Scandinavian Economic History Review

ISSN: (Print) (Online) Journal homepage: https://www.tandfonline.com/loi/sehr20

Connecting formal education and practice to agricultural innovation in Denmark (1860s–1920): a note on sources and methods

Kristin Ranestad

To cite this article: Kristin Ranestad (2020): Connecting formal education and practice to agricultural innovation in Denmark (1860s–1920): a note on sources and methods, Scandinavian Economic History Review, DOI: 10.1080/03585522.2020.1806920

To link to this article: https://doi.org/10.1080/03585522.2020.1806920

Published online: 21 Sep 2020.

SCANDINAVIAN ECONOMIC HISTORY REVIEW
https://doi.org/10.1080/03585522.2020.1806920

Connecting formal education and practice to agricultural innovation in Denmark (1860s–1920): a note on sources and methods

Kristin Ranestad

Department of Economic History, Lund University, Lund, Sweden

ABSTRACT

It is generally found that human capital has had positive effects on industrial development and economic growth. But the relationship between formal education, work practice, industrial development and economic growth, and changes over time, remains unclear, largely because of a lack of empirical evidence. This note argues that an investigation of the Danish dairy industry can contribute to further our understanding of the impacts and limitations of formal education and practice. It describes unique sources that can be used to construct a database, which in turn can be used to make an empirically solid investigation of whether, and how, knowledge learned at school and through practice contributed to technological changes, diffusion of technology and increased productivity in the Danish dairy industry from the 1860s to 1920, a period when this industry went through a technological and industrial transformation. The purpose of this planned investigation will be to fill a gap in Danish historiography, but also to contribute to the wider literature about the role of education and practice in innovation with empirical evidence, and by further developing concepts of knowledge and technology.

ARTICLE HISTORY
Received 24 November 2019
Accepted 29 July 2020

KEYWORDS
Denmark; agriculture; education; innovation; technology

JEL CODES
N33; N34; N53; N54

Introduction

This note describes the sources and methods, which can be used to make an empirical study of the impacts of formal education and practical work experience on the industrial and economic development of the Danish dairy industry from around the 1860s to after the First World War; a period when production in this industry radically altered and became highly productive. The aims here are (1) to describe unique Danish sources, namely 'the graduate biographies' which include detailed individual-level information about the education and careers of virtually all individuals with high school-, technical school-, agricultural school and university-level degrees – from Denmark or abroad – who worked in the Danish dairy industry; dairy cooperative reports with detailed information about each dairy cooperative' owners, managers, infrastructure, organisation and techniques, and other supplementary sources about the dairy industry and education; and (2) to demonstrate how these sources can be used to identify knowledge transfer from educational institutions and previous workplaces to the dairy industry; in particular whether, and how, knowledge learned at school, and through practice, encouraged and contributed to changes in technology, and to changes in productivity.

CONTACT Kristin Ranestad kriranestad@hotmail.com

Denmark is among the richest countries in the world, and its strong economic growth has relied heavily on agriculture, which from around 1870 started to become particularly productive compared to other European countries. This productivity increase was based on a change from vegetable to large-scale animal production, and a specialisation in products for exports to Britain, notably butter and pork. This transformation largely involved the introduction of new raw materials and machinery, and the organisation of small-sized farmers in dairy cooperatives.[1]

Economic historians present a number of factors when explaining the advances of the dairy cooperatives, and education is generally seen as an important factor. Yet, we lack empirical evidence of the content of the different formal educations and study programmes, and whether and how knowledge acquired at school was transferred dairies and used productively. Further analyses of the direct role that education might play in the development of the Danish dairy industry in the late nineteenth and early twentieth centuries are highly useful for at least two reasons: (1) to fill an important gap in Danish historiography, and (2) to exemplify relationships between learning systems and industrial development with an industry that was, at the time, growing radically. How can we investigate the impacts of education on the Danish dairy production? The note will describe how graduate biographies and supplementary sources can be used to 'follow' educated individuals – in particular individuals who completed primary or secondary schooling (including education at a farming or dairying school), or graduated with a degree from the Royal Veterinary and Agricultural College, Polytechnic College and foreign educational institutions – into dairies and to link their acquired knowledge, learned through formal education and work experience, to innovation.

A lack of knowledge about the impacts of education and practice on the Danish dairy industry

Denmark is today among the richest, happiest and safest countries in the world. It has developed and maintained a welfare state and ranks highly on the Human Development Index. Denmark's position was attained after a transition from being relatively backward in the eighteenth century to catching up with European industrial powers during the nineteenth century and developing unusually rapidly from the end of the nineteenth century. Agriculture played a key role in Danish economic development and from around 1870 started to become particularly productive compared to other European countries (see, e.g. Bjørn, 1988; Crafts, 1985; Ernle, 1912; Henriksen, 1993; Jensen, 1937; Kindleberger, 1951; Lampe & Sharp, 2015).

This productivity increase was based on specialised large-scale animal production for exports, notably butter and pork. The transformation involved the adoption of new raw materials, complex equipment and machinery and the organisation of small-sized farmers in cooperative dairies and slaughterhouses. Economic historians suggest that this development was due to a number of factors. Ingrid Henriksen summarises the factors that are emphasised in the literature: large cultivated land per head, investments in pigs, calves, heifers, bulls and agricultural equipment, available funds for investment, state loans, high literacy rates among farmers, perseverance of rural labour and high standard of living among workers (Henriksen, 1993). Kevin O'Rourke points out the cultural homogeneity of the Danes, which eased the formation of the cooperatives (O'Rourke, 2007, pp. 1357–1379) and Henriksen, Hviid and Sharp show that the cooperatives relied on legal institutions, which were beneficial, in particular compared to other countries (Henriksen, Hviid, & Sharp, 2012). Henriques and Sharp demonstrate that cheap and available coal from Britain, used to give power to cream separators, contributed to the formation of the cooperatives (Henriques & Sharp, 2015). Lampe and Sharp have added considerably to this history by showing in their new book that the development of the Danish dairy cooperative tradition was largely built on knowledge transferred via German elites (Lampe & Sharp, 2019).

[1] In 1882, the first dairy cooperative was established and after six years, there were cooperatives all over the country. C. Bjørn, *Dansk mejeribrug 1882–2000* (Odense, 1982), pp. 19 and 74.

The dairy cooperatives became mechanised, productive and specialised in animal products, which in turn might suggest that increased knowledge about animal farming and technical experience would be increasingly important. The cooperatives, which began expanding from 1882, largely relied on finding the best possible location; construction and installation of buildings; acquiring centrifuges, steam engines and other equipment; the implementation of cooperative laws: making of suitable contracts and organisation of work and transport (Bjørn, 1982). After planning and preparations, accounting, skills of how to use and repair equipment and machinery, building maintenance, extensive knowledge about breeding, good hygiene, keeping the right temperatures and knowledge of how to provide right fodder for the right type of cows and pigs seemed to be key for production of high-quality butter and pork. It is reasonable to assume that the agricultural performance built on complex knowledge and professionals with in-depth scientific and technical understanding, as well as long practice in the field.

This implies that formal agricultural education played a key role in the agricultural transformation. From the 1830s, study programmes were established in Denmark with the aim of providing capable professional workers for agriculture at the higher and intermediate technical levels. Folk high schools and farming schools, established from the first half of the nineteenth century, were arguably vital in the training of farmers and dairymen in Denmark (e.g. Bjørn, 1971; Henriksen, 1993; Klitmøller, 2008; Nielsen, 2012; Østergård, 1992). Lampe and Sharp find that a comprehensive set of both official and quasi-official educational institutions were involved in building the Danish dairy cooperatives. The number of students enrolled at agricultural schools increased radically from a few tens in the 1840s to more than 1000 in the 1900s (Lampe & Sharp, 2019). The Polytechnic University of Denmark was established in 1829 and offered courses in natural sciences and mechanics and the Royal Veterinary and Agricultural University opened in 1856 and provided study programmes in agriculture, agricultural economy, natural resource management, etc. However, the argument that the high level of education among farmers facilitated the spread of new and useful ideas is made without systematically exploring links between formal education and its practical use. On the one hand, there is literature focusing on the building of formal educational institutions (Agronomforening, 1996; Bendz, 1992; Boas & Oppermann, 1908; Fritzbøger, 2015; Hermansen & Lobedanz, 1958; Klitmøller, 2008; Lerche, 1999), and on the other hand, there are descriptions of the development of the industry and the technological changes (Bjørn, 1982, 1988). The work and consultancy of some of the scientists involved in building the industry have been described and a couple of surveys have been made of the educational background of some cooperative managers (Nielsen, 2004, pp. 167–172; Bjørn, 1982, pp. 32–34 and 106). In relation to the latter, we know that workers were hired and that managers were employed to administer operation at the cooperatives, and that farmers used advisory services and consultants to improve cultivation and cattle breeding (see Henriksen, 1993, p. 170; Hviid, 2006, pp. 157–184). Claus Bjørn characterises the dairy consultants as the 'intermediaries' between the science and the practical dairy work (Bjørn, 1982, p. 185), and they thus might play a key role in innovation processes. This system began officially with the 'public dairy consultant institution' in 1888–1889, yet there were dairy consultants even before then. The Royal Danish Agricultural Society, for example, employed a dairy consultant in the early 1880s. In 1894, there were four consultants, all of them employed by the dairy consultant institution, each of them responsible for their respective district in the country (Bjørn, 1982, p. 79). The consultants' work included informing about and introducing new techniques and results to the dairies, improving butter and cheese production methods, and searching for new markets (Bjørn, 1982, p. 186).

In the extension of this, it should be noted that women in Denmark were allowed to finish high school and enter university from 1875. Consequently, they could acquire formal higher education and perhaps aspire to jobs and positions in industries that they did not have access to before. However, this pattern was not necessarily evident in the dairy industry. Deborah Fink finds that women played a central role in the industry prior to mechanisation. But as the industry became mechanised from the late nineteenth century, men replaced them (Fink, 2009). Similarly, according to Bodil Hansen, men took over and women were removed from the 'cutting edge' and became marginalised

(Hansen, 2006). At this point, the hypothesis is that the dairy industry increasingly absorbed individuals – and largely men – with formal education and that knowledge learned in school contributed to the industrial transformation. However, whether formal schooling and the initiatives to train people in dairying, natural sciences, and other relevant subjects, in fact led to changes in the industry, remains unknown, and the specific role of educated women in this transition is unclear. We do not know who the educated individuals were, and whether the knowledge and skills that were learned through education, and work practice, was used in agricultural innovation, and if so, how, and for what purposes. What positions did educated individuals hold? Were they concentrated in certain work areas, technical fields or management level? What kind of tasks did they perform? The idea here is to extend our knowledge of how innovation occurred by analysing the knowledge acquired through formal education and work practice and eventually how it contributed to technical and organisational changes in the industry, and changes in productivity. Most of the educated individuals in the dairy industry probably held managing, directing and strategic technical positions, although educated workers might also hold lower practical, or technical, positions. Whether there were any difference in this respect between men and women would also be relevant to explore. An important aim will be to map which positions educated workers held before exploring why educated, or non-educated, workers would hold certain positions.

The lack of studies about the role of education in the advancement of the Danish dairy industry is in line with the broader historical studies of 'human capital', education and industrial performance, and the scarce evidence for the relationships between them. Human capital is often defined as the stock of habits, knowledge, social and personality attributes embodied in the ability to perform labour so as to produce economic value (Goldin, 2016). This concept is widely used, and was applied by the well-known economists Jacob Mincer (Mincer, 1974) and Gary Becker. In their view, human capital can be created, and can be invested in through education, practical training, etc. Gary Becker sees schooling, along with on-the-job training and so on, as an investment in human capital and regards education as a factor, which directly increases productivity. He distinguishes between 'specific' and 'general' human capital. Specific human capital refers to skills that are useful only to a single firm, whereas general human capital, such as literacy and numeracy, but also for example knowledge about mechanics or chemistry, can be useful across industries (Becker, 1975, pp. 19–37). Although there are many historical studies about human capital and education, few analyses actually investigate in detail the direct connection between learning and the use of this knowledge in a work situation (for such criticism see Locke, 1984, pp. 2–5). To fully understand the function of education and the type of knowledge that was relevant for industrial development, the ways in which learning was transformed into technological innovation should be examined more carefully.

In my doctoral research, close to all formally trained workers in Norwegian mining are mapped through the use of Norwegian graduate biographies; what they learned through their formal education, practical experience, travels and careers are analysed before their work positions and daily technical and administrative responsibilities and tasks are examined. Here, an important finding is that the recruitment of educated workers to the mining industry increased, and that their educational background largely diversified from the turn of the twentieth century. Workers with all kinds of educational degrees were recruited, such as engineering, mechanics, law, economics, high school and many others, which suggests that transfer of knowledge from schools and universities to the mining industry increased, and that the knowledge that was used by mining organisations became more specialised (Ranestad, 2018). I propose to use similar Danish sources to the ones that exist for Norway — the 'Danish graduate biographies', and complementary sources about education and dairies — to make a unique in-depth analysis of knowledge transfer from formal intermediate technical dairying and farming schools and higher technical and scientific educational institutions to the Danish dairy industry, and links between education, work and productivity.

The high literacy rates in Denmark at the time suggest that the high literacy rates in Denmark at the time, which suggests that most, if not the entire, population, including small farmers, dairymen, directors and property owners knew how to read, and perhaps also to write and calculate. This, in

turn, might have a general positive influence on people's work abilities. In particular, the mechanisation of industries during the nineteenth century and the adoption of complex machinery and equipment led to an increased use of technical manuals, user's guides and instructions, which made literacy and numeracy essential (Bruland, 2003). A highly literate population was probably an advantage for the late nineteenth-century Danish dairy industry – where a great variety of equipment tools, including centrifuges, compressors, refrigerators, pumps, kneader machines, steam engines, weighs, etc. – was introduced. This instalment, use and repair probably required a broad set of skills, including precision, accuracy and abilities to read and understand texts, figures and numbers. Such skills were less prevalent in other countries with lower literacy and numeracy rates. Taken this into account, the focus of analysis will not be on the mandatory primary education, which the entire population in Denmark was bound to, but instead on specialised educational levels. I propose using an empirical mapping approach in which entire cohorts of graduates are systematically followed through school, travels and working career, and with the purpose of analysing which practical skills and theoretical knowledge they acquired. The aim of this approach is to answer the following questions: what type of knowledge did the educational institutions provide? Was this knowledge used in the dairy industry, and if so how? Were knowledge and skills accumulated through practice at previous workplaces used at the dairies? In line with Ranestad's analysis of the Norwegian mining industry (2018), we might expect to find an increased number and share of workers in the Danish dairy industry with a broad spectre of educational backgrounds and varied work experiences in this period. At the same time, considering the radical changes that occurred in the dairy industry, industry-specific differences will probably reveal themselves. This will be important for our further understanding of the role of education in industrial development, and particularly in 'natural resource industries', i.e. industries based on natural resource utilisation. It will be relevant to consider the role of educated women in the transformation of this industry. Mapping the women with formal education in Danish agriculture, their work positions and their tasks will further our understanding of the specific effect they might have. A key point to be made here is that Danish historical sources not only enable mapping all formally educated workers in an entire industry and assessing whether their acquired knowledge and skills were relevant for the used technology – similar to the analysis of the Norwegian mining industry – but they also allow for a quantitative analysis related to specific outcomes of all firms in an industry that transformed the Danish economy.

Theories and concepts concerning education, knowledge, technology and innovation

Most historians take the view that economic development is closely connected to the creation, diffusion and adaptation of technology and much of the theoretical literature about technology conceptualises technology as knowledge. In 1965, Simon Kuznets identified useful knowledge as the source of modern economic growth (Kuznets, 1965), and since then historians, and most notably Joel Mokyr, have sought to probe what the nature and characteristics of useful knowledge is. Mokyr's argument is that an enormous increase in the knowledge base has occurred over the past two centuries, starting with British Industrial Revolution in the late eighteenth century, and is the foundation of modern economic growth and today's material world (Mokyr, 2005).

It is generally found that investment in 'human capital', and 'good quality' basic, technical and higher education systems have had positive effects on industrial development and economic growth (e.g. Easterlin, 1981; Sandberg, 1982; Ahlström, 1982; Fox and Guagnini, 1993). Part of the argument is that skilled individuals, i.e. those with formal education, were more aware of, and better able to use, new technologies than people with no or little education. Lars Sandberg stresses the importance of human capital in Swedish industrial and economic growth before the First World War (Sandberg, 1979, pp. 225–241). In another paper, Sandberg shows that there is a correlation between countries with high literacy in 1850 and the ones with high income per capita in 1970, even if they were poor in

1850. His argument is that a literate population did not necessarily lead to immediate economic growth, but gradually changed and prepared people, over generations, for a capitalist way of thinking (Sandberg, 1982; see also Cipolla, 1969). The literature dealing specifically with technical education generally finds that rich and developed countries had a high number of highly trained scientists, engineers, technicians, architects, etc., especially from the late nineteenth century onwards, while poor, less developed countries had fewer such people, suggesting that 'the more engineers the better' for industrial growth (e.g. Fox & Guagnini, 1993; Caicedo and Maloney, 2014; Lundgreen, 1990; Ahlström, 1982). Despite the achievements that have been made in our knowledge about education as a source of growth, we are a long way from a satisfactory understanding of the role of education in industrial development. In particular we lack knowledge about whether and how knowledge learned in school (primary-, secondary-, technical-, or higher schools and universities) was transferred to industries and businesses, but also whether economic development drove more people to take part in formal education over time. Our lack of knowledge arises largely because it remains very difficult to measure the effects of education, particularly in a historical context. Economists often construct measures such as 'average years of education' and 'school enrolment rates' to gauge levels of human capital (Schultz, 1961; Becker, 1975; Barro and Lee, 1996; Castelló and Domenéch, 2002; Sandberg, 1979; Baten and van Zanden, 2008; Diebolt and Hippe, 2019; Valero and Reenen, 2019); but these measures are often used to analyse quite general economic and social historical trends, leading to generalisations and simplifications. They do not show direct connections between education, industrial development and economic growth, and only analyse knowledge indirectly. A correlation between schooling, literacy and economic growth does not show the link between education and economic growth, and does not explain why, or how, a specific type of learning would be important for innovation. This, in turn, can generally be linked to a lack of historical sources and a lack of empirical evidence. I propose, through this planned investigation, to examine links in more detail by connecting learned knowledge through education and work to specific outcomes, such as changes in technology and productivity.

Scholars have at their disposal an abundance of concepts related to knowledge and innovation. Knowledge is often divided into different categories, or 'branches', such as 'scientific', 'theoretical' or 'practical' knowledge, or classified as 'codified' knowledge; knowledge which has been articulated in writing or symbols, and 'tacit' knowledge; silent knowledge that can hardly be described or explained. 'Know-what', 'know-why', 'know-who' and 'know-how' have been developed to understand the knowledge requirements for technology transfer (Foray & Lundvall, 2000). Gary Becker found that some types of knowledge are best learned in a 'practical working situation', while other types of knowledge require 'specialisation' (Becker, 1975, p. 37). While one can partly teach oneself algebra from a book, it is difficult to learn how to use a tool in this way; one needs to familiarise oneself with the tool in a practical setting in order to use it successfully (Nelson & Winter, 1982). Such tacit knowledge normally passes from person to person through 'learning by observing' and 'learning by doing' (Polanyi, 1983, p. 4; Mokyr, 2005, p. 73). 'Technology transfer' and 'knowledge transfer' — when techniques and knowledge are transferred to new settings, normally involving adaptations — is also a relevant concept in this context, since workers switched jobs and transferred skills from workplace to workplace.

All of the concepts listed are useful, but there is a need for more specific characterisations and classifications of learning and knowledge; exactly how different types of knowledge are linked to innovation and growth remains undeveloped. I propose to carefully consider the concepts we have, notably human capital and the different categorisations of learning and knowledge outlined above; but also to further advance knowledge concepts relevant for the dairy industry based on an empirical analysis of 'places of learning', i.e. locations from where individuals who worked at dairies acquired knowledge, notably educational institutions, such as agricultural schools, technical schools, universities and polytechnic universities, but also places where learning by doing might be more dominant, such as laboratories and workplaces (either in agriculture or in other industries, in Denmark or abroad), or other organisations. An important part of the planned analysis should

include conceptualising the knowledge that people with education learned through 'education' and 'work', before determining whether, and if so how, this knowledge was transferred and applied in the dairy industry (for details, see methodology).

A wide definition of 'technology' would be 'the manipulation of nature for human material gain', or all the knowledge and processes required in relation to production for economic uses (Mokyr, 2005). More precisely, innovation refers to all changes in technology, both radical changes, such as the introduction of a new machine, which for example enables the production of a new product, as well as small, incremental changes, such as modifying a technique that is already in use. Bruland and Mowery provide a more concrete definition; they divide technology into three main categories: knowledge, techniques and organisation. *Knowledge* entails the understanding and skills necessary for production and can involve scientific knowledge and natural laws as well as engineering, know-how and operative skills; *techniques*, are the use of machines, tools and equipment in production, as well as the instructions and processes required to employ, repair and maintain these; and *organisation* involves the administration, management and coordination systems enabling production to occur. All three aspects of technology are integrated into the production process (Bruland & Mowery, 2014). Bruland and Mowery's definition is appropriate in an analysis of the Danish dairy industry, although it would be useful to specify the concept further by identifying and characterising the particular *techniques* and *organisation* used by dairies in their production of agricultural products. The next step would be to link these outcomes to what educated workers at dairies learned at school and from work experience.

Empirical material

I propose to analyse the knowledge that was acquired through formal education and work experience, and how this knowledge eventually was used to change and adopt technology, and to increase productivity, by using a combination of (1) individual graduate biographies; (2) detailed reports of all dairies; (3) historical census registers, (4) dairy cooperative archives; (5) study programme curricula; (6) magazines and journals.

Individual graduate biographies

Denmark had a tradition of publishing printed 'graduate yearbooks' in the nineteenth and early twentieth centuries. The University, high schools, folk high schools, farming schools, the Polytechnic College and the Royal Veterinary and Agricultural College published yearbooks in which the graduates reported about their life and work after they had finished their education. These volumes include rich, detailed biographies on the individual-level describing, among other things, formal education, working experience, name of workplaces, positions, and travels abroad, of entire cohorts of high school, folk high school, agricultural school and university-level cohorts. The information was collected individually from the graduates via questionnaires, which were sent out to the entire cohort by yearbook editors – anniversary book committees, former students, or external editors – who then collated, organised and published the information. It should be noted that the questionnaires used as basis for the biographies vary slightly from year to year, but they cover information about family, education and travel and work career. The information found in the biographies normally includes the following details: (1) first and last name; (2) birthplace; (3) date of birth; (4) school/university (name and graduation); (5) parents' names; (6) father's occupation; (7) spouse (name and family); (8) children (names, sometimes birthplace and date of birth); (9) study travels (purpose of travels, countries, organisations visited, and travel period); (10) scholarships (often the names); (11) work abroad (countries, companies/organisations, often work positions and often period of work); (12) work in home country (companies/organisations, often work positions and often period of work) and (13) memberships (often associations, professional organisations, etc.). The biographies thus provide much more comprehensive personal information than that found in historical

Table 1. Four examples from Danish yearbooks.

Søren Madsen, graduated from the Royal Veterinary and Agricultural College in 1880. He was a teacher at Jandrup College 1880-82, school tenant at Søgaard Farming School 1882-84, teacher at Lustrupholm College at Ribe 1884-85 and teacher at Grejsdalens Farming School 1885-88, before becoming manager of the dairy cooperative Kronborg at Lunderskov in 1888. The year after, in 1889 he switched, as manager, to the dairy cooperative Hjortsberg at Nykøbing. In 1894, he became owner of the dairy in Ring at Avning, a position he held until 1897.
Ivar Nissen Dall, born in 1851, graduated from the Royal Veterinary and Agricultural College in 1874. He "learnt about dairying" at farms in Gjeddesdal at Taastrup and Havarthi at Holte, and became "dairy assistant" in Sallin in 1875. During winters, he was teacher at Søgaard College. From 1877 to 1904 he owned a farm in Bastrup at Vamdrup, and in 1889, he became dairy consultant for Funen and Southern Jutland. In 1903, he became state consultant in dairying, a position he held until he died in 1907. In parallel, he held positions as manager at the Office for Dairy-Statistics.
I. Nissen Dall graduated from the Royal Veterinary and Agricultural College in 1874. He was owner of a farm (Skanderup at Vamdrup) and at the same time state consultant in dairying in Fredericia from 1885 to 1897.
S. Jørgensen graduated from the Royal Veterinary and Agricultural College in 1885. He worked in dairying ("mejerist") from 1885 and became manager at Asaa dairy cooperative from 1890, a position he held until at least 1897.

Sources: L. P. M. Larsen, Danske landbrugskandidater deres virksomhed og addresser (Copenhagen, 1911); Foreningen af danske Landbrugskandidater, Fortegnelse over Danske Landbrugskandidater Deres virksomhed og adresser (Copenhagen, 1897); Foreningen af danske Landbrugskandidater, Fortegnelse over Danske Landbrugskandidater Deres virksomhed og adresser (Copenhagen, 1918).

censuses as they include specifics on study programmes followed, educational institutions attended, type and date of degrees awarded, plus often complete career histories up to the date of publication.

The Danish yearbooks were part of a larger Nordic tradition of publishing biographies of graduates from universities and technical schools. The 'Nordic graduate yearbooks' are markedly different from 'student yearbooks' published by schools and colleges in other countries to commemorate the past year, as they include information about study and work *after* graduation (see examples in Table 1).

Because of the extensive information that can be found, it is clear that the graduate biographies are highly useful in analyses of education and industrial performance. I propose to use all existing Danish graduate yearbooks that include graduates who at some point during their career worked in the dairy industry (between 1860s and 1920), which – found – are shown in Table 2.

Detailed reports of all dairies

In addition to the biographies, reports of the dairy industry – Appel, H. (red.) (1915–1918): *Danske mejerier*, *vol. 1–4* – include historical descriptions of each and every cooperative that were registered in Denmark in 1915–1918.[2] These reports were made when dairy cooperatives were at their height

Table 2. Danish graduate yearbooks.

Type of yearbook	Description	Reference
'Polytechnic College and The Royal Veterinary and Agricultural College yearbooks'	These yearbooks include short biographies with names, degree (name of discipline and exam year), line of work and workplaces of all individuals who graduated from the Polytechnic College and The Royal Veterinary and Agricultural College.	Voigt, J. J. (1903): *Danske Landbrugskandidater, deres Virksomhed og Adresser. København*. Foreningen af danske Landbrugskandidater (1869, 1883, 1897, 1911, 1918, 1928, 1944, 1955): Danske Landbrugskandidater, deres Virksomhed og Adresser. København; Dansk Agronomforening (1996): *Biografisk fortegnelse over danske agronomer.* København.; *Festskrift udgivet i anledning af Foreningen af Agronomstuderendes 50 års jubilæum* (1971): København; Suhr, K. (1996): *Danske landbrugskandidater og agronomer 1856–1995, en oversigt over personer, som i perioden 1856–1995 har fået tildelt titlen som landbrugskandidat, cand.agro., agronom eller andet tilsvarende fra Den Kongelige Veterinær – og Landbohøjskole* (1887). Danmark.
'High school yearbooks'	These yearbooks include rich and detailed biographies with information about names, education (high school and higher education, institution, degree and year), travels abroad and career histories of entire high school graduate cohorts in Denmark from 1812 to 1923. The volumes were published 25, 30, 40 and/or 50 years after graduation.	*Studenterne, personalhistoriske* oplysninger (1812–1923). København.
'Polytechnic College yearbooks'	These yearbooks include biographies with information about names, degrees, year of graduation, careers and occupations of all the Polytechnic College's graduates.	Dansk Ingeniørforening. *Dansk Civilingeniørstat 1942. Biografiske Oplysninger om polytekniske Kandidater 1829–1941. Med et Tillæg indeholdende biografiske Oplysninger om 226 af Dansk Ingeniørforenings Medlemmer, der ikke er udgaaet fra Den polytekniske Læreanstalt*. København: Dansk Ingeniørforening; Hannover, Aage (ed.) (1956): *Dansk civilingeniørstat 1955: biografiske Oplysninger om polytekniske Kandidater 1829–1955*. København; Jespersen, R. (1930): *Biografiske Oplysninger angaaende Den polytekniske Læreanstalts Kandidater 1829–1929, Med et Tillæg indeholdende biografiske Oplysninger om Medlemmer af Dansk Ingeniørforening, Som ikke er udgaaet fra Den polytekniske Læreanstalt*. Danmark: Dansk Ingeniørforening; *Statistiske Oplysninger angaaende den polytekniske Læreanstalts Kandidater samt Fortegnelse over dens Direktører og Lærere 1829–1902* (1897, 1911, 1928, 1944, 1955). København; Foreningen af danske Landbrugskandidater
'Technical and engineering school yearbooks'	These yearbooks include biographies with information about names, date and place of birth, school, degree, year of graduation, and career (including occupations and companies) of the graduates from Copenhagen machine and electro-technical school, Odense technical school, Horsens technical school, Aarhus electro-technical school.	*Danske teknika og deres Dimmitender gennem 50 år, Ingeniør- og Konstruktørsammenslutningen gennem 35 Aar* (1931): Københavns,; *Danske Ingeniører fra* Teknika (1945): København,
'Magister-Stat yearbooks'	These yearbooks include biographies with information about names, date and place of birth, degree, year and institution, and career and occupation, of all graduates from Copenhagen and Aarhus universities.	Hegermann-Lindencrone, C. and Henrichsen, C. L. (1926): *Magister-Stat, Fortegnelse over nulevende candidati philologiæ, candidati magisterii, magistri artium og magistri scientiarium*. Kolding; Hansen, E. Bjørn, Henrichsen, C. L., Ravn, J. Øbro (1945): *Magister-Stat, biografiske Oplysninger om nulevende Candidati Magisterii 1884 II –1944 I, Magistri Artium og Magistri Scientiarum Febr. 1883–Jan. 1944*. Denmark.

Table 3. Questionnaire submitted to the dairy cooperatives 1915–1918[3].

1. Have you had expert assistance - Architect, Consultant, Manufacturer - in building, rebuilding, etc. of the Dairy?
2. Is the residence a) separate? How many rooms do you have b) in the Dairy building? (including staff)
3. How Many Suppliers?
4. How many cows?
5. Is the Dairy member of the Milk Assessment Association?
6. Is there an artesian or dug well or spring? If so, how deep?
7. Is the sewage used for irrigation?
8. How many persons usually work at the Dairy, yourself included?
9. Is a dairywomen employed? If so, is it your wife?
10. What is the employees' cash salary?
11. Which accounting method: weight, factor 2, factor 3, cream units or fat units?
12. Is a special acid used ("modersyre)?
13. Is cheese made of pasteurised milk?
14. Is the cheese "parafinised"?
15. How is the cheese store cooled?
16. Is the butter sold to merchants or export associations?
17. How much does the ice house hold?
18. The shape and height of the chimney?
19. The area of a) the Dairy building, and b) living quarters
20. Which weights are used?
21. Which Pasteurisers?
22. Which preheaters?
23. Which coolers?
24. Which centrifuges?
25. Which core kneaders?
26. Which boiler?
27. Which power machine?
28. Which cooling machine?
29. Which type of cheese kettle is used?
30. Acidification in barrels or basins?
31. Are special tools or kettles used for acid breeding?
32. Which lightening?
33. Are normal or aluminium bins used?
34. Are there any other machines or tools that you wish to mention in addition to the ones listed above?
35. What kind of fuel is used?
36. Is there an acidification system for skimmed milk?

The chairman
The owner[1]
The tenant
} Name, title, address, as well as a short biography (including the names of former managers (including picture)

The manager's name and biography (picture included)
(Picture of the Dairy included).

Source: Appel, H. (red.) (1915-1918): *Danske mejerier, vol. 1–4.*

and, according to Appel, include information about *all* the dairy cooperatives in Denmark at the time, classified into 'cooperative dairies', 'joint dairies' and 'commercial dairies'. The descriptions of each dairy were made based on detailed questionnaires and include information about the dairy cooperatives' year of establishment, infrastructure (buildings), machinery and equipment (types of centrifuges, cooling equipment, air compressors, buckets, pumps, etc.), number and salaries of workers, details of the educational and work background of owners and managers and specifics of

[2]Dairies that worked solely with hand centrifuges are not included in these reports.
[3]My translation.

production and whether a consultant assisted in the establishment. Annual dairy statistics (*Danmarks Mejeri-drifts-statistik*) from 1897 include lists with similar details as *Danske mejerier* – but not complete lists of all dairies – and can be used as supplementary sources. See Table 3 for a translation of the questionnaire used by H. Appel.

The use of individual-level information in the yearbooks, the dairy reports, and supplementary student and graduate lists makes registering all individuals with higher education, technical education, high school or practical dairy school training – i.e. individuals with different types of specialised 'skills' – who worked at Danish dairies between the 1860s and 1920, possible. Furthermore, it will be possible to register details of most of these skilled individuals' travels and entire careers. An arrangement, which involved important learning, but which is not included in these sources, was apprenticeship. The Danish Agricultural Society established an apprenticeship system in 1837 by letting young girls learn about dairying at different farms and manors (Appel, 1915-1918), however Appel does not account for who they were or how many they were.

Censuses

The historical censuses of 1860, 1870, 1880, 1890, 1901, 1906, 1911, 1916 and 1921 include information about the total number of workers according to industry, which can be used to calculate the total number of individuals working in the dairy industry (Statistisk tabelværk, 1860, 1870, 1880, 1890, 1901, 1906, 1911, 1916, 1921). This, in turn, can be compared to the total number of workers in the dairy industry who were formally educated. From the 1890 census, and onwards, there is information about the number of workers in 'dairying' according to district. The censuses from 1860 and onwards are categorised according to district, and into genders and occupations, such as 'owners', 'farmers', etc. in 'agriculture'.

Archives

Cooperative and farm records can be used as complementary sources to the graduate yearbooks and cooperative reports. Archival records, including information about owners, managers and other workers; their background, work, responsibilities and daily assignments, as well as accounts, business and production reports and descriptions of used technology would be relevant here. Archives of all the dairy cooperatives – of which there are many – would be useful, but there will be a need for selection, according to size, production, location, etc. Of key importance is the selection of dairy cooperative archives which include documentation of staff, technical reports, accounts, inventory lists, correspondence, etc., which would provide additional insight into operation and work. Archives which include such types of written documentation are for example the ones from Aldrup Andelsmejeri, Andelsmejeriet 'Albion' and Holbøl Andelsmejeri.

Study programmes and plans with descriptions of courses were published in reports by the Royal Veterinary and Agricultural College, Polytechnical College, the University of Copenhagen and farming and dairy schools (Segelcke, 1891; Böggild, 1889; Uddrag, 1895; Aarbog, 1793–2006). Historical archives of the Royal Veterinary and Agricultural College and some of the farming and dairy schools[4], located at the National Archive in Copenhagen, include extensive written material about the teaching; i.e. lecture plans, lecture notes, subjects, exams, etc. which can be used to analyse what educated workers at dairies learned at school.

Agricultural magazines, such as *Vort Landbrug, Ugeskrift for landmæn, Tidsskrift for landøkonomi*, *Tidsskrift for det praktiske Landbrug og dets Binæringer*, *Landbrug og Naturvidenskab*, *Mælkeritiderne*, *Andelsbladet* and *Dansk landbrug* include articles about agricultural studies, reforms, apprentice

[4]Den Kongelige Veterinær- og Landbohøjskole's archive (1887–1967), Rigsarkivet, Copenhagen. Historical records exist of Ladelund Dairy School and Dalum Agricultural School.

programmes, technology and supplementary information about managers and workers, and can be used to further discuss the formal agricultural education and the supply and demand of agronomists, surveyors, dairymen and other professionals relevant for the dairy industry.

Methodology: was knowledge transferred from 'places of learning' to the Danish dairy industry, and if so how?

By following graduates throughout their educational and professional careers, the overall purpose of the planned investigation is to explore knowledge transfer from places of learning, notably schools, universities and workplaces to the dairy industry, and in particular to analyse the kind of knowledge that was transferred and used to change, diffuse or adopt technology, and to increase productivity.

Testing the reliability of the sources

It will be important to analyse the reliability of the sources. 'Source criticism', which involves checking sources against each other to assess the reliability of the information conveyed in them, will be useful here (Howell & Prevenier, 2001; Lorenz, 2001). First, any biases in relation to the remaining records of cooperatives should be assessed, since the archives that include materials about employees and recruitment will be used. Did cooperatives with no remaining employee and recruitment records have anything to hide? In this regard, the performance of the cooperatives might play a role, and should be measured and compared (see 'three-step analysis'). Second, there will be a need to map the entirety of the information found in the biographies in order to assess how it can be used in the analysis. Third, the information in the biographies and dairy reports may be wrong for several reasons: (i) the respondents might fail to provide certain information or remember it incorrectly; (ii) editors might omit information and (iii) there may be transcription errors. Moreover, some of the graduates are not listed in the yearbooks; did the questionnaires not reach them or did they refuse to answer? To address these questions, (a) the internal consistency of the biographies and reports can be tested by comparing the information listed in them. The biographies are organised chronologically and are all set up in a similar way. Therefore, omitted information can be detected by comparing the chronology and content of a sample of biographies, to see if there are 'gaps' in the CVs and checking whether all the questions in a questionnaire were answered. For instance, one could imagine that unemployment, working for a company that went bankrupt, or other sensitive information would be left out. It should be noted that there are several examples in the biographies of graduates complaining about lack of jobs, of periods when they were unemployed, etc., which suggests that sensitive information, i.e. information that would not necessarily put themselves 'in a good light', was also provided; and (b) information in the biographies and reports can be compared to that in supplementary independent sources. Dates, educational degrees, work positions, organisations, businesses and dairies where graduates claim to have worked can for example be compared to student and graduate lists, business reports and company employee lists found in dairy cooperatives. It is expected, however, that the information found in the biographies is generally reliable.

Making a database of all educated individuals in Danish dairy production

A number of educational institutions trained young people who could, after graduation, potentially work in the Danish dairy industry. To make a solid analysis, the question of whether the supply was exogenous to changes in the industry, or not, and the reasons for eventual increases or decreases in the number of students and graduates, should be addressed.

As an extension of this, a database of practically all individuals who worked in the Danish dairy production in Denmark (1860s–1920) who had completed secondary education, or who had a degree from technical schools, the University of Copenhagen, the Polytechnical College, Royal Veterinary and Agricultural College, dairy schools or foreign educational institutions, can be constructed by

extracting, entering and coding information from the biographies, dairy cooperative reports and supplemental graduate lists. The educational background of dairy consultants, employed by agricultural associations to assist farms to improve their butter, will be highly important here, and it will be possible to map their employment, and how many they were at any given time, using the yearbooks and Appel's lists. The dairy production entities included in 'the dairy industry' can be defined using official statistics and Appel's dairy industry reports and the annual *Mejeri-drift-statistik*, which specify the year of establishment of each and every dairy cooperative (Barløse, 1899; 1892, 1904; Dansk Mejeriforening, 1888; Dansk Mejeriforening, 1897-1920; Hertel, 1917).

The following information can be registered of the educated workers working in the dairy production: (1) first and last name (all); (2) gender (all); (3) degree, educational institution, graduation year (all); (4) work in dairy production (all); (5) period of work in dairy production (seemingly most cases); (6) entire career and travels in Denmark and abroad (some). Using Appel's dairy reports, information about owners and managers of dairy cooperatives *without* education can also be extracted and entered into the database. The database will thus include virtually (i) all educated individuals in Danish dairy industry from 1860s to 1920, and (ii) the educational and/or professional background of all owners and managers at dairy cooperatives in Denmark until the 1910s. Additionally, the censuses of 1860, 1870, 1880, 1890, 1901, 1906, 1911, 1916 and 1921 can be used to calculate the total number of workers in agriculture more widely, and in the dairy industry specifically. The total number of workers can then be compared to the number of formally educated workers in the industry over time. Considering the complexity of the agricultural production systems, it might be useful to make different categorisations, comparing both total workers in the 'dairy industry' alone, and total workers in 'agriculture'. In the former, the total number of workers in the dairy industry will be included, and the farmers producing the milk will be excluded, while in the latter the entire production system will be included.

A three-step analysis of knowledge transfer and use

A combination of quantitative and qualitative methods seem to be useful for this type of analysis. Where the quantitative analysis will provide insight into general causal effects that education and practical knowledge might have on the dairy industry, qualitative assessments of historical documents may, for example, give further in-depth understanding of the content of the study programmes, of the graduates' education and experience, and of the technology installed and used at the dairies. I propose a three-step analysis:

(1) ***Learned knowledge at school***. *What did the graduates (individuals with different skills) working in the Danish dairy industry learn at school/technical school/university?* This question can be addressed by analysing magazines, journals and curricula from (a) high school/dairy and farm schools, and (b) university-level study programmes, which the individuals who worked in the dairy industry attended.

The 'type of learning', in particular related to the established concepts of learning by doing and theoretical learning, and 'knowledge fields', such as 'physics', 'mathematics', 'chemistry', 'biology', etc. can be identified and assessed according to study programme, subjects, topics, teaching methods, exams, etc. For example, based on the descriptions of courses presented in the university annuals, the knowledge fields of the course 'chemistry', taught at the Polytechnic College in Copenhagen for chemist students in the late 1880s, can be categorised as 'chemistry', and 'theory', and the subcategories 'inorganic substances', 'organic substances', 'inorganic technical chemistry' and 'organic chemistry'.

(2) ***Knowledge acquired on the job.*** *What did the graduates who worked in the dairy industry learn at previous workplaces?* This question can be addressed by defining the type of learning and skills that the graduates gained from their previous work experiences.

The graduates' classified gender and careers (companies/organisations and work positions) should be used here as a starting point. Types of learning and skills that they gained from their work experiences will be defined based on (a) country (b) industry/sector, (c) work position/occupation and, when information is available; (d) daily tasks, responsibilities and work projects.

In relation to these first two steps, identifying and characterising the 'knowledge' – using existing, but also developing new knowledge concepts – acquired at the different places of learning, such as technical-dairy and high schools, university, higher technical schools and work sites (companies/organisations in Denmark, or abroad) will be key. For example, Thovald Jensen Brask graduated as an agronomist in 1904 and worked as a teacher at Jandrup College until 1905. Thereafter he went to North America; he graduated at the Dairy school in Wisconsin in 1908 before he moved back to Denmark, and from 1908, he worked as state consultant in dairy farming in Fredericia (Larsen, 1911, p. 14). His work experience can be defined as 'teaching practice', and his formal education can be defined as 'agronomist', 'North America' and 'formal dairying education'. Careful assessments of the way knowledge was acquired; either through learning by doing and 'work' or through theoretical learning and 'education' will be needed here.

(3) ***Use of knowledge.*** *Was knowledge learned at school and previous work experience used?* Whether knowledge and skills were used in the dairy industry; to diffuse or change technology can be analysed by using (a) the database, (b) US Department of Labor's Dictionary of Occupation Titles and the Handbook for Analyzing Jobs to codify and classify jobs and work tasks in the dairy industry, and (c) historical archives (notably employment lists, contracts, reports, and other relevant documentation).

First, the graduates' accumulated knowledge and skills can be compared to the relevance and applicability of their current work in the dairy industry (work position, responsibilities, daily tasks, work projects, etc.). For example, a degree from a dairy or farm school and work experience at a chemical laboratory might be considered relevant for the performed daily tasks as manager at a dairy cooperative. In-depth qualitative assessments are needed here to address the relevance and usefulness of acquired knowledge and skills.

Second, in the extension of this, the US Department of Labor's Dictionary of Occupational Titles (DOT) can be used to classify and codify the different jobs in the dairy industry; i.e. the tasks that each work position entailed, in terms of duties and responsibilities, physical tasks, use of machinery, tools, techniques, etc., and the types of capabilities that were needed to carry out these tasks (Autor, Levy, & Murnane, 2003). *Handbook for Analyzing Jobs*, which includes a systematic study of 'the worker' – in terms of (1) what he/she does in relation to 'data', 'people' and 'things (worker functions)'; (2) the methodologies and techniques employed (work fields); (3) the machines, tools, equipment and work aids used; (4) the materials, products, subject matter, or services which result and (5) the traits required (worker traits) – describes a method that can be used in this context (US Training and Employment Service, 1972). This model is used in relation to workplaces of more recent times, but can still be useful for the type of historical analysis proposed here because it allows for a deep dive into 'work areas', i.e. specific tasks, duties and responsibilities, related to each work position, and thereby into how to classify each employer and employee and their skills. In particular, when making such classifications, it will be important to consider the fact that individuals with formal education and long work experience who worked in the dairy industry often held manager-, director- and technical positions. Their tasks and duties – on the one hand – often covered a great variety of work fields, and – on the other hand – might vary considerably from workplace to workplace. Individuals in management and director positions had the overall responsibility, for example, for an entire plant, a division, a laboratory and for several workers, and each plant differed considerably in terms of prospects, size, geography, number of workers and related farmers, etc. In such cases, the *Handbook* recommends to organise the information of the job in question 'according to function'. A manager of a dairy plant did not necessarily work hands-on with dairy production, and his/her daily tasks might

be less 'routine' than milkmen or dairy workers, who might be more involved in the practical tasks of 'milking', 'curdling', 'crushing', 'pressing', etc. Being in charge of infrastructure, machinery, workers and production, the tasks of the managers tended to be related to a broad spectre of assignments concerning 'supervision', 'decision-making', 'surveillance', 'administration', 'management', as well as more hands-on tasks, such as 'accounting', 'book-keeping', 'testing and buying tools and equipment', etc. Information about each work position and the traits required to perform the tasks – which, in the case of managing and strategic technical positions, would be related for example to features such as being 'flexible', 'creative', capable of 'solving problems' and of 'communicating clearly' – will be collected from dairy archives, Appel's reports and other historical documentation and carefully compared to the study programmes at the different educational institutions. Did formally trained workers in the dairy industry acquire such skills through formal education? What kind of skills did they obtain? Were acquired skills used? The aim is to relate the skills and knowledge that were learned to what the educated individuals did in the dairy industry. It may turn out to be problematic, or impossible, to assess fully these questions, however the classification system seeks to be flexible enough for considerations, but also detailed enough to be able to detect whether acquired skills and knowledge were in fact used. It will be essential to describe differences between the functions of individuals in similar positions across the industry, which might play a role in the differences in performance across dairies. This type of codification and classification method will enable the tracing of skills that students learned through the different places of learning into their work at the individual dairies to analyse which part of the formal education and practical experience, that might lead to high performance (see point four). Although the biographies and archival records probably will not enable making a complete overview of such links, they will allow for in-depth case study analyses. While the biographies and Appel's reports include details about each educated person's acquired work positions – as illustrated in Table 1 – archival material in the form of reports, brochures, documentation of staff and, perhaps in particular, contracts and job instructions, will – as they may – make it possible to follow some of the individuals, not only into their workplaces and work positions, but also into their daily tasks, assignments and Duties. This will enable an examination of how acquired skills and knowledge were used.

Third, using historical inventory lists, accounts, reports, etc., found in cooperative archives, the work of educated individuals can be placed in the wider technological context, particularly to their role in adopting and changing techniques (such as machinery, tools, equipment and techniques) and organising dairies, and implementing organisational changes (such as number of workers, management, accounting and coordination systems). The hypothesis that educated individuals in the dairy industry largely held managing, directing and technical positions leads to the question of how new machinery and tools were purchased, installed and used, and who the people involved in such decisions were. In the extension of this, the access to technical literature, such as the journal *Mælketidende* should be considered, as well as the contact that managers or owners at the dairies might, or might not, have with any particular dairy consultant. The purpose here is to discover whether there were links between acquired knowledge and skills and the adoption of any particular technology, or technological change. Figure 1 shows a simple model of the planned analysis in terms of exploring links between educational institutions, and previous workplaces, and the Danish dairy industry; learned knowledge might turn out to be used in dairy work, which in turn might lead to the adoption of new technology.

Fourth, the level of detail in the dairy reports enables an analysis of links between the level of education and work experience of the owners and managers at the dairy cooperatives, installed and used technology at the dairies (work organisation, machinery, tools and techniques) and changes in milk consumption; which can be used as a measure for productivity, over time. Was there a connection between higher and lower concentration of skills – or different types of skills – used technology, and levels of productivity? A relevant quantitative method in this regard is the production function estimation methods for milk to identify the determinants of productivity and efficiency advances used by Lampe and Sharp for the Danish dairy industry (2015). For example,

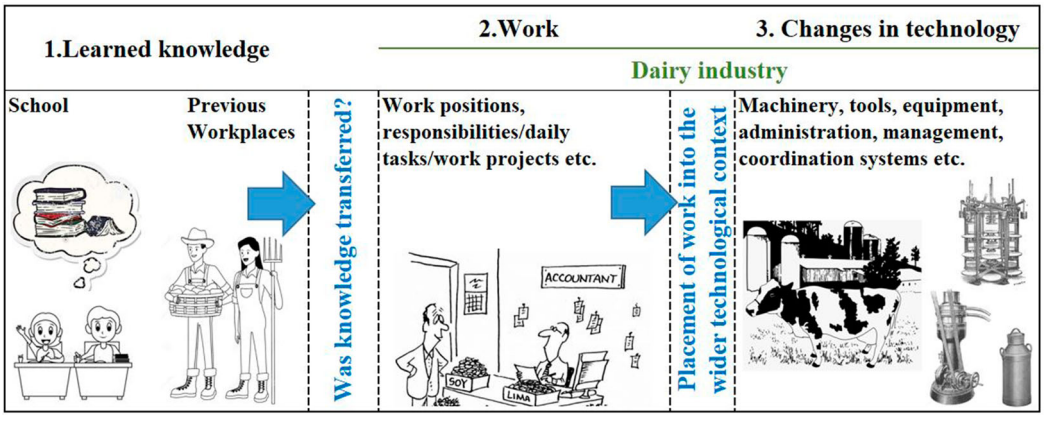

Figure 1. Simple model of the analysis of knowledge transfer from school and workplaces to Danish dairy industry.

at Ferslev-Vellerup dairy cooperative, the manager, H. C. Hansen, had a degree from Ryslinge Højskole (folk school) and practiced 'dairying' at several dairies before he became employed at Reslev (Appel, 1915, p. 12). The cooperative had three employees, 161 milk suppliers (1200 cows) and had installed different types of weights, pasteurisers, Titan (T.A. 44) centrifuges, aluminium coolers, core kneader, oil separator, wooden lilac basin, steam kettle and oil lightening. This cooperative had lower milk consumption per kilo of butter (higher productivity) than Havreholm dairy cooperative, which had employed a manager who had practiced at several dairies in Denmark and in Russia, but did not have any formal education. Havreholm cooperative had three workers, 182 milk suppliers (1300 cows); it had installed the same type of weights, oil separator, coolers and core kneader as Reslev, but used different pasteuriser, kettles, centrifuges and lightning system (Appel, 1915, p. 18). A systematic comparative statistical analysis including all cooperatives is needed to assess whether there was a connection between different types of skills (acquired in Denmark and abroad), installed technology and differences in productivity.

Summing up, the Appel reports should first be used to classify dairies with different levels of productivity. Second, the dairies with high and low productivity can then be compared to the techniques, equipment and organisation system that they applied; and third, to the consultants, managers and owners' educational background and work experience, notably (a) whether they had formal education, or not, (b) which school/university they acquired their degree from (in Denmark and abroad), (b) the educational degree (level, discipline and courses), and (c) previous work experience (country, sector/industry and work positions/occupations). The aim here is to discover any links that might exist between different types of skills and used technology, and levels of productivity, in the dairy industry.

Conclusion

Considering the importance of education, and human capital more widely, for industrial and economic development a solid empirical analysis of the historical impacts of scientific and theoretical education, and work practice on one of Denmark's historically most important industries, the dairy industry, seems timely. Economic historians have emphasised numerous aspects in their explanations for the advances of the dairy cooperatives in Denmark, yet we lack empirical analyses of the role of education in this development. Further analyses of the direct role that education might play in the development of the Danish dairy industry from ca. 1860–1920 are highly useful for at least two reasons: (1) to fill an important gap in the Danish historiography, and (2) to exemplify relationships between learning systems and industrial development at a time when this industry was in major expansion. How can we investigate the impacts of education on the Danish dairy production? This note has sought to describe how this can be done by outlining unique Danish sources and the method of how to carry

out an analysis of the impacts of education and practice on Danish dairy industry, focusing on a time when the dairy industry went through radical technological and industrial changes. The main argument of this note is that rich and detailed Danish biographies of high school, technical and dairy school and university-level graduates, and additional reports and historical documentation, will enable an empirical analysis of knowledge transfer between schools, universities, and other places of learning, in Denmark and abroad, and dairy cooperatives, notably (1) how knowledge learnt in school, or at work, was applied by men and women to bring about changes in technology, big or small; and (2) links between skills, technology and productivity. The purpose of the planned empirical analysis will be to investigate how knowledge and skills were used in the dairy industry to change technology and economic performance.

The planned empirical analysis might reveal that a broad spectrum of educated individuals acquired a wide range of theoretical knowledge and skills through both formal education and work practices; both at home and abroad, and that the knowledge they accumulated became increasingly important, and contributed to the new technology, the more efficient management and accounting systems and the use of new equipment and science-based techniques that were adopted to develop the new and productive dairy industry during the late nineteenth and early twentieth centuries. Theoretical and scientific training in combination with long and varied work experience possibly led to higher productivity. Being able to show that individuals acquired increasingly complex and diversified knowledge at school and through work practice, and that this knowledge was increasingly used in the growing dairy industry to change techniques, methods and work systems, and to increase productivity; but also that there were limitations to the knowledge learned at school, will make the planned empirical analysis key. It will also have significant implications for the general foundation of economic and social historical research about agriculture, and also for the research of the historical role of education in industrial development and for innovation more widely. The planned investigation will speak to the wider debates about human capital within economic history and will aim to contribute to fill empirical gaps concerning the links between education, learning and innovation and economic performance. If education and work practice were found to have had little or no effect on innovation and productivity in the dairy industry, it would be an interesting finding in itself. In fact, the 'Nordic graduate yearbook tradition', of which the Danish biographies form part, produced biographies of entire graduate cohorts and their backgrounds, education and work over generations. The use of the Nordic biographies – in combination with historical censuses and school and business records – opens up the possibility of making a great variety of quantitative and qualitative historical comparative empirical analyses related to the role of education in Denmark, Sweden, Norway and Finland. In particular, the sources enable long-term historical micro-level analyses of different topics related to education, such as educational opportunity, educational mobility, the value of education over time and education and industrial development, using all kinds of interdisciplinary approaches.

Acknowledgements

The author wants to thank Professor Paul Sharp for highly valuable comments and suggestions in the writing process. She would also like to thank anonymous reviewers for very useful suggestions.

Disclosure statement

No potential conflict of interest was reported by the author(s).

References

Aarbog for Kjøbenhavns Universitet. (1793–2006). *Den polytekniske Læreanstalt og Kommunitet, Meddelser for de akademiske Aar 1892-95 med Sagsregister*. København: Københavns universitet.

Agronomforening, D. (1996). *Biografisk fortegnelse over danske agronomer*. København: Dansk Agronomforening.

Ahlström, G. (1982). *Engineers and industrial growth*. London: CROOM HELM.
Appel, H. (red.). (1915-1918). *Danske mejerier, vol. 1*. København: Hertz's bogtrykkeri.
Autor, D. H., Levy, F., & Murnane, R. J. (2003). The skill content of recent technological change: An empirical exploration. *Quarterly Journal of Economics*, *116*(4), 1279–1333.
Barløse, C. P. (1899, 1892, 1904). *Kongeriget Danmarks handels- og industrikalender over herregårds-, fælles- og andelsmejerier, teglværker, damptærskeværker, møller, fabrikker*. København.
Barro, R. J., & Lee, J. W. (1996). International measures of schooling years and schooling quality. *American Economic Review*, *86*(2), 218–223.
Baten, J., & Van Zanden, J. L. (2008). Book production and the onset of modern economic growth. *Journal of Economic Growth*, *13*(3), 217–235.
Becker, G. S. (1975). *Human capital*. New York: Colombia University Press.
Bendz, H. C. B. (1992). *Landbohøjskolens oprettelse*. Denmark: Kandrup Bogtrykkeri.
Bjørn, C. (1971). Folkehøjskolen og andelsbevægelsen. In *Årbog for Dansk Skolehistorie 1971 5. årgang*. Odense: Selskabet for dansk skolehistorie.
Bjørn, C. (1982). *Dansk mejeribrug 1882-2000*. Odense: De danske Mejeriers Fællesorganisation.
Bjørn, C. (red.). (1988). *Det danske landbrugs historie, vol 3, 1810-1914*. Odense: Landbohistorisk Selskab.
Boas, J. E. V., & Oppermann, A. (1908). *Den kongelige Veterinær- og Landbohøjskole 1858-1908, Festskrift ved Højskolens halvtredsindstyveaars Jubilæum 24. August 1908*. København: Den kgl. Veterinær- og Landbohøjskole.
Böggild, B. (1889). *Mælkeri-regnskaber, særlig til brug for elever i centrifugemælkerier*. Kjøbenhavn: Nielsen & Lydiche.
Bruland, K. (2003). Education. In *Oxford encyclopedia of economic history* (Vol. II, pp. 161–162). Oxford: Oxford University Press.
Bruland, K., & Mowery, D. C. (2014). Technology and the spread of capitalism. In L. O'Neil & J. G. Williamson (Eds.), *Cambridge history of capitalism, vol. II* (pp. 82–126). Cambridge: Cambridge University Press.
Caicedo, V. F., & Maloney, W. F. (2014). *Engineers, innovative capacity and development in the Americas* (Policy Research working paper; no. WPS 6814). Washington, DC: World Bank Group.
Castelló, A., & Domenéch, R. (2002). Human capital inequality and economic growth: Some new evidence. *The Economic Journal*, *112*(478).
Cipolla, C. M. (1969). *Literacy and development in the West*. Baltimore: Penguin Books Ltd.
Crafts, N. F. R. (1985). *British economic growth during the industrial revolution*. Oxford: Clarendon.
Danske Ingeniører fra Teknika. (1945). København.
Danske teknika og deres Dimmitender gennem 50 år, Ingeniør- og Konstruktørsammenslutningen gennem 35 Aar (1931): København.
Dansk Ingeniørforening. (1942). *Dansk Civilingeniørstat. Biografiske Oplysninger om polytekniske Kandidater 1829-1941. Med et Tillæg indeholdende biografiske Oplysninger om 226 af Dansk Ingeniørforenings Medlemmer, der ikke er udgaaet fra Den polytekniske Læreanstalt*. København: Dansk Ingeniørforening.
Dansk Mejeriforening. (1888). *Mælkeritidende*, Udg. som medlemsblad for. l. årg. ff, Kolding.
Dansk Mejeriforening. (1897–1920). *Mejeridriftstatistik*.
Den Kongelige Veterinær- og Landbohøjskole's archive (1887-1967). Copenhagen: Rigsarkivet.
Diebolt, C., & Hippe, R. (2019). The long-run impact of human capital on innovation and economic development in the regions of Europe. *Applied Economics*, *51*(5), 542–563.
Easterlin, R. A. (1981). Why isn't the whole world developed? *Journal of Economic History*, *41*(1), 1–17.
Ernle, R. E. L. P. (1912). *English farming past and present*. London: Cornell University Library.
Festskrift udgivet i anledning af Foreningen af Agronomstuderendes 50 års jubilæum (1971): København.
Fink, D. (2009). Do not intrude. A Danish perspective on gender and class in nineteenth-century dairying. *Agricultural History*, *83*(4), 446–476.
Foray, D., & Lundvall, B-Å. (2000). *From the economics of knowledge to the learning economy*. Paris: OECD.
Fox, R., & Guagnini, A. (1993). *Education, technology, and industrial performance in Europe, 1850-1939*. Cambridge: University of Cambridge.
Fritzbøger, B. (2015). *Mellem land og by Landbohøjskolens historie*. Copenhagen: Copenhagen University.
Goldin, C. (2016). Human capital. In *Handbook of cliometrics*. Heidelberg: Springer Verlag.
Hannover, A. (ed.). (1956). *Dansk civilingeniørstat 1955: Biografiske Oplysninger om polytekniske Kandidater 1829-1955*. København.
Hansen, B. K. (2006). *Familie-og arbejdsliv på landet ca. 1870-1900*. Auning: Landbohistorisk selskab.
Hansen, E. B., Henrichsen, C. L., & Ravn, J. Ø. (1945). *Magister-Stat, biografiske Oplysninger om nulevende Candidati Magisterii 1884 II - 1944 I, Magistri Artium og Magistri Scientiarum Febr. 1883–Jan.* 1944. Denmark.
Hegermann-Lindencrone, C., & Henrichsen, C. L. (1926). *Magister-Stat, Fortegnelse over nulevende candidati philologiæ, candidati magisterii, magistri artium og magistri scientiarium*. Kolding.
Henriksen, I. (1993). The transformation of Danish agriculture 1870-1914. In K. G. Persson (Ed.), *The economic development of Denmark and Norway since 1870* (pp. 153–178). Aldershot: Edward Elgar.
Henriksen, I., Hviid, M., & Sharp, P. (2012). Law and peace: Contracts and the success of the Danish dairy cooperatives. *Journal of Economic History*, *72*, 197–224.

Henriques, S. T., & Sharp, P. (2015). The Danish agricultural revolution in an energy perspective: A case of development with few domestic energy sources. *Economic History Review*, *69*(3), 745–1054.
Hermansen, N. K., & Lobedanz, M. (red.) (1958). *Den kongelige veterinær- og landbohøjskole 1858-1958*. Copenhagen: Kandrup & Wunsch.
Hertel, H. (1917). *Andelsbevægelsen i Danmark*. København: Andelsudvalget.
Howell, M., & Prevenier, W. (2001). *From reliable sources: An introduction to historical methods*. Ithaca, NY: Cornell University Press.
Hviid, M. (2006). Performance-related pay in Danish cooperative creameries. In P. Kalmi & M. Klinedinst (Eds.), *Participation in the Age of Globalization and information* (pp. 149–176). JAI Press.
Jensen, E. (1937). *Danish agriculture. Its economic development. A description and economic analysis centering on the free trade epoch 1870-1930*. Copenhagen.
Jespersen, R. (1930). *Biografiske Oplysninger angaaende Den polytekniske Læreanstalts Kandidater 1829-1929, Med et Tillæg indeholdende biografiske Oplysninger om Medlemmer af Dansk Ingeniørforening, Som ikke er udgaaet fra Den polytekniske Læreanstalt*. Danmark: Dansk Ingeniørforening.
Kindleberger, C. (1951). Group behavior and international trade. *Journal of Political Economy*, *59*(1), 30–46.
Klitmøller, L. (2008). *Som en skorsten – Mejeribrugets uddannelser i Danmark 1837-1972*. Auning: Landbohistorisk Selskab.
Kuznets, S. S. (1965). *Economic growth and structure*. New York: Norton.
Lampe, M., & Sharp, P. (2015). Just add milk: A productivity analysis of the revolutionary analysis of the revolutionary changes in Nineteenth century Danish dairying. *Economic History Review*, *68*(4), 1132–1153.
Lampe, M., & Sharp, P. (2019). *A land of milk and butter, how elites created the modern Danish dairy industry*. Chicago: University of Chicago Press.
Larsen, L. P. M. (1911). Foreningen af danske Landbrugskandidater (1869, 1883, 1897, 1911, 1918, 1928, 1944, 1955): *Danske Landbrugskandidater, deres Virksomhed og Adresser*: København. Foreningen af danske Landbrugskandidater.
Lerche, G. (1999). *The Royal Veterinary and Agricultural University*. Denmark: KVL.
Locke, R. R. (1984). *The end of the practical man*. London: JAI Press Inc.
Lorenz, C. (2001). History: Theories and methods. In N. J. Smelser & P. B. Baltes (Eds.), *International encyclopedia of the social and behavioral sciences volume 10* (pp. 6869–6876). Oxford: Elsevier.
Lundgreen, P. (1990). Engineering education in Europe and the U.S.A, 1750-1930: The rise to dominance of school culture and the engineering professions. *Annals of Science*, *47*(1).
Mincer, J. (1974). *Schooling, experience and earnings*. New York: National Bureau of Economic Research.
Mokyr, J. (2005). *Gifts of Athena*. Princeton: Princeton University Press.
Nelson, R. R., & Winter, S. G. (1982). *An evolutionary theory of economic change*. Cambridge: Belknap Press.
Nielsen, A. K. (2004). The making of scientific butter: Injecting scientific reasoning into agriculture. *Endeavour*, *28*(4), 167–171.
Nielsen, K. (2012). Denmark 1740-1940. A centralized cultural Community. In J. P. Árnasson & B. Wittrock (Eds.), *Nordic paths to modernity* (pp. 66–68). New York: Berghahn Books.
O'Rourke, K. H. (2007). Culture, conflict and cooperation: Irish dairying before the great War. *Economic Journal*, *117* (523), 1357–1379.
Østergård, U. (1992). Peasants and Danes: The Danish national identity and political culture. *Comparatives Studies in Society and History*, *34*(1), 3–27.
Polanyi, M. (1983). *The tacit dimension*. Gloucester: Peter Smith.
Ranestad, K. (2018). *Knowledge-based growth in natural resource intensive economies –mining, knowledge development and innovation in Norway*. Cham: Palgrave Macmillan.
Sandberg, L. (1979). The case of the impoverished sophisticate: Human capital and Swedish economic growth before World War 1. *Journal of Economic History*, *49*(1), 225–241.
Sandberg, L. (1982). Ignorance, Poverty and economic Backwardness in the early stages of European industrialization: Variations on Alexander Gerschenkron's grand theme. *Journal of Economic History*, *11*, 675–697.
Schultz, T. W. (1961). Investment in human capital. *The American Economic Review*, *51*(1), 1–17.
Segelcke, Th. R. Forelæsninger over Landbrugsholderi. (1891). [nedskrevne af Niels Larsen]; Bilag til Forelæsningser over Landbrugsbogholderi (1877).
Statistisk tabelværk. (1860, 1870, 1880, 1890, 1901, 1906, 1911, 1916, 1921). *Folketælling*. København: Bianco Lunos Bogtrykkeri.
Studenterne, personalhistoriske oplysninger. (1812–1923). København.
Suhr, K. (1996). *Danske landbrugskandidater og agronomer 1856-1995, en oversigt over personer, som i perioden 1856-1995 har fået tildelt titlen som landbrugskandidat, cand.agro., agronom eller andet tilsvarende fra Den Kongelige Veterinær- og Landbohøjskole*. Danmark: Dansk Agronomforening.
Uddrag af Undervisnings- og Eksamensplan for Den kgl. Veterinær- og Landbohøjskole vedrørende Undervisning og Eksamen for Landbrugere, Meddelt af Foreningen af danske Landbrugskandidater (1895).

U.S. Training and Employment Service. (1972). *Handbook for analyzing jobs*. Washington, D.C.: U.S. Manpower Administration.
Valero, A., & Van Reenen, J. (2019). The economic impact of universities: Evidence from across the globe. *Economics of Education Review*, *68*, 53–67.
Voigt, J. J. (1903). *Statistiske Oplysninger angaaende den polytekniske Læreanstalts Kandidater samt Fortegnelse over dens Lærere 1829-90*. København.