The Knowledge Structure of the Danish Economy - Does Formal Education Matter in Production?

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Abstract

This paper performs a preliminary analysis of the importance of formal education in production using input-output statistics combined with statistics on the formal educational qualifications of the employed workforce. The main aim of the paper is to contribute to the ongoing debate of the "knowledge based economy" and the increased importance of human capital. The analysis is limited to the manufacturing sectors.. The sectoral analysis is performed on an aggregation of the manufacturing sectors according to their production and innovation characteristics in relation to Pavitt's Taxonomy. Remarkable sectoral differences are found when assessing the importance of formal education on productivity

1. Introduction

The main aim of this paper is to contribute to the ongoing discussion on the concept of a *knowledge-based economy* (see e.g. OECD, 1996) through an empirical analysis of the knowledge structure of the Danish economy. A knowledge based economy is characterised by an increasing importance of human capital which is expanded with an increased knowledge through learning[1] as well as diffusion of knowledge through interaction.

The analysis is part of a project aiming at enhancing the knowledge on the Danish System of Innovation and to give policy making in Denmark a stronger analytical foundation.[2] A more general objective is to confront the theoretical analysis on systems of innovation, defined as

> *constituted by elements and relationships which interact in production, diffusion and use of new, and economically useful, knowledge and .... encompasses elements and relationships, either located within or rooted inside borders of a nation state.*
> (Lundvall, 1992, p. 2)

which is presented in Lundvall (1992), with systematic empirical testing and to develop a general methodology for studying national innovation systems which takes into account that innovation is an interactive learning process rooted in the system of production. One element of this analysis is to map the structure of the Danish Innovation System in order to identify the most and the least dynamic parts of the system. Central questions concern the dynamics of the system in relation to different factors of production, learning processes and the development of demand. The over all objective of the project is to analyse the development towards a more knowledge-intensive economic structure and to confront it with economic performance in terms of economic growth and employment.

This paper presents an analysis of the knowledge structure of the Danish economy as expressed by formal educational qualifications. Through the combination of input-output-tables and educational statistics the paper performs an analysis of the knowledge used in production for final demand, as well as the linkage between formal education and productivity growth at the sectoral level.[3]

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1 The term "learning economy" is preferred by some in order to stress the dynamic character of the system in question, see e.g. Foray and Lundvall (1996).

2 The DISKO project (a comparative analysis of the Danish innovation system).

3 An alternative way of analysing human capital in an input-output framework is presented in Aulin-Ahmavaara and Aulin (1992). Here the ordinary input-output production sectors are supplemented with sectors of human capital, defined as education obtainable by studying in schools or courses, as well as

The paper focus on the manufacturing sectors, using Pavitt's Taxonomy as a framework for the analysis. Pavitt's Taxonomy (1984) identifies differences in the importance of different sources of innovation according to which broad sector the individual firm belongs to. The taxonomy of firms according to principal activity - explained by the sources of technology; the nature of users needs; and means of appropriation - emerged out of a statistical analysis of more than 2,000 postwar innovations in Britain.

Using the taxonomy for an analysis of sectoral development is transferring the underlying structure to a different context which is expected to share some basic characteristics.

The four sectoral groupings are:

* the supplier dominated sectors which use their suppliers as the main source of technology;

* the scale intensive sectors which engage mainly in production engineering and R&D in order to acquire and develop technology;

* the specialised suppliers which are to a large extent relying on design and development and well as their users as sources of technology;

* the science based sectors which rely heavily on R&D, public science and research as well as production engineering as their main sources of technology.

2. Human capital in the knowledge based economy

The characteristics of a knowledge based economy is that knowledge, in all its forms, plays a growing and crucial role in economic processes such as production, competition, distribution and growth. Thus intangible investments are growing more rapidly than physical investments: we see increasing investments in all forms of knowledge by individuals, firms and nations (Guellec, 1996, p. 18-19). Knowledge can appear in various forms: it can be disembodied in the form of blueprints or procedures; it can be embodied in material devices, machines or intermediate goods (physical capital); or it can be embodied in human brains or bodies or in groups of individuals, i.e. human

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sectors of human time. The aim of the model is to incorporate the production of human capital in order to give a more accurate picture of the state and progress of national economies in a time where the importance and production of human capital resources increases all the time. While the overall aim of the Aulin-Ahmavaara/Aulin model is to influence national accounting in order to take human capital into account, the aim of the present analysis is a more moderate assessment of the importance of education in production in the Danish economy during the past decade.

capital (ibid., p. 20).

There are severe problems in defining and measuring the skills and competences as well as the related knowledge and understandings, which together represent the human capital of an individual. Formal education is chosen as an indicator of human capital building in this paper based on the assumption that formal education increases the abilities for expanding the multifaceted human capital. There are several weaknesses in using educational attainment as a proxy of skills and competences: it does not capture experience; it understates participation in further education and training; it is to a large extent one-dimensional since it often only measures the length of studies; it is a bad indicator of the quality of what has been learned etc. Despite all these “pitfalls” of using educational statistics measures of educational attainment do show a fairly consistent relationship with what is commonly referred to as “human capital” and they correlate well with occupation and earnings (OECD, 1994, p. 114).[4] This does not by any means imply that the learning and skill acquisition which takes place after completion of formal education, either through self-learning, on-the-job learning, and formal enterprise-based training is without significant importance in relation to human capabilities (OECD, 1996).

The influence of technology on the need for human capital is not obvious. Guellec (1996, p. 21-22) presents two opposite views on this relationship, expressing changes in the need for human capital by the relative need for skilled as opposed to unskilled labour:

* technology is a complement for unskilled labour, or a substitute for skilled labour based on the hypothesis that technical change results in a de-skilling of the labour force, and an embodiment of a decreasing quantity of knowledge in the labour force as the knowledge stock grows, with an increasing share being embodied in machines and products (i.e. the “Marxian” view that capitalists try to weaken the bargaining position of the workers by depraving them control of knowledge);

* the higher the level of technology, the larger is the demand for skilled labour based on the assumption that technology is complementary to physical capital and to skilled labour due to the importance of the human component in the implementation, maintenance and adaption to special uses of technology.

This paper builds on the second assumption, that human capital is necessary in order to master

4 The argument for using educational statistics for an analysis of this sort is parallel to Schmookler’s reasoning behind using patent statistics as an indicator of inventions: "We have a choice of using patent statistics cautiously and learning what we can from them, or not using them and learning nothing about what they can teach us." (Schmookler, 1966, p. 56).

technology and drive technological development. This is to some extent based on empirical results. In this context, European studies comparing firms making the same products with similar technology but with production workers possessing different levels of skills, found a higher productivity among those firms with higher levels of skill (Mason, 1992;OECD, 1994). However these comparisons were performed across national borders and should be interpreted with caution due to possible other, country specific determining factors.

The relation between level of formal education and productivity in the Danish economy is explored in section 4. Before turning to this analysis, the relation between educational levels and production for final demand is explored in order to reveal which areas of production are the most knowledge intensive.

3. The knowledge content in the production for final demand

As shown in table 1, the science based sectors have the largest fraction of highly educated employees. This observation is in accordance with what can be expected for sectors which, to a large extent, depend on R&D and the use of public science and research, following the assumption that human skills are necessary, not only to develop new technology, but also to use technology acquired from the outside (e.g. public R&D). The fraction of unskilled employees is also quite high though which could indicate either that there is also some element of truth in the opposite statement, that human capital is not necessary for the “on the floor production” using high technology, or it could be an indicator of the limitations in using formal education alone as an indicator of human capital ignoring the possibilities of on the job expert training. This question will be left open for further research.

The scale intensive sectors are, also not surprisingly, the largest employers of unskilled labour with no formal education since these are the sectors relying heavily on assembly line production. The supplier dominated sectors, together with the specialised suppliers, have a majority of skilled employees, i.e. employees with vocational training. The supplier dominated sectors differ from the specialised suppliers in the importance of higher educated employees, where specialised suppliers have a considerably larger fraction of highly educated employees which illustrates the need for knowhow and knowledge of users (specialised suppliers are expected to work closely together with science based sectors). All sectors show an increased fraction of both employees with vocational training as well as higher educated employees, with the science based sectors showing the largest relative increase in the importance of graduates from advanced studies. This overall increase in educational level is in accordance with observations from the OECD, showing that there has been an increase in the use of skilled labour relative to unskilled labour across all industrial sectors (Guellec, 1996, p. 28).

Table 3.1: Educational levels of employees (percentage of all)

	Supplier dominated		Scale intensive		Specialised suppliers		Science based		Total economy[5]	
	1984	1992	1984	1992	1984	1992	1984	1992	1984	1992
No formal education[6]	39	33	48	40	31	27	38	31	38	31
Vocational training	53	57	44	50	53	56	42	43	43	47
Advanced studies (short)	4	4	3	4	5	7	7	10	6	7
Advanced studies (medium)	3	5	3	4	7	8	7	9	9	10
Advanced studies (long)	1	1	1	2	2	2	5	7	4	5
Engineers	5	7	4	5	10	12	12	15	3	4

When limiting the knowledge indicator to number of engineers as a percentage of the total workforce[7] the science based sectors again stands out as having a large fraction of engineers compared to the economy average. This is also the case for the specialised suppliers. The supplier dominated and scale intensive sectors have a considerably lower fraction of engineers, but they are, as should be expected for manufacturing sectors, above the average for the economy as a whole. The conclusion from the findings in table 3.1 is that the manufacturing industries mainly increase their knowledge levels by substituting unskilled labour with skilled labour, but the fraction of higher educated employees is also raising, mainly in the form of engineers.

Even though the data shows an increase in the relative importance of educated employees, 30 per cent of the employed part of the work force is still lacking any form of formal education in 1992 though, which invites to a further investigation of the role that formal education plays in relation to production.

Moving further on to an analysis of the development of the composition of the production for final

5 Also including non-manufacturing sectors.

6 In the sense no formal education other than elementary school (or grammar school).

7 The use of technical engineers as an expression or indicators of technological capabilities is commonly used, e.g. by Schmookler (1966, pp. 27-8) who links technological change to educational qualifications. His findings displayed a similar trend in the development in the number of corporate patents issued in the United States and in the development in the number technical engineers in the US economy.

demand[8], we come to a result of stability: the composition of the final demand show very small changes between 1984 and 1992, with export being dominated by scale intensive sectors (46 per cent), domestic consumption being dominated by trade & services (39-41 per cent), but with scale intensive sectors being the dominant manufacturing sectors also in relation to this final demand group.

Table 3.2: Production for final demand, selected demand groups (percentage)

	Private consumption		Public consumption		Investment		Export		Total	
	1984	1992	1984	1992	1984	1992	1984	1992	1984	1992
Supplier dominated	5.2	3.8	0.0	0.0	67.8	65.7	11.5	9.1	12.6	10.7
Scale intensive	16.4	15.1	0.0	0.0	9.0	9.3	46.0	46.4	19.8	22.1
Specialised suppliers	0.2	0.2	0.0	0.0	8.5	8.3	9.7	8.1	3.9	3.6
Science based	0.3	0.4	0.0	0.0	2.6	2.2	5.8	5.6	2.1	2.3
Primary sectors	1.7	1.5	0.0	0.0	0.0	0.0	5.3	4.5	2.4	2.0
Trade & services	38.6	40.5	0.0	0.0	12.2	14.5	21.3	25.8	23.1	25.2
Public services	10.3	12.3	100.0	100.0	0.0	0.0	0.5	0.6	26.9	25.5
Other	27.2	26.3	0.0	0.0	0.0	0.0	0.0	0.0	9.3	8.7

In relation to investments the supplier dominated sectors are by far the largest (due to investments in construction), with supplier dominated sectors and specialised suppliers playing a secondary role, and science based sectors playing a minor role. In relation to other final demand categories, manufacturing is of little importance.

There has been no increase in the importance of the most knowledge intense sectors, i.e. science based sectors and specialised suppliers, when measured as percentage of production for final demand during the observed period.

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Calculated via a combination of input-output and education matrices:

$$U^{D} = \overline{U} q^{diag} (\overline{I} - \overline{A})^{-1} (\overline{F}) D'$$

U^D is a vector of number of employees of different educations involved in the production for final demand;
Overline**U** is matrix of coefficients of education;
q^{diag} is a diagonal-matrix of no. of employees per monetary unit of production in the sectors;
Overline **I** is a unity matrix;
Overline **A** is the traditional coefficient matrix;
Overline **F** is the coefficient matrix for final demand;
D´ is a vector for final demand (e.g. export).

The production for final demand can also be analysed in accordance to the "content" of formal education used in the production. Not surprisingly, following the dominance of scale intensive sectors in production for export, this production has a quite low knowledge content in terms of the educational level of the employees engaged in this production. In terms of engineers it is only production for investment (particularly investment in construction) which has a higher degree of engineers engaged in the production. There has been a large shift in the production for investment towards skilled workers (vocational training) during the observed period - this is mainly due to changes in the composition of skills engaged in the production for investment in machinery and inventory.

Table 3.3: The "content" of formal education in production for final demand
(percentage of employees)

	Private consumption		Public consumption		Investment		Export		Total	
	1984	1992	1985	1992	1984	1992	1984	1992	1984	1992
No formal education	44.1	36.8	37.4	31.5	41.7	31.7	49.2	40.7	41.7	34.9
Vocational training	45.0	48.1	29.4	31.8	39.6	53.9	40.2	45.5	39.6	42.9
Advanced studies (short)	3.5	4.4	9.0	10.8	5.6	4.9	4.0	5.0	5.6	6.7
Advanced studies (medium)	4.5	6.4	16.9	17.6	8.9	6.2	4.4	5.8	8.9	10.1
Advanced studies (long)	3.0	4.3	7.2	8.4	4.3	3.3	2.2	3.1	4.3	5.4
Engineers	1.90	2.20	2.11	2.58	4.48	4.93	3.23	3.85	2.53	2.96

The main picture emerging from the analysis of the production for final demand is that the Danish knowledge acquired through the formal education system has been and still is primarily engaged in production for domestic, public consumption produced in non-manufacturing sectors. As we shall see in the next section, this does not imply, that formal education is of no importance in manufacturing.

4. Formal education and performance

An incentive for hiring educated employees is that they - in theory - have a higher productivity than non-educated employees. Studies of the use of knowledge in the form of formal education in production in Denmark, treating education as an ordinary production factor, have come to the conclusion that education does only result in an individual economic gain, while the national economic benefits from education are limited: no influence on productivity could be shown, and the influence from education on *how* goods and services were produced, and on *which* goods and services were produced, turned out to be very limited in Denmark in the period 1980-1986 (Hansen, 1993, p. 262-3). Hansen draws, among other ,these conclusions on results showing no relation between productivity and educational variables. This paper argues that one reason for the lack of correlation between productivity and formal education is differences in sectoral characteristics. Table 4.1 and 4.2 below show the results of regression analyses on the relation between education and productivity in each of the four Pavitt sectoral groups. Education is measured as average years of formal education in table 4.1 and fraction of engineers (graduates from technical or science studies) in table 4.2. Productivity is in both cases measured as value added per employee. The data are pooled for the period 1984-1992; i.e. assuming a stable relationship between education and productivity during the observed period in each sector.

The tables reveals clear sectoral differences.[9] When education is measured as average years of formal education, the largest explanatory power is found for scale intensive sectors which intuitively[10] would be an indication of productivity differences between skilled and unskilled labour rather than a productivity effect of higher education. For the specialised suppliers on the other hand, it is assumed that the higher educations are of a crucial importance in determining the productivity level of the sectors. The results of table 4.2, where the fraction of engineers turn out to have a very high explanatory power, supports this assumption.

Table 4.1: The impact of educational level productivity (average years of formal education)

	Estimated intercept	Estimated independent variable	R^2	R^2(adj.)	N
Supplier dominated	60.17 (22.23)	42.83 (10.85)*	0.08	0.07	192
Scale intensive	-1,991.32 (192.51)	1,265.17 (97.67)*	0.29	0.29	408
Specialised suppliers	35.90 (35.74)	38.83 (13.85)**	0.15	0.14	45
Science based	208.23 (22.11)	-5.68 (8.57)	0.01	-0.01	45

Dependent variable: value added pr. employee
Independent variable: average number of years of formal education of employees
Standard error in brackets. */** denotes significance at the 0.1% and 1% levels respectively.

For the supplier dominated sectors, the explanatory power of the average level of education is

9 It should be noted that these simple regressions do not operate with either lags nor changes. Introduction of this could alter the results.

10 And according to table 4.2, where the number of engineers have no explanatory power in relation to productivity.

significant, but accounting for a low percentage of the variation (7 per cent),[11] while the fraction of engineers explain 21 percent of the variation of productivity, also indicating in this case, that it is rather the proportion of higher educated than skilled compared to unskilled labour, which influences the productivity.

A surprising result is that no significant effect of education on productivity can be found for the science based sectors. This can mainly be ascribed to problems of classification and aggregation[12] (see appendix 1 for a description of the aggregation of sectors) making the sectors very heterogeneous.

Table 4.2: The impact of number of engineers on productivity (no. of engineers as percentage of total employees in sector)

	Estimated intercept	Estimated independent variable	R^2	R^2(adj.)	N
Supplier dominated	165.29 (8.01)	-149.80 (21.05)*	0.21	0.21	192
Scale intensive	393.87 (80.95)	-97.94 (217.32)	0	0	408
Specialised suppliers	88.20 (6.17)	488.98 (57.94)*	0.62	0.61	45
Science based	212.25 (15.70)	-158.90 (128.31)	0.03	0.01	45

Dependent variable: value added pr. employee
Independent variable: relative number of engineers (technicians and scientists)
Standard error in brackets. * denotes significance at the 0.1% level.

If each of the sectors included in the group of science based sectors is analysed separately it shows that the fraction of engineers do explain 50 per cent of the variation in productivity (at a 5% level of significance) in manufacturing of drugs and medicine as well as manufacturing of telecommunication equipment, while the explanatory power is very low for some electronics sectors, thus making the overall explanatory powers neglectable.

When average number of years of formal education is used as the independent variable, the

11 The low explanatory power underlines the importance of expanding the analysis through including additional explaining variables, such as capital investments etc. in later versions of the paper.

12 The aggregation of sectors according to the Pavitt Taxonomy is based on Kristensen (1992).

explanatory power is again very high for manufacturing of telecommunication equipment (40 per cent at a 5% significance level) and quite high for some electronics sectors, but again the sectors that do not fit into this picture distort the aggregate regression.

5. Concluding remarks

The results of the analysis show that formal educational qualifications do matter in production, not as much in relation to final demand groups as in relation to labour productivity at the sectoral level. According to the technological characteristics of the sectors, the results indicate that it is *either* a high fraction of higher educated employees (here expressed by engineers) *or* a high average number of years of education (an expression of a large fraction of educated/skilled labour to non-educated/unskilled labour) which affects productivity. These findings illustrates the importance of further studies in this area, both in relation to a more desegregate analysis, and in relation to comparing the importance of education as an explanatory variable in relation to productivity to other, more traditional production function inspired explanatory variables. The possibility of lag structures is another field that needs further investigation. A comparison with other, closely related countries will also be very relevant in order to increase the understanding of the Danish characteristics.

The policy implications of a detailed analysis of the knowledge structure in the Danish economy concern macro policies in terms of national education strategies, as well as meso and micro sector and firm strategies. In this context this paper is a first step in order to reach a better understanding of different requirements concerning educational levels and related different economic results of investments in formal education.

References

Aulin-Ahmavaara, P., and A. Aulin (1992), 'Extended Input-Output Dynamics and the Concept of National Economy', in A. Aulin (ed.), *Foundations of Economic Development*, Berlin, Springer-Verlag.

Foray, D., and B.-Å. Lundvall (1996), 'The knowledge-based economy: From the economics of knowledge to the learning economy', mimeo, Aalborg, Department of Business Studies.

Guellec, D. (1996), 'Knowledge, Skills and Growth: some economic issues', in OECD (ed.), *STI Review No. 18*, Paris, OECD.

Hansen, C. (1993), *Uddannelse som produktionsfaktor - formelle uddannelsers betydning for økonomien i 1980'erne (Education as a factor of production - the impact of formal education on the economy in the 1980's)*, Haderslev, Institut for grænseregionsforskning (The Danish Border Region Research Institute).

Kristensen, A. (1992), 'Industriel Innovation i Danmark (*Industrial Innovation in Denmark*)', Aalborg, Aalborg University.

Lundvall, B.-Å., (ed.) (1992), *National Systems of Innovation. Towards a Theory of Innovation and Interactive Learning*, London, Pinter Publishers.

Mason, G., S.J. Prais, and B. van Ark (1992), 'Vocational Education and Productivity in the Netherlands and Britain', *National Institute Economic Review*, no. , pp. 45-63.

OECD (1994), 'The OECD Jobs Study, part II on "The adjustment potential of the labour market"', Paris, OECD.

OECD (1996), 'Indicators on Human Capital Investment: a feasibilty study', Paris, OECD.

Pavitt, K. (1984), 'Sectoral Patterns of Technical Change: Towards a Taxonomy and a Theory', *Research Policy*, Vol. 13, no. 6, pp. 343-373.

Schmookler, J. (1966), *Invention and Economic Growth*, Cambridge, Mass. and London, Harvard University Press.

Appendix 1 -Aggregation of manufacturing sectors

Supplier dominated:

29000 Other mining
32118 Spinning, weaving etc. textiles
32120 manuf. of made-up textile goods
32130 Knitting mills
32158 Cordage, rope and twine industries
32200 Manuf. of wearing apparel
32300 manuf. of leather products
32400 manuf. of footware
33100 Manuf. of wood products, excl. furniture
33200 Manuf. of wooden furniture etc.
34110 Manuf. of pulp, paper, paperboard
34128 Manuf. of paper containers, wallpaper
34210 Reproducing and composing services
34221 Book printing
34222 Offsett printing
34223 Other printing
34230 Bookbinding
34240 Newspaper printing and publishing
34291 Book and art publishing
34292 Magazine publishing
34293 Other publishing
39010 Manuf. of jewellery, etc.
39098 Manuf. of toys, sporting goods, etc.
50000 Construction

Scale intensive:

20099 Extraction of coal, oil and gas
31113 Slaughtering etc. of pigs and cattle
31117 Poultry killing, dressing, packing
31121 Dairies
31123 Processed cheese, condensed milk
31124 Ice cream manuf.
31130 Processing of fruit and vegetables
31140 Processing of fish
31151 Oil mills
31152 Margarine manuf.
31153 Fish meal manuf.
31160 Grain mill products
31171 Bread factories
31173 Cake factories
31174 Bakeries
31180 Sugar factories and refineries
31190 Chocolate and sugar confectionery
31210 Manuf. of food products n.e.c.
31229 Manuf. of prepared animal feeds
31310 Distilling and blending spirits
31338 Breweries
31400 Tobacco manuf.
35110 Manuf. of basic industrial chemicals
35120 Manuf. of fertilizers and pesticides
35130 Manuf. of basic plastic materials
35210 Manuf. of paints and varnishes
35230 Manuf. of soap and cosmetics
35290 Manuf. of chemical products n.e.c.
35300 Petroleum refineries
35400 Manuf. of asphalt and roofing materials
35510 Tyre and tube industries
35590 Manuf. of rubber products n.e.c.
35600 Manuf. of plastic products n.e.c.
36100 Manuf. of earthenware and pottery
36200 Manuf. of glass and glass products
36910 Manuf. of structural clay products
36920 Manuf. of cement, lime and plaster
36993 Concrete products and stone cutting
36998 Non-metallic mineral products n.e.c.
37101 Iron and steel works
37102 Iron and steel casting
37201 Non-ferrous metal works
37202 Non-ferrous metal casting
38121 Manuf. of metal furniture
38138 Manuf. of structural metal products
38191 Manuf. of metal cans and containers
38198 Manuf. of other fabricated metal products
38293 Manuf. of household machinery
38410 Ship building and repairing
38438 Railroad and automobile equipment
38498 Manuf. of cycles, mopeds, etc.

Specialised suppliers:

38220 Manuf. of agricultural machinery
38238 Manuf. of industrial machinery
38280 Repair of machinery
38298 Manuf. of refrigerators, accessories
38500 Proffesional and measuring equipment

Science based:

35220 Manuf. of drugs and medicine
38320 Manuf. of telecommunication equipment
38330 Manuf. of electrical home appliances
38392 Manuf. of accumulators and batteries
38398 Manuf. of other electrical supplies