digitalisering stammer fra Danmarks Statistiks undersøgelse om IT-anvendelsen i danske virksomheder i 2007 og 2008. Disse data er suppleret med virksomhedsspecifikke oplysninger om værditilvækst, antal medarbejdere, kapitalapparat mm. fra Danmarks Statistiks erhvervsstatistiske registre.

Figur R2 illustrerer, at virksomheder, som har digitaliseret mindst en af de fire interne funktioner, generelt har bedre uddannede medarbejdere end virksomheder, som ikke har digitaliseret nogen af funktionerne.

Det fremgår endvidere af Figur R3, at virksomheder, der har digitaliseret mindst en af de fire funktioner, er mere produktive (skaber større værditilvækst pr. medarbejder) end virksomheder, som ikke har digitaliseret nogen af funktionerne. Den gennemsnitlige værditilvækst pr. medarbejder i virksomheder, der ikke har digitaliseret nogen af funktionerne, er 398.000 kroner pr. år, mens den gennemsnitlige værditilvækst pr. medarbejder i virksomheder, der har digitaliseret mindst én af de fire funktioner, er 554.000 kroner.



Figur R2 *– Virksomheder, der har digitaliseret mindst én af de fire funktioner, har gennemsnitligt 4,6 % points flere medarbejdere med en uddannelse ud over grundskole. Bemærk, at den observerede sammenhæng kan være forårsaget af bagvedliggende faktorer, som både påvirker virksomhedernes uddannelsesmønstre og digitaliseringsbeslutninger.*



***Figur R3** – Produktiviteten pr. medarbejder i virksomheder, der har digitaliseret mindst én af de fire funktioner, er gennemsnitligt 39 % højere end i virksomheder, der ikke har digitaliseret. Bemærk, at den observerede sammenhæng kan være forårsaget af bagvedliggende faktorer, som både påvirker virksomhedernes produktivitet og digitaliseringsbeslutninger.*

Man kan dog ikke heraf konkludere, at øget digitalisering medfører højere produktivitet. Den observerede sammenhæng kan være forårsaget af bagvedliggende faktorer, som både påvirker virksomhedernes produktivitet og digitaliseringsbeslutninger.

Vi har derfor gennemført en omfattende statistisk analyse af de mange virksomhedsdata for at isolere relationen mellem digitalisering, uddannelsesmønstre og produktivitet fra effekten af andre forhold i og omkring virksomhederne. Analysen er en to-trins procedure, hvor vi i første trin estimerer et mål for virksomhedernes individuelle ”digitaliseringsintensitet” i forhold til uddannelsesmønstret; og i andet trin estimerer en produktivitetsligning til at kvantificere sammenhængen mellem digitalisering og produktivitet.

Denne analyse har to hovedresultater:

1) ***Andelen af veluddannede medarbejdere i virksomheden er positivt relateret til virksomhedens digitaliseringsbeslutninger.*** Den positive sammenhæng er stærkest for medarbejdere med enten en samfundsvidenskabelig eller teknisk/naturvidenskabelig kandidatgrad.

2) ***En forøgelse på 1 procent-point i andelen af virksomheder, der har digitaliseret mindst én af de fire funktioner, er relateret til en stigning på 0,72 % i gennemsnitsproduktiviteten blandt virksomhederne i stikprøven.*** Denne positive sammenhæng mellem digitalisering og værdiskabelse pr. medarbejder er særdeles robust.

Politiske perspektiver

Vi skønner på grundlag af disse analyseresultater, at en forøgelse på 1 procent-point i andelen af virksomheder, der har digitaliseret mindst én af de fire funktioner, er relateret til en forbedring af virksomhedernes værdiskabelse på op til 6,5 milliarder kroner om året. Det svarer til 0,44 % af den årlige danske bruttoværditilvækst.

Rapportens resultater har også relevans for den uddannelsespolitiske debat i Danmark. Det er for eksempel vores vurdering, at hvis andelene af medarbejdere i virksomhederne med henholdsvis en erhvervsuddannelse eller en kort, mellemlang eller lang videregående uddannelse hver især var 1 procent-point højere (og dermed at andelen af medarbejdere uden uddannelse var 4 procent-points lavere), så ville andelen af virksomheder, der havde digitaliseret mindst én af de fire funktioner, være 4,5 procent-points højere.

For hele den danske økonomi ville effekten af en sådan forøgelse af digitaliseringsintensiteten i virksomhederne være en forbedring af bruttoværditilvæksten på mellem 12 og 29 milliarder kroner.

Et enkelt, men vigtigt forbehold

Selv om denne undersøgelse bygger på data af god kvalitet og *state-of-the-art* analysemetoder, så kan resultaterne udelukkende dokumentere *sammenhænge* mellem variable, ikke kausale effekter. Undersøgelse har med andre ord ikke dokumenteret, at bestemte uddannelsesmønstre i virksomhederne har kausal indvirkning på virksomhedernes tilbøjelighed til at digitalisere. Undersøgelsen har heller ikke dokumenteret, at øget digitalisering har kausal indvirkning på virksomhedernes produktivitet.

Undersøgelsesresultaterne er imidlertid et første skridt mod en dybere forståelse af digitaliseringens betydning for produktiviteten. Rapportens resultater rejser en række nye spørgsmål, hvis besvarelse har stor relevans for såvel erhvervslivet som økonomer og politikere. Arbejdet med at finde frem til disse svar kræver flere data og yderligere forskning.

3 Executive summary

Based on a high-quality sample of approximately 8,500 Danish firms, this report, prepared by CEBR for the Danish National IT and Telecom Agency, identifies a clear link between digitalization choices and productivity of Danish firms. In essence, a 1 percentage point larger share of firms who have digitalized certain business processes is related to 0.72 percent higher value added per employee. In a macroeconomic perspective, this translates into between 2.6 and 6.5 billion kroner in annual gross value added.

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A study of the links between education mix, digitalization, and productivity

In this study we estimate the relationship between the educational mix of firms' employees and the firms' internal digitalization on the one hand, and internal digitalization and firm productivity on the other hand.

Internal digitalization

\- refers to the implementation of automated (i.e. IT based) information sharing regarding received and/or placed orders within one or more of four internal functions: *inventory control*, *accounting*, *distribution*, and *production control*.

This definition of internal digitalization follows from the EU harmonized question on "automated information sharing within the firm" which Statistics Denmark includes in its annual large-scale survey of IT use in Danish firms.

The *underlying mechanism* linking internal digitalization with education mix, and productivity is based on two hypotheses. The *first* hypothesis is that education is complementary to successful implementation and use of IT, including internal digitalization; digitalized functions take over routine tasks previously handled by less educated employees. At the same time digitalized functions produce more data, which requires analytical skills possessed by better educated employees.

The *second* hypothesis is that productivity is higher in firms that successfully implement internal digitalization than in those that do not. These ideas are illustrated in Figure ES1.

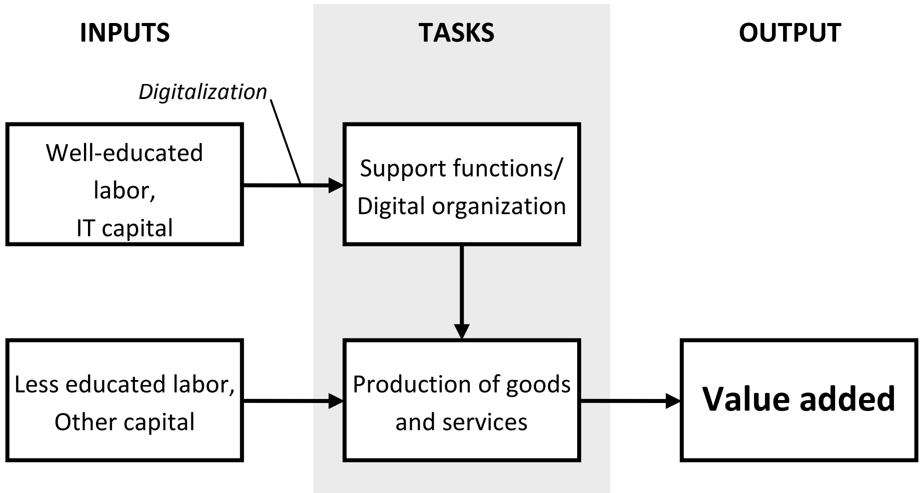


Figure ES1 *– In this study we estimate the relationship between firms' education mix and internal digitalization on the one hand, and internal digitalization and firm productivity on the other.*

Digitalization goes hand in hand with higher productivity and better educated staff

The data on digitalization come from a survey conducted by Statistics Denmark of the use of IT by Danish firms in 2007 and 2008 that are the most recent data available. Statistics Denmark's register data bases allow us to combine the survey data with firm level register data, including value added, number of employees, size of capital stock etc.

As is clearly illustrated in Figure ES2*,* firms that have digitalized at least one of the four functions under consideration in general have better educated employees than firms that have not digitalized any of the four functions.

Further, it appears from Figure ES3 that firms that have digitalized at least one of the four functions are more productive, i.e. have higher value added per employee, than firms that have not digitalized any functions. The average value added per employee in firms that have not digitalized any of the four functions is 398,000 kroner, while the average value added per employee in firms that have digitalized at least one of the four functions is 554,000 kroner.

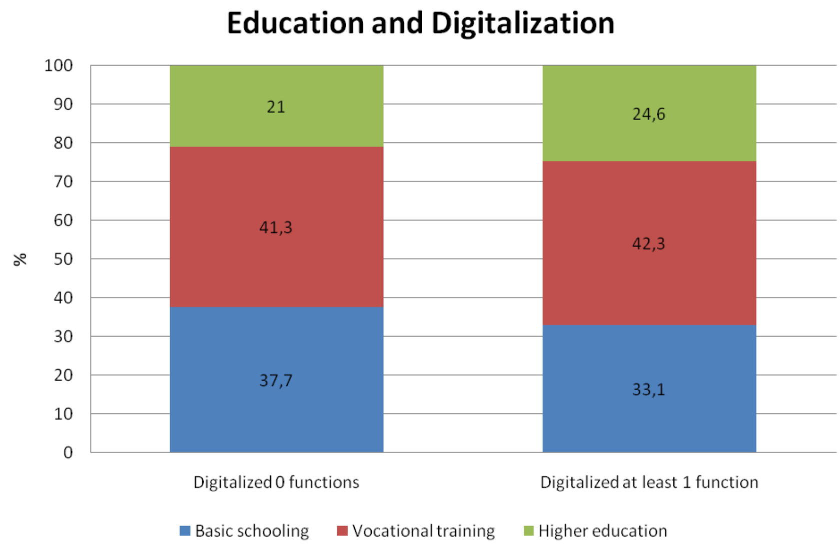


Figure ES2 *– On average, the education mix of firms who have digitalized at least one function includes 4.6 % more employees with an education above basic schooling. We emphasize that the relationship can be caused by other factors that influence both education mix and digitalization choices.*

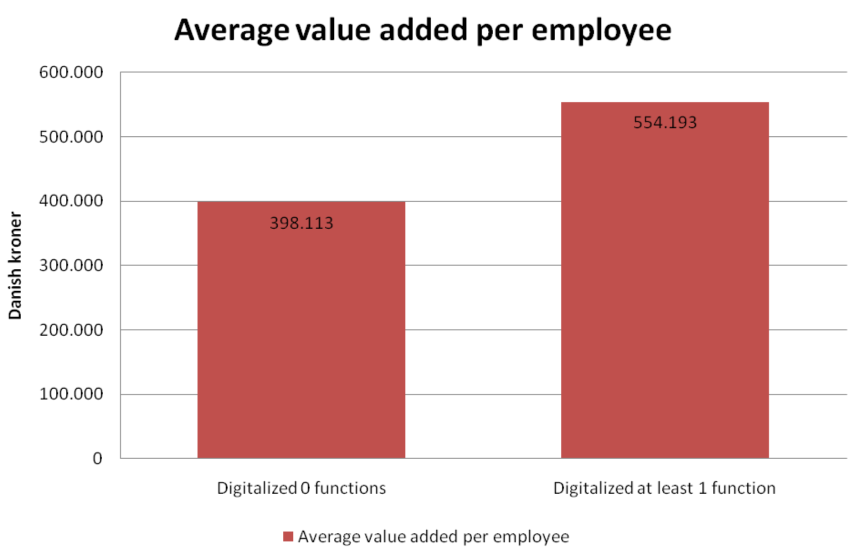


Figure ES3 *– Firms who have digitalized at least one function enjoy a 39 % productivity advantage relative to firms who have not digitalized any functions. We emphasize that the relationship could be caused by other factors that influence both digitalization choices and productivity.*

Importantly though, this does not imply that digitalization causes higher productivity because the relationship can be caused by other factors that influence both digitalization choices and productivity, e.g. firm size and industry.

We therefore put the data through a rigorous statistical analysis to isolate the relationship between digitalization, education mix and productivity. We employ a two-step procedure, which involves 1) estimating a firm specific measure of the digitalization intensity based on the education mix and 2) estimating a productivity equation that measures the strength of the relationship between digitalization intensity and productivity.

We find that

1) ***Better educated employees are positively related to the digitalization choices of the firm.*** The positive relationship with digitalization is strongest for employees with either a social science degree or with a science or engineering degree.

2) ***A 1 percentage point increase in the proportion of firms that have digitalized at least one of the four functions is related to a 0.72 % increase in the average productivity of the firms in the sample.*** This relationship between digitalization and value added per average employee is very robust.

Policy perspectives

Based on these findings we estimate that an increase of 1 percentage point in the share of firms who have digitalized at least one of the four functions would be accompanied by an increase in value added of up to 6.5 billion kroner per year. This corresponds to 0.44 % of gross value added in Denmark.

We can also relate our findings to the debate on Danish education policy by means of a thought experiment. Assume that the shares of employees with vocational training, short tertiary education, bachelor degrees, and postgraduate degrees each were 1 percentage point larger (and the share of employees who have only basic schooling was 4 percentage points lower). Then we would predict that the share of firms who have digitalized at least one of the four functions to be 4.5 percentage points higher.

This, in turn, would translate into an estimated annual improvement of gross value added for the entire Danish economy of between 11.6 billion kroner and 29 billion kroner.

A word of caution

Even though the data analysis in this study is state-of-the-art and based on high quality data, our results only provide evidence about *relationships* between variables, not evidence of what causes what. We do not claim to document either causal effects of educational mix on the probability that a firm will digitalize one or more functions or causal effects of digitalization on firm productivity.

Even so, the study is the first analysis of the relationship between internal digitalization and firm productivity. The established results are a first attempt to understand the economic importance of digitalization for firm productivity, and open up for a myriad of new questions. Good answers to these questions are highly relevant – for businesses, economists, and policy makers. But in order to get an answer to these questions, more data and further research is needed.

4 Digitalization and productivity

This chapter is an 'easy-to-read' summary of appendices A, B, and C below. For full details of the analysis, we refer the reader to these appendices. Appendix A describes the data set and the empirical methods that we utilize, and provides definitions of the main digitalization variables in the analysis. Appendix B of the report gives an overview of the data that we use in the analysis by providing graphs and tables of relevant features of the data. The intention in Appendix B is to provide background for the regression analysis in Appendix C.

4.1 Summary

Four main results emerge from the analysis in the report:

1) The educational mix of the firms' employees (measured either as educational lengths or as educational types) is positively correlated with the digitalization choices of the firm.
2) Digitalization is positively correlated with productivity. Our main estimate shows that a one percentage point increase in the probability that a firm has digitalized at least one internal function is correlated with a 0.72 % increase in value added per average employee. We are not able to estimate separate relationships between the different functions that can be digitalized and productivity.
3) The predicted probabilities of digitalization of a function are (virtually) identical with the actual percentage of firms in the data that actually have digitalized this function. The results from the estimations of the production function are therefore readily interpreted in terms of the correlation between digitalization and productivity in the sample: If the proportion of firms that have digitalized at least one of the main 4 functions increases by one percentage point the aggregate productivity of the firms in the sample will be predicted to be 0.72 % higher than before.
4) As the average value added per employee in our sample of firms was 525,807 kroner on average over the years 2007 and 2008, 0.72 % amounts to 3,786 kroner per employee. Depending on the assumptions made about whether the correlation between digitalization and growth is present also in those Danish firms that were not included in our sample, this amounts to between 2.6 billion kroner and 6.5 billion kroner per year for the whole Danish economy.

5) Table 4.1 below shows the changes in shares of the better educated groups (and corresponding decrease in the share of the employed that have only basic schooling) that are associated with a 1 percentage point increase in digitalization.

TABLE 4.1 Educational shares and Digitalization	
Vocational training	1.2
Short tertiary education	0.5
Bachelor degree	1.9
Postgraduate degree	0.8

Note: The table shows the percentage point increase in share of the indicated educational group associated with a 1 percentage point increase in digitalization (and a corresponding percentage point decrease in the share of the employed that have only basic schooling).
Source: Authors own calculations

The main results can be elaborated upon as follows:

1) A large share of vocationally trained employees and a large share of employees with a short tertiary education (and with a correspondingly lower share of employees with only basic schooling) are conducive to digitalization choices of the firm.
2) The share of employees with a bachelor degree exhibits a positive but relatively weak relationship with the digitalization choices of the firm. The share of employees with a postgraduate degree does exhibit a statistically significant positive relationship with the digitalization choices of the firm but the coefficients are often smaller than for vocational training and short tertiary education.
3) The share of employees with a humanities degree does not exhibit a strong positive relationship with the digitalization choices of the firm while the share of employees with either a social science degree or with a science degree does exhibit a statistically significant positive relationship with the digitalization choices of the firm.
4) The relationship between digitalization and value added per average employee is very robust to alternative measures of digitalization. For example, a prediction of more advanced Internet access is correlated with a prediction of higher productivity. In virtually all regressions, a one percentage point increase in the probability of digitalization is correlated with an increase in productivity on the order of 0.6 % to 1 %. This is by any measure a sizeable economic correlation. At the same time, this implies that we cannot estimate separate relationships

between productivity and the 4 internal functions that can be digitalized. The results in this report should therefore be interpreted as saying something about the relationship between digitalization of firm functions in general and productivity, rather than saying something about the relationship between, for example, digitalization of accounting and productivity.

4.2 Motivation, data, and implementation

Motivation

The productive implementation of IT in firms depends to a large extent on which other business practices are used. For example, Brynjolfsson (2005) argues that seven business practices are much more common in IT-intensive firms than in firms that do not have an intensive IT use, and that the adoption and use of these will raise firm productivity. In the following we will focus on two of these business strategies and study the importance of these for firm productivity. These two business strategies are (Brynjolfsson, 2005):

1) "*Move from analog to digital processes*: Moving an increasing number of processes into the paperless, digital realm is one of the keys to making productive use of IT. This practice frees the company from the physical limitations of paper [..]. Digitalization also makes it easier to track key performance indicators."
2) *"Investment in human capital*: The 6 [other] business practices all require substantial investment in human capital, but this isn't satisfied by hiring alone. For that reason, digital organizations provide more training than their traditional counterparts. This helps employees operate new digital processes, find information, make decisions, cope with exceptions, meet strategic goals etc."

These two business strategies are the focus of the present study of the relationship between internal digitalization and (two different measures of) the education mix on the one hand and firm productivity on the other.

Internal digitalization

- refers to the implementation of automated (i.e. IT based) information sharing regarding received and/or placed orders within one or more of four internal functions: *inventory control*, *accounting*, *distribution*, and *production control*.

This definition of internal digitalization follows from the EU harmonized question on “automated information sharing within the firm” which Statistics Denmark includes in its annual large-scale survey of IT use in Danish firms.

Educational mix

- refers to educational mix defined by educational length: Basic schooling, vocational training, short tertiary education, bachelor degree, or postgraduate degree,

- or refers to educational mix defined by educational type: Basic schooling or vocational training, tertiary education in humanities, tertiary education in social sciences, and tertiary education in sciences (including engineering).

In this respect, firms that use the business strategy of internal digitalization have to some extent moved from analog to digital processes; and firms that use large shares of skilled and educated workers have as a consequence of digitalization to some extent invested in human capital; at least after taking other firm characteristics into account. To the best of our knowledge this is the first study of the productive effects of internal digitalization.

The other 5 business practices – open information access, empower the employees, use performance-based incentives, invest in corporate culture and recruit the right people – are also potentially important for firm productivity and therefore relevant to include. It may of course be the case that Danish firms that have implemented these business practices are more productive than their peers that have not. However, the issue is not explored in further detail because data on the use of these practices has not been collected for Danish firms.

The underlying mechanism linking the education mix to internal digitalization and further to productivity is based on two relationships. The first relationship is between increasing use of IT and a related increase in demand for skilled and educated labor. The idea is that declines in the price of IT lead to higher adoption and use of IT including internal digitalization, which to a greater extent results in higher demand for skills. The second relationship suggests that productivity should be higher in firms that successfully implement internal digitalization than in those that do not invest in internal digitalization.

Before the empirical analysis is described the mechanism linking the education mix and internal digitalization is illustrated (Breshanan, Brynjolfsson, and Hitt, 2002):

1) The use of computer business systems substitute for certain types of tasks that used to be performed by firm employees. This is especially the case for record keeping, remembering, and similar tasks. In other words, routine and simple decisions related to this work have been affected by digitalization. As a consequence, the use of computer business systems substitutes for clerical and similar work to a high extent, implying that the demand for workers with low qualifications decreases.
2) Complex and cognitively challenging work has been difficult to automate through computerization so far. Consequently, the effect from computerization on the use of workers with high qualifications has been limited.
3) A third mechanism works through higher production of data and gathering of information as a consequence of digitalization. This calls for analytical and abstract decision making such as analyzing demand and needs of customers, studying new markets, evaluating the need for product innovation. This increases the demand for skilled and educated workers.

The above described relationships between internal digitalization and the use of skilled and educated labor and between internal digitalization and productivity will be studied in the following.

Data

All our data come from Statistics Denmark. The data on digitalization come from a survey conducted by Statistics Denmark of the use of ICT by Danish firms. In order to select firms to include in the survey, Statistics Denmark stratified all Danish firms not in the agriculture industry according to size and industry. Strata with larger firms were overrepresented but firms were sampled at random within each selected strata.

Statistics Denmark’s register data bases allow us to combine the data from the survey with firm level register data. From the register data bases we obtain information on each firms’ number of employees, size of capital stock, share of revenues obtained from exports etc.

Compared to the usual data used in the literature on this subject, our data set is unique in two respects. First, it is unique because we have 8,560 observations (4,257 firms answered the questionnaire in 2008 and 4,303 firms answered the questionnaire in 2009), which is a lot more than is available to other research in this area. Other studies are usually based on several hundred, rather than several thousand, observations. Secondly, we are also very fortunate in that the response rate to the questionnaire is exceptionally high, about 97 percent. This is because the firms that Statistics Denmark selects for the survey are required by law to respond to the questionnaire. Data attrition is therefore not much of an issue in our study compared to other studies where it often is a major issue.

Our study is the first of its kind done using Danish data. To the best of our knowledge this is also the first study on the connection between digitalization and productivity that is able to utilize data on digitalization of specific processes within the firm. Because of a lack of data, most of the literature in this area is restricted to using broad proxies for digitalization like for example ICT investment expenditures.

Even though the data analysis is state-of-the-art and based on high quality data, we must emphasize that the results that we obtain only provide evidence about relationships between variables, not evidence of what causes what. We do not claim to document either causal effects of educational mix on the probability that a firm will digitalize one or more functions or causal effects of digitalization on firm productivity.

Data limitations are important for the choice of the empirical framework.

- The Danish IT use surveys measure internal digitalization, by asking whether relevant information is shared electronically and in an automated fashion with IT-systems in different functions (inventory control, accounting, distribution, product control) when the firm receives or places an order. The only possible answer choice is to state whether internal digitalization is implemented or not. This implies that the measure of internal digitalization does not provide information on the extent of internal digitalization.
- Data availability only allows estimation of cross-sectional relations between productivity and internal digitalization of firms. Consequently, issues of the timing of internal digitalization and its contribution to productivity are ignored. This is a reflection of the nature of the surveys

for IT use, which only asks about "internal digitalization" in the 2007 and 2008 editions. Therefore, it is not possible to study how productivity grew in years after internal digitalization was implemented and compare these growth rates to firms that did not digitalize. Thus, the analysis relates productivity in 2007 and 2008 to firms that were already digitalized to firms that were not; it does not trace out any dynamic response. In this sense the established results have a long run nature.

Implementation

Due to the long-run nature of the analysis, we formulate two hypotheses:

- Firms that have an education mix skewed towards skilled and educated workers have higher probability of internal digitalization.
- Firms with a high probability of internal digitalization have higher productivity.

As mentioned above, the measure of internal digitalization has the drawback that it does not reveal the extent of internal digitalization within firms. Therefore, the aim is to estimate a firm specific measure that can be interpreted as the digitalization potential or intensity. To obtain this measure of internal digitalization, an equation that describes the probability of internal digitalization in firms is estimated as a function of the education mix and other firm characteristics. This equation is then used to predict the probability that firms are internally digitalized and it is this probability that constitutes the measure of digitalization intensity.

The above described procedure is based on the idea that most firms do internal digitalization but do not report it separately to the statistical agency performing the survey. In a sense, this approach fills in the firms value for internal digitalization with what might have been expected given their educational mix, size, industry, etc.

Next, a productivity equation is estimated that includes the measure of internal digitalization probability. The resulting estimates give the contribution of the digitalization intensity conditional on the education mix and other firm characteristics to productivity.

Finally, it should be emphasized that the applied model is very similar in nature to the CDM model (Crepon, Duguet, and Mairesse, 1998), which is an important work horse in the literature on innovation and productivity. The use of this model framework is found suitable due to similarities in data access and limitations in the two areas of the economic literature.

Future research

The study presents the first study of the relationship between internal digitalization and firm productivity. As argued in the report, no empirical methods have been used to account for causality, which means that we have not investigated whether digitalization influences productivity or whether productivity influences digitalization. The established results are important as the first attempt to understand the economic importance of digitalization for firm productivity. However, it also opens up for a myriad of new questions that need to be answered. Good answers to these questions are highly relevant – both for businesses, policy makers, and economists – and could be studied on the basis of high quality Danish data that combine survey data with register data.

Examples of interesting questions are: (i) Is digitalization an “all or nothing” decision? This question is motivated by the findings in the present project. (ii) What is the causal economic effect of internal digitalization for firm productivity? (iii) What are the dynamic responses of digitalization on productivity? (iv) How does labor demand change in firms that digitalize? (iv) What other business practices are important for a productive use of digitalization? In order to get an answer to these questions, more data and further research is needed.

4.3 Descriptive statistics

Table 4.2 below shows the distribution of digitalization decisions of firms in the data set. In the table ‘IADP’ indicates the relevant functions so ‘I’ stands for ‘Inventory’, ‘A’ stands for ‘Accounting’, ‘D’ stands for ‘Distribution’, and ‘P’ stands for ‘Production’. A sequence of numbers in the first column then indicates a combination of digitalized functions. For example, the sequence ‘0110’ means that a firm has not digitalized inventory, has digitalized accounting, has digitalized distribution, and has not digitalized production control.

Table 4.2 shows that a third of the firms in our data set have not digitalized any of the 4 functions, Inventory control, Accounting, Distribution, and Production control, while a quarter of the firms have digitalized all 4 functions. The rest of the firms are spread fairly evenly across the spectrum of options with regard to internal digitalization choices even though only digitalizing accounting or digitalizing only accounting and inventory control are also popular options among firms. When we also take into account that many firms in the sample produce services rather than physical goods and therefore do not have inventories or distribution processes for example, these facts may indicate that digitalization of functions within a firm to some extent may be an ‘all or nothing’ decision.

TABLE 4.2 Distribution of digitalized functions across firms

IADP	Frequency	Percent	Cum. Percent
0000	2.622	33.06	33.06
1000	141	1.78	34.83
0100	767	9.67	44.50
0010	40	0.50	45.01
0001	109	1.37	46.38
1100	722	9.10	55.48
1010	26	0.33	55.81
1001	46	0.58	56.39
0110	72	0.91	57.30
0101	388	4.89	62.19
0011	54	0.68	62.87
1110	196	2.47	65.34
1101	468	5.90	71.24
1011	55	0.69	71.94
0111	229	2.89	74.82
1111	1.997	25.18	100.00
Total	7.932	100.00	

With respect to firm characteristics that are correlated with the decision to digitalize one or more functions Appendix B shows that a variety of firm characteristics in addition to the educational mix of the employed influence the probability that a firm will digitalize one or more of the 4 functions. Specifically, we find that

- Exporting firms are more likely to have digitalized one or more functions.
- Firms with a larger capital stock or a larger number of employees are more likely to have digitalized one or more functions.
- Manufacturing firms and firms in the retail industry are more likely to have digitalized one or more functions, while firms in the business services industry are less likely to have digitalized one or more functions.

4.4 Education and digitalization

The full results from the regression analysis are presented in Appendix C. Here, we summarize the results on the relationship between the educational mix of the firm and the probability that the firm has digitalized at least one of the 4 main internal functions under consideration (Inventory control, Accounting, Distribution, and Production control).

The results about the relationship between educational mix and digitalization choices can best be understood by considering 5 hypothetical firms. The firms are hypothesized to differ only with respect to the educational mix of the employed while all other firm characteristics are set at the average value of the whole sample of firms. As presented in Table 4.3, 100% of the first firms' employees are hypothesized to have basic schooling, 42 % of the second firms' employees are hypothesized to have vocational training (which is the average percentage of employees with vocational training in the whole sample of firms) with a correspondingly lower percentage of the employed with basic schooling etc. The fifth firm is hypothesized to employ the average percentage of workers in each educational length category.

Table 4.3 shows that with an employment structure where 100 % of the employees have basic schooling, the probability that the firm has digitalized at least one of the 4 functions under consideration is 56.1 %[1]. Each percentage point of workers with vocational training rather than basic schooling increases the probability that the firm has digitalized at least one of the 4 functions by 0.8 percentage points so replacing 42 % percent of the workers with basic schooling with workers who have vocational training increases the probability that the firm has digitalized at least one function by 23.1 percentage points

[1] The probability of digitalization of 56.1 % even though all employees are hypothesized to have basic schooling comes from the fact that we hypothesize that the firm has average values for control variables other than the educational mix, i.e. the firm has an average sized capital stock, average number of employees etc.

from 56.1 % to 79.2 %. Employees with short tertiary education also have a strong positive relationship with the probability of digitalization so replacing a further 7 % of the original employees who have basic schooling with 7 % who have short tertiary education raises the probability further, from 79.2 % to 84.5 %. Bachelors do not exhibit a strong relationship with digitalization, so substituting an additional 7 % of the original employees who have basic schooling with 7 % who have a bachelor degree only raises the probability of digitalization slightly from 84.5 % to 85.7 %. Finally, postgraduates exhibit a moderately strong positive relationship with digitalization, so substituting an additional 8 % of the original employees who have basic schooling with 8 % who have a postgraduate degree raises the probability of digitalization moderately from 85.7 % to 88.7 %.

TABLE 4.3 EDUCATIONAL LENGTHS AND DIGITALIZATION PROBABILITIES

	Firm 1	Firm 2	Firm 3	Firm 4	Firm 5
Basic schooling %	100	58	51	44	36
Vocational %	0	42	42	42	42
Short tertiary %	0	0	7	7	7
Bachelor %	0	0	0	7	7
Postgraduate %	0	0	0	0	8
Predicted probability %	56.1	79.2	84.5	85.7	88.7

Notes: The calculations are based on the regression results of the linear probability model shown in column 1 of Table 6.1 in Appendix C. Predicted probabilities are calculated probabilities of a hypothesized firm having digitalized one or more functions based on the hypothesized firm having the educational mix shown.

Source: Authors own calculations

Table 4.4 shows the results from the same exercise with educational types rather than educational lengths as a measure of educational mix. Starting from a hypothetical firm who's employees all come from the basic category of educational types, in this case employees with either only basic schooling or with vocational training, we then gradually replace them with employees with different types of tertiary education. With employees who either have basic schooling or vocational training, a hypothetical firm with otherwise average values of the capital-labor ratio, export intensity etc. has a probability of 71.6 % of having digitalized at least one of the 4 internal functions. Replacing 4 percent of the employees with employees with a humanities education only raises the probability that the firm has digitalized at least one function by 0.4 percentage points. Adding the average value of employees with a social science education (about 8 %) increases the predicted probability by 5.6 percentage points to 77.6 %. The largest impact comes from assuming that 11 % of the employees have a science education rather than basic schooling or vocational training. Because of the large change in the educational mix and because science education has a strong positive relationship with digitalization this hypothetical raises the probability of digitalization from 77.6 % to 85.9 % which is the average probability in this model, i.e. the probability of digitalization when all explanatory variables are set at their average value.

TABLE 4.4 EDUCATIONAL LENGTHS AND DIGITALIZATION PROBABILITIES

	Firm 1	Firm 2	Firm 3	Firm 4
Basic education %	100	96	88	77
Humanities %	0	4	4	4
Social science %	0	0	8	8
Science %	0	0	0	11
Predicted probability %	71.6	72.0	77.6	85.9

Notes: The calculations are based on the regression results of the linear probability model shown in column 1 of Table 7.2 in Appendix C. Predicted probabilities are calculated probabilities of a hypothesized firm having digitalized one or more functions based on the hypothesized firm having the educational mix shown. Basic education includes basic schooling and/or vocational training.

Source: Authors own calculations

When we plug in the average values of all explanatory variables in the linear probability model in Table 4.2, the probability of digitalization of 88.7 % (85.9 % in Table 4.4) does not coincide with the actual probability of 67 % that a firm selected at random from the data set has digitalized at least one of the 4 functions. In order to get probabilities of digitalization from a model that equal the actual probabilities in the data set we need to use another probability model[2]. The drawback of this probability model is that the coefficients on the explanatory variables that measure the strength of the relationship between the explanatory variables and the probability of digitalization are not as easy to interpret. Only the relative sizes of the coefficients have meaningful interpretations, i.e. whether one coefficient is larger than another coefficient. This drawback of the probability model is the reason why we used the linear

[2] Economists call this probability model the 'probit model'.

probability model to illustrate the relationships between educational lengths and digitalization decisions of firms.

We illustrate this in Table 4.5 below which displays the results for estimations of the basic relationship with probability models. Note that the table only includes some of the variables that are included in the estimation of the predicted values shown in the bottom line of the table. Therefore, the variables included in the table are not sufficient to calculate the predicted probability shown in the bottom line.

As in Table 4.4 the coefficients on the vocational training and short tertiary education are the largest of the 4 coefficients on the education variables and both are statistically significant. The coefficient on the bachelor variable is the smallest of the 4 coefficients but in contrast to Table 4.4 the coefficients are generally statistically significant. And as in Table 4.4 the coefficient on postgraduates is intermediate in size between the vocational and short tertiary coefficients and the bachelor coefficient. The average probability that a firm has digitalized at least one of the 4 internal functions is 67.9 % which is very similar to the actual probability of 67 % that a firm randomly selected from the data set has digitalized at least one of the 4 functions[3].

[3] The small difference between the model probability and the actual probability mainly stems from the fact that some observations drop out in the regressions because of missing observations on some of the other control variables

TABLE 4.5 PROBABILITY ESTIMATIONS OF DETERMINANTS OF DIGITALIZATION (EDUCATIONAL LENGTHS).

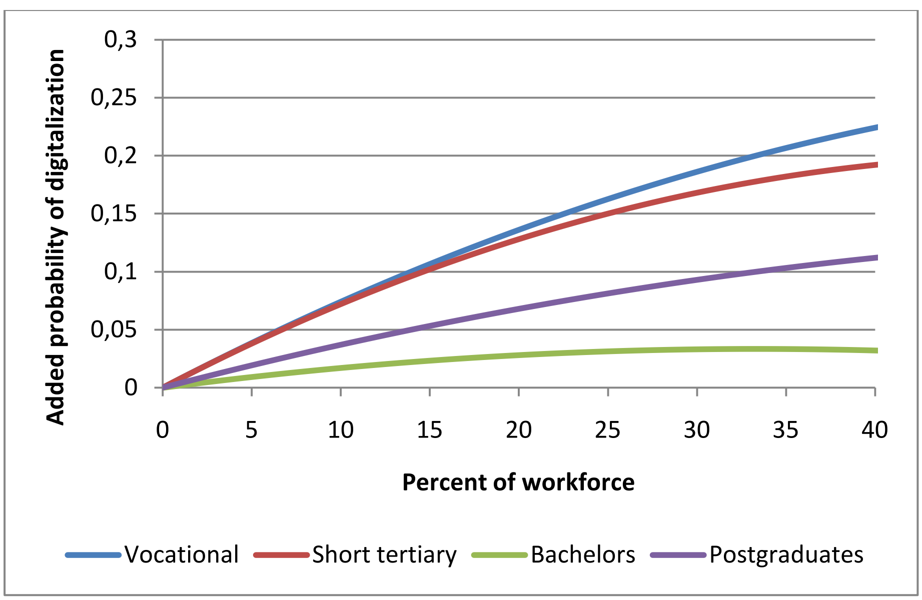
The dependent variable is a dummy (0-1) variable indicating digitalization of the relevant function.

Function	Any function	Inventory control	Accounting	Distribution	Production control
% Vocational training	**0.024**	**0.030**	**0.026**	**0.026**	**0.024**
% Short tertiary training	**0.022**	**0.026**	**0.022**	*0.016*	*0.016*
% Bachelors	0.006	**0.013**	**0.014**	**0.013**	**0.015**
% Postgraduates	**0.014**	*0.010*	**0.017**	**0.019**	**0.013**
Mean predicted probability	0.679	0.482	0.617	0.345	0.428

Notes: *Italics* indicate statistical significance at the 5% level. **Boldface** indicates statistical significance at the 1% level.

The relationship in the first column is illustrated in Figure 1 below. The lines in the figure are curved because squared terms of the education variables (that are not displayed in Table 4.5) are included in the determination of the lines.

Figure 1



4.5 Digitalization and productivity

Table 4.6 below shows a positive, statistically significant relationship between digitalization and productivity. The relationship is also, by any standard, significant in a practical sense. Across the internal functions, a one percent increase in the probability of digitalization implies between 0.6 % higher productivity (for distribution) and 0.95 % higher productivity (for production control). The coefficient on the probability of digitalization of at least one function says that a one percent increase in the probability of digitalization of at least one of the 4 functions implies 0.72 % higher productivity.

The close correspondence between the actual proportion of firms who have digitalized at least one function and the average probability of digitalization estimated in the probability model provides a nice interpretation of the relationship between digitalization and productivity: A one percentage point larger proportion of firms that have digitalized at least one of the main 4 functions is predicted to be associated with 0.72 % higher aggregate productivity.

TABLE 4.6 RESULTS FROM ESTIMATIONS OF PRODUCTION FUNCTIONS. FIRST STAGE: PROBABILITY WITH EDUCATIONAL LENGTHS

The dependent variable is the logarithm of value added per employee.	
Inventory control	**0.635**
Accounting	**0.768**
Distribution	**0.605**
Production control	**0.951**
Any function	**0.717**

Notes: **Boldface** indicates statistical significance at the 1% level.

4.6 Economic effects of digitalization

In order to estimate the economy wide effects of digitalization we restrict the sample of firms to those who reported positive value added and a positive number of employees in 2007 and 2008, and who answered 'yes' or 'no' to the 4 questions about whether they have digitalized the relevant processes within the firm (accounting, inventory control, distribution and production control). This implies a sample size of 7,513 firms (over 2 years) with a total of 1,365,980 employees (i.e. 682,990 employees per year). The total number of employed in the private sector in Denmark was 1,713,143 on average over the years 2007 and 2008.

The analysis shows that a 1 percentage point larger proportion of firms who have digitalized at least one of the 4 functions is associated with 0.72 % higher aggregate value added. If we divide this aggregate effect by the total number of employees in the firms we find that as the value added per employee in our sample of 7,513 firms was 525,807 kroner on average over the years 2007 and 2008, 0.72 % amounts to 3,786 kroner per employee.

On the basis of these data we can conclude the following:

1) An estimate of the upper limit for how much larger value added would be if the share of firms who have digitalized at least one of the 4 functions were 1 percentage points larger can be found be assuming that the estimated relationship is representative for all firms in the private sector in Denmark. If this assumption is correct, a 1 percentage point larger share of firms who have digitalized at least one of the 4 functions is associated with approximately 6.5 billion kroner higher value added per year (6,486,960 thousand kroner to be precise). This corresponds to 0.44 % of average gross value added in Denmark over the years 2007 and 2008.
2) An estimate of the lower limit for how much larger value added would be if the share of firms who have digitalized at least one of the 4 functions were 1 percentage points larger can be found be assuming that the estimated relationship is only to be found in the firms who are included in our sample. If this assumption is correct, a 1 percentage point larger share of firms who have digitalized at least one of the 4 functions is associated with approximately 2.6 billion kroner higher value added per year (2,585,800 thousand kroner to be precise). This

corresponds to 0.18 % of average gross value added in Denmark over the years 2007 and 2008.

The full economic effect is somewhere in between these two extremes. It is not possible to say exactly what the full effect is. That depends on which assumptions about the association between digitalization and productivity in those firms that are not in our sample are considered to be most realistic.

We can relate the above numbers to the debate on Danish education policy by means of a thought experiment. Assume that the shares of employees with vocational training, short tertiary education, bachelor degrees, and postgraduate degrees each were 1 percentage point larger (and the share of employees who have only basic schooling was 4 percentage points lower). Then we would – based on our analysis – predict that the share of firms who have digitalized at least one of the 4 functions was 4.5 percentage points larger. Instead of 68 % of the firms having digitalized at least one of the 4 functions, we would predict that 72.5 % of the firms had digitalized at least one of the 4 functions.

Based on the above conclusions we would predict that as a consequence of the changed educational mix, gross value added for the entire Danish economy would be between 11.6 billion kroner and 29 billion kroner larger than it is in our data.

An alternative way to see the relationship between education, digitalization and productivity is to consider which changes in the educational mix of the employed would be associated with a 1 percentage point increase in the digitalization rate of firms. In the table below we see that one possible answer is that a 1.2 percentage points increase in the share of the employed who have vocational training (and a 1.2 percentage point decrease in the share of the employed who have only basic schooling) would be associated with a 1 percentage point increase in the share of firms who have digitalized at least one of the 4 main functions that we look at.

TABLE 4.7 Educational shares and Digitalization	
Vocational training	1.2
Short tertiary education	0.5
Bachelor degree	1.9
Postgraduate degree	0.8

Note: The table shows the percentage point increase in share of the indicated educational group associated with a 1 percentage point increase in digitalization (and a corresponding percentage point decrease in the share of the employed that have only basic schooling).
Source: Authors own calculations

4.7 Robustness

In addition to the basic model estimations and results summarized in section 4.3 and section 4.4 above, we perform a variety of robustness check the full details of which are provided in Appendix C. As the two examples in Table 4.8 and Table 4.9 show, the main insight from the robustness checks is that the economically and statistically significant positive relationship between digitalization and productivity are very robust to alternative measures of digitalization.

Table 4.8 shows the results for estimations of the relationships between productivity and two measures of digitalization, first the probability that a firm has digitalized at least one internal function and second the probability that the firm has digitalized Supply Chain Management, a measure of external function digitalization. The first two columns show the results for estimations of productivity functions when we use educational lengths as the measure of educational mix in the first stage and columns (3) and (4) show the results for estimations of productivity functions when we use educational types as the measure of educational mix in the first stage.

Table 4.8 shows that digitalization of Supply Chain Management is statistically significantly positively related to productivity. Further, the relationship is large in a practical sense. For example, the coefficient estimate of 1.565 in column (2) implies that a one percent increase in the probability that a firm has digitalized Supply Chain Management is correlated with a 1.57 % increase in productivity. Note that the range of probabilities of digitalization obtained in the first stage may differ between the two variables 'Supply Chain Management' and 'Any internal function'. Therefore, the size differences between the coefficients on 'Supply Chain Management' and 'Any internal function' do not imply a difference in the strength of the relationship between internal digitalization and productivity on the one hand, and external digitalization and productivity on the other hand. All we can say is that both relationships are statistically and economically significant.

TABLE 4.8 RESULTS FROM ESTIMATIONS OF PRODUCTION FUNCTIONS. FIRST STAGE: PROBABILITY WITH EDUCATIONAL LENGTHS

The dependent variable in each column is the logarithm of value added per employee.

	(1)	(2)	(3)	(4)
Any internal function	**0.725**		**0.783**	
Supply chain management		**1.565**		**1.593**

Notes: **Boldface** indicates statistical significance at the 1% level.

Table 4.9 shows the results with the probability that a firm has a specific type of Internet access (basic, high speed, mobile) used as the main explanatory variables - rather than digitalization measures - when educational lengths are used as measures of educational mix in the first stage (see Table 7.17 for the results with educational types used as measures of educational mix in the first stage). The table shows that firms that the first stage model predicts to have only basic Internet access are predicted to have lower productivity than other firms. A one percentage point increase in the probability that a firm only has basic Internet access is correlated with 1.58 % lower productivity which is an economically significant relationship. Firms that have a one percentage point higher probability of having access to high speed Internet are predicted to have 0.43 % higher productivity than firms that do not have access to high speed Internet. Finally, firms that have a one percentage point higher probability of having access to mobile Internet are predicted to have about 0.6 % higher productivity than firms that do not have access to mobile Internet. This is a practically large effect. The inference from the table is therefore clear: A prediction of more advanced Internet access is correlated with a prediction of higher productivity.

TABLE 4.9 RESULTS FROM ESTIMATIONS OF PRODUCTION FUNCTIONS. FIRST STAGE: PROBABILITY WITH EDUCATIONAL LENGTHS.

The dependent variable in each column is the logarithm of value added per employee.	
Basic internet (ISDN, ADSL etc.)	*-1.584*
High speed internet (fiber, FWA, WIMAX etc.)	**0.426**
Mobile internet (3G/UMTS, Turbo 3G etc.)	**0.585**

Notes: *Italics* indicate statistical significance at the 5% level. **Boldface** indicates statistical significance at the 1% level.

5 Appendix A: Data, definitions, and other preliminaries

The present appendices document the results presented in the above chapters. The appendices present details on the project carried out by CEBR for the Danish National IT and Telecom Agency that investigates

1) The relationship between the educational mix of the employed and the decisions of the firms to digitalize specific functions within the firm
2) The relationship between the digitalization of these functions within the firm and the productivity of the firm.

The main functions considered are Inventory control, Accounting, Distribution, and Production control and an overall measure of digitalization which indicates whether a firm has digitalized at least one of the 4 main functions. In addition, a variety of robustness checks are performed to investigate whether the results are robust to different measures of digitalization, for example we also test the relationships mentioned above but with measures of *external digitalization* substituted for measures of internal digitalization.

We investigate the relationship between educational mix and digitalization by using two different measures of educational mix:

- Educational mix defined by educational length: Basic schooling, vocational training, short tertiary education, bachelor degree, or postgraduate degree.
- Educational mix defined by educational type: Basic schooling or vocational training, tertiary education in humanities, tertiary education in social sciences, and tertiary education in sciences (including engineering).

Well formulated hypotheses about the relationship to be tested are necessary in order to render statistical tests meaningful because the hypotheses provide information on which factors we must control for when we test the hypotheses. As we do not have specific hypotheses about unconditional correlations in the data we therefore do not include formal statistical tests of hypotheses in Appendix B. Formal statistical analyses of relevant hypotheses, where we take account of external factors are presented in Appendix C.

Appendix C reports the results from the estimation and formal testing of the **hypotheses** about

1) Positive conditional correlations between the educational mix of the employed and the decisions of the firms to digitalize specific functions within the firm (Inventory control, Accounting, Distribution, and Production control)
2) Positive conditional correlations between the digitalization of any of these functions within the firm and the productivity of the firm.

As robustness checks we also test hypotheses about

3) Positive conditional correlations between the digitalization of Supply Chain Management, Enterprise Resource Planning, and Customer Relationship Management and firm productivity
4) Positive conditional correlations between the type of Internet access available to the firm (Basic, High speed, and Mobile) and firm productivity
5) Positive conditional correlations between types of external digitalization and firm productivity

We emphasize that what we obtain in the regression analysis in Appendix C are conditional correlations, i.e. correlations that exist between educational mix and digitalization or between digitalization and productivity when other external factors, for example the size of the capital stock, the number of employees, and the export share of firm revenue, are controlled for. We do not claim to document either causal effects of educational mix on the probability that a firm will digitalize one or more functions or causal effects of digitalization on firm productivity. Theoretical arguments can be put forward about all of the relationships that we investigate which imply predictions about causality running both ways. Further, with the data at our disposal, it is not possible to determine whether, for example, a positive conditional correlation between digitalization and productivity implies that digitalization drives firm productivity to become higher or whether the positive conditional correlation implies that more productive firms for some reason choose to digitalize one or more functions.

The study presents the first study of the relationship between internal digitalization and firm productivity. Although we have not investigated whether digitalization influences productivity or whether productivity influences digitalization, the established results are important as the first attempt to understand the economic importance of digitalization for firm productivity. The report leaves open a myriad of questions that need to be answered. Good answers to these questions are highly relevant – for businesses, economists, and policy makers.

Examples of interesting questions are: (i) Is digitalization an "all or nothing" decision? This question is motivated by the findings in the present project. (ii) What is the causal economic effect of internal digitalization for firm productivity? (iii) What are the dynamic responses of digitalization on productivity? (iv) How does labor demand change in firms that digitalize? (iv) What other business practices are important for a productive use of digitalization? These questions could be studied on the basis of high quality Danish data that combine survey data with register data.

5.1 Motivation and theoretical mechanism

The productive implementation of IT in businesses depends to a large extent on which other business practices are used. For example, Brynjolfsson (2005) argues that seven business practices are much more common in IT-intensive firms than in firms that do not have an intensive IT use, and that the adoption and use of these will raise firm productivity. In the report we focus on two of these business strategies and study the importance of these for firm productivity. These two business strategies are (Brynjolfsson, 2005):

1) "*Move from analog to digital processes*: Moving an increasing number of processes into the paperless, digital realm is one of the keys to making productive use of IT. This practice frees the company from the physical limitations of paper [..]. Digitalization also makes it easier to track key performance indicators."
2) *"Investment in human capital*: The 6 [other] business practices all require substantial investment in human capital, but this isn't satisfied by hiring alone. For that reason, digital organizations provide more training than their traditional counterparts. This helps employees operate new digital processes, find information, make decisions, cope with exceptions, meet strategic goals etc."

These two business strategies are the focus of the present study of the relationship between internal digitalization and the education mix on the one hand and firm productivity on the other. Internal digitalization refers to implementation of automated and electronic information sharing regarding received and/or placed orders of different functions within the firm. In this respect, firms that use the business strategy of internal digitalization have to some extent moved from analog to digital processes; and firms that use large shares of skilled and educated workers have as a consequence of digitalization to some extent invested in human capital; at least after taking other firm characteristics into account. To the best of our knowledge this is the first study of the productive effects of internal digitalization.

The other 5 business practices – open information access, empower the employees, use performance-based incentives, invest in corporate culture and recruit the right people – are also potentially important for firm productivity and therefore relevant to include. It may of course be the case that Danish firms that have implemented these business practices are more productive than their peers that have not. However, the issue is not explored in further detail because data on the use of these practices has not been collected for Danish firms.

The underlying mechanism linking the education mix to internal digitalization and further to productivity is based on two relationships. The first relationship is between increasing use of IT and a related increase in demand for skilled and educated labor. The idea is that declines in the price of IT lead to higher adoption and use of IT including internal digitalization, which to a greater extent results in higher demand for skills. The second relationship suggests that productivity should be higher in firms that successfully implement internal digitalization than in those that do not invest in internal digitalization.

Before the empirical analysis is described the mechanism linking the education mix and internal digitalization is illustrated (Breshanan, Brynjolfsson, and Hitt, 2002):

- The use of computer business systems substitute for certain types of tasks that used to be performed by firm employees. This is especially the case for record keeping, remembering, and similar tasks. In other words, routine and simple decisions related to this work have been affected by digitalization. As a consequence, the use of computer business systems substitutes for clerical and similar work to a high extent, implying that the demand for workers with low qualifications decreases.

- Complex and cognitively challenging work has been difficult to automate through computerization so far. Consequently, the effect from computerization on the use of workers with high qualifications has been limited.
- A third mechanism works through higher production of data and gathering of information as a consequence of digitalization. This calls for analytical and abstract decision making such as analyzing demand and needs of customers, studying new markets, evaluating the need for product innovation. This increases the demand for skilled and educated workers.

The above described relationships between internal digitalization and the use of skilled and educated labor and between internal digitalization and productivity will be studied in the following.

5.2 Data and sample selection

The data set used in the report is composed from data obtained from a sample of Danish firms that have answered a questionnaire constructed by Statistics Denmark about their use of IT and digitalization of functions ('Danske virksomheders brug af it') supplemented by register data with firm characteristics (value added, capital intensity, export intensity, number of employees etc.) from Statistics Denmark. 4,257 firms answered the questionnaire in 2008 and 4,303 firms answered the questionnaire in 2009. Of the 8,560 obtained answers, 1,681 are repeated observations, i.e. 1,681 firms answered the questionnaire in both 2008 and 2009.

In the figures and tables in Appendix B and Appendix C the number of observations is less than 8,560. This is because in each figure or table we do not have information on all characteristics for all firms that are used in the construction of the figures and tables. This is either because the information does not exist in the data set or because the available information is obviously incorrect. Table 5.1 below provides information on the most common reasons why some firms may not be included either in a descriptive statistics table or figure, or a table with regression results.

TABLE 5.1 COMMON REASONS FOR MISSING OBSERVATIONS

	Number of observations
Full sample	8,560
No industry information	41
Negative export	5
No employees	9
No capital stock	109
No educational mix information	76
No information on inventory control	322
No information on accounting	265
No information on distribution	548
No information on production control	462

Notes: The categories are not exclusive. Information on several characteristics may be missing for an individual firm.

Source: Authors own calculations

Even though the response rate to the survey is very high (more than 97 % of firms answered the questionnaire) the sample of firms is not representative of the full population of Danish firms. In the questionnaire Statistics Denmark oversampled larger firms such that the size distribution of the firms in the sample is skewed towards the larger firms relative to the size distribution of the full population of Danish firms and firms in particular industries. In the regression analysis in Appendix C we include firm size (as measured by the size of the capital stock and the number of employees) and industry dummies as control variables in order to take care of this problem.

5.3 Methods

Data limitations are important for the choice of the empirical framework.

- The only possible answer choice to the questions about internal digitalization is to state whether internal digitalization is implemented or not. This implies that the measure of internal digitalization does not provide information on the extent of internal digitalization.
- Data availability only allows estimation of cross-sectional relations between productivity and internal digitalization of firms. Consequently, issues of the timing of internal digitalization and its contribution to productivity are ignored. This is a reflection of the nature of the surveys for IT use, which only asks about “internal digitalization” in the 2007 and 2008 editions. Therefore, it is not possible to study how productivity grew in years after internal digitalization was implemented and compare these growth rates to firms that did not digitalize. Thus,

the analysis relates productivity in 2007 and 2008 to firms that were already digitalized to firms that were not; it does not trace out any dynamic response. In this sense the established results have a long run nature.

Due to the long-run nature of the analysis, we formulate two hypotheses:

- Firms that have an education mix skewed towards skilled and educated workers have higher probability of internal digitalization.
- Firms with a high probability of internal digitalization have higher productivity.

As mentioned above, the measure of internal digitalization has the drawback that it does not reveal the extent of internal digitalization within firms. Therefore, we implement a two stage procedure: In the first stage, we use probit models to investigate the conditional correlations between the educational mix of the firms' employees and the probability that a firm will digitalize a given function. By conditional correlations we mean correlations that exist between variables when other potential correlates (such as firm size and industry) are controlled for. We investigate the conditional correlations between digitalization choices and two ways of defining educational mix, 1) as defined by educational length – i.e. employees with vocational training, short tertiary education, bachelor degree, or postgraduate degree, and 2) as defined by educational type – i.e. basic schooling or vocational training, a humanities education, a social science education, or a science (including engineering) education. When we define educational mix as educational length the set of employees with no education beyond basic schooling is the excluded base category. When we define educational mix as educational type the set of employees with either basic schooling or vocational training (the joint group is denoted basic education) is the excluded base category. In addition to educational mix, we include the size of the capital stock, the number of employees, the share of export revenue of total revenue, a year dummy, and industry dummies (primary, manufacturing, energy, construction, retail, transportation, communication, and business services) as explanatory variables.

The above described procedure is based on the idea that most firms do internal digitalization but do not report it separately to the statistical agency performing the survey. In a sense, this approach fills in the firms value for internal digitalization with what might have been expected given the educational mix of their employees, size, industry, etc.

In the second stage, we estimate production functions in order to investigate the conditional correlations between the probability that a firm digitalizes a given function and productivity. Specifically, we include the predicted probability that a firm has digitalized a given function obtained in the first stage regressions as an explanatory variable in regressions of productivity on variables implied by the production function approach. To ensure that productivity is measured relative to a standardized base unit, we use value added per quality adjusted labor input (alternatively, the total factor productivity of the firm), where the quality adjusted labor input corrects for the fact that different types of labor inputs have different productivities because of differences in work experience, education, gender, and which industry they are employed in. In addition, we include the capital-labor ratio, the number of employees, the share of export revenue of total revenue, a year dummy, and industry dummies as explanatory variables.

Data obtained from survey questionnaires are prone to measurement error because of wrongful or incomplete reporting by firms. Measurement error in an explanatory variable causes the parameter estimate to be biased towards zero. Therefore, the first stage in our implementation procedure, in addition to providing information on the relationship between the educational mix and digitalization choices, also remedies the problem with measurement error bias. Because we use generated explanatory variables in the estimations of the production function (the predicted probability that a firm will digitalize a function, obtained in the first stage) the standard errors from standard estimation procedures will be too small so we need to correct the standard errors in the second stage estimations. For this, we use a bootstrap procedure.

Finally, it should be emphasized that the applied model is very similar in nature to the CDM model (Crepon, Duguet, and Mairesse, 1998), which is an important work horse in the literature on innovation and productivity. The use of this model framework is found suitable due to similarities in data access and limitations in the two areas of the economic literature.

5.4 Definitions of digitalization

Digitalization is a central concept in the report and while all other variables used in the report are standard in economic analysis our particular definition of digitalization is not. Because we have the detailed data on digitalization choices of Danish firms we can construct indicators of digitalization that are not available elsewhere in the literature on the relationship between ICT and productivity. The definition of internal digitalization follows from the EU harmonized questions asked by Statistics Denmark that conducts a yearly large-scale survey of IT use in Danish firms.

We focus mainly on *internal digitalization* but in robustness tests we also include measures of *external digitalization*. By internal digitalization we mean digitalization of information sharing within the firm. The questionnaire used to obtain the data on the use of ICT by firms asks about 4 functions internal to the firm which may be digitalized. The question asked was:

When the firm receives an order: Is relevant information regarding the order shared electronically and in an automated fashion with IT-systems in the following functions within the firm?

- *Inventory control*
- *Accounting*
- *Distribution*
- *Production control*

The same question with respect to the firm placing an order was also included. In this case the only relevant functions included were inventory control and accounting. In the data set we record the answers such that a firm is coded as having digitalized for example inventory control if the firm answered yes to having digitalized inventory control with respect to receiving and/or placing an order. We construct indicator variables for each of these 4 functions which serve as our internal digitalization variables. We also construct an indicator variable for internal digitalization which is coded '1' if the firm has digitalized at least one of the 4 functions and '0' otherwise.

In the report, **external digitalization** refers to digitalization of Supply Chain Management, i.e. information sharing between suppliers, the firm, and customers. We do not have information on which, if any, networks the firms are part of, so we cannot identify possible network effects.

In robustness tests we investigate the conditional correlations between a different set of measures of internal digitalization. Specifically, we use digitalization of Enterprise Resource Planning (ERP) and Customer Relations Management (CRM) as alternative measures of internal digitalization.

Finally, even though ICT does not have an independent role in this report, in robustness tests we also investigate the conditional correlations between the educational mix, **Internet access**, and firm productivity. The questionnaire sent to the firms asks:

Which type of Internet connection does the firm have?

- *Traditional modem*
- *ISDN*
- *xDSL (ISDN, ADSL etc.)*
- *Other Internet access (fiber, FWA, WIMAX etc.)*
- *Mobile Internet access (3G/UMTS, Turbo 3G etc.)*

We group the first 3 categories into one, so that we categorize firms' Internet access into 3 nonexclusive categories: Basic Internet access, high speed Internet access, and mobile Internet access.

6 Appendix B: Descriptive statistics

This appendix gives an overview of relevant features of the data set. As such it is not meant to test formal hypotheses but rather to present salient firm characteristics present in the data sample and to suggest which external factors we need to control for when we test hypotheses in the formal statistical analysis in Appendix C.

6.1 Summary

This Appendix shows that a third of the firms in our data set have not digitalized any of the 4 functions, Inventory control, Accounting, Distribution, and Production control, while a quarter of the firms have digitalized all 4 functions. Given that for many firms, some of the 4 functions are not relevant for their productive activities, this indicates that digitalization of functions within a firm to a certain extent may be an 'all or nothing' decision. When a firm decides to digitalize it digitalizes not just a single function. Rather, the firm digitalizes a swath of functions.

With respect to firm characteristics that are correlated with the decision to digitalize one or more functions the overview shows that a variety of firm characteristics in addition to the educational mix of the employed (measured either as educational lengths or as educational types) influence the probability that a firm will digitalize one or more of the 4 functions. Specifically, we find that

- Exporting firms are more likely to have digitalized one or more functions.
- Larger firms are more likely to have digitalized one or more functions.
- Manufacturing firms and firms in the retail industry are more likely to have digitalized one or more functions, while firms in the business services industry are less likely to have digitalized one or more functions.

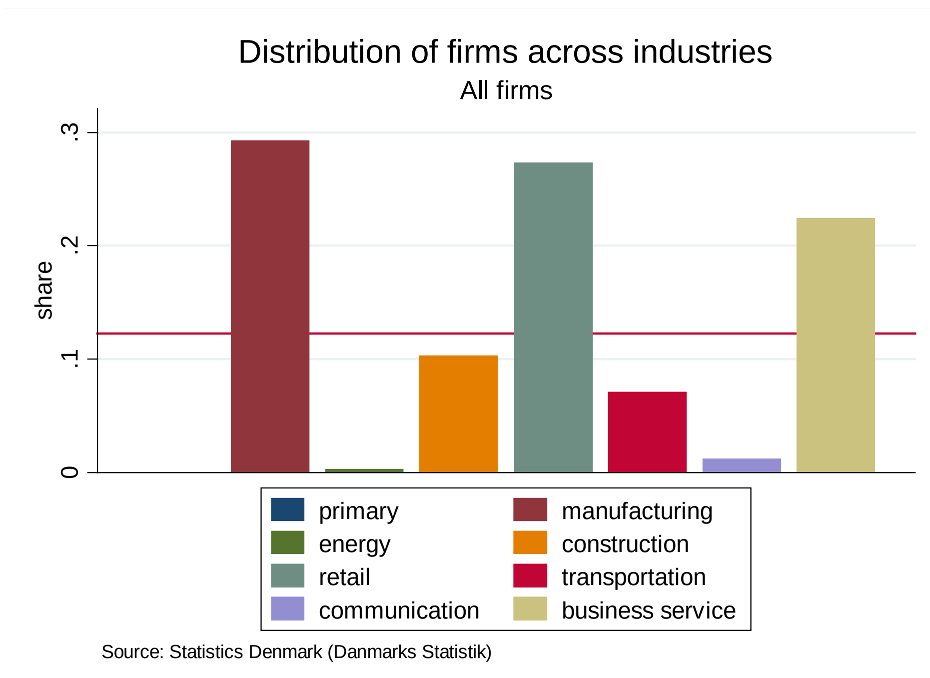
In order to take account of these observations, in the regression analyses in Appendix C we include a variety of control variables for how export oriented the firm is, firm size, and which industry the firm operates in.

Finally, value added per employee is higher among those firms that have digitalized at least one of the functions under consideration than among firms that haven't digitalized any of the 4 functions. This feature in the data lends support to the hypothesis about a positive relationship between digitalization and productivity. In Appendix C we investigate whether there is a positive conditional correlation between digitalization and productivity, i.e. whether there still is a correlation between digitalization and productivity when we control for factors such as work experience and capital intensity amongst other control variables.

6.2 Firm characteristics

We start by looking at some basic characteristics of the firms in the sample. Figure 2 indicates that manufacturing, retail, and business services are the 3 largest industries in the sample measured by number of firms accounting for approximately 75 percent of the firms in the sample.

Figure 2



The business services industry consists of a very large variety of different subgroups. The largest subgroups in the business services industry are ICT developers and consultants and temporary work agencies with 15 percent and 8 percent of the firms in the industry respectively. Other subgroups are for example real estate brokers, data processing, research and development, legal services, accounting and book keeping, consulting engineers, advertising and marketing, cleaning services and other business services.

We group firms in 4 groups according to the number of employees: Very small firms with less than 10 employees, small firms with between 10 and 50 employees, medium sized firms with between 50 and 250 employees, and large firms with more than 250 employees.

Figure 3

Figure 3 shows that a large majority of the firms in the sample are either small or medium sized. More than 80 percent of the firms fall into the small or medium sized groups.

Figure 4

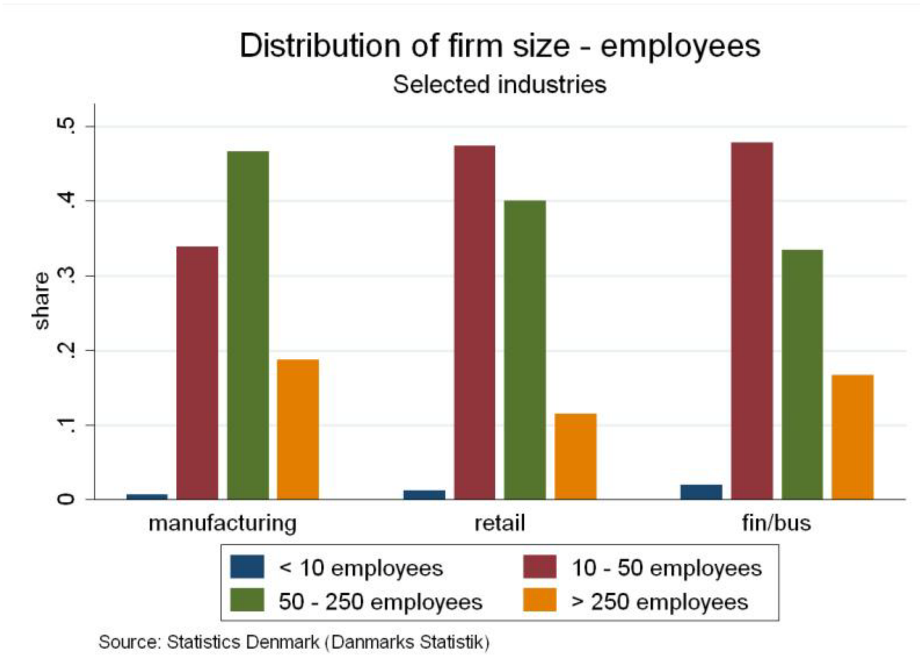


Figure 4 shows that the 3 largest sectors - i.e. manufacturing, retail and business services - are also dominated by small and medium sized firms (for expositional purposes we only display the distributions for the 3 largest sectors that represent 80 percent of the firms in the sample). The manufacturing sector is slightly more skewed towards medium sized and large firms than the average distribution calculated over all sectors with more medium sized firms than small firms. The size distribution of the firms in the retail sector is qualitatively similar to the size distribution of the whole sample of firms but with slightly fewer large firms and more small firms. The size distribution in the business services industry is also qualitatively similar to the size distribution of the whole sample of firms but with fewer small firms and more medium sized and large firms.

Figure 5

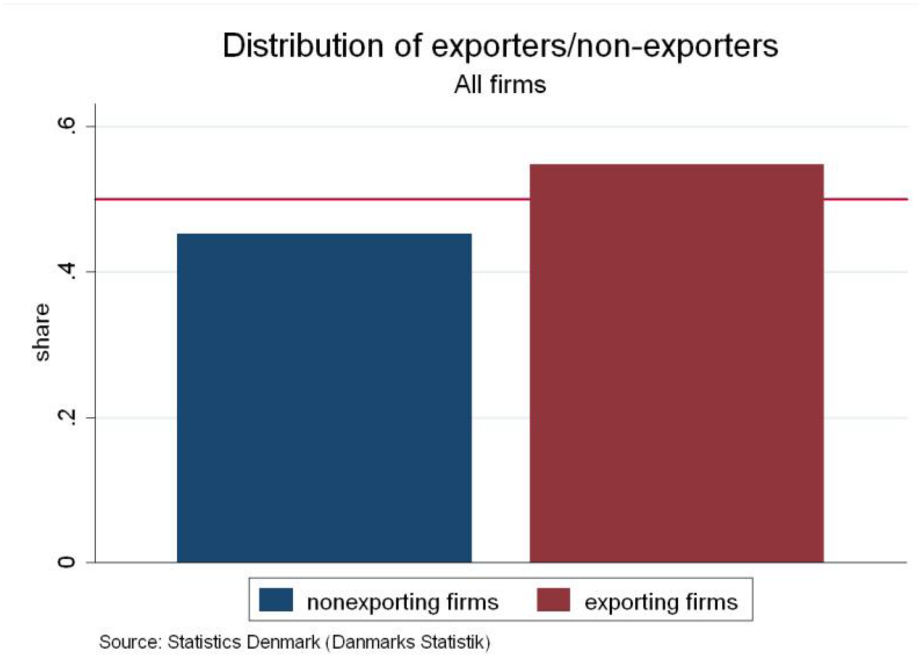


Figure 5 indicates that a little more than half of the firms in the sample export at least some of their production.

Figure 6

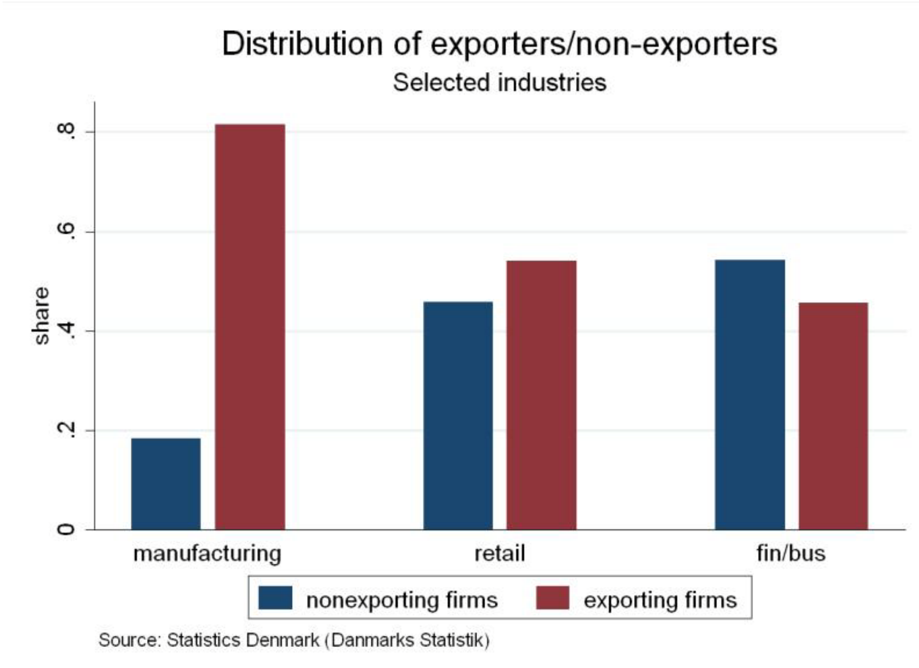


Figure 6 shows that the retail sector also in this respect is representative of the distribution taken over all firms as a little over half of the firms in the retail industry export at least some of their production. The manufacturing industry has a very large proportion of exporting firms, as more than 80 percent of the firms in this industry export at least some of their production while the business services industry has the smallest proportion of exporting firms among the 3 large business sectors.

6.3 Digitalized functions and firm characteristics

In this section we look at some measures which give a picture of the relationship between the internal digitalization decisions of firms and some other firm characteristics.

TABLE 6.1 Distribution of digitalized functions across firms

IADP	Frequency	Percent	Cum. Percent
0000	2,622	33.06	33.06
1000	141	1.78	34.83
0100	767	9.67	44.50
0010	40	0.50	45.01
0001	109	1.37	46.38
1100	722	9.10	55.48
1010	26	0.33	55.81
1001	46	0.58	56.39
0110	72	0.91	57.30
0101	388	4.89	62.19
0011	54	0.68	62.87
1110	196	2.47	65.34
1101	468	5.90	71.24
1011	55	0.69	71.94
0111	229	2.89	74.82
1111	1,997	25.18	100.00
Total	7,932	100.00	

Notes: 'IADP' indicates the relevant functions so 'I' stands for 'Inventory', 'A' stands for 'Accounting', 'D' stands for 'Distribution', and 'P' stands for 'Production'. A sequence of numbers in the first column then indicates a combination of digitalized functions. For example, the sequence '0110' means that a firm has not digitalized inventory, has digitalized accounting, has digitalized distribution, and has not digitalized production control. There are 1,681 repeated observations with 653 firms reporting the same state of the 4 digitalized functions, i.e. whether they have digitalized the function under consideration or not, in both years.

Source: Authors own calculations.

Table 6.1 shows the distribution of digitalized functions across firms. The largest clusters are firms that have not digitalized any of the 4 functions under consideration (33 %) and firms that have digitalized all 4 functions (25 %). Other large clusters are firms that only have digitalized accounting (9.7 %) and firms that have digitalized accounting and inventory control (9.1 %).

Given that for many firms, some of the 4 functions are not relevant for their productive activities, this indicates that digitalization of functions within a firm to a certain extent may be an 'all or nothing' decision. When a firm decides to digitalize it digitalizes not just a single function. Rather, the firm digitalizes a swath of functions.

Table 6.2 Means of value added per employee and digitalization (DKK)

	Manufacturing	Retail	Business services	All firms
Average	615,965	370,336	461,976	525,807
No digital.	465,260	270,321	398,810	398,113
Inventory	636,000	398,514	534,949	574,471
Accounting	634,960	393,103	491,742	558,635
Distribution	644,486	435,476	556,648	607,789
Production	634,995	429,991	472,144	590,725
All functions	652,427	436,442	615,601	632,808

Source: Authors own calculations.

Table 6.2 displays means of value added per employee (i.e. the difference between the total sales revenue and the total cost of components, materials, and services purchased) among different subsets of the firms in the sample. The firms are grouped according to industry and whether they have digitalized the function indicated in the first column (in addition to possible digitalization of other functions). In all 3 sectors shown and in the sample as a whole value added per employee is higher among those firms that have digitalized at least one of the functions under consideration than among firms that haven't digitalized any of the 4 functions. Further, in all 3 industries and in the sample as a whole value added is highest among firms that have digitalized all 4 functions.

A likely explanation for the pattern in the table is that digitalization is positively correlated with value added. The results in the table therefore lend support to the hypothesis about a positive relationship between digitalization and productivity.

But there are also other possible explanations for the results in the table. For example, it could be that digitalization in a firm is correlated with the employees in the firm having larger human and real capital stock available to them, which in turn implies that the employees are more productive. In Appendix C we investigate whether there is a positive conditional correlation between digitalization and productivity, i.e. whether there still is a correlation between digitalization and productivity when we control for factors such as work experience and capital intensity.

Figure 7

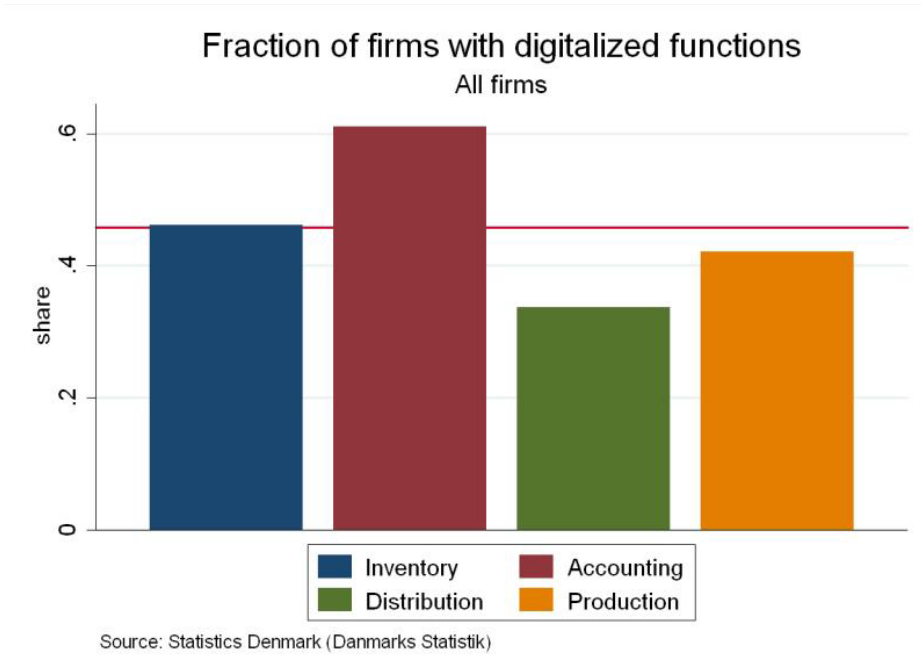


Figure 7 shows that accounting is the most frequently digitalized function as some 61 percent of firms in the sample have digitalized accounting, which implies that most firms who have digitalized at least one function have digitalized accounting. Approximately 46 percent of the firms have digitalized inventory control while the corresponding numbers for distribution and production control are 34 percent and 42 percent, respectively.

Figure 8

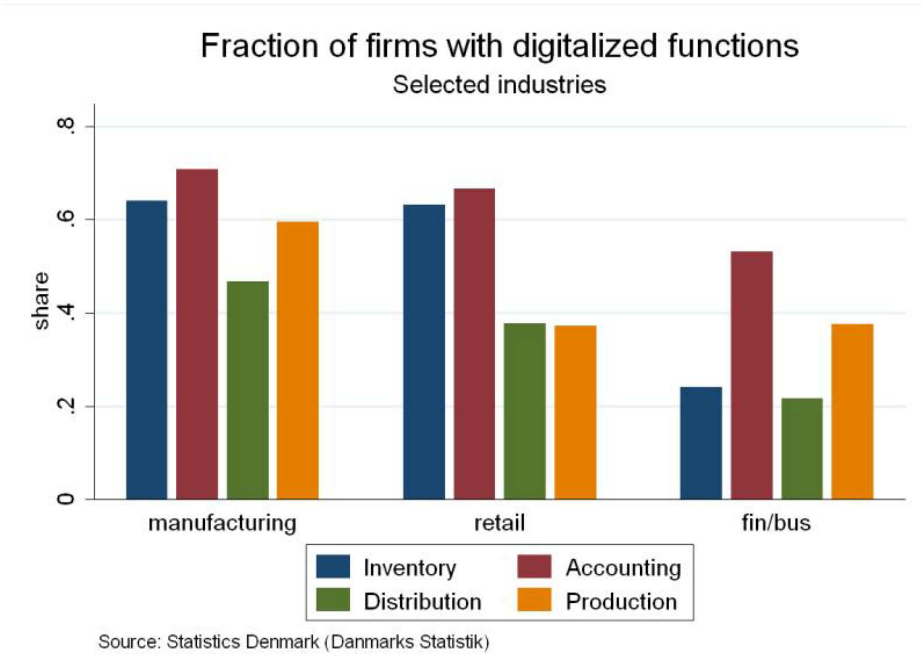


Figure 8 shows that the fraction of firms that have digitalized the functions under consideration varies across industries. The manufacturing industry has generally a high percentage of firms that have digitalized functions. The business services industry has a low frequency of digitalization, especially inventory and distribution. This is of course not surprising given that this is a service industry so that many of the firms in this industry almost by definition do not produce physical goods that need inventory space and physical distribution. Still, over 50 percent of the firms in this industry have digitalized accounting. The retail sector is intermediate between manufacturing and business services with respect to digitalization. The retail industry has almost as high digitalization rates of inventory control and accounting as the manufacturing industry (above 60 percent for both functions) while the digitalization rate of these functions in the business services industry are about 22 % and 53 % respectively. The frequency of digitalization of production control in the retail industry is virtually identical to the frequency in the business services industry (slightly below 40 percent) which is a lower digitalization rate than in the manufacturing industry where the digitalization rage of production control is 60 %. This seems reasonable as firms in the retail industry must be expected to have a limited physical production of goods compared to manufacturing firms.

Figure 9

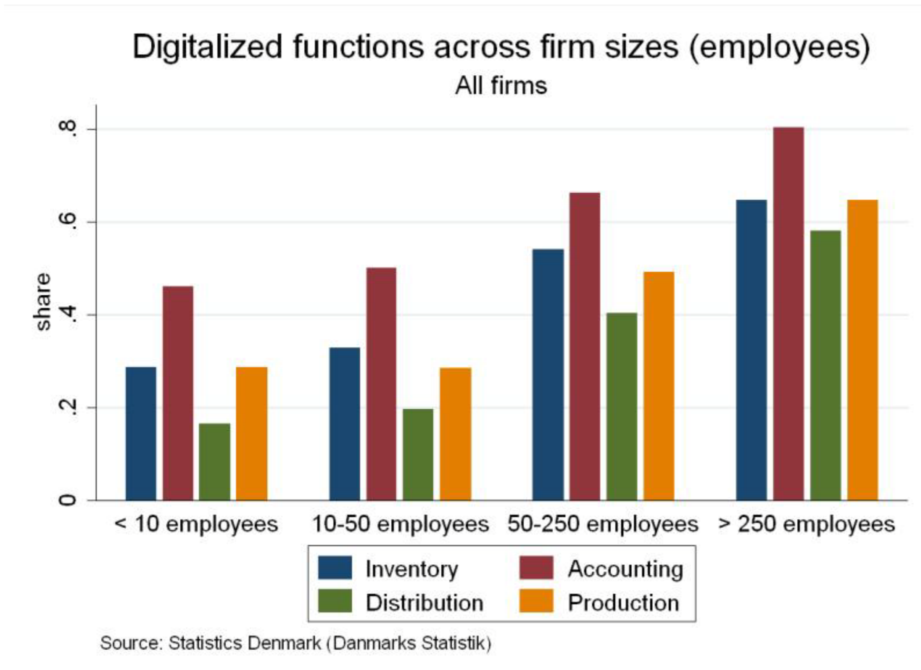


Figure 9 shows that the more employees a firm has the more likely is it that the firm has digitalized a given function. Firms with less than 10 employees are least likely to have digitalized a given function. For example, less than 20 percent of firms with less than 10 employees have digitalized distribution while almost 60 percent of firms with more than 250 employees have digitalized the distribution function. As another example, a full 80 percent of firms with more than 250 employees have digitalized accounting. The percentages for the other groups of firms are approximately 65 percent for firms with more than 50 employees but less than 250 employees, about 50 percent for firms with more than 10 employees but less than 50 employees, and 45 percent for firms with less than 10 employees.

Figure 10

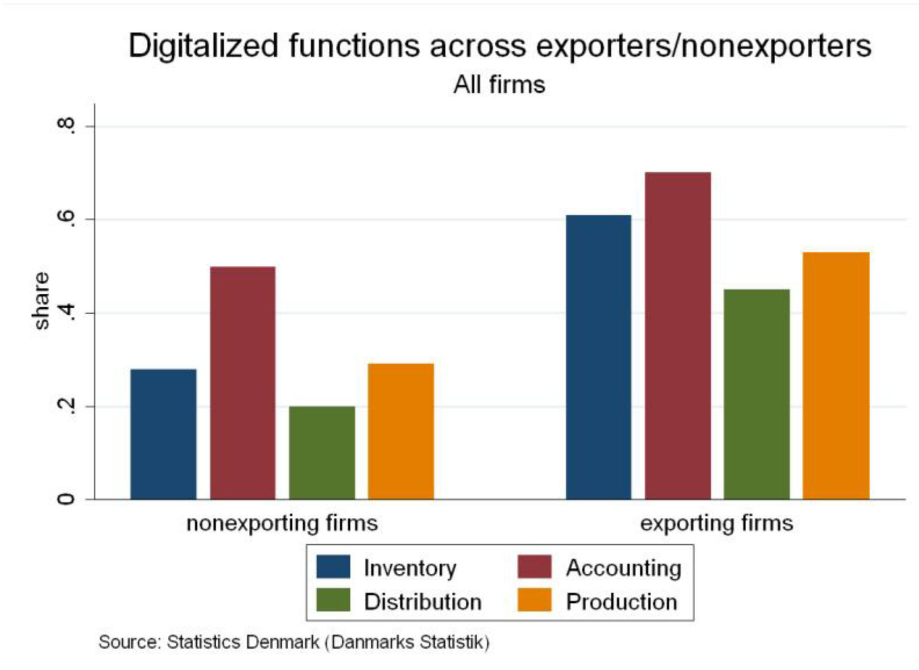


Figure 10 shows that another dimension that is correlated with the probability that a firm has digitalized a given function is whether the firm is an exporter or not. For all 4 functions under consideration, exporters are more likely to have digitalized the function than non-exporters.

6.4 Number of digitalized functions and firm characteristics

In this section we look at various figures that show a possible relationship between on the one hand the number of functions under consideration that a firm has digitalized and firm characteristics on the other hand.

Figure 11

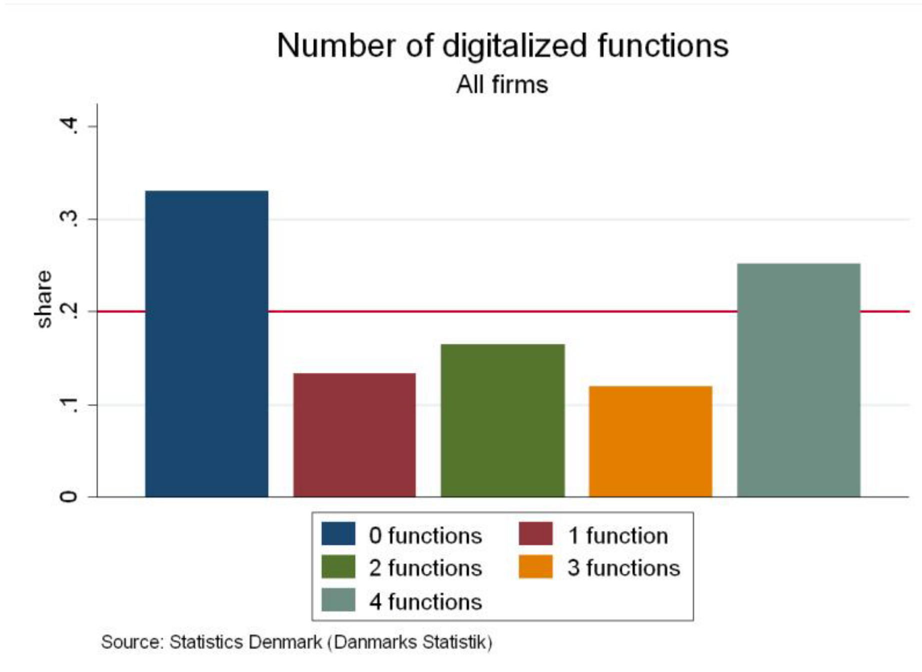
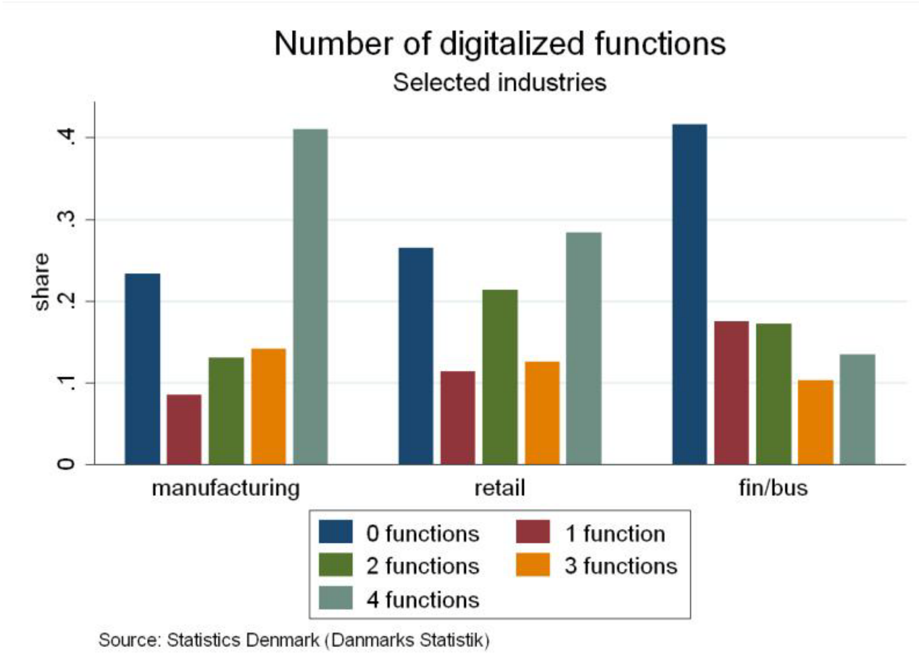


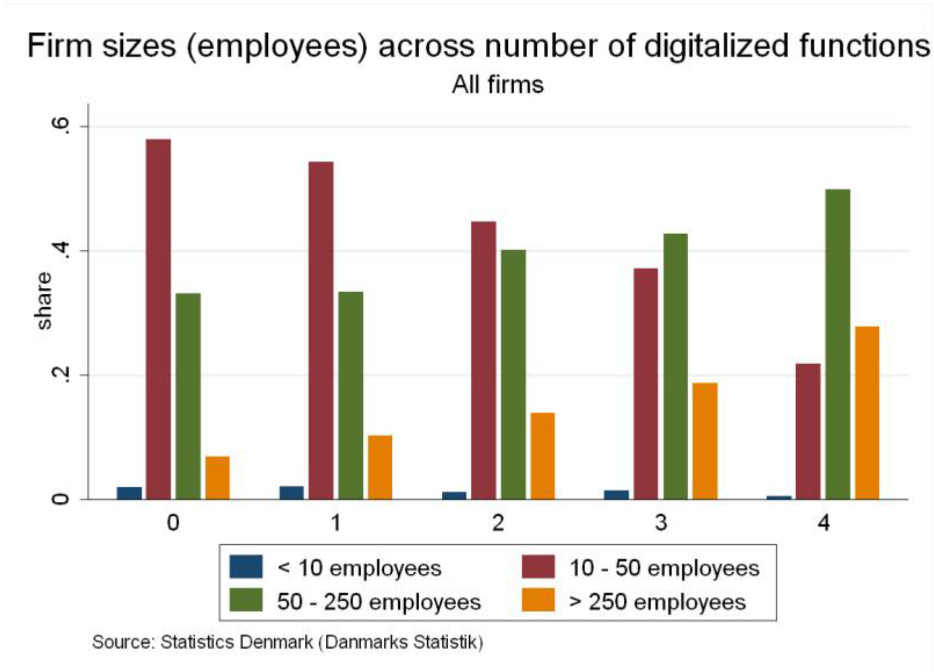
Figure 11 shows the distribution of number of digitalized functions across the firms in the sample. As such the figure gives a graphical summary of the information in Table 6.1. A third of the firms haven't digitalized any of the 4 functions under consideration. A quarter of the firms have digitalized all 4 functions. Approximately 13 percent of the firms have digitalized one function, 16.5 percent have digitalized 2 functions, and 12 percent of firms in the sample have digitalized 3 functions.

Figure 12



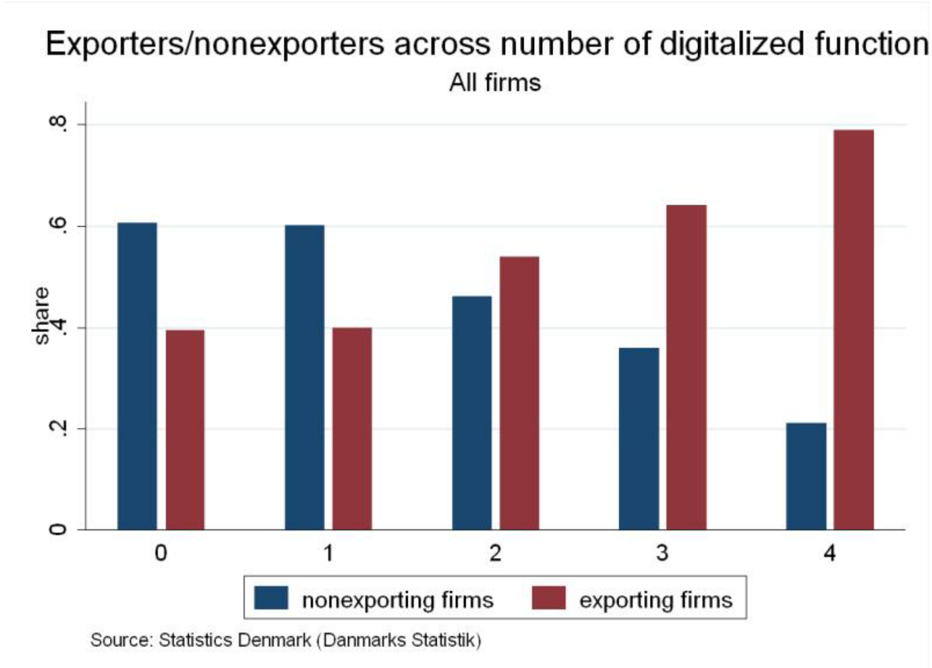
We see in Figure 12 that the number of digitalized functions in a firm varies substantially according to which industry the firm is in. Firms in manufacturing are substantially more likely to have digitalized all 4 functions under consideration than firms in other industries. More than 40 percent of firms in manufacturing have digitalized all 4 functions, while 28 percent in the retail industry and 14 percent in the business service industry have digitalized all 4 functions. Accordingly, the share of firms that have not digitalized any functions is largest in the business services industry. More than 40 percent of the firms in the business services industry have not digitalized any of the 4 functions, while 26 percent of firms in the retail industry have not digitalized any of the 4 functions, and 24 percent of firms in manufacturing have not digitalized any of the 4 functions under consideration.

Figure 13



From Figure 13 we find that the smaller firms are overrepresented amongst those firms that haven't digitalized any of the 4 functions under consideration. The micro sized and small sized firms with less than 50 employees constitute 60 percent of the firms in this category. As we consider groups of firms with more digitalized functions the size distribution of firms shifts progressively towards the larger firms. In the group of firms that have digitalized two functions, the smaller and the larger firms are almost equally split but when we look at the group of firms that have digitalized all four functions we see that the larger firms constitute approximately 75 percent of the group.

Figure 14

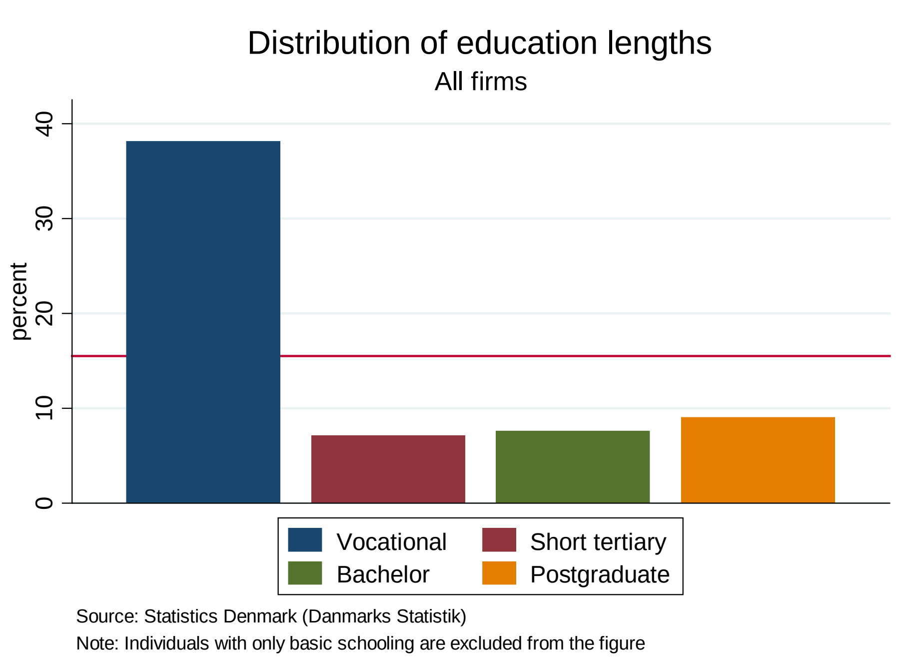


The distribution of exporters versus non-exporters across the number of digitalized functions also shows a distinct pattern. Figure 14 shows that non-exporting firms constitute the majority amongst those firms that have digitalized one function or that haven't digitalized any function. Exporters on the other hand are the majority in the groups of firms that have digitalized two or more of the 4 functions under consideration.

6.5 Employees' education length and firm characteristics

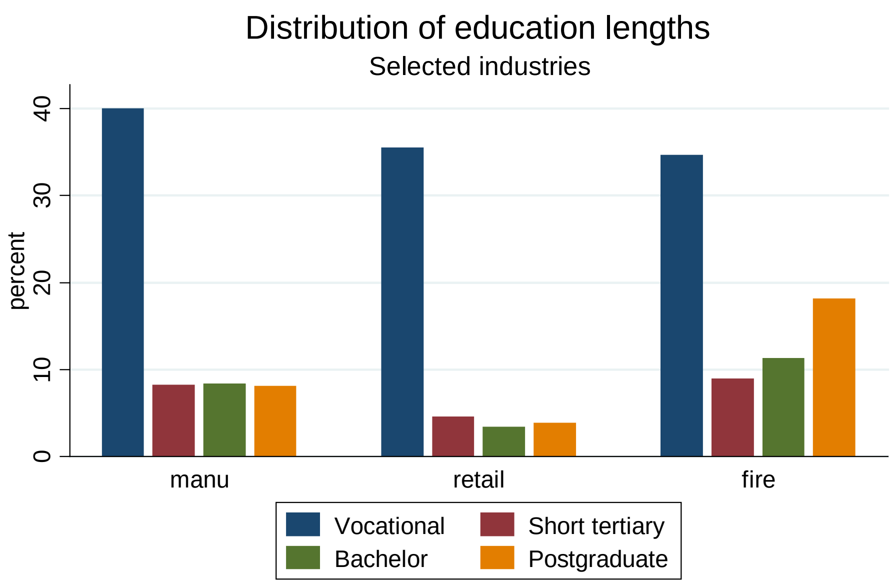
In this section we look at the relationship between the educational achievements of the employed (as measured by length of education) within firms and various firm characteristics. We sort the employees into 4 groups: Individuals with vocational training (this group includes high school graduates), individuals with some tertiary education (typically individuals with short tertiary education), individuals with a bachelor degree, and individuals with a postgraduate degree. Individuals with no education beyond basic schooling (i.e. 9^{th} or 10^{th} grade) are the residual group so the sum of the shares for each distribution shown in the figures will be equal to 100 minus the share of employment in the specific category with only basic schooling. In this section and the next, we weight each firm observation with the number of employees in the firm so that the shares indicate the share of all employed in the sample population.

Figure 15



To a large extent, the employees of the firms in the sample have vocational training. Figure 15 shows that employees with vocational training constitute approximately 38 percent of all employees. Employees with a short tertiary education and employees with a bachelor's degree each constitute approximately 7 percent of all employees, while employees with a master's degree or Ph.D. constitute around 9 percent of all employees. The remainder of the employed, i.e. about 40 percent, has no education beyond compulsory schooling.

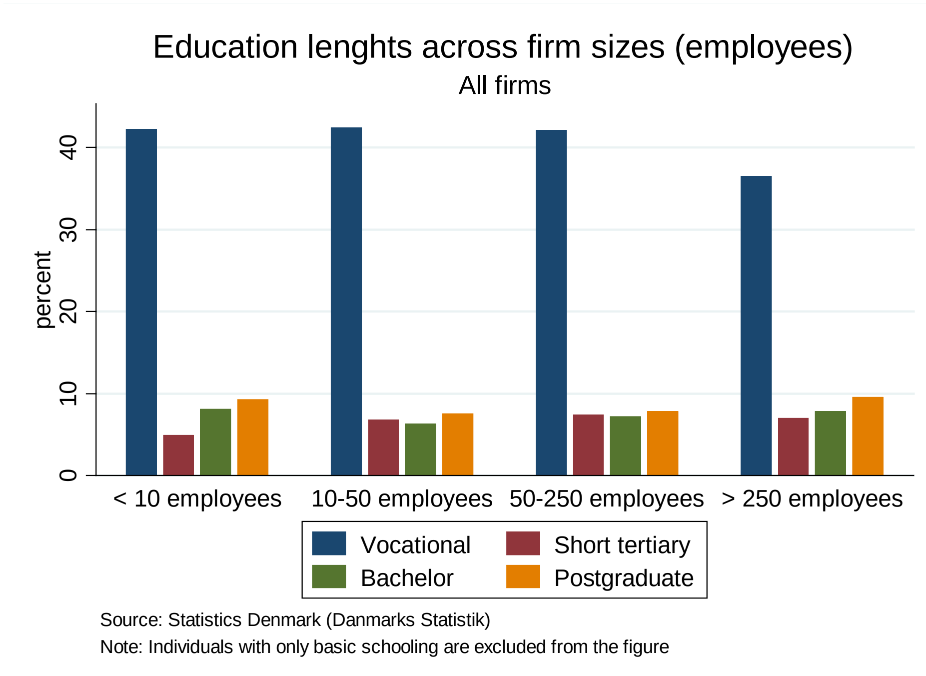
Figure 16



Source: Statistics Denmark (Danmarks Statistik)
Note: Individuals with only basic schooling are excluded from the figure

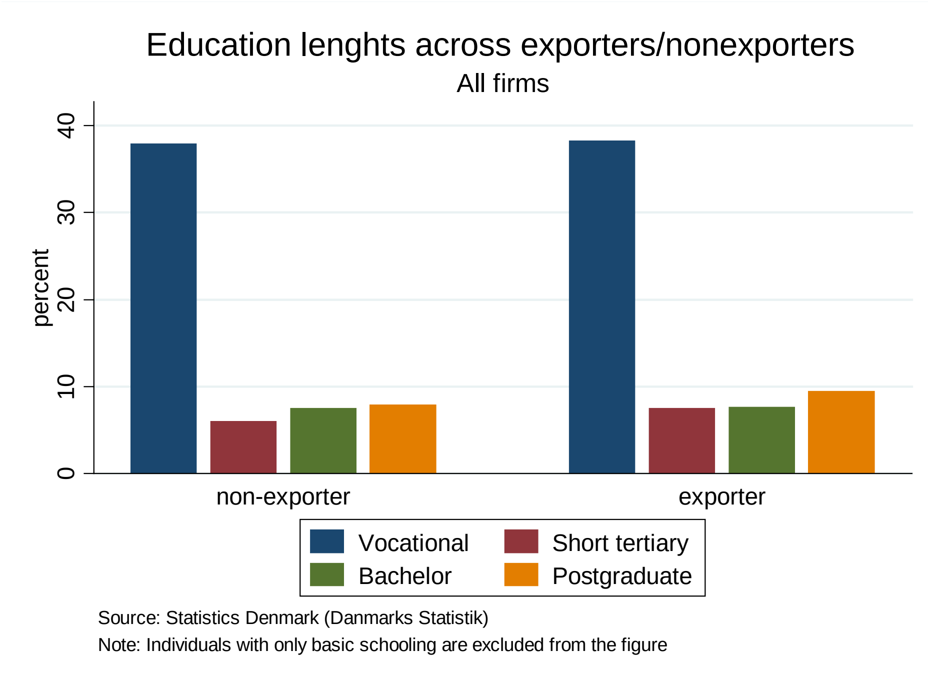
In Figure 16 we see that the distribution of the educational lengths of the employed is quite different in different industries. The manufacturing industry is characterized by a large concentration of vocationally trained employees, as employees with vocational training constitute 40 percent of all employees. Employees with 2 year degrees beyond high school and employees with a bachelor degree each constitute about 8 percent of all employees in manufacturing while employees with a master’s degree constitute about 7 percent. The educational distribution in the retail industry is qualitatively similar to the distribution in manufacturing with a heavy concentration of vocationally trained employees. The shares of employees with at least some college education are even lower than in manufacturing, though. The picture is quite different in the business services industry. Even though employees with vocational training are still in the majority, the distribution is more tilted towards employees with tertiary education than in the other two industries. For example, employees with a master’s degree constitute 20 percent of all employees.

Figure 17



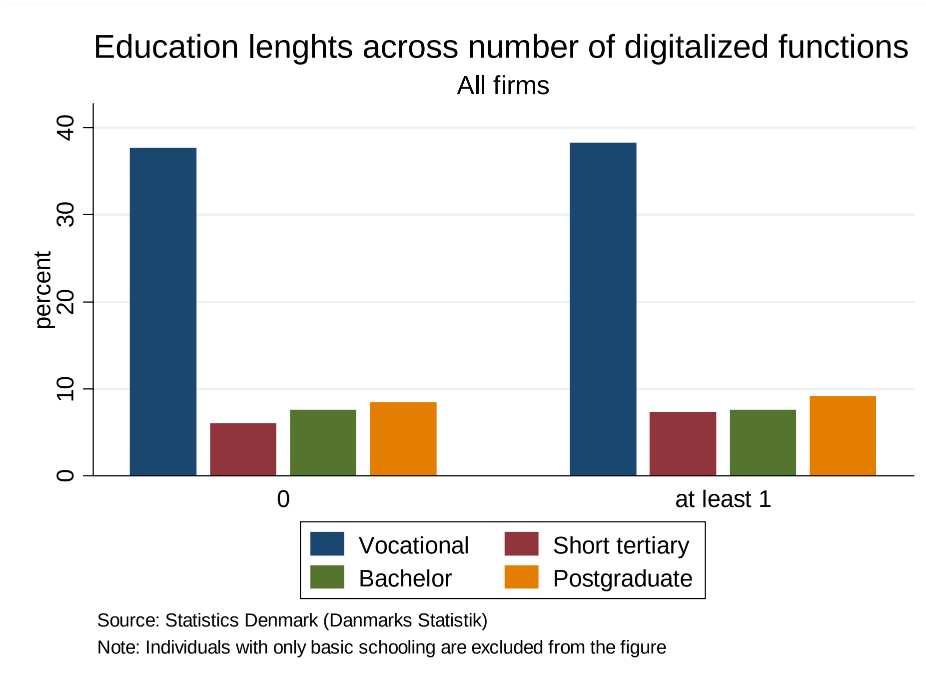
The distributions of educational lengths are qualitatively similar across different sizes of firms but differ in their details. Figure 17 shows that with respect to the shares of the employed that have at least some tertiary education, the distribution of educational lengths of employees is similar in the group of firms with less than 10 employees to the distribution of educational lengths of employees in the group of firms with more than 250 employees. In both groups of firms, employees with each type of tertiary training constitute less than 10 percent each of all employees with shares increasing in educational length. The distributions differ with respect to the shares of the employed who have vocational training as the share of the employed with vocational training is 42 percent in the micro sized firms and about 36 percent in group with the largest firms. In the two groups of intermediate sized firms, employees with vocational training constitute more than 40 percent of all employees while again the three groups of employees with at least some tertiary education constitute less than 10 percent each.

Figure 18



In Figure 18 we see that when we group firms according to whether they are exporters or non-exporters there is not a large difference in the distribution of employees' educational lengths. Even so, the shares of employees with at least some tertiary education are somewhat larger in the group of exporting firms. In the group of exporters the shares of employees with tertiary education are in the range 7 to 9 percent while in the group of non-exporting firms the shares of employees with tertiary education range between 6 and 8 percent.

Figure 19

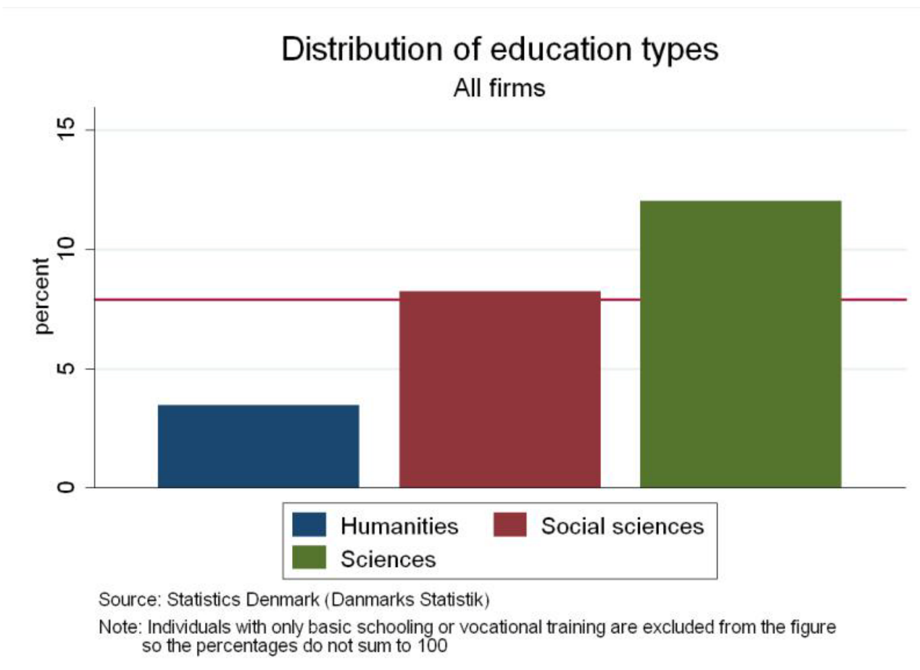


In Figure 19 we group the firms according to whether they have digitalized at least one of the 4 functions under consideration or not, and look at the distribution of educational lengths of the employed within each group. We do see some variation across the two distributions. In particular, for vocational training, short tertiary education and postgraduates the shares are higher in the group of firms that have digitalized at least one function. The share of the employed with vocational training is 42.3 percent in the group of firms that have digitalized at least one function in contrast to 41.3 percent in the group if firms that have not digitalized any function. The shares of the employed with short tertiary education is 7.5 percent in the group of firms that have digitalized at least one function in contrast to 5 percent in the group of firms that have not digitalized any function. The share of the employed with a bachelor degree is 7.5 percent in both groups of firms. The share of employees with a postgraduate degree is 8.5 percent in the group of firms who have not digitalized any function in contrast with 9.5 percent in the group of firms that have digitalized at least one function.

6.6 Employees' education types and firm characteristics

In this section we look at the relationship between educational types among the employed and various firm characteristics. By educational type we mean whether the employee has tertiary education within the sciences (including engineering), humanities, or social sciences. Individuals with no education beyond basic schooling and individuals with vocational training are the residual group so the sum of the shares for each distribution shown in the figures will be equal to 100 minus the share of the employed in the specific category with only basic schooling or with vocational training.

Figure 20



We see in Figure 20 that approximately 11 percent of the employed have a science education while approximately 8 percent have a social science education, and only about 3 percent have an education from within the humanities (the remaining 76 percent of the employed are categorized as having no education beyond basic schooling - just below 39 percent - or having received vocational training - just below 38 percent.)

Figure 21

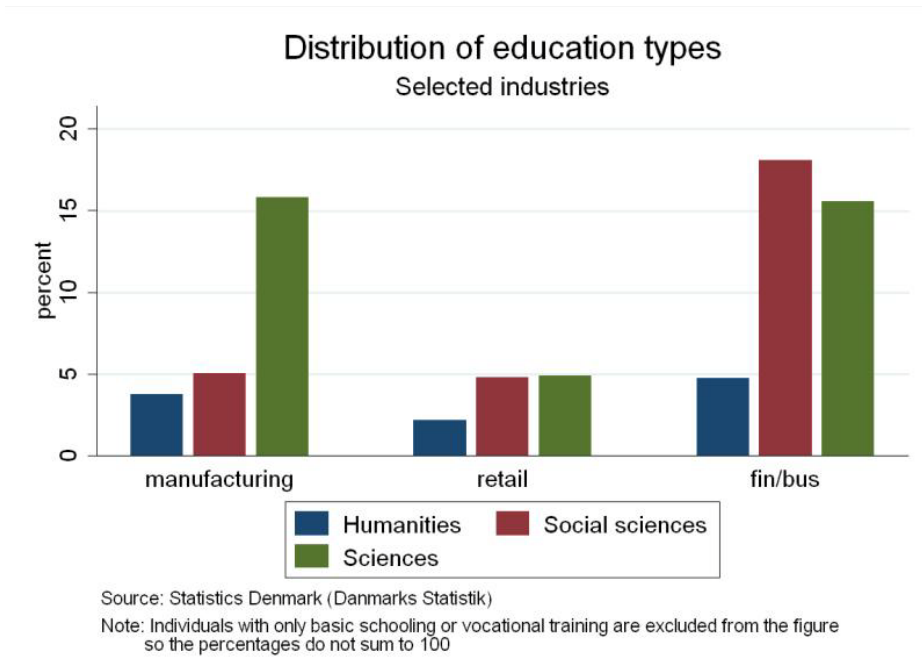
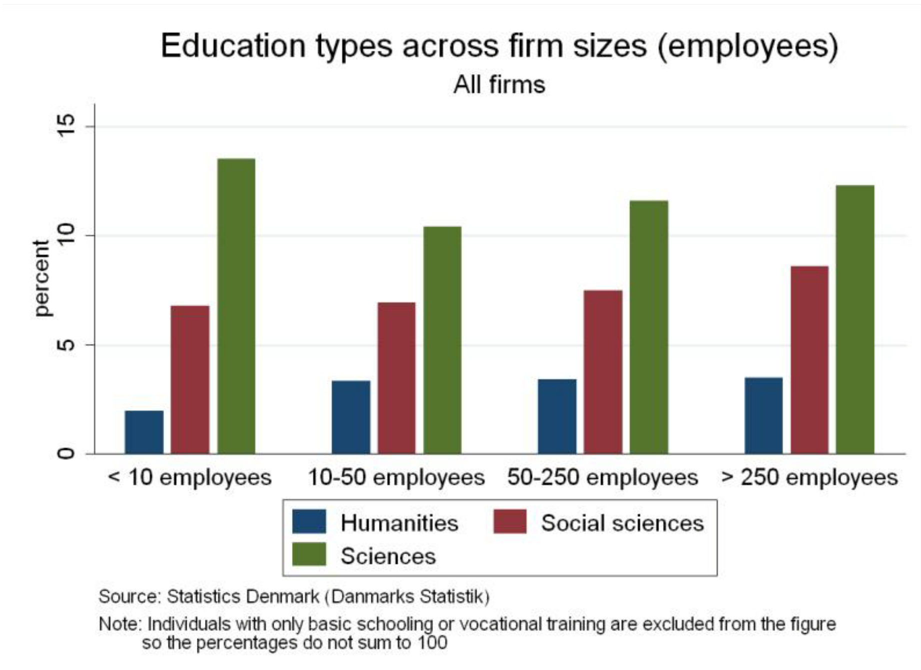


Figure 21 shows large differences across industries in the distribution of educational types among the employed with tertiary education. In manufacturing, about 16 percent of the employed has a science education while the shares of the employed with a humanities education is about 3 percent and the share of the employed with a social science education is 5 percent. The picture is rather different in the retail industry, where only 5 percent of the employed have a science education while the share of the employed with a social science education is about the same as in manufacturing. The business services industry differs from the other two industries in that the share of the employed with a social science education is about 18 percent and therefore substantially larger than in the other two industries. The share of the employed with a humanities education is also somewhat higher than in the manufacturing and retail industries but the differences are not as substantial as for those educated in the social sciences.

Figure 22



In Figure 22 the distributions of education types are qualitatively similar across firm sizes (where firms are grouped according to number of employees). In all distributions, the share of the employed with an education in the humanities is smallest, ranging from about 1.5 percent in the group with the smallest firms to about 3.5 percent in the other three groups of firms. The share of the employed with an education in the social sciences is intermediate between humanities and science with about 7 percent in the two groups with the smallest firms and about 8.5 percent in the group with the largest firms. Finally, the share of the employed with a science education is the largest in all groups, ranging from a little more than 10 percent in the group with firms with between 10 and 50 employees to about 13.5 percent in the group of firms with less than 10 employees.

Figure 23

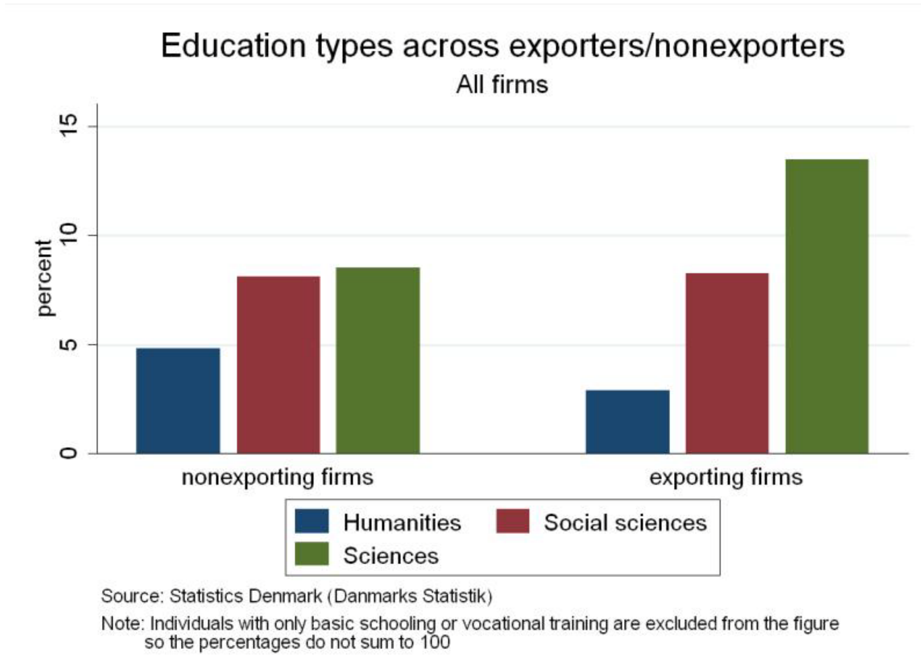
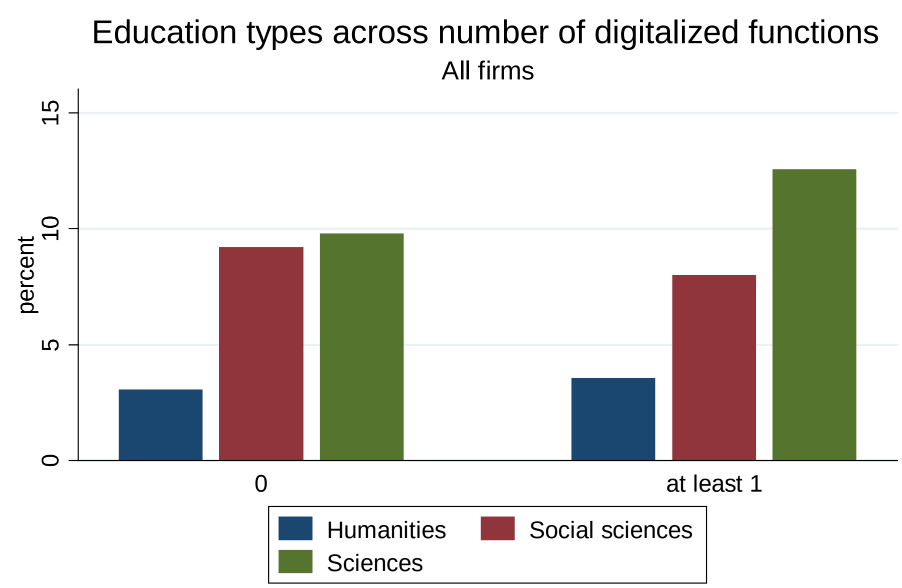


Figure 23 indicates one substantial difference between the distributions of educational types across exporting firms and non-exporting firms. The distribution of educational types in the group of non-exporting firms is relatively uniform with 5 percent of the employed having a humanities education and about 8 percent having a science education. The distribution of educational types in the group of exporting firms is more heavily tilted towards individuals with a science education. About 3 percent of the employed in exporting firms have a humanities education while about 13 percent have a science education. Also, the share of the employed among exporting firms with a social science education is marginally larger at approximately 8 percent while the share among non-exporting firms is about 7 percent.

Figure 24



Source: Statistics Denmark (Danmarks Statistik)
Note: Individuals with only basic schooling or vocational training are excluded from the figure

In Figure 24 we group the firms according to whether they have digitalized at least one of the 4 functions under consideration or not, and look at the distribution of educational lengths of the employed with tertiary education within each group. There is some variation across the two distributions. In particular, for all educational types, the shares are higher in the group of firms that have digitalized at least one function. The share of the employed with a humanities education is about 4 percent in the group of firms that have digitalized at least one function in contrast to 3 percent in the group if firms that have not digitalized any function. The shares of the employed with a social science education is 9 percent in the group of firms that have digitalized at least one function in contrast to 8 percent in the group if firms that have not digitalized any function. Finally, the share of the employed with a science education (including engineering) is 12.5 percent in the group of firms that have digitalized at least one function in contrast to 10 percent in the group if firms that have not digitalized any function.

7 Appendix C: Results of the statistical analysis

One of the main insights we get from Appendix B is that there is an *unconditional positive correlation* between shares of the various educational lengths or educational types among the firms' employees and digitalization decisions in the firm. Another main insight is that there is a strong *unconditional positive correlation* between the digitalization decision of a firm and the productivity of the employees of the firm.

We now want to investigate whether we can find support for

- An hypothesis about positive *conditional correlations* between educational mix and digitalization
- An hypothesis about positive *conditional correlations* between digitalization and productivity

These two main hypotheses are investigated in sections 7.1 and 7.2 respectively. We therefore switch to regression analysis, where we

- Control for a variety of characteristics that may plausibly influence the relationship between the educational mix of the firms' employees (measured either as educational lengths or as educational types) and the digitalization decisions of the firm.
- Control for a variety of characteristics that may plausibly influence the relationship between the digitalization decisions of the firm and the productivity of the employees of the firm.

As noted in Appendix A, because not all firms have answered all questions in the survey distributed by Statistics Denmark we do not have information on all variables that we want to include in the analyses for all firms. Therefore, the number of observations in the regression analysis is smaller than the total number of firms in the data set with the reduction in sample size varying according to which control variables we include in the regressions. The sample size for each regression model that we estimate is reported in the notes to the tables with regression results.

7.1 Summary

Four main lessons emerge from the regression analysis documented in this Appendix:

1) The educational mix of the firms' employees (measured either as educational lengths or as educational types) shows a strong positive conditional correlation with the digitalization choices of the firm.
2) Digitalization (defined as at least one function being digitalized) shows a strong positive conditional correlation with productivity. Our main estimate shows that a one percentage point increase in the likelihood that a firm has digitalized at least one internal function is conditionally correlated with a 0.72 % increase in value added per (quality adjusted) employee. We are not able to estimate separate relationships between the different functions that can be digitalized and productivity, i.e. we cannot determine whether for example accounting has a stronger correlation with productivity than inventory control.
3) As the predicted probabilities of digitalization of a function are (virtually) identical with the actual percentage of firms in the data set that actually have digitalized this function, the results from the estimations of the production function are readily interpreted in terms of the correlation between digitalization and productivity in the sample: If the proportion of firms that have digitalized at least one of the main 4 functions increases by one percentage point the average productivity of the firms in the sample will be predicted to be 0.72 % higher than before.
4) As the average value added per employee in our sample of 7,513 firms was 525,807 kroner on average over the years 2007 and 2008, 0.72 % amounts to 3,786 kroner per employee. Depending on the assumptions made about whether the correlation between digitalization and growth is present also in those Danish firms that were not included in our sample, this amounts to between 2.6 billion kroner and 6.5 billion kroner per year for the whole Danish economy.

The main lessons can be elaborated upon as follows:

1) A large share of vocationally trained employees and a large share of employees with a short tertiary education (and with a correspondingly lower share of employees with only basic schooling) are positively conditionally correlated with the digitalization choices of the firm.
2) The share of employees with a bachelor degree does not exhibit a strong conditional correlation with the digitalization choices of the

firm. The share of employees with a postgraduate degree does exhibit a statistically significant positive conditional correlation with the digitalization choices of the firm though the coefficients are smaller than for vocational training and short tertiary education.

3) The share of employees who are academically trained with a humanities degree does only exhibit a small positive conditional correlation with the digitalization choices of the firm while the shares of employees with either a social science degree or with a science degree do exhibit a statistically significant positive conditional correlation with the digitalization choices of the firm.
4) The conditional correlation between digitalization and value added per quality adjusted employee is very robust to alternative measures of digitalization. For example, a prediction of more advanced Internet access is correlated with a prediction of higher productivity. In virtually all regressions, a one percentage point increase in the predicted likelihood of digitalization is correlated with an increase in productivity on the order of 0.6 % to 1 %. At the same time, this implies that we cannot enter different digitalization variables into the same production function regression and estimate separate relationships between the different functions that can be digitalized and productivity. The results in this report should therefore be interpreted as saying something about the relationship between digitalization of firm functions in general and productivity, rather than saying something about the relationship between, for example, digitalization of accounting and productivity.

The very similar results obtained regardless of which digitalization measure is used leads us to conclude that we cannot on the basis of the results in this Appendix separate the conditional correlations between our different digitalization measures and productivity. Two plausible explanations for the inability to separate the effects of the different types of digitalization are

1) Digitalization is to a large extent an ‘all or nothing’ decision. When a firm decides to digitalize it digitalizes not just a single function. Rather, the firm digitalizes a swath of functions.
2) Educational mix, on which we have based our predictions of the likelihood of a firm digitalizing, cannot explain why a firm may choose to digitalize one function while choosing not to digitalize another function. In order to estimate different conditional correlations

between digitalization of different functions and productivity, we would need additional explanatory variables that correlate with the digitalization choices of the firm.

7.2 Correlates of digitalization

In this section we use two set ups of the probability models that we estimate. In one set of regressions, a dummy variable indicating whether a firm has digitalized the function under consideration or not is regressed on educational lengths plus a variety of control variables like industry dummies and an export dummy (the notes to each table explain which additional control variables are included). In the other set of regressions, the same regressions are performed with the sole change that we substitute educational types for educational lengths in the regressions. Tables 7.1 through 7.4 show the results from the main regressions where the focus is on internal digitalization, while Tables 7.5 through 7.10 show the results from various robustness tests.

The results from linear probability models are tabulated in Table 7.1 and Table 7.2 below. Table 7.1 reports the results from regression where shares of the employees of the firm with different educational lengths are included as control variables. Our interest centers on the educational variables. In the linear probability model a coefficient on '% vocational training' of 0.008 in the first column implies that a 1 percentage point increase in the share of the employed of a firm with vocational training relative to another firm with otherwise identical characteristics (and a corresponding decline in the share of the employed with only basic schooling) is correlated with a 0.8 percentage point larger probability that the firm has digitalized at least one of the 4 functions under consideration. The coefficient on short tertiary education is also 0.8 percent and as for vocational training it is statistically significant. The coefficient on bachelors on the other hand is only 0.2 percent and statistically insignificant. The coefficient on postgraduates is 0.4 percent and statistically significant, but only half the size of the coefficient on vocational training and short tertiary education. The coefficients on the squared educational terms are small in absolute terms but can have a relatively large negative impact for larger values of education shares in the sample.

The large coefficients on the vocational training and short tertiary education variables and the small coefficient on bachelors are surprising. A priori, we would expect that the coefficients increase in size with the length of education of the employed but that is not unconditionally the case.

The coefficient on '% vocational training' is very similar across the measures of digitalization, ranging from 0.8 percent for 'Distribution' and 'Production' to 0.9 percent for 'Accounting' and 1 percent for 'Inventory'. The coefficients on the other education variables vary slightly more with the change in the dependent variable used but the qualitative results are similar across all model specifications: Vocational training and short tertiary education exhibit the strongest correlations with the probability that the firm will digitalize a given function or one or more functions followed by postgraduates and finally bachelors where the correlation is weak.

TABLE.7.1 LINEAR PROBABILITY MODELS WITH EDUCATIONAL LENGTHS.

The dependent variable is a dummy (0-1) variable indicating digitalization of the relevant function.

Function	Any function	Inventory control	Accounting	Distribution	Production control
Export intensity	0.069	0.230	0.082	0.169	0.119
	(3.52)	(10.98)	(3.98)	(7.52)	(5.22)
Capital stock	0.019	0.032	0.020	0.026	0.018
	(4.80)	(8.30)	(4.86)	(6.77)	(4.55)
No. employees	0.057	0.054	0.059	0.074	0.074
	(9.57)	(8.78)	(9.52)	(12.24)	(11.32)
% Vocational training	0.008	0.010	0.009	0.008	0.008
	(6.11)	(8.31)	(6.49)	(6.90)	(6.37)
% Short tertiary training	0.008	0.008	0.008	0.005	0.006
	(3.33)	(2.97)	(3.34)	(2.21)	(2.45)
% Bachelors	0.002	0.004	0.004	0.004	0.005
	(1.66)	(2.89)	(3.07)	(3.40)	(3.98)
% Postgraduates	0.004	0.003	0.005	0.006	0.005
	(3.28)	(2.37)	(4.05)	(4.69)	(3.27)
$(\% \text{ Vocational training})^2$	-0.00006	-0.00007	-0.00007	-0.00007	-0.00007
	(-4.37)	(-5.77)	(-4.59)	(-5.70)	(-4.90)
$(\% \text{ Short tertiary training})^2$	-0.00008	-0.00006	-0.00007	-0.00001	-0.00003
	(-1.02)	(-0.66)	(-0.90)	(-0.19)	(-0.43)
$(\% \text{ Bachelors})^2$	-0.00003	-0.00005	-0.00005	-0.00005	-0.00007
	(-0.98)	(-2.12)	(-2.08)	(-1.99)	(-2.73)
$(\% \text{ Post-graduates})^2$	-0.00003	-0.00003	-0.00004	-0.00007	-0.00003
	(-1.26)	(-1.52)	(-1.87)	(-3.54)	(-1.49)
Constant	-0.120	-0.509	-0.243	-0.570	-0.508
	(-1.26)	(-6.19)	(-2.59)	(-6.85)	(-6.24)
Mean predicted probability	0.887	0.601	0.784	0.566	0.601

Notes: Robust t-statistics adjusted for repeated observations of the same firm are in parenthesis. Reported are effects for the probability of digitalization for selected control variables (control variables included in the regressions but not included in the table are a year dummy and industry dummies). The omitted educational category is % of employees with only basic schooling. Export intensity is defined as the export share of total revenue. The capital stock variable and the variable indicating the number of employees are entered in logarithmic form in the regressions. The dependent variable in the first column is a dummy variable indicating whether the firm has digitalized at least one of the 4 functions which are considered separately in columns 2 to 5. Separate linear regressions were performed for each digitalization variable. The regressions are based on 7369 observations from 6010 firms.

Source: All data used in the regressions are from Statistics Denmark.

The relationship between the probability of digitalization and the education lengths of the employed estimated in the first column of Table 7.1 is illustrated in Figure 25. The importance of the squared terms can be seen in the curvature of the lines.

Figure 25

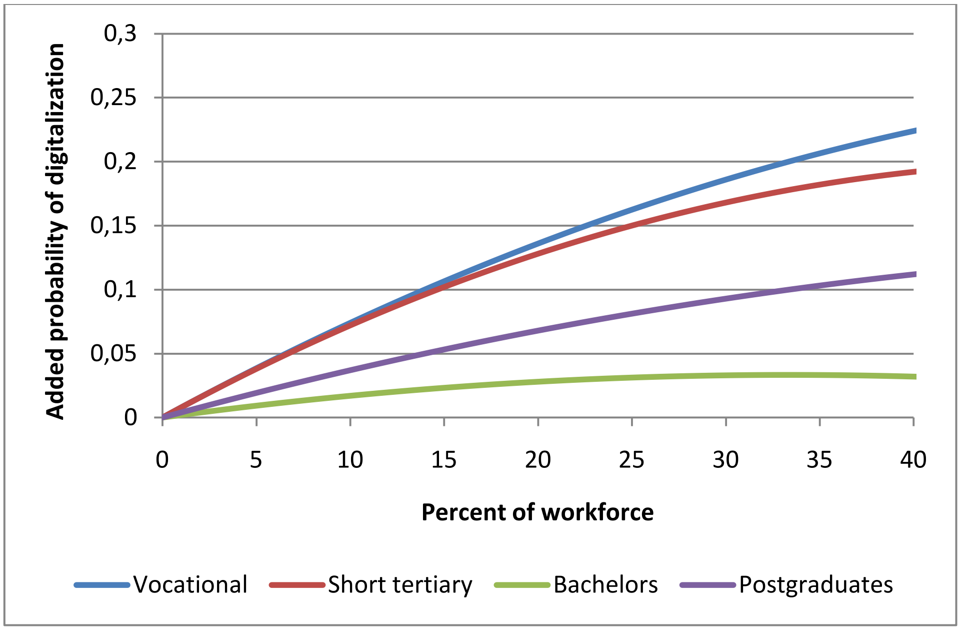


Table 7.2 reports the results from regressions where shares of the employees of the firm with different educational types where included as control variables. The coefficient on the humanities percentage of the employed of 0.001 implies that a 1 percentage point increase in the share of the employed of a firm with a humanities education relative to another otherwise identical firm (and a corresponding decrease in the percentage of the employed with either only basic schooling or with vocational training) is correlated with a 0.1 percent larger probability that the firm has digitalized one or more of the 4 functions. The coefficient estimate is economically small and it is statistically insignificant. The coefficients on the social sciences and science education variables on the other hand are economically large at 0.008 which implies that, all else equal, a 1 percentage point increase in for example the percentage of the firms' employees with a science education is correlated with a 0.8 percentage point increase in the probability that the firm has digitalized one or more of the 4 functions. Further, both are statistically significant.

The coefficients on the humanities variable differ somewhat across the specifications in Table 7.1 but only for ‘Distribution’ where it is 0.004 is the coefficient statistically significant. The coefficients on social sciences and sciences on the other hand are stable, economically large, and statistically significant across all specifications. Again, the squared education terms are numerically small but can have real impact for larger values of educational shares.

TABLE.7.2 LINEAR PROBABILITY MODELS WITH EDUCATIONAL TYPES.

The dependent variable is a dummy (0-1) variable indicating digitalization of the relevant function.

Function	Any function	Inventory control	Accounting	Distribution	Production control
Export intensity	0.077	0.226	0.092	0.182	0.134
	(4.03)	(10.96)	(4.59)	(8.30)	(6.06)
Capital stock	0.019	0.029	0.020	0.026	0.018
	(4.76)	(7.51)	(4.83)	(6.71)	(4.55)
No. employees	0.058	0.057	0.061	0.077	0.076
	(9.94)	(9.36)	(9.95)	(12.81)	(11.88)
% Humanities	0.001	-0.000	0.003	0.004	0.003
	(0.70)	(-0.10)	(1.58)	(2.39)	(1.45)
% Social sciences	0.008	0.008	0.010	0.008	0.008
	(5.06)	(4.17)	(5.92)	(4.55)	(4.19)
% Sciences	0.008	0.011	0.008	0.008	0.008
	(5.90)	(8.75)	(5.89)	(6.81)	(6.32)
$(\% \text{ Humanities})^2$	0.00006	0.00003	0.00002	0.00002	0.00004
	(1.99)	(0.92)	(0.56)	(0.58)	(1.08)
$(\% \text{ Social sciences})^2$	-0.00010	-0.00009	-0.00011	-0.00008	-0.00009
	(-2.65)	(-2.09)	(-3.07)	(-2.05)	(-2.01)
$(\% \text{ Sciences})^2$	-0.00005	-0.00008	-0.00005	-0.00006	-0.00006
	(-4.31)	(-6.73)	(-4.03)	(-5.50)	(-4.64)
Constant	-0.152	-0.494	-0.259	-0.635	-0.557
	(-1.54)	(-5.76)	(-2.68)	(-7.40)	(-6.61)
Mean predicted probability	0.859	0.610	0.772	0.530	0.573

Notes: Robust t-statistics adjusted for repeated observations of the same firm are in parenthesis. Reported are effects for the probability of digitalization for selected control variables (control variables included in the regressions but not included in the table are a year dummy and industry dummies). The omitted educational categories are basic schooling and vocational training. Export intensity is defined as the export share of total revenue. The capital stock variable and the variable indicating the number of employees are entered in logarithmic form in the regressions. The dependent variable in the first column is a dummy variable indicating whether the firm has digitalized at least one of the 4 functions which are considered separately in columns 2 to 5. Separate linear regressions were performed for each digitalization variable. The regressions are based on 7369 observations from 6010 firms.

Source: All data used in the regressions are from Statistics Denmark.

Table 7.3 and Table 7.4 display the results for estimations of the basic model specifications with probit models instead of linear probability models. In Table 7.3 educational lengths are the main variables of interest, while in Table 7.4 educational types are the variables of interest. The sizes of the coefficients in these tables do not have a natural interpretation as in Table 7.1 and Table 7.2

but their relative size and their statistical significance can be readily interpreted.

As in Table 7.1 the coefficients on the vocational training and short tertiary education variables in Table 7.3 are positive and the largest of the 4 coefficients on the education variables. Both are statistically significant. The coefficient on the bachelor variable is the smallest of the 4 coefficients (though it is still positive) but in contrast to Table 7.1 the coefficients are generally statistically significant. And as in Table 7.1 the coefficient on postgraduates is intermediate in size between the vocational and short tertiary coefficients and the bachelor coefficient.

TABLE.7.3 PROBIT ESTIMATIONS OF DETERMINANTS OF DIGITALIZATION (EDUCATIONAL LENGTHS).

The dependent variable is a dummy (0-1) variable indicating digitalization of the relevant function.

Function	Any function	Inventory control	Accounting	Distribution	Production control
Export intensity	0.270 (3.82)	0.776 (10.57)	0.312 (4.63)	0.468 (6.98)	0.369 (5.59)
Capital stock	0.062 (5.26)	0.102 (8.24)	0.064 (5.56)	0.083 (6.56)	0.056 (4.76)
No. employees	0.192 (10.00)	0.169 (8.64)	0.168 (9.52)	0.216 (11.11)	0.203 (10.89)
% Vocational training	0.024 (6.31)	0.030 (7.39)	0.026 (6.77)	0.026 (5.85)	0.024 (5.83)
% Short tertiary training	0.022 (3.67)	0.026 (3.60)	0.022 (3.49)	0.016 (2.48)	0.016 (2.49)
% Bachelors	0.006 (1.51)	0.013 (2.85)	0.014 (3.44)	0.013 (2.86)	0.015 (3.67)
% Postgraduates	0.014 (3.63)	0.010 (2.48)	0.017 (4.39)	0.019 (4.02)	0.013 (3.35)
(% Vocational training)^2	-0.0002 (-4.50)	-0.0002 (-4.82)	-0.0002 (-4.74)	-0.0002 (-4.45)	-0.0002 (-4.45)
(% Short tertiary training)^2	-0.0002 (-1.01)	-0.0002 (-0.90)	-0.0001 (-0.28)	-0.0001 (-0.35)	-0.0001 (-0.35)
(% Bachelors)^2	-0.0001 (-0.81)	-0.0002 (-2.15)	-0.0002 (-1.42)	-0.0002 (-2.24)	-0.0002 (-2.24)
(% Post-graduates)^2	-0.0001 (-1.61)	-0.0001 (-2.26)	-0.0002 (-2.63)	-0.0001 (-1.50)	-0.0001 (-1.50)
Constant	-1.997 (-7.68)	-3.100 (-10.93)	-2.221 (-9.10)	-3.303 (-10.92)	-2.909 (-10.10)
Mean predicted probability	0.679	0.482	0.617	0.345	0.428

Notes: Robust t-statistics adjusted for repeated observations of the same firm are in parenthesis. Reported are marginal effects at the sample means for the probability of digitalization for selected control variables (control variables included in the regressions but not included in the table are a year dummy and industry dummies). The omitted educational category is % of employees with only basic schooling. Export intensity is defined as the export share of total revenue. The capital stock variable and the variable indicating the number of employees are entered in logarithmic form in the regressions. The dependent variable in the first column is a dummy variable indicating whether the firm has digitalized at least one of the 4 functions which are considered separately in columns 2 to 5. A separate probit regression was performed for the model in the first column while the models in columns 2 to 5 were estimated jointly in a multivariate probit model. The regressions are based on 7369 observations from 6010 firms.

Source: All data used in the regressions are from Statistics Denmark.

Table 7.4 shows similar qualitative results as Table 7.2 with the coefficient on humanities being the smallest of the coefficients on the educational type variables. It is generally positive but statistically insignificant. The social science and science educated exhibit a large and statistically significant positive conditional correlation with digitalization.

TABLE.7.4 PROBIT ESTIMATIONS OF DETERMINANTS OF DIGITALIZATION (EDUCATIONAL TYPES).

The dependent variable in each column is a dummy (0-1) variable indicating digitalization of the relevant function.

Function	Any function	Inventory control	Accounting	Distribution	Production control
Export intensity	0.289 (4.18)	0.767 (10.78)	0.342 (5.17)	0.512 (7.80)	0.408 (6.30)
Capital stock	0.064 (5.33)	0.095 (7.59)	0.064 (5.56)	0.084 (6.54)	0.055 (4.74)
No. employees	0.196 (10.23)	0.179 (9.23)	0.175 (9.98)	0.224 (11.62)	0.210 (11.41)
% Humanities	0.004 (0.76)	-0.000 (-0.02)	0.008 (1.80)	0.011 (2.29)	0.007 (1.49)
% Social sciences	0.025 (4.81)	0.026 (3.54)	0.029 (5.68)	0.027 (4.20)	0.022 (4.06)
% Sciences	0.022 (5.94)	0.032 (8.05)	0.023 (6.23)	0.025 (5.87)	0.024 (5.79)
$(\% \text{ Humanities})^2$	0.0002 (1.80)	0.0000 (0.46)	0.0001 (1.04)	0.0001 (1.19)	0.0001 (1.19)
$(\% \text{ Social sciences})^2$	-0.0003 (-2.43)	-0.0003 (-2.92)	-0.0003 (-1.90)	-0.0002 (-1.90)	-0.0002 (-1.90)
$(\% \text{ Sciences})^2$	-0.0001 (-4.26)	-0.0001 (-4.20)	-0.0002 (-4.65)	-0.0002 (-4.29)	-0.0002 (-4.29)
Constant	-2.091 (-7.68)	-3.074 (-10.28)	-2.256 (-8.97)	-3.501 (-11.28)	-3.044 (-10.31)
Mean predicted probability	0.679	0.482	0.617	0.345	0.428

Notes: Robust t-statistics adjusted for repeated observations of the same firm are in parenthesis. Reported are marginal effects at the sample means for the probability of digitalization for selected control variables (control variables included in the regressions but not included in the table are a year dummy and industry dummies). The excluded educational categories are basic schooling and vocational training. Export intensity is defined as the export share of total revenue. The capital stock variable and the variable indicating the number of employees are entered in logarithmic form in the regressions. The dependent variable in the first column is a dummy variable indicating whether the firm has digitalized at least one of the 4 functions which are considered separately in columns 2 to 5. A separate probit regression was performed for the model in the first column while the models in columns 2 to 5 were estimated jointly in a multivariate probit model. The regressions are based on 7369 observations from 6010 firms.

Source: All data used in the regressions are from Statistics Denmark.

Table 7.5 shows that the results using Enterprise Resource Planning (ERP) as a measure of internal digitalization does not change the main results from Tables 7.1 through 7.4. The pattern remains qualitatively the same as vocational training and short tertiary education exhibit the strongest correlations with digitalization and postgraduates also being statistically significant. As opposed to the main tables though, the percentage of bachelors among the employed also has a strong correlation with digitalization of ERP, even though not as strong as the percentage of the employed that have vocational training or have a short tertiary education. As for educational types, the percentage of the employed that have a humanities education is not statistically significantly correlated with digitalization of ERP while the percentage with a social science or a science education is strongly correlated with digitalization of ERP.

The results for Customer Relationship Management (CRM), which serves as one of our measures of external digitalization, are somewhat different. For CRM, vocational training is not statistically significantly correlated with digitalization, while tertiary education in general is positively correlated with digitalization. With regards to educational types, all types of tertiary education are highly positively correlated with digitalization of CRM.

TABLE 7.5 PROBIT ESTIMATIONS OF DETERMINANTS OF DIGITALIZATION OF ENTERPRISE RESOURCE PLANNING (ERP) AND CUSTOMER RELATIONSHIP MANAGEMENT (CRM).

The dependent variable in each column is a dummy (0-1) variable indicating digitalization of the relevant function.

Function	ERP	CRM	ERP	CRM
Export intensity	0.597 (8.25)	-0.106 (-1.55)	0.644 (9.09)	-0.006 (-0.09)
Capital stock	0.085 (6.83)	0.039 (3.13)	0.082 (6.53)	0.042 (3.29)
No. employees	0.286 (13.58)	0.251 (12.31)	0.296 (14.23)	0.254 (12.45)
% Vocational training	0.027 (6.59)	0.010 (2.50)		
% Short tertiary training	0.028 (4.29)	0.033 (5.99)		
% Bachelors	0.018 (4.26)	0.026 (5.07)		
% Postgraduates	0.016 (3.87)	0.035 (8.63)		
% Humanities			0.009 (1.77)	0.025 (4.82)
% Social sciences			0.034 (6.06)	0.051 (10.43)
% Sciences			0.029 (6.91)	0.018 (4.25)
(% Vocational training)^2	-0.0002 (-4.93)	0.0000 (0.08)		
(% Short tertiary training)^2	-0.0002 (-0.85)	-0.0002 (-1.01)		
(% Bachelors)^2	-0.0002 (-2.83)	-0.0003 (-2.72)		
(% Post-graduates)^2	-0.0001 (-1.76)	-0.0003 (-5.07)		
(% Humanities)^2			-0.0000 (-0.36)	-0.0000 (-0.32)
(% Social sciences)^2			-0.0003 (-2.50)	-0.0004 (-4.11)
(% Sciences)^2			-0.0002 (-5.05)	-0.0001 (-1.34)

Table continues on next page

Constant	-3.121 (-10.38)	-2.842 (-10.13)	-3.131 (-10.09)	-3.119 (-10.35)
Mean predicted probability	0.574	0.417	0.574	0.417

Notes: Robust t-statistics adjusted for repeated observations of the same firm are in parenthesis. Reported are marginal effects at the sample means for the probability of digitalization for selected control variables (control variables included in the regressions but not included in the table are a year dummy, educational variables squared, and industry dummies). The excluded educational category in columns 1 and 2 are basic schooling. The excluded educational categories in columns 3 and 4 are basic schooling and vocational training. Export intensity is defined as the export share of total revenue. The capital stock variable and the variable indicating the number of employees are entered in logarithmic form in the regressions. The dependent variable in the first column and the third columns is a dummy variable indicating whether the firm has digitalized Enterprise Resource Planning (ERP). The dependent variable in the columns 2 and 4 is a dummy variable indicating whether the firm has digitalized Customer Relationship Management (CRM). The models in columns 1 and 2 were estimated jointly in a bivariate probit regression and the models in columns 3 and 4 were estimated jointly in a bivariate probit regression. The regressions are based on 7271 observations from 5852 firms.

Source: All data used in the regressions are from Statistics Denmark.

Table 7.6 shows the results from a robustness check where we have substituted measures of Internet access for measures of digitalization. The firms are not separated into exclusive groups as firms may have access to more than one type of Internet access.

Table 7.6 shows that the results are as one would expect with more education correlated with more advanced Internet access. In particular, higher percentages of workers with tertiary training or a postgraduate degree are strongly correlated with higher probability of high speed or mobile internet access (and negatively correlated with basic Internet access).

TABLE 7.6 PROBIT ESTIMATIONS OF DETERMINANTS OF INTERNET ACCESS TYPE (EDUCATIONAL LENGTHS).

The dependent variable in each column is a dummy (0-1) variable indicating whether the firm has the indicated internet access.

Internet	Basic (ISDN, ADSL etc.)	High (fiber, FWA, WIMAX etc.)	Mobile (3G/UMTS, Turbo 3G etc.)
Export intensity	-0.198 (-2.00)	0.170 (1.85)	0.053 (0.56)
Capital stock	-0.030 (-1.61)	0.104 (5.63)	0.093 (5.33)
No. employees	-0.066 (-2.22)	0.382 (12.32)	0.238 (8.27)
% Vocational training	0.001 (0.15)	0.019 (3.18)	0.013 (2.32)
% Short tertiary training	-0.039 (-4.06)	0.046 (5.23)	0.032 (4.32)
% Bachelors	-0.009 (-1.34)	0.021 (3.26)	0.012 (1.95)
% Post-graduates	-0.006 (-1.00)	0.034 (5.80)	0.020 (3.72)
(% Vocational training)^2	-0.0000 (-0.66)	-0.0001 (-2.22)	-0.0001 (-1.09)
(% Short tertiary training)^2	0.0010 (3.15)	-0.0010 (-3.60)	-0.0004 (-1.88)
(% Bachelors)^2	0.0000 (0.23)	-0.0002 (-1.27)	-0.0001 (-0.39)
(% Post-graduates)^2	0.0000 (0.52)	-0.0002 (-2.80)	-0.0001 (-0.95)
Constant	1.645 (4.04)	-3.520 (-8.68)	-2.002 (-5.06)
Mean predicted probability	0.846	0.443	0.538

Notes: Robust t-statistics adjusted for repeated observations of the same firm are in parenthesis. Reported are marginal effects at the sample means for the probability of internet access for selected control variables (control variables included in the regressions but not included in the table are a year dummy, educational variables squared, and industry dummies). The excluded educational category is basic schooling. Export intensity is defined as the export share of total revenue. The capital stock variable and the variable indicating the number of employees are entered in logarithmic form in the regressions. The dependent variable in the first column is a dummy variable indicating whether the firm has basic internet access. The dependent variable in the second column is a dummy variable indicating whether the firm has advanced internet access. The dependent variable in column 3 is a dummy variable indicating whether the firm has mobile internet access. The models in columns 1 through 3 were estimated jointly in a multivariate probit regression. The regressions are based on 3349 observations from 3020 firms.

Source: All data used in the regressions are from Statistics Denmark.

Table 7.7 shows that humanities and social science education is most strongly correlated with the firm having high speed or mobile Internet access. A larger percentage of the employed with a science education is also positively correlated with better Internet access but not as strongly as humanities and social science.

TABLE 7.7 PROBIT ESTIMATIONS OF DETERMINANTS OF INTERNET ACCESS TYPE (EDUCATIONAL TYPES).

The dependent variable in each column is a dummy (0-1) variable indicating whether the firm has the indicated internet access.

Internet	Basic (ISDN, ADSL etc.)	High (fiber, FWA, WIMAX etc.)	Mobile (3G/UMTS, Turbo 3G etc.)
Export intensity	-0.246 (-2.62)	0.297 (3.30)	0.131 (1.45)
Capital stock	-0.045 (-2.30)	0.119 (6.31)	0.095 (5.40)
No. employees	-0.060 (-2.02)	0.387 (12.37)	0.242 (8.41)
% Humanities	-0.029 (-3.40)	0.044 (5.68)	0.020 (2.71)
% Social sciences	-0.015 (-2.44)	0.043 (5.82)	0.032 (5.41)
% Sciences	0.000 (0.08)	0.017 (2.76)	0.015 (2.68)
$(\% \text{ Humanities})^2$	0.0003 (1.78)	-0.0004 (-2.44)	-0.0001 (-0.92)
$(\% \text{ Social sciences})^2$	0.0003 (2.46)	-0.0004 (-2.86)	-0.0002 (-1.79)
$(\% \text{ Sciences})^2$	-0.0001 (-1.06)	-0.0001 (-1.08)	-0.0001 (-1.04)
Constant	1.952 (4.93)	-3.968 (-10.32)	-2.123 (-5.08)
Mean predicted probability	0.845	0.443	0.538

Notes: Robust t-statistics adjusted for repeated observations of the same firm are in parenthesis. Reported are marginal effects at the sample means for the probability of internet access for selected control variables (control variables included in the regressions but not included in the table are a year dummy, educational variables squared, and industry dummies). The excluded educational category is basic schooling. Export intensity is defined as the export share of total revenue. The capital stock variable and the variable indicating the number of employees are entered in logarithmic form in the regressions. The dependent variable in the first column is a dummy variable indicating whether the firm has basic internet access. The dependent variable in the second column is a dummy variable indicating whether the firm has advanced internet access. The dependent variable in column 3 is a dummy variable indicating whether the firm has mobile internet access. The models in columns 1 through 3 were estimated jointly in a multivariate probit regression. The regressions are based on 3349 observations from 3020 firms.

Source: All data used in the regressions are from Statistics Denmark.

Table 7.8 shows the results for an aggregative measure of internal digitalization and a measure of external digitalization, namely digitalization of Supply Chain Management. The first two columns show the results obtained when we include educational lengths as explanatory variables and the last two columns show the results when we include educational types as explanatory variables. Not surprisingly, the results for the internal digitalization measure are very similar to the results in Table 7.1 and 7.2 with vocational training and short tertiary education showing the strongest correlation with internal digitalization, bachelors showing no correlation with internal digitalization, and postgraduates showing a moderately strong positive correlation with internal digitalization. The only qualitatively different result for the measure of external digitalization relative to internal digitalization is that vocational training is not correlated with external digitalization. Other than that, the correlations between the educational mix and external digitalization are very similar to the correlations between the educational mix and external digitalization.

TABLE 7.8 PROBIT ESTIMATIONS OF DETERMINANTS OF DIGITALIZATION OF INTERN FUNCTIONS AND SUPPLY CHAIN MANAGEMENT.

The dependent variable in each column is a dummy (0-1) variable indicating digitalization of the relevant function.

Function	Any intern function	Supply chain	Any intern function	Supply chain
Export intensity	0.278 (3.91)	0.097 (1.45)	0.293 (4.21)	0.088 (1.34)
Capital stock	0.060 (5.00)	0.025 (1.99)	0.061 (5.07)	0.023 (1.84)
No. employees	0.202 (10.34)	0.186 (9.75)	0.205 (10.58)	0.183 (9.64)
% Vocational training	0.025 (6.37)	0.003 (0.69)		
% Short tertiary training	0.021 (3.40)	0.017 (3.01)		
% Bachelors	0.005 (1.22)	-0.004 (-0.96)		
% Postgraduates	0.015 (3.72)	0.019 (4.36)		
% Humanities			0.005 (0.94)	-0.001 (-0.16)
% Social sciences			0.024 (4.62)	0.024 (5.04)
% Sciences			0.023 (5.87)	0.015 (3.37)
(% Vocational training)^2	-0.0002 (-4.65)	0.0000 (0.60)		
(% Short tertiary training)^2	-0.0002 (-0.93)	-0.0002 (-1.62)		
(% Bachelors)^2	-0.0001 (-0.65)	0.0001 (0.68)		
(% Post-graduates)^2	-0.0001 (-1.65)	-0.0002 (-3.43)		
(% Humanities)^2			0.0002 (1.60)	0.0002 (1.86)
(% Social sciences)^2			-0.0003 (-2.36)	-0.0004 (-3.47)

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(% Sciences)^2			-0.0002 (-4.30)	-0.0001 (-2.63)
Constant	-2.002 (-7.73)	-2.254 (-7.05)	-2.104 (-7.72)	-2.459 (-7.41)
Mean predicted probability	0.681	0.268	0.682	0.267

Notes: Robust t-statistics adjusted for repeated observations of the same firm are in parenthesis. Reported are marginal effects at the sample means for the probability of digitalization for selected control variables (control variables included in the regressions but not included in the table are a year dummy, educational variables squared, and industry dummies). The excluded educational category in columns 1 and 2 are basic schooling. The excluded educational categories in columns 3 and 4 are basic schooling and vocational training. Export intensity is defined as the export share of total revenue. The capital stock variable and the variable indicating the number of employees are entered in logarithmic form in the regressions. The dependent variable in the first column and the third column is a dummy variable indicating whether the firm has digitalized any of the functions, Inventory control, Accounting, Distribution, or Production control. The dependent variable in columns 2 and 4 is a dummy variable indicating whether the firm has digitalized supply chain management. The models in columns 1 and 2 were estimated jointly in a bivariate probit regression and the models in columns 3 and 4 were estimated jointly in a bivariate probit regression. The regressions are based on 7226 observations from 5896 firms.

Source: All data used in the regressions are from Statistics Denmark.

In Table 7.9 and 7.10 we show the results from regressions of the basic internal functions but in contrast to the regressions in Table 7.1 and 7.2 we include the logarithm of firm expenses on IT in 2008 as an explanatory variable. The data on the IT expenditures of firms comes from a different survey from the one that provides data on the internalization decisions of firms so that the data set for the regressions in Table 7.9 and Table 7.10 is the data for firms that answered both surveys. Only 1168 firms have answered both questionnaires so the data sample for the regressions in Table 7.9 and Table 7.10 are much smaller than the samples available for the regressions shown in Table 7.1 and Table 7.2. The results in Table 7.9 and table 7.10 show a positive and statistically significant correlation between IT expenditures and digitalization decisions of firms. The results are very similar whether we use educational lengths as the educational mix variables (Table 7.9) or whether we use educational types as the educational mix variables (Table 7.10).

TABLE.7.9 PROBIT ESTIMATIONS OF DETERMINANTS OF DIGITALIZATION (EDUCATIONAL LENGTHS AND IT EXPENDITURES).

The dependent variable is a dummy (0-1) variable indicating digitalization of the relevant function.

Function	Any function	Inventory control	Accounting	Distribution	Production control
Export intensity	0.104 (0.57)	0.678 (4.12)	0.059 (0.37)	0.444 (3.04)	0.270 (1.87)
Capital stock	0.012 (0.37)	0.088 (2.84)	0.053 (1.72)	0.074 (2.52)	0.055 (1.88)
ICT expenditures	0.127 (2.95)	0.101 (2.57)	0.108 (2.80)	0.100 (2.68)	0.111 (3.04)
No. employees	0.161 (2.64)	0.119 (2.20)	0.117 (2.14)	0.131 (2.48)	0.059 (1.14)
% Vocational training	0.032 (2.66)	0.029 (2.43)	0.033 (2.95)	0.033 (2.63)	0.034 (2.93)
% Short tertiary training	0.063 (3.47)	0.066 (3.83)	0.063 (3.86)	0.022 (1.31)	0.043 (2.63)
% Bachelors	-0.005 (-0.40)	0.005 (0.35)	0.009 (0.82)	0.025 (2.05)	0.020 (1.77)
% Postgraduates	-0.013 (-1.17)	-0.004 (-0.35)	-0.008 (-0.72)	0.019 (1.64)	-0.010 (-0.97)
(% Vocational training)^2	-0.0003 (-2.39)	-0.0002 (-1.89)	-0.0003 (-2.23)	-0.0003 (-2.08)	-0.0003 (-2.56)
(% Short tertiary training)^2	-0.0011 (-2.08)	-0.0013 (-2.48)	-0.0013 (-2.68)	-0.0003 (-0.66)	-0.0008 (-1.68)
(% Bachelors)^2	0.0001 (0.56)	-0.0001 (-0.37)	-0.0000 (-0.07)	-0.0004 (-1.46)	-0.0003 (-1.09)
(% Post-graduates)^2	0.0002 (1.27)	0.0000 (0.17)	0.0002 (1.29)	-0.0003 (-1.63)	0.0001 (0.92)
Constant	-2.585 (-5.90)	-3.785 (-7.38)	-2.853 (-6.21)	-4.298 (-7.78)	-3.281 (-6.45)
Mean predicted probability	0.805	0.618	0.744	0.517	0.596

Notes: Robust t-statistics adjusted for repeated observations of the same firm are in parenthesis. Reported are marginal effects at the sample means for the probability of digitalization for selected control variables (control variables included in the regressions but not included in the table are a year dummy, educational variables squared, and industry dummies). The omitted educational category is % of employees with only basic schooling. Export intensity is defined as the export share of total revenue. The capital stock variable, ICT expenditures, and the variable indicating the number of employees are entered in logarithmic form in the regressions. The dependent variable in the first column is a dummy variable indicating whether the firm has digitalized at least one of the 4 functions which are considered separately in columns 2 to 5. A separate probit regression was performed for the model in the first column while the models in columns 2 to 5 were estimated jointly in a multivariate probit model. The regressions are based on 1183 observations from 1183 firms.

Source: All data used in the regressions are from Statistics Denmark.

TABLE.7.10 PROBIT ESTIMATIONS OF DETERMINANTS OF DIGITALIZATION (EDUCATIONAL TYPES AND IT EXPENDITURES).

The dependent variable is a dummy (0-1) variable indicating digitalization of the relevant function.

Function	Any function	Inventory control	Accounting	Distribution	Production control
Export intensity	0.136 (0.76)	0.680 (4.14)	0.072 (0.46)	0.479 (3.28)	0.301 (2.09)
Capital stock	0.026 (0.79)	0.076 (2.46)	0.051 (1.66)	0.063 (2.11)	0.048 (1.63)
ICT expenditures	0.117 (2.75)	0.104 (2.65)	0.098 (2.57)	0.103 (2.73)	0.104 (2.87)
No. employees	0.153 (2.53)	0.121 (2.23)	0.127 (2.34)	0.155 (2.93)	0.078 (1.51)
% Humanities	0.013 (0.89)	-0.009 (-0.66)	0.013 (0.96)	0.008 (0.60)	0.006 (0.46)
% Social sciences	0.024 (1.77)	0.025 (1.80)	0.030 (2.35)	0.032 (2.34)	0.023 (1.86)
% Sciences	0.025 (2.11)	0.034 (2.91)	0.033 (2.99)	0.048 (3.85)	0.035 (3.08)
$(\% \text{ Humanities})^2$	-0.0001 (-0.55)	0.0002 (0.74)	-0.0001 (-0.56)	0.0003 (1.05)	0.0001 (0.26)
$(\% \text{ Social sciences})^2$	-0.0006 (2.25)	-0.0006 (-2.00)	-0.0006 (-2.27)	-0.0007 (-2.43)	-0.0005 (-2.14)
$(\% \text{ Sciences})^2$	-0.0002 (-1.88)	-0.0003 (-2.45)	-0.0002 (-2.20)	-0.0004 (-3.37)	-0.0003 (-2.67)
Constant	-2.627 (-5.68)	-3.614 (-6.61)	-2.820 (-5.80)	-4.941 (-7.86)	-3.423 (-6.31)
Mean predicted probability	0.805	0.620	0.744	0.517	0.597

Notes: Robust t-statistics adjusted for repeated observations of the same firm are in parenthesis. Reported are marginal effects at the sample means for the probability of digitalization for selected control variables (control variables included in the regressions but not included in the table are a year dummy, educational variables squared, and industry dummies). The omitted educational category is % of employees with only basic schooling. Export intensity is defined as the export share of total revenue. The capital stock variable, ICT expenditures, and the variable indicating the number of employees are entered in logarithmic form in the regressions. The dependent variable in the first column is a dummy variable indicating whether the firm has digitalized at least one of the 4 functions which are considered separately in columns 2 to 5. A separate probit regression was performed for the model in the first column while the models in columns 2 to 5 were estimated jointly in a multivariate probit model. The regressions are based on 1183 observations from 1183 firms.

Source: All data used in the regressions are from Statistics Denmark.

7.3 Correlates of productivity

This section reports the results from the second stage regressions, i.e. regressions of productivity on the predicted probabilities of digitalization (in addition to other explanatory variables) obtained from the first stage regressions reported in section 7.2.

The basic results regarding the relationship between internal digitalization and productivity are reported in Table 7.11 and Table 7.12 below. Table 7.11, which shows the results obtained when educational lengths are used as explanatory variables in the first stage, shows a positive, economically and statistically significant conditional correlation between digitalization and productivity. Across the internal functions, a one percent increase in the likelihood of digitalization implies a prediction of between 0.6 % higher productivity (for distribution) and 0.95 % higher productivity (for production control). The coefficient in column (5) on the predicted probability of digitalization of any function says that a one percent increase in the likelihood of digitalization of at least one of the 4 functions implies a prediction of 0.72 % higher productivity.

It is important to notice an issue that pervades the results in Table 7.11 as well as all the other results in our estimations of the conditional correlations between digitalization and productivity. We are not able to estimate separate relationships between the different functions that can be digitalized and productivity. High correlation between the digitalization variables implies that we cannot enter them all into the same production function regressions and find separate relationships between the different functions that can be digitalized and productivity. The results should therefore be interpreted as saying something about the relationship between digitalization of firm functions in general and productivity, rather than saying something about the relationship between, for example, digitalization of accounting and productivity.

TABLE 7.11 RESULTS FROM ESTIMATIONS OF PRODUCTION FUNCTIONS. FIRST STAGE: PROBIT WITH EDUCATIONAL LENGTHS

The dependent variable in each column is the logarithm of value added per average employee.

	(1)	(2)	(3)	(4)	(5)
Inventory control	0.635 (4.67)				
Accounting		0.768 (4.44)			
Distribution			0.605 (3.42)		
Production control				0.951 (4.41)	
Any function					0.717 (3.54)
Capital/labor ratio	0.099 (10.85)	0.104 (11.69)	0.103 (11.28)	0.102 (11.56)	0.105 (11.66)
Export intensity	-0.030 (-0.65)	0.036 (0.97)	0.008 (0.16)	-0.027 (-0.54)	0.061 (1.74)
No. employees	-0.196 (-3.81)	-0.232 (-4.10)	-0.175 (-3.45)	-0.230 (-4.20)	-0.233 (-3.78)
$(\text{No. employees})^2$	0.021 (4.15)	0.024 (4.54)	0.0178 (3.61)	0.021 (4.21)	0.025 (4.45)
Constant	12.898 (87.40)	12.789 (88.45)	12.888 (85.04)	12.993 (81.35)	12.736 (85.83)

Notes: Robust t-statistics adjusted for repeated observations of the same firm and the inclusion of a generated regressor are in parenthesis. An F-test of the exclusion restriction that all 4 functions can be excluded from the production function yields a test statistic of $F(4,5932) = 22.15$ with a corresponding P-value = 0.00. The regressions are based on 7271 observations from 5933 firms.

Source: All data used in the regressions are from Statistics Denmark.

Table 7.12, which shows the results obtained when educational types are used as explanatory variables in the first stage, also shows a positive, economically and statistically significant conditional correlation between digitalization and productivity. Across the internal functions, a one percent increase in the likelihood of digitalization implies a prediction of between 0.67 % higher productivity (for distribution) and 1 % higher productivity (for production control). The coefficient in column (5) on the predicted probability of digitalization of any function says that a one percent increase in the likelihood of digitalization of at least one of the 4 functions implies a prediction of 0.76 % higher productivity. We consider the strong positive conditional correlation between digitalization of any of the 4 internal functions and productivity found in columns (5) of Table 7.11 and Table 7.12, respectively, to be the main result of the report.

TABLE 7.12 RESULTS FROM ESTIMATIONS OF PRODUCTION FUNCTIONS. FIRST STAGE: PROBIT WITH EDUCATIONAL TYPES

The dependent variable in each column is the logarithm of value added per average employee.

	(1)	(2)	(3)	(4)	(5)
Inventory control	0.710 (4.58)				
Accounting		0.861 (4.96)			
Distribution			0.666 (3.65)		
Production control				1.037 (4.65)	
Any function					0.763 (3.77)
Capital/labor ratio	0.097 (10.56)	0.102 (11.47)	0.102 (11.28)	0.099 (11.55)	0.104 (11.78)
Export intensity	-0.050 (-0.98)	0.021 (0.56)	-0.006 (-0.11)	-0.042 (-0.80)	0.055 (1.52)
No. employees	-0.203 (-3.83)	-0.241 (-4.30)	-0.181 (-3.53)	-0.236 (-4.21)	-0.237 (-3.91)
$(\text{No. employees})^2$	0.021 (4.09)	0.024 (4.54)	0.018 (3.50)	0.021 (4.06)	0.025 (4.47)
Constant	12.916 (85.43)	12.782 (87.46)	12.905 (85.47)	13.013 (80.14)	12.731 (85.45)

Notes: Robust t-statistics adjusted for repeated observations of the same firm and the inclusion of a generated regressor are in parenthesis. An F-test of the exclusion restriction that all 4 functions can be excluded from the production function yields a test statistic of F(4,5932) = 18.61 with a corresponding P-value = 0.00. The regressions are based on 7271 observations from 5933 firms.

Source: All data used in the regressions are from Statistics Denmark.

The close correspondence between the actual proportion of firms that have digitalized and the predicted probability of digitalization in the probit model provides a nice interpretation of the correlation between digitalization and productivity: A one percentage point increase in the proportion of firms that have digitalized at least one of the main 4 functions implies that the aggregate productivity of the employees in the sample is predicted to increase by 0.72 %. As the average value added per employee was 525,807 kroner on average over the years 2007 and 2008, 0.72 % amounts to 3,786 kroner.

On the basis of these data we can conclude the following:

1. An estimate of the upper limit for how much larger value added would be if the share of firms who have digitalized at least one of the 4 functions were 1 percentage points larger can be found be assuming that the estimated relationship is representative for all firms in the private sector in Denmark. If this assumption is correct, a 1 percentage point increase in the share of firms who have digitalized at least one of the 4 functions is associated with approximately 6.5 billion kroner extra value added per year (6,486,960 thousand kroner to be precise). This corresponds to 0.44 % of average gross value added in Denmark over the years 2007 and 2008.
2. An estimate of the lower limit for how much larger value added would be if the share of firms who have digitalized at least one of the 4 functions were 1 percentage points larger can be found be assuming that the estimated relationship is only to be found in the firms who are included in our sample. If this assumption is correct, a 1 percentage point increase in the share of firms who have digitalized at least one of the 4 functions is associated with approximately 2.6 billion kroner extra value added per year (2,585,800 thousand kroner to be precise). This corresponds to 0.18 % of average gross value added in Denmark over the years 2007 and 2008.

Thus, our best estimate of the full economic effect is that it is somewhere in between these two extremes. It is not possible to say exactly what the full effect is. That depends on which assumptions about the association between digitalization and productivity in those firms that are not in our sample are considered to be most realistic.

Table 7.13 and Table 7.14 show the results from regressions where we substitute the logarithm of total factor productivity (TFP) for productivity per average employee. Total factor productivity is the portion of value added not explained by the amount of inputs used in production. The level of TFP is therefore determined by how efficiently the inputs are utilized in production and is often connected to new technologies and other innovations.

Table 7.13, which shows the results obtained when educational lengths are used as explanatory variables in the first stage, shows a positive, economically and statistically significant conditional correlation between digitalization and total factor productivity (TFP). Across the internal functions, a one percent increase in the likelihood of digitalization implies a prediction of between 0.76 % higher TFP (for inventory control) and 1.4 % higher TFP (for accounting). The coefficient in column (5) on the predicted probability of digitalization of any function says that a one percent increase in the likelihood of digitalization of at least one of the 4 functions implies a prediction of 1.6 % higher TFP. The reason why the coefficients in Table 7.13 are somewhat larger than the corresponding coefficients in Table 7.11 is that the base level of TFP as measured by the coefficient on the constant term is much smaller than the base level of labor productivity or value added per employee in Table 7.11. This implies that an equally sized variation in the dependent variable resulting from the introduction of the predicted digitalization variable is a much larger percentage of the base level in Table 7.13 than in Table 7.11.

TABLE 7.13 RESULTS FROM ESTIMATIONS OF PRODUCTION FUNCTIONS. FIRST STAGE: PROBIT WITH EDUCATIONAL LENGTHS

The dependent variable in each column is the logarithm of TFP (total factor productivity).

	(1)	(2)	(3)	(4)	(5)
Inventory control	0.757 (9.42)				
Accounting		1.394 (10.26)			
Distribution			0.793 (7.93)		
Production control				1.322 (10.05)	
Any function					1.596 (8.98)
No. employees	0.128 (2.38)	0.017 (0.29)	0.147 (2.76)	0.062 (1.15)	-0.031 (-0.49)
(No. employees)^2	0.006 (1.07)	0.013 (2.27)	0.002 (0.40)	0.006 (1.18)	0.017 (2.84)
Constant	11.212 (6.31)	11.027 (6.11)	11.094 (6.21)	11.071 (6.01)	10.850 (5.92)

Notes: Robust t-statistics adjusted for repeated observations of the same firm and the inclusion of a generated regressor are in parenthesis. An F-test of the exclusion restriction that all 4 functions are irrelevant as correlates of total factor productivity yields a test statistic of $F(4,5904) = 58.81$ with a corresponding P-value = 0.00. The regressions are based on 7243 observations from 5905 firms.

Source: All data used in the regressions are from Statistics Denmark.

Table 7.14, which shows the results obtained when educational types are used as explanatory variables in the first stage, also shows a positive, economically and statistically significant conditional correlation between digitalization and total factor productivity. Across the internal functions, a one percent increase in the likelihood of digitalization implies a prediction of between 0.85 % higher TFP (for distribution) and 1.5 % higher TFP (for accounting). The coefficient in column (5) on the predicted probability of digitalization of any function says that a one percent increase in the likelihood of digitalization of at least one of the 4 functions implies a prediction of 1.7 % higher TFP.

TABLE 7.14 RESULTS FROM ESTIMATIONS OF PRODUCTION FUNCTIONS. FIRST STAGE: PROBIT WITH EDUCATIONAL TYPES

The dependent variable in each column is the logarithm of TFP (total factor productivity).

	(1)	(2)	(3)	(4)	(5)
Inventory control	0.896 (9.80)				
Accounting		1.509 (10.13)			
Distribution			0.850 (8.26)		
Production control				1.378 (9.67)	
Any function					1.691 (9.26)
No. employees	0.111 (2.00)	0.006 (0.09)	0.141 (2.58)	0.060 (1.05)	-0.039 (-0.60)
$(\text{No. employees})^2$	0.006 (1.11)	0.013 (2.21)	0.002 (0.38)	0.006 (1.08)	0.017 (2.77)
Constant	11.210 (6.28)	11.001 (6.08)	11.086 (6.20)	11.056 (5.99)	10.815 (5.89)

Notes: Robust t-statistics adjusted for repeated observations of the same firm and the inclusion of a generated regressor are in parenthesis. An F-test of the exclusion restriction that all 4 functions are irrelevant as correlates of total factor productivity yields a test statistic of F(4,5904) = 55.41 with a corresponding P-value = 0.00. The regressions are based on 7243 observations from 5905 firms.

Source: All data used in the regressions are from Statistics Denmark.

Table 7.15 shows the results when we use ERP and CRM as measures of digitalization and regress again on value added or productivity. As in the basic model, there is an economically and statistically significant positive conditional correlation between digitalization and productivity. With educational length used as a measure of educational mix the coefficient on the ERP variable in column (1) implies that a one percent increase in the predicted probability that a firm has digitalized Enterprise Resource Planning is correlated with a 0.69 % increase in productivity. With educational types used as the measure of educational mix in the first stage probit model, the coefficient on the ERP variable in column (3) implies that a one percent increase in the predicted probability that a firm has digitalized ERP is correlated with a 0.83 % increase in productivity.

The results for CRM in columns (2) and (4) are similar. With educational length used as a measure of educational mix the coefficient on the CRM variable in column (2) implies that a one percent increase in the predicted probability that a firm has digitalized CRM is correlated with a 0.68 % increase in productivity. With educational types used as the measure of educational mix in the first stage probit model, the coefficient on the CRM variable in column (4) implies that a one percent increase in the predicted probability that a firm has digitalized Customer Relations Management is correlated with a 0.74 % increase in productivity.

TABLE 7.15 RESULTS FROM ESTIMATIONS OF PRODUCTION FUNCTIONS. FIRST STAGE: PROBIT WITH EDUCATIONAL LENGTHS/TYPES

The dependent variable in each column is the logarithm of value added per average employee.

	(1)	(2)	(3)	(4)
ERP	0.689 (4.54)		0.829 (5.47)	
CRM		0.678 (7.12)		0.735 (8.07)
Capital/labor ratio	0.104 (11.76)	0.115 (14.78)	0.099 (11.24)	0.113 (14.50)
Export intensity	-0.018 (-0.42)	0.086 (2.92)	-0.051 (-1.18)	0.081 (2.68)
No. employees	-0.277 (-4.20)	-0.192 (-3.83)	-0.306 (-4.61)	-0.198 (-3.90)
$(\text{No. employees})^2$	0.027 (4.67)	0.019 (3.81)	0.028 (4.85)	0.019 (3.73)
Constant	12.991 (71.17)	12.762 (81.08)	13.049 (69.68)	12.768 (79.42)

Notes: Robust t-statistics adjusted for repeated observations of the same firm and the inclusion of a generated regressor are in parenthesis. Columns (1) and (2) use probabilities of digitalization of ERP and CRM (as estimated in the first stage with educational lengths as explanatory variables) as explanatory variables. An F-test of the exclusion restriction that both ERP and CRM can be excluded from the production function yields a test statistic of F(2,5851) = 43.50 with a corresponding P-value = 0.00. Columns (3) and (4) use probabilities of digitalization of ERP and CRM (as estimated in the first stage with educational types as explanatory variables) as explanatory variables. An F-test of the exclusion restriction that both ERP and CRM can be excluded from the production function yields a test statistic of F(2,5851) = 51.69 with a corresponding P-value = 0.00. The regressions are based on 7271 observations from 5852 firms.

Source: All data used in the regressions are from Statistics Denmark.

Table 7.16 and Table 7.17 show the results with the predicted probability that a firm has a certain type of Internet access used as the main explanatory variables rather than digitalization measures (see Tables 7.6 and 7.17 for the first stage estimations).

In Table 7.16 where educational lengths are used as measures of educational mix, firms that the first stage model predicts to have only basic Internet access are predicted to have lower productivity than other firms. A one percentage point increase in the probability that a firm only has basic Internet access is correlated with 1.6 % lower productivity which is an economically significant correlation. The coefficient estimate is also statistically significant. Firms that have a one percentage point higher predicted probability of having access to high speed Internet are predicted to have 0.4 % higher productivity than firms that do not have access to high speed Internet. Finally, firms that have a one percentage point higher predicted probability of having access to mobile Internet are predicted to have about 0.6 % higher productivity than firms that do not have access to mobile Internet. The inference from the table is that clear: A prediction of more advanced Internet access is correlated with a prediction of higher productivity.

TABLE 7.16 RESULTS FROM ESTIMATIONS OF PRODUCTION FUNCTIONS. FIRST STAGE: PROBIT WITH EDUCATIONAL LENGTHS.

The dependent variable in each column is the logarithm of value added per average employee.

Internet	(1)	(2)	(3)
Basic (ISDN, ADSL etc.)	-1.584 (-2.36)		
High (fiber, FWA, WIMAX etc.)		0.426 (3.23)	
Mobile (3G/UMTS, Turbo 3G etc.)			0.585 (3.21)
Capital/labor ratio	0.109 (8.95)	0.105 (9.35)	0.101 (8.83)
Export intensity	-0.020 (-0.25)	0.044 (0.96)	0.057 (1.27)
No. employees	-0.114 (-1.79)	-0.181 (-2.49)	-0.184 (-2.47)
$(\text{No. employees})^2$	0.013 (2.04)	0.017 (2.49)	0.017 (2.53)
Constant	14.034 (23.80)	12.875 (63.22)	12.705 (58.00)

Notes: Robust t-statistics adjusted for repeated observations of the same firm and the inclusion of a generated regressor are in parenthesis. Column (1) uses the probability of basic internet access (as estimated in the first stage with educational lengths as explanatory variables) as explanatory variables. Column (2) uses the probability of advanced internet access (as estimated in the first stage with educational lengths as explanatory variables) as explanatory variables. Column (3) uses the probability of mobile internet access (as estimated in the first stage with educational lengths as explanatory variables) as explanatory variables. An F-test of the exclusion restriction that all three internet variables can be excluded from the production function yields a test statistic of F(3,2985) = 6.64 with a corresponding P-value = 0.00. The regressions are based on 3310 observations from 2986 firms.

Source: All data used in the regressions are from Statistics Denmark.

In Table 7.17 where educational types are used as measures of educational mix, the results are qualitatively similar to the results in Table 7.16 even though the size of the estimated coefficients are somewhat different: Firms that the first stage model predicts to have only basic Internet access are predicted to have lower productivity than other firms. A one percentage point increase in the probability that a firm only has basic Internet access is correlated with 0.8 % lower productivity which again is an economically significant correlation. In this case though, the coefficient estimate is statistically insignificant. Firms that have a one percentage point higher predicted probability of having access to high speed Internet are predicted to have about 0.5 % higher productivity than firms that do not have access to high speed Internet. Finally, firms that have a one percentage point higher predicted probability of having access to mobile Internet are predicted to have about 0.8 % higher productivity than firms that do not have access to mobile Internet. As in Table 7.16, the inference from Table 7.17 is that clear: A prediction of more advanced Internet access is correlated with a prediction of higher productivity.

TABLE 7.17 RESULTS FROM ESTIMATIONS OF PRODUCTION FUNCTIONS. FIRST STAGE: PROBIT WITH EDUCATIONAL TYPES.

The dependent variable in each column is the logarithm of value added per average employee.

Internet	(1)	(2)	(3)
Basic (ISDN, ADSL etc.)	-0.791 (-0.90)		
High (fiber, FWA, WIMAX etc.)		0.473 (3.40)	
Mobile (3G/UMTS, Turbo 3G etc.)			0.761 (4.01)
Capital/labor ratio	0.112 (8.59)	0.102 (9.08)	0.095 (8.17)
Export intensity	0.055 (0.58)	0.034 (0.71)	0.035 (0.73)
No. employees	-0.093 (-1.49)	-0.188 (-2.65)	-0.210 (-2.88)
$(\text{No. employees})^2$	0.013 (1.94)	0.017 (2.54)	0.018 (2.69)
Constant	13.359 (17.68)	12.899 (63.31)	12.706 (55.83)

Notes: Robust t-statistics adjusted for repeated observations of the same firm and the inclusion of a generated regressor are in parenthesis. Column (1) uses the probability of basic internet access (as estimated in the first stage with educational lengths as explanatory variables) as explanatory variables. Column (2) uses the probability of advanced internet access (as estimated in the first stage with educational lengths as explanatory variables) as explanatory variables. Column (3) uses the probability of mobile internet access (as estimated in the first stage with educational lengths as explanatory variables) as explanatory variables. An F-test of the exclusion restriction that all three internet variables can be excluded from the production function yields a test statistic of $F(3,2985) = 6.98$ with a corresponding P-value = 0.00. The regressions are based on 3310 observations from 2986 firms.

Source: All data used in the regressions are from Statistics Denmark.

Table 7.18 shows the results for estimations of the conditional correlations between productivity and two measures of digitalization, first the probability that a firm has digitalized at least one internal function and second the probability that the firm has digitalized Supply Chain Management, a measure of external function digitalization. The first two columns show the results for estimations of productivity functions when we use educational lengths as the measure of educational mix in the first stage and columns (3) and (4) show the results for estimations of productivity functions when we use educational types as the measure of educational mix in the first stage.

Table 7.18 shows that digitalization of Supply Chain Management is economically and statistically significantly positively correlated with productivity. The coefficients on the predicted probability of digitalization of Supply Chain Management in columns (2) and (4) are more than twice as large as the coefficients on our main measure of internal function digitalization shown in columns (1) and (3). For example, the coefficient estimate of 1.565 in column (2) implies that a one percent increase in the probability that a firm has digitalized Supply Chain Management is correlated with a 1.57 % increase in productivity.

TABLE 7.18 RESULTS FROM ESTIMATIONS OF PRODUCTION FUNCTIONS. FIRST STAGE: PROBIT WITH EDUCATIONAL LENGTHS

The dependent variable in each column is the logarithm of value added per average employee.

	(1)	(2)	(3)	(4)
Any internal function	0.725 (3.57)		0.783 (3.92)	
Supply chain management		1.565 (3.30)		1.593 (3.98)
Capital/labor ratio	0.105 (12.63)	0.106 (12.50)	0.104 (12.64)	0.106 (12.60)
Export intensity	0.056 (1.51)	0.058 (1.31)	0.049 (1.29)	0.057 (1.26)
No. employees	-0.236 (-3.80)	-0.183 (-3.44)	-0.241 (-4.00)	-0.191 (-3.64)
$(\text{No. employees})^2$	0.025 (4.44)	0.014 (2.55)	0.025 (4.52)	0.015 (2.71)
Constant	12.736 (84.56)	12.800 (80.50)	12.732 (83.26)	12.815 (80.30)

Notes: Robust t-statistics adjusted for repeated observations of the same firm are in parenthesis. Columns (1) and (2) use probabilities of digitalization of any of the functions, Inventory control, Accounting, Distribution, and Production control and supply chain management (as estimated in the first stage with educational lengths as explanatory variables) as explanatory variables. An F-test of the exclusion restriction that both ERP and CRM can be excluded from the production function yields a test statistic of F(2,5819) = 20.69 with a corresponding P-value = 0.00. Columns (3) and (4) use probabilities of digitalization of any of the functions, Inventory control, Accounting, Distribution, and Production control and supply chain management (as estimated in the first stage with educational types as explanatory variables) as explanatory variables. An F-test of the exclusion restriction that both ERP and CRM can be excluded from the production function yields a test statistic of F(2,5819) = 28.64 with a corresponding P-value = 0.00. The regressions are based on 7129 observations from 5820 firms.

Source: All data used in the regressions are from Statistics Denmark.

Table 7.19 and Table 7.20 show the results when we use the basic setup from Table 7.11 and Table 7.12 respectively, but where we have added IT expenditures of firms as an explanatory variable in the first stage probit models the results of which are displayed in Table 7.9 and Table 7.10. Because only 1168 firms have answered both questionnaires used to obtain data on digitalization and IT expenditures the data sample for the regressions in Table 7.19 and 7.20 are much smaller than the samples available for the regressions shown in Table 7.11 and 7.12.

In contrast to the results in Table 7.11 and Table 7.12, all coefficient estimates on the digitalization variables in Table 7.19 and Table 7.20 are statistically insignificant, with the sole exception of the coefficient on the predicted probability of digitalization when educational types are used as measures of educational mix, even though they are positive and in some cases economically significant. We do not believe however, that the insignificant coefficient estimates challenge our main results. The sample is very small and the coefficients on the digitalization variables in the second stage are also small and statistically insignificant if we estimate the basic model – i.e. the model without IT expenditures – but with the same restricted set of observations as in Table 7.19 and Table 7.20 which suggests that the reason for the change in results is the reduction in the sample size rather than the inclusion of IT expenditures.

TABLE 7.19 RESULTS FROM ESTIMATIONS OF PRODUCTION FUNCTIONS. FIRST STAGE: PROBIT WITH EDUCATIONAL LENGTHS AND IT EXPENDITURES.

The dependent variable in each column is the logarithm of value added per average employee.

	(1)	(2)	(3)	(4)	(5)
Inventory control	0.160 (0.46)				
Accounting		0.394 (1.14)			
Distribution			0.571 (1.91)		
Production control				0.407 (1.21)	
Any function					0.056 (0.14)
Capital/labor ratio	0.098 (4.68)	0.096 (5.13)	0.089 (4.57)	0.093 (4.63)	0.102 (5.52)
Export intensity	-0.002 (-0.02)	0.005 (0.008)	-0.098 (-1.11)	-0.026 (-0.36)	0.031 (0.52)
No. employees	0.082 (0.70)	0.038 (0.31)	0.031 (0.28)	0.055 (0.49)	0.096 (0.74)
$(\text{No. employees})^2$	-0.004 (-0.38)	-0.001 (-0.11)	-0.003 (-0.29)	-0.003 (-0.28)	-0.004 (-0.40)
Constant	12.341 (36.28)	12.354 (39.45)	12.529 (37.58)	12.404 (37.60)	12.280 (39.20)

Notes: Robust t-statistics adjusted for repeated observations of the same firm and the inclusion of a generated regressor are in parenthesis. An F-test of the exclusion restriction that all 4 functions can be excluded from the production function yields a test statistic of $F(4,1167) = 4.60$ with a corresponding P-value = 0.00. The regressions are based on 1168 observations from 1168 firms.

Source: All data used in the regressions are from Statistics Denmark.

TABLE 7.20 RESULTS FROM ESTIMATIONS OF PRODUCTION FUNCTIONS. FIRST STAGE: PROBIT WITH EDUCATIONAL TYPES AND IT EXPENDITURES.

The dependent variable in each column is the logarithm of value added per average employee.

	(1)	(2)	(3)	(4)	(5)
Inventory control	0.276 (0.70)				
Accounting		0.645 (1.70)			
Distribution			0.619 (2.35)		
Production control				0.521 (1.43)	
Any function					0.366 (0.73)
Capital/labor ratio	0.094 (4.36)	0.092 (4.73)	0.088 (4.61)	0.091 (4.50)	0.098 (5.17)
Export intensity	-0.029 (-0.28)	-0.012 (-0.19)	-0.108 (-1.30)	-0.044 (-0.56)	0.013 (0.20)
No. employees	0.066 (0.56)	-0.001 (-0.01)	0.026 (0.24)	0.043 (0.39)	0.044 (0.32)
$(\text{No. employees})^2$	-0.003 (-0.32)	0.001 (0.09)	-0.003 (-0.29)	-0.002 (-0.25)	-0.001 (-0.11)
Constant	12.387 (35.22)	12.403 (38.69)	12.553 (38.42)	12.438 (37.57)	12.335 (37.90)

Notes: Robust t-statistics adjusted for repeated observations of the same firm and the inclusion of a generated regressor are in parenthesis. An F-test of the exclusion restriction that all 4 functions can be excluded from the production function yields a test statistic of F(4,1167) = 9.94 with a corresponding P-value = 0.00. The regressions are based on 1168 observations from 1168 firms.

Source: All data used in the regressions are from Statistics Denmark.

Table 7.21 and Table 7.22 use a somewhat different setup from the other tables in section 7.3. For each first stage regression the firms were separated into two exclusive categories: Those that have digitalized at least a certain number of functions and those that had not. For example, the main explanatory variable of interest in column (2) in Table 7.21 is the predicted probability - obtained from a first stage regression - that a firm has digitalized at least two of the main functions under consideration. The coefficient on the '2 or more functions' variable can therefore be interpreted to mean that a one percent increase in the probability of having digitalized at least 2 functions implies a 0.75 % increase in productivity. Across the columns in Table 7.21 the coefficients on the predicted probability variable are qualitatively similar so that in general firms that have a one percentage point higher probability of having digitalized more functions are predicted to be between 0.65 % and 0.82 % more productive than otherwise identical firms. The results do not allow us, however, to conclude that 'more is better' with respect to number of functions that are digitalized.

TABLE 7.21 RESULTS FROM ESTIMATIONS OF PRODUCTION FUNCTIONS. FIRST STAGE: ORDERED PROBIT WITH EDUCATIONAL LENGTHS

The dependent variable in each column is the logarithm of value added per average employee.

	(1)	(2)	(3)	(4)
At least 1 function	0.652 (4.69)			
2 or more functions		0.754 (5.62)		
3 or 4 functions			0.821 (5.87)	
All 4 functions				0.784 (5.12)
Capital/labor ratio	0.104 (11.37)	0.100 (10.83)	0.099 (10.87)	0.103 (11.63)
Export intensity	0.041 (1.18)	-0.013 (-0.34)	-0.053 (-1.26)	-0.035 (-0.81)
No. employees	-0.237 (-3.51)	-0.242 (-3.67)	-0.206 (-3.31)	-0.155 (-2.60)
(No. employees)^2	0.025 (3.76)	0.024 (3.67)	0.019 (3.06)	0.0150 (2.39)
Constant	13.451 (55.93)	13.681 (53.79)	13.794 (52.61)	13.683 (52.41)
Mean probability of being in category	0.317	0.446	0.614	0.740

Notes: Robust t-statistics adjusted for repeated observations of the same firm are in parenthesis. The excluded category in each column is firms predicted to have digitalized the number of functions not listed in the name of the row variable (e.g. the excluded category in column 1 is firms that are predicted not to have digitalized any, while the excluded category in column 3 is firms that are predicted to have digitalized 0, 1, or 2 functions). The regressions are based on 7271 observations from 5933 firms.

Source: All data used in the regressions are from Statistics Denmark.

Table 7.22 shows the results where educational types rather than educational lengths were used in each of the first stage regressions to predict the probability that a firm belongs to either of the two categories into which the firms were separated. The coefficients are somewhat larger than in Table 7.21 but the results are otherwise qualitatively similar. For example, a one percent increase in the probability of having digitalized at least 2 functions implies a 0.84 % increase in productivity compared to 0.75 % in Table 7.21. As in Table 7.21, across the columns in Table 7.22 the coefficients on the predicted probability variables are qualitatively similar so that in general firms that have a one percentage point higher probability of having digitalized more functions are predicted to be between 0.71 % and 0.91 % more productive than otherwise identical firms.

TABLE 7.22 RESULTS FROM ESTIMATIONS OF PRODUCTION FUNCTIONS. FIRST STAGE: ORDERED PROBIT WITH EDUCATIONAL TYPES

The dependent variable in each column is the logarithm of value added per average employee.

	(1)	(2)	(3)	(4)
At least 1 function	0.714 (4.98)			
2 or more functions		0.837 (6.12)		
3 or 4 functions			0.906 (6.23)	
All 4 functions				0.841 (5.15)
Capital/labor ratio	0.102 (11.21)	-0.837 (-6.12)	0.097 (10.50)	0.101 (11.28)
Export intensity	0.029 (0.81)	-0.031 (-0.81)	-0.072 (-1.68)	-0.045 (-1.01)
No. employees	-0.246 (-3.77)	-0.253 (-3.91)	-0.212 (-3.44)	-0.155 (-2.62)
(No. employees)^2	0.026 (3.89)	0.024 (3.74)	0.019 (3.03)	0.014 (2.29)
Constant	13.516 (58.50)	13.782 (55.48)	13.901 (52.95)	13.751 (51.58)
Mean probability of being in category	0.317	0.446	0.614	0.740

Notes: Robust t-statistics adjusted for repeated observations of the same firm are in parenthesis. The excluded category in each column is firms predicted to have digitalized the number of functions not listed in the name of the row variable (e.g. the excluded category in column 1 is firms that are predicted not to have digitalized any, while the excluded category in column 3 is firms that are predicted to have digitalized 0, 1, or 2 functions). The regressions are based on 7271 observations from 5933 firms.

Source: All data used in the regressions are from Statistics Denmark.

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