Origins of the knowledge economy

Higher education and Scandinavia's development, ca. 1800–1929

Ford, Nick

2025

Document Version:
Publisher's PDF, also known as Version of record

Origins of the knowledge economy

Higher education and Scandinavia's development, ca. 1800–1929

NICHOLAS MARTIN FORD

LUND STUDIES IN ECONOMIC HISTORY 115 | LUND UNIVERSITY

Origins of the knowledge economy

Origins of the knowledge economy

Higher education and Scandinavia's development, ca. 1800–1929

by Nicholas Martin Ford

LUND
UNIVERSITY

Thesis for the degree of Doctor of Philosophy
Thesis advisors: Prof. Kristin Ranestad, Prof. Paul Sharp,
Prof. Emer. Jonas Ljungberg
Faculty opponent: Prof. Jørgen Modalsli

To be presented, with the permission of the Lund University School of Economics and Management, for public criticism at *Holger Crafoords Ekonomicentrum* (EC3:211) on Thursday, 23 January 2025 at 14:15.

Organization	Document name
LUND UNIVERSITY Department of Economic History Box 7080 SE–220 07 LUND Sweden	**DOCTORAL DISSERTATION** Date of disputation 2025-01-23 Sponsoring organization
Author(s) Nicholas Martin Ford	

Title and subtitle

Origins of the knowledge economy: Higher education and Scandinavia's development, ca. 1800–1929

Abstract

High school and university-level education was long an elite pursuit. However, with economic growth and rising technical complexity, the need for specialised knowledge and skills increased. In the run-up to and during industrialisation, higher education systems admitted a growing number of students and diversified across an increasing range of courses and types of educational institutions.

Denmark, Norway and Sweden provide rich case studies for examining the growth of higher education during the nineteenth and early twentieth centuries. I examine higher education through two lenses: To what extent did changes in the provision of higher education increase access to education beyond a small elite in society? How did changes in the provision of and access to higher education influence Scandinavia's development in the lead-up to and during industrialisation?

This dissertation comprises four papers that explore key developments in Scandinavian higher education including:

- the admission of female students
- the opening of Norway's first university
- the introduction and expansion of polytechnic education
- the growth in demand for highly trained engineers.

Using detailed individual-level data on the graduates of higher education, my results offer new insights into social mobility and economic development during a critical period of history.

Key words

economic history, human capital, higher education, industrialisation, social mobility, innovation

Classification system and/or index terms (if any)

Supplementary bibliographical information	Language
	English
ISSN and key title 1400-4860 Lund Studies in Economic History	ISBN 978-91-989641-4-1 (print) 978-91-989641-5-8 (pdf)
Recipient's notes	Number of pages 304 / Price
	Security classification

Origins of the knowledge economy

Higher education and Scandinavia's development, ca. 1800–1929

by Nicholas Martin Ford

LUND
UNIVERSITY

Lund Studies in Economic History is a series of doctoral dissertations and edited volumes of high scholarly quality in subjects related to the Department of Economic History at the School of Economics and Management, Lund University. All volumes have been reviewed and approved prior to publication.

Cover illustration: AI generated image using Adobe Firefly.

Funding information: The thesis work was financially supported by *Jan Wallanders och Tom Hedelius stiftelse* (project number P20-0030).

School of Economics and Management, Department of Economic History

ISBN: 978-91-989641-4-1 (print)
ISBN: 978-91-989641-5-8 (pdf)
ISSN: 1400-4860 Lund Studies in Economic History

Printed in Sweden by Media-Tryck, Lund University, Lund 2025

Media-Tryck is a Nordic Swan Ecolabel certified provider of printed material. Read more about our environmental work at www.mediatryck.lu.se

MADE IN SWEDEN

The first axiom of philosophy is to know yourself,
and the more you do that, the more modest you become,
and the more conscious of how much is still to be learned.

Ludwig Holberg's *Erasmus Montanus*
translated by Peter Toft (1871)

Contents

Acknowledgements v
Abbreviations ix

Introduction **1**

1 The few who knew 1
1.1 Scope of the study 2
1.2 Data and sources 4
1.3 Contribution to the literature 5
1.4 Limitations 6
1.5 Roadmap 7
2 Empirical context 7
2.1 Political history 8
2.2 Economic development 9
2.3 Education in Scandinavia 12
2.4 Trends in higher education 15
3 Theory and relevant literature 19
3.1 Human capital and the upper-tail 19
3.2 Institutions 22
3.3 Social mobility 24
3.4 Additional themes 25
4 Methods 26
4.1 Correlation and causation 28
4.2 A critical view 29
5 Source material and data 30
5.1 Student records and grade lists 30
5.2 Graduate biographies 32
5.3 Data extraction 33
5.4 Limitations 35
6 Summary of papers 37
6.1 Paper I: Breaking barriers 37
6.2 Paper II: Lessons from Oslo 39
6.3 Paper III: The engineering classes 40

6.4 Paper IV: Students of technology, captains of industry? . . . 42
7 Concluding discussion . . . 43
7.1 Findings . . . 44
7.2 Future work . . . 46
References . . . 48

Papers **57**
Author contributions . . . 57
Paper I: Breaking barriers . . . 59
Paper II: Lessons from Oslo . . . 99
Paper III: The engineering classes . . . 155
Paper IV: Students of technology, captains of industry? . . . 211

List of papers

This thesis includes the following papers, referred to by their Roman numerals. All are previously unpublished manuscripts.

I **Breaking barriers**
Gender disparities in high school performance, 1813–1929

N. Ford, C. Møller Dahl, K. Ranestad, P. Sharp, C.E. Westermann

II **Lessons from Oslo**
National universities and access to higher education

N. Ford, T. Andersen, K. Ranestad, P. Sharp

III **The engineering classes**
First steps in the transition from elite to mass higher education? Evidence from Denmark, 1829–1929

N. Ford

IV **Students of technology, captains of industry?**
Higher education, entrepreneurship and inventive activity in Sweden and Denmark, 1829–1929

N. Ford

Acknowledgements

I have always been somewhat reluctant to tell people outside academia that I am a PhD student. A typical reaction is, 'Oh, you must be so smart!'. There have been many times during the past four and a half years that I certainly have not felt that way. I suspect many, if not all, PhD students experience a fair degree of 'imposter syndrome'. We engage constantly with smart people who have built reputations as experts on any number of topics. How could we possibly hope to achieve anything like what they have?

Yet somewhere along the way, we PhD students do become experts in our respective fields. This dissertation represents just a fraction of the things I have learned about higher education, industrialisation, Scandinavian economic and social history — to say nothing of the practical aspects of data cleaning and management, econometric analysis and the use of machine learning and artificial intelligence. I would not have believed five years ago that I would end up working with big data and using large language models — let alone combining those modern approaches and tools with historic source material from Denmark, Norway and Sweden. That, however, is the basis for what I have accomplished with this dissertation.

I have had wonderful supervisors who have guided me through this journey. My primary supervisor, Kristin Ranestad, took a gamble when she hired me in 2020. (It was the pandemic; we probably all made strange decisions!) I have learned much from her about research design, historical sources and the range of gluten-free options in Copenhagen. My second supervisor, Paul Sharp, has tolerated my ceaseless production of new regression specifications and results — with the tradeoff that I should actually explain what I did, and provide a meaningful interpretation of the results, before we discuss whether they are worth using. Were it not for him, this dissertation might have ended up twice as long. In addition to their role as supervisors and caffeine dealers, Kristin and Paul have also been fantastic colleagues, with whom I have co-authored two of the papers in this dissertation as well as two other papers outside the dissertation. Beyond the project, Jonas Ljungberg has served as third supervisor. I have been grateful for the various exchanges we have had along the way, and the external sanity check his feedback has provided. While this dissertation is my work, I would not have reached this point without the advice, humour and patience of Kristin, Paul and Jonas.

I must also thank Karol Jan Borowiecki, who encouraged me to apply for this position. As a student research assistant years ago, he tasked me with any number of things that — at the time — I had no idea how to do. But I learned. The lessons from my time working with Karol have served me well during the course of my PhD studies.

I have benefitted enormously from the large group of talented researchers at the Department of Economic History at Lund University. In each their own way, every

member of the department has contributed to an outstanding centre for research. I would like to acknowledge the leadership of Mats Olsson and Anna Tegunimataka as head of the department during my time. Moreover, none of the work any of us at the department do would be possible without the administrative management of Anneli Nilsson Ahlm, Madeleine Jarl, Mari Lundberg and Tina Wueggertz. *Tack så mycket!*

My thanks as well to Ellen Hillbom, our department's director of PhD studies. The PhD programme has been intellectually stimulating, and instrumental in shaping my thinking. I started at the end of summer 2020 along with four other PhD students: Louise Cormack, Clara Dallaire-Fortier, Marcus Falk and Dominic Mealy. We were probably all equally daunted by the task ahead of us when we began, but it has been a pleasure to share the PhD adventure with them. Clara was also my first officemate, followed by Vinzent Ostermeyer, and now Mark Melles. All deserve credit for putting up with me — especially Mark, with whom I have now shared an office for some time, including the stressful final stages of both our dissertations. Although Mark pokes fun at my accent almost every time we are together in the office, I will miss our regular conversations deconstructing the world and putting it back together again.

I have appreciated the interaction with all my fellow PhD students, but to name those with whom I have discussed research ideas and methods the most, I should thank Marcos Castillo, Johanna Fink, Jonathan Jayes, Jonas Kreutzer, Youssouf Merouani and Anton Svensson. And to my Danish-speaking peers, Johanne Arnfred and David Husfeldt, *tak skal I have*!

This dissertation is the conclusion of a multi-stage process, including two sets of departmental research seminars, with detailed comments provided at both. At the midway seminar, Tobias Karlsson reviewed my work, while Kerstin Enflo and Christian Larsen (from the Danish National Archives) were discussants for the final seminar. I greatly appreciate the thoughtfulness of their feedback; it has been invaluable in shaping the final product. Beyond these formal channels, I am also grateful for the input and insights of Faustine Perrin and Jaco Zuijderduijn.

Outside of Lund, I have participated in two sets of events organised by the European Graduate School for Training in Economic and Social Historical Research (ESTER). I am grateful to Ben Gales and Nuno Valerio for comments on early stages of my work — along with all my peers at ESTER's events, who contributed to a friendly and collaborative environment. I can strongly recommend ESTER's activities to any new PhD student in economic history.

One of the greatest sources of inspiration for me has come not from my own coursework or research, but from the opportunity to teach and supervise students. During my time at Lund University, I have had the privilege of teaching different courses, running econometrics labs for master's students and supervising three bachelor's theses. I find

it intensely rewarding to see how students think and watch them develop their ideas. As they grapple with converting a basic concept to a concrete research question to a fully fleshed piece of analysis, I learn from them as much as (if not more than) they learn from me. To all my students over the past few years, thank you.

My position as a PhD student was funded by a grant from the Handelsbanken-affiliated research foundation, *Jan Wallanders och Tom Hedelius stiftelse*. I am grateful for their financial support. That grant also helped lay the foundation for what has become a larger project mapping the Human Capital of the Nordic Countries (HCNC). It has been exciting for me to get in on the 'ground floor' of this growing enterprise, now spanning more than 20 researchers across institutions in Denmark, Germany and Norway. While I am the first PhD student to have completed my studies as part of the HCNC project, many others are set to follow. To Maret Grapengeter (University of Oslo), Tom Görges (Technical University of Dortmund), Martin Hørlyk Kristensen and Christian Nielsen (University of Southern Denmark), and Lina Sophie Würfel (University of Tromsø – The Arctic University of Norway): I look forward to seeing your work unfold in the coming years!

For my part, I will continue to be involved in HCNC, working alongside a great team at the University of Southern Denmark — including two of my former classmates, Torben Johansen and Christian Vedel. As a master's student, both Torben and Christian left me in awe with their technical proficiency and their ability to process the most complex of ideas. Back then, their brilliance pushed me to be a better student; I expect the same will be true now as a researcher.

Finally, I would like to thank my parents, Bev and Glenn, for their unwavering support through this process and — more fundamentally — their years of love to both me and my sister, Heather. I was the first in my family to go to university; Heather was the first to become a doctor (though in her case, the kind that comes with hospital scrubs and a stethoscope). In choosing to study the contribution of education to development, I am in large part inspired by the encouragement my parents gave me to use education to forge my own path in life. I suspect they did not imagine that path would lead me from Melbourne, Australia to the other side of the world. But life, like research, leads us all in unexpected directions.

In the time I have completed this dissertation, my sister has also been busy with her own great undertaking. I have become an uncle. While Penelope is still too young to read any of this, she has a lifetime ahead of her to learn and grow. I dedicate this dissertation to her.

Abbreviations

AI	Artificial intelligence
HCNC	Human Capital in the Nordic Countries project
HISCLASS	Historical International Social Class Scheme (Leeuwen and Maas 2011)
HISCO	Historical International Standard of Classification of Occupations (Leeuwen, Maas, and Miles 2002)
LLM	Large Language Model
OLS	Ordinary Least Squares (linear regression)
regex	Regular expression (text pattern matching)
Institutions	
Chalmers	Chalmers University of Technology (Chalmers Craft School, established in 1829 in Gothenburg, and later Chalmers Technical Institute)
DTU	Technical University of Denmark (The Polytechnic Institute, established in 1829 in Copenhagen)
KTH	Royal Institute of Technology (Technological Institute, established in 1827 in Stockholm)
Country codes	
DK	Denmark
NO	Norway
SE	Sweden

Introduction

> Human capital matters a great deal for technological progress, but just counting aggregate education and technical training may be meaningless. What counts is what the few who mattered knew, how they knew it, and what they did with this knowledge. (Mokyr 2002, p. 291)

1 The few who knew

In contemporary settings, there is broad support for the notion that education acts as an engine of economic growth (Barro 1991; G. S. Becker 1964; Galor 2011; Goldin and Katz 2008; Nelson and Phelps 1966). However, there is less to support this argument in historical contexts. Whereas Britain was a first-mover in terms of industrialisation, relatively low rates of literacy imply that education did not play a major role (Clark 2005; Mitch 1999). Sandberg (1979) described nineteenth-century Sweden as an 'impoverished sophisticate', characterised by widespread schooling but relatively low living standards.

Allen (2003) concludes that literacy, as a measure of basic levels of education, mattered little for economic development in the lead-up to industrialisation; for the majority of workers, the ability to read had little practical application in employment. Similarly, Mokyr and Voth (2010) find it 'doubtful' that literacy and the aggregate stock of human capital acted as a driving force for industrialisation. Literacy and basic skills perhaps mattered more once industrialisation commenced, enhancing the 'social capability' of societies to catch up to industrial leaders (Abramovitz 1986).

Differences across the distribution of human capital might matter more for development than the overall stock or average levels of education. Mokyr (2005) posits that the technical changes that characterised industrialisation depended more on the capabilities of a specialised elite than the skill level of the population at large. This upper-tail human capital was instrumental for the development and dissemination of new ideas, techniques and products. Moreover, the social gains from higher education were not confined to industrial applications: in different settings,

both Cantoni and Yuchtman (2014) and Maloney and Valencia Caicedo (2022) suggest that lawyers and other officials schooled in law enabled the development of property rights, which in turn facilitated market activity and innovation. More generally, such qualified officials inhabited senior roles in public administration, with responsibility for the functions of state that supported economic and social development. In line with Dittmar and Meisenzahl (2020), I thus adopt a broader definition of upper-tail human capital, which allows for higher education to foster economic development through improvements in scientific and technical skills as well as support improvements in the quality of growth-enabling institutions through the supply of a range of professional administrative skills.

1.1 Scope of the study

This dissertation is a study of higher education — upper secondary and tertiary levels of education — as a channel for the accumulation of upper-tail human capital. Inextricably linked to examining higher education is a question of access: prior to World War II, only a small share of the youth population studied at high school and university (Goldin and Katz 2008). To borrow from Mokyr (2002, p. 291), my research considers who 'the few' were as a necessary step to understanding what they knew and 'what they did with this knowledge'.

My work is governed by the following pair of linked research questions: To what extent did changes in the provision of higher education increase access to education beyond a small elite in society? How did changes in the provision of and access to higher education influence Scandinavia's development in the lead-up to and during industrialisation? The changes in the provision of higher education that I explore include permitting female students to study (paper I), establishing new institutions (paper II), expanding teaching capacity and restructuring course content (paper III), and evolving from intermediate to tertiary-level institutes of higher education (paper IV). While each looking at different countries, institutions and types of educational changes, the four papers in this dissertation collectively serve to explore higher education as a channel for the accumulation of upper-tail human capital (figure 1).

The Scandinavian countries — Denmark, Norway and Sweden — provide rich case studies for empirical examination of higher education. By 1800, all three countries already had widespread access to basic levels of education and high literacy rates (Feldbæk 1990; Ljungberg 2002; Sandberg 1979). By contrast, higher education was limited in its reach, principally servicing an elite in society. Prior to the opening of the University of Oslo, only around 0.5 per cent of the Norwegian youth cohort graduated the high school exam. In Denmark, estimates put the equivalent level at between one and two per cent during the first half of the nineteenth century (Grane and Hørby

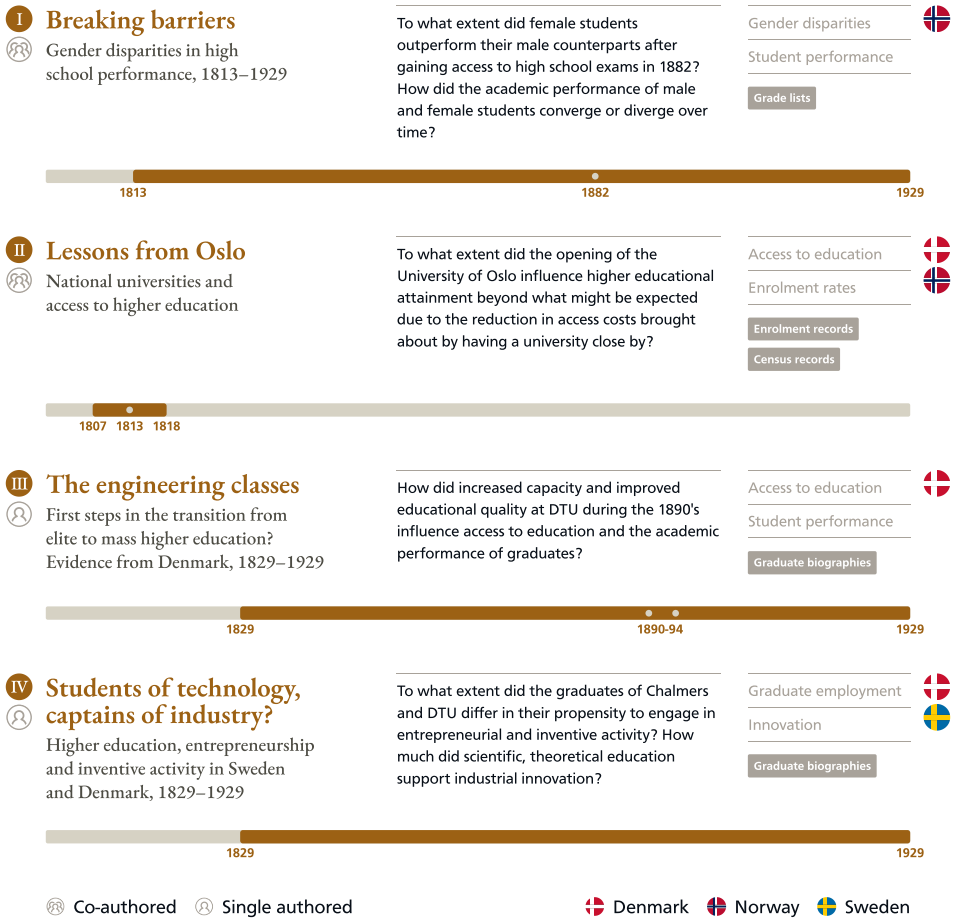

Figure 1 Structure of the dissertation

1993). The lack of access to higher education was especially pronounced in Norway, which only had four high schools in 1813 — the year when the first university on Norwegian soil opened.

Participation in higher education began to increase during the nineteenth century, and accelerated during the twentieth century. Moreover, the content of higher education changed with a greater focus on modern languages and natural sciences: reflected in the introduction of new subjects and study programmes, and the establishment of new types of educational institution. This expansion and diversification of higher education was just one feature of a broader mix of changes in the Scandinavian societies — political, social and economic.

The stated time period for this body of work is around 1800 to 1929. The end point is determined principally by the source material: in particular, papers III and IV rely on graduate biographies which capture graduation cohorts up to 1929. The starting point is deliberately fuzzy, and relates to paper II. The analysis in that paper focuses on those who graduated high school exams in Denmark and Norway between 1807 to 1818. However, controlling for parental education levels also means that graduates prior to this relatively narrow window are indirectly included. Moreover, the historical context requires discussion of events in the lead up to the central focus of that paper: the opening of the University of Oslo.[1]

1.2 Data and sources

While standard measures of educational attainment, such as literacy rates and years of schooling, give a useful picture of average human capital, the challenge with respect to *non-average* measures of human capital is finding high quality data that captures those who possessed useful skills and knowledge. Various studies have attempted to estimate the effect of scientific knowledge and technical skills in the context of industrialisation using a mix of measures including encyclopedia subscriptions (Squicciarini and Voigtländer 2015), membership of economic societies (Cinnirella et al. 2022), and clustering of skilled workers (Mokyr, Sarid, et al. 2022).

My dissertation uses two sets of novel source material from Scandinavia, which directly observe who pursued higher education. The first set comprises student enrolment records and grade lists from Denmark and Norway, which provide a comprehensive basis for examining high school education and academic performance. The second set are graduate biographies from Denmark and Sweden, which capture the universe of graduates from two polytechnic institutes and report their employment outcomes. These sources have been transcribed using a combination of machine learning techniques and artificial intelligence (AI) tools — accompanied by a considerable amount of manual checks and quality control.

As Griliches noted more than half a century ago:

> There are many different types and qualities of 'education' and much of the richness and the mystery of the world is lost when all are lumped into one index or number (Griliches 1970, p. 87).

In contrast to conventional measures of educational attainment — where everything is 'lumped into one index of number' — my data enable disaggregation by individual

[1] For consistency and convenience, I refer to all places and institutions by their contemporary names.

subjects and types of studies. Moreover, I can account for the 'quality' of educational attainment, by measuring the performance of students through their grades (papers I and III).

Furthermore, the use of biographies facilitates detailed analysis of career outcomes. While other sources, such as census records, give an indication of employment, biographies can chart the full scope of graduate careers — including changes in occupations over time, periods of overseas employment, and other extracurricular activities that can shed light on what contribution individuals made to society. Collectively, the data I present in this dissertation constitute a rich, individual-level evidence base for identifying who pursued higher education, what they studied, and how they applied their skills.

1.3 Contribution to the literature

While each paper in this dissertation offers its own independent research contribution, the dissertation as a consolidated product offers insights in three key fields.

First, this dissertation offers new findings on the accumulation of upper-tail human capital. All four papers illustrate the expansion of higher education during the nineteenth and (especially) early twentieth centuries, with rising graduate totals across different levels and types of education. But what, as (Mokyr 2002) asks, did those graduates do with the knowledge? In paper IV, I evaluate the propensity of highly skilled scientists and engineers to establish businesses and register patents, and thereby show that higher education was a relevant channel for supporting entrepreneurial innovation. But additionally, I discuss how higher education supported the operation of growth-enabling institutions. This consideration of both channels (innovation and institutions) is relevant, as they may also be mutually reinforcing: innovation underpins institutional changes, while institutional quality supports innovation.

Thus, second, given my extended definition of upper-tail human capital, I explore the relationship between higher education and institutions. The University of Oslo was central to the formation of the Norwegian nation state during the nineteenth century through its education of the ruling elite. The increase in high school graduations following the establishment of the university was not exclusively concentrated on the area in and around Oslo. Paper II discusses how community values and preferences relating to education were associated with the geographic distribution of the first cohorts admitted to the new university.

Third, in contemplating the socioeconomic composition of graduate cohorts, my work relates to studies of social and educational mobility. My data reveal that the elite nature of higher education did not change markedly during the nineteenth and early twentieth centuries. The socioeconomic distribution of graduates, as measured by

their fathers' occupational status, was more or less constant across time — a pattern observed across the different settings and institutions included in the various papers. Graduates predominantly came from households where the father was employed in professional, technical, administrative or managerial occupations: capturing the types of 'white-collar' positions that typically required higher education (for example, priests, lawyers and doctors). That is, I find relatively high social and educational immobility.

In addition to the three broad thematic contributions, my dissertation demonstrates the applicability of emerging methods relating to machine learning and AI. These tools and techniques enable the construction of large datasets from historic sources, and have the potential to be applied in a broader range of contexts. Furthermore, my empirical focus on Scandinavia is itself novel. While there is much literature on the economic and educational history of Denmark, Norway and Sweden, these most commonly concentrate on one specific country rather than — as I do in this dissertation — use the similarities and differences between the three as a basis for comparison. My use of individual-level data allows for a detailed analysis of differences between graduates within higher education, in contrast to the standard focus on education at a system-wide or institutional level.

1.4 Limitations

No piece of research can answer every imaginable question; my dissertation is no exception. The scope of this dissertation is limited to higher education (that is, upper secondary and tertiary education) — and thus excludes a range of other educational institutions that in their own right could warrant detailed examination. The growth of lower secondary schooling, including *realskoler* (Larsen 2010a,b), is an obvious candidate. Likewise, the intermediate and vocational institutes which gained a foothold during the nineteenth century, such as technical institutes and schools (Bek et al. 1931; Torstendahl 1975), would also be relevant to investigate in terms of their contribution to industrialisation. In choosing to focus on higher education, I do not mean to imply that other forms of education are irrelevant. On the contrary, I think of higher education as a good place to start, but not the only place worth exploring.

Given my reliance on source material about the graduates of higher education, I am limited in commenting on how much these graduates (and their skills and knowledge) differed from the wider population. With the exception of paper II, I do not link graduate data with census records. Thus, my results largely rely on comparing different subsets of graduate cohorts (papers I and III) or graduates of different institutions (paper IV). While not so much a limitation in the context of the individual papers, I am necessarily unable to assess the *additional* contribution of higher education, controlling for what individuals might otherwise have achieved had they not pursued higher education.

Moreover, as an exercise in quantitative analysis, my dissertation does not fully exploit the richness of especially the biographical source material. These life stories could in and of themselves justify a qualitative approach, using selected cases to build a narrative of industrialisation. My choice of quantitative methods mostly reflects a preference for exploiting the breadth of the data rather than the depth of the individual source. But one could just as easily take an alternative approach, and offer rewarding results.

1.5 Roadmap

Not every paper presented in this dissertation is exclusively my own work. Papers I and II are co-authored with my colleagues in a larger, interdisciplinary project mapping the Human Capital of the Nordic Countries (HCNC). The HCNC project is transcribing grade lists and graduate biographies to construct a comprehensive database of historic graduates of higher education. Papers I and II draw on a subset of this source material, which we intend to use across a range of research outputs over the years ahead. However, the analysis contained within those two papers are substantially my work. Papers III and IV constitute research I have conducted independently, and are entirely my own work. More detail on the distribution of work between authors is provided on page 57.

This introduction to the dissertation — the *kappa*/*kappe*, as it is known in the Scandinavian languages — provides a comprehensive overview of my research. Beyond a mere summary of the four papers I present, the introduction serves to bind the papers in one cohesive story. To this end, the rest of this introduction proceeds as follows. Section 2 outlines the economic-historic context for this study. Section 3 establishes the theoretical framework for the dissertation, and draws connections between my work and previous research. Section 4 describes the methods I use, while section 5 details the source material that underpins the dissertation. The four papers are summarised in section 6. Section 7 concludes with a discussion of the key findings and avenues for further research.

2 Empirical context

This dissertation draws on evidence of higher educational attainment in Scandinavia during the nineteenth and early twentieth centuries. Specifically, my data relate to four tertiary-level institutes of higher education across Denmark, Norway and Sweden (figure 2), along with dozens of high schools in Denmark and Norway. Of the four institutions, the University of Copenhagen is the oldest (founded in 1479). The remaining three institutions all opened during the period I examine: what are today known as the University of Oslo in 1813, and Chalmers University of Technology

Figure 2 Tertiary-level institutes of higher education for which data are included in this dissertation

Institutions given by their contemporary names. Current country borders used.

(Chalmers) and the Technical University of Denmark (DTU) in 1829. The latter two institutions were respectively located in Gothenburg, on Sweden's west coast, and in Copenhagen (initially adjacent to the University of Copenhagen).

Over a time span of more than a century, there are inescapably many events and institutional changes that have a bearing either directly or indirectly on the provision of and access to higher education. This section discusses the economic and historical context for this dissertation. It outlines the political history and economic development of the three countries, focusing on the aspects most relevant to this dissertation. It also describes the institutional settings with respect to education in Scandinavia, including the expansion of higher education during the nineteenth and early twentieth centuries.

2.1 Political history

At the start of the nineteenth century, Scandinavia consisted of two powers in conflict or competition with each other: Denmark–Norway and Sweden, the latter also including Finland. The Napoleonic Wars at the start of the century brought about significant changes in Scandinavia's borders and political interests (Hårdstedt 2010). Finland was annexed by Russia, forcing its separation from Sweden in 1809. Denmark was forced to cede Norway to Sweden in 1814 under the Treaty of Kiel. Norway initially reacted by pursuing independence, but eventually accepted a union with Sweden — though with a relatively high degree of autonomy, including its own constitution (Østergård

2008). Other smaller shifts in territorial possessions and borders also followed: Swedish Pomerania eventually passed to Prussian hands; the territories of the Faroe Islands, Greenland and Iceland were retained by Denmark.

In the middle of the century, Denmark lost further territory that had been in union with the Danish crown. A constitutional effort to fully absorb the duchies of Schleswig, Holstein and Lauenburg into Denmark prompted a Prussian invasion in 1864. While the nuances of the so-called 'Schleswig–Holstein question' are beyond the scope of this brief overview, it is sufficient to say that the war of 1864 quickly ended with Denmark's defeat, with the Danish king renouncing his claims to the duchies (Lesaffer 2024). The northern part of the lost territory was returned to Denmark in 1920 following a referendum in Schleswig (Fink 2020). That outcome defines the border between Denmark and Germany today.

Another key change in the twentieth century was the dissolution of the union between Sweden and Norway in 1905. While the separation was precipitated by a political standoff between the Norwegian parliament and the Swedish king, the two sides negotiated an agreement without direct conflict (Eriksson 2018). Later, Iceland moved to separate from Denmark, first establishing a constitutional monarchy in union with Denmark in 1918, before becoming a fully independent republic in 1944. (Iceland is nevertheless outside the scope of this dissertation.)

2.2 Economic development

The Scandinavian countries were unmistakably agrarian societies at the start of the period I examine. Figure 3 uses historic census data to illustrate the occupational status of households, as categorised using the Historical International Standard of Classification of Occupations (HISCO) (Leeuwen, Maas, and Miles 2002). In 1801, over half of all households in Denmark and Norway were associated with agriculture, declining to around 25–30 per cent by the the start of the twentieth century. By contrast, the share of households associated with production activities — including manufacturing and construction — approximately doubled during the nineteenth century. While there is a lack of Swedish census data on occupations prior to 1880, alternative sources indicate a similar pattern of declining employment in agriculture and increasing employment in production industries (Krantz and Schön 2007; SCB 1969).

This trend is also evident when measuring the value of industry output by sector over time. While the precise composition of the industry sectors as reported in figure 4 vary somewhat between countries, the clear trend over the period is one of a declining share of agriculture and a rising share of manufacturing.

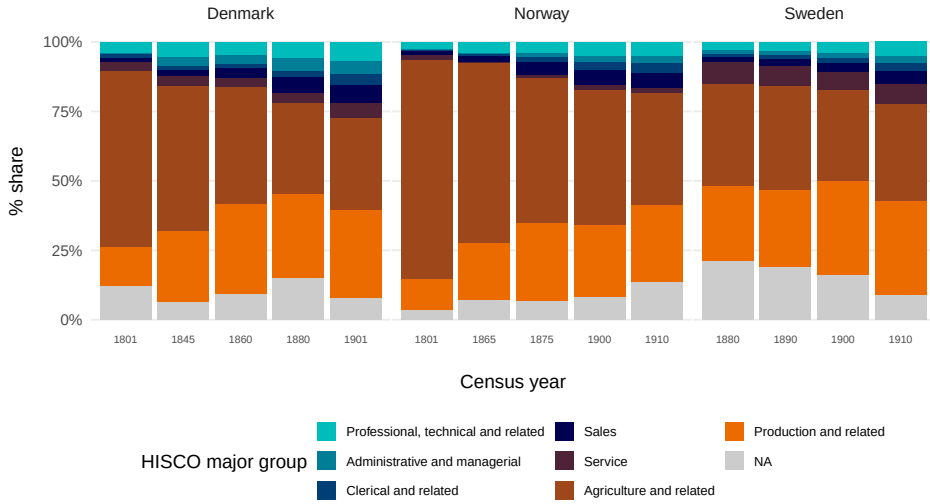

Figure 3 Household occupational status for Denmark, Norway and Sweden, selected census years, 1801–1910

Shares depict the percentage of households (not individuals) in each census associated with each occupational status (HISCO major group). Occupational status derived from census records for Denmark, Norway and Sweden. For each household in the given census, the lowest numeric value HISCO code of all individuals in the household (excluding household servants) is identified. NA values indicate either that no occupation associated with a given household can be matched to a HISCO code, or that no occupation is recorded for any individual in the household.

Danish (1801), Norwegian (all) and Swedish (all) HISCO codes as reported by Ruggles et al. (2024). For Danish censuses besides 1801, HISCO codes are generated from recorded occupations and/or household positions using the 'OccCANINE' algorithm (Christian Møller Dahl et al. 2024).

Sources: Arkivverket, Norwegian Historical Data Centre, et al. (2008a,b, 2011), Arkivverket, University of Bergen, et al. (2011), Clausen and Rigsarkivet (2000), Mathiesen et al. (2022), Norwegian Historical Data Centre and Minnesota Population Center (2008), Riksarkivet and Minnesota Population Center (2016), Riksarkivet, Umeå University, et al. (2011a,b, 2014), and Ruggles et al. (2024).

Characteristic of the early stages of industrialisation, the nineteenth century marked a shift in demographic patterns. Hildebrand (1978) notes that the combined population of Denmark, Norway and Sweden more than doubled between 1800 and 1900. Schön (2012) observes a redistribution of the population within Sweden, with greater growth in the south-west and north of Sweden (including Gothenburg) compared to the capital, Stockholm. Common to Norway and Sweden, and to a lesser extent Denmark, was rising emigration: in net terms, Hildebrand (1978) reports a 'loss' to migration of around two million Scandinavians between 1850 and 1910.

All three countries experienced growth through industrialisation, although the industry-level drivers differed between Denmark, Norway and Sweden. Hildebrand (1978)

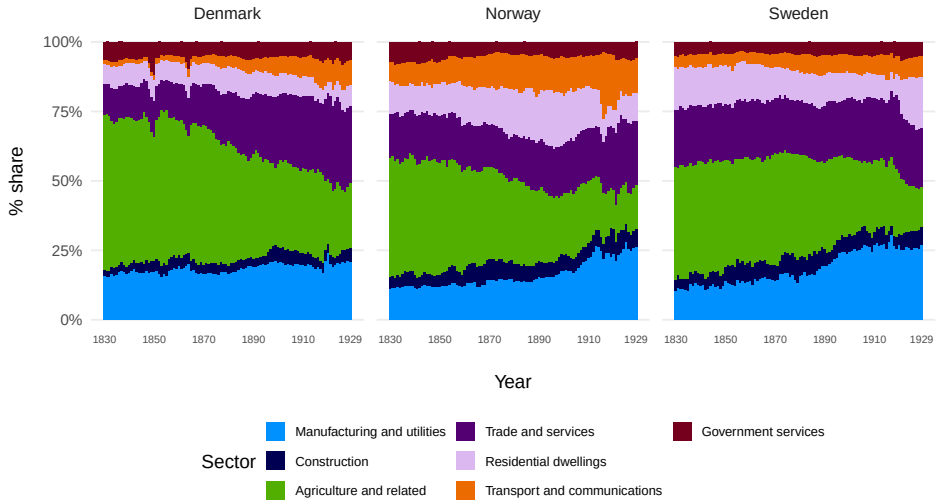

Figure 4 Industry shares of gross domestic product for Denmark, Norway and Sweden, 1830–1929

Industry sector definitions vary between countries. As such, the data are not directly comparable between countries, though are useful to illustrate the long-term trends within each country.

Sources: Grytten (2015), Johansen (1985), and Schön and Krantz (2015).

asserts that the principal industry driving Denmark's development was agriculture — but now with sophisticated processing techniques and innovative organisational practices, such as cooperative creameries (Henriksen et al. 2011). While Ljungberg and Schön (2013) find that high agricultural productivity in Denmark resulted in a higher initial income level relative to Norway and Sweden, they observe that Denmark's manufacturing sector exhibited higher productivity growth than its Scandinavian peers over the period 1865–1910. Boje (2020) similarly downplays the Danish agricultural story, noting the rise of new industrial titans, in part due to rising technical skill levels.

With respect to Norway, Hildebrand (1978) observes that during the second half of the nineteenth century, Norway's growth was led by shipping and fisheries. While the latter remained a source of employment for much of the rural population, the role of shipping came under threat due to technical changes: the shift from sails to steam engines. Through the turn of the century, energy of a different kind played an increasing role in Norway's development: electrical technologies facilitated by hydro-electric power (Grytten 2022; Hodne 1981). This enabled the growth of energy-intensive industries, particularly with respect to metallurgical and chemical production.

Schön (2012) argues that Sweden's industrial take-off did not begin until the 1880's. Until this time, agriculture remained the dominant sector in the Swedish economy. Outside of agriculture, exports — while growing substantially in the second half of the

nineteenth century — were principally focused on raw materials and commodities (for example, wood products and iron). From 1880, industrial activity in cities increased, and the Swedish economy shifted towards manufacturing, including in pulp and paper and consumer goods. Schön (2012) specifically notes electrical engineering as central to Sweden's development between 1890 and 1930. Hildebrand (1978) describes a pattern of progression up the value chain: from wood to pulp and paper, from iron to processed metals, and from increasing sophistication in the production of industrial output.

A broad theme of industrialisation, according to Schön (2012), is the rising role of scientists and engineers in economic development. Education and skills fostered technical change, which in turn increased the returns to education and skills.

2.3 Education in Scandinavia

The Scandinavian countries were early leaders in promoting literacy and facilitating widespread access to primary education. The first attempt at compulsory education was introduced in Denmark and Norway in 1739. This was initially connected to the (Protestant) church and the traditions of confirmation, ensuring that youth could read and understand the bible. A comprehensive public school system came to fruition in Denmark from 1814, providing elementary education through until confirmation age (Feldbaek 2016). Universal public primary schooling first came to Sweden later in the mid-nineteenth century, though this — as in Denmark and Norway — followed a long history of church-led education, which facilitated a high rate of literacy among young Swedes (Sandberg 1979). Over time, expansion of the school system also manifested itself in new pathways, including the establishment of various types of lower secondary schools, including *realskoler* (Larsen 2010a,b), Norwegian *middelskoler* (Paludan 1885) and Danish *mellemskoler* (Gjerløff and Jacobsen 2014).

While key features of the Scandinavian education system, these primary and lower secondary institutions are not the focus of this dissertation. Instead, this dissertation considers upper secondary and tertiary-level education: high schools (in Denmark and Norway) and university-level institutions.

High school

In contrast to the widespread availability of primary schooling, access to secondary schooling was considerably more limited. High schools emerged historically from cathedral and monastery schools — still evident in several of the oldest Scandinavian high schools, including those in Roskilde (Denmark) and Lund (Sweden), which were both founded in the eleventh century. By the start of the nineteenth century, over 30 high schools were located across the territories of the Dano-Norwegian union — though with the bulk to be found in Denmark.

The function of high school was to prepare students for university (Larsen et al. 2013). As such, Danish and Norwegian students graduated from high school or private tutoring by means of the university admissions exam: *examen artium*. As the number of high schools and high school students increased, the administration of the exam was eventually devolved to high schools. In Denmark, the student exam was first administered by high schools in 1850, while it continued as a university entrance exam in Norway until 1883. Though Swedish high schools are not in the scope of this dissertation, a similar university-administered entrance exam (*studentexamen*) was held in Sweden until 1862, before switching to a high school graduation exam (*mogenhetsprövning*) (Paludan 1885). Until 1870 in Sweden, 1875 in Denmark and 1882 in Norway, only men were permitted to sit the high school exam and pursue university studies.[2]

Across all three countries, high school studies were in the early nineteenth century grounded in a classic *Latin* education with a focus on languages and history. However, additional study programmes were introduced in the second half of the century. First was the *Real* line — the mathematics and natural sciences programme — which was established in 1856 in Sweden, 1871 in Denmark and 1875 in Norway. Further changes included the modern-language or *English* line from 1903 in Denmark and Norway.

Universities and related institutions

Scandinavia is home to some of Europe's oldest universities. A Franciscan academy (*studium generale*) was established in Lund in 1425 — over two centuries before Sweden's Lund University was founded in 1666.[3] Uppsala University (Sweden) and the University of Copenhagen (Denmark) both opened later in the fifteenth century. By 1800, the Dano-Norwegian and Swedish realms had universities in respectively Copenhagen and Kiel (the latter now in Germany[4]), and Uppsala, Lund, Griefswald (Swedish Pomerania, now in Germany), Tartu (Estonia) and Turku/Åbo (Finland). The University of Oslo was founded in 1811, and admitted its first students in 1813 — just one year before the separation of Denmark and Norway.

---

[2] In the case of Sweden, it was only from 1873 that women could be admitted to university — excluding theology and advanced legal studies (Bergman 2001).

[3] While both located in Lund, the two institutions are not directly related. *Studium generale* was a Catholic institution, established when Lund was part of Denmark, and which closed as a consequence of the Reformation. Lund University was established under Swedish rule (Staaf and Tersmeden 2016).

[4] Kiel University was historically directed at the German-speaking population of the duchies of Schleswig and Holstein. As such, even historically, it was closely connected with the German university system rather than the Danish (Grane and Hørby 1993).

The principal role of universities was to train public officials. In the case of the University of Copenhagen, this was reflected in the use of official exams (*embedseksamen*), which were mandated for every discipline by university statutes enacted in 1788 (Grane and Hørby 1993). These official exams qualified graduates for entry into professions such as the priesthood (theology), state administration (law), medical practice (medicine) and high school teaching (philosophy). This practice was also continued by the University of Oslo upon its establishment. However, the role of the university as a research institution was also established by the 1788 statutes, emphasising higher education as a function of science rather than moral imperative (G. B. Nielsen and Brichet 2007).

During the nineteenth century, the natural sciences came to play a larger role in the context of higher education. Of relevance for this dissertation was the establishment of polytechnic institutes: what are today the Technical University of Denmark (DTU) in Copenhagen and Chalmers University of Technology in Gothenburg (which both opened in 1829), as well as the Royal Institute of Technology in Stockholm (KTH, which opened in 1827). Other specialised institutes also opened including Denmark's Royal Veterinary and Agricultural College, and military academies which were among the first sources of (civil) engineering education (Boje 2014). Additionally, a range of secondary- and intermediate-level institutes of scientific and technical education opened during the late nineteenth and early twentieth centuries, including technical institutes and schools (Torstendahl 1975).

Just as with respect to the first university on its soil, Norway was also later than its Scandinavian neighbours in establishing an advanced-level institute of technical education — though the Free Mathematical School in Oslo, a specialised educational academy which later became the Norwegian Military Academy (*Krigsskolen*), was established in 1750, while a mining academy at Kongsberg (which was folded into the University of Oslo) had been established in 1757 (Collett 1999). The Technical Institute of Trondheim was established in 1870, followed in 1910 by the Norwegian Institute of Technology (which in 1996 merged with other institutions in Trondheim to form the Norwegian University of Science and Technology). However, around 250 Norwegians graduated from Chalmers — accounting for seven per cent of the total recorded graduates of Chalmers between 1829 and 1929. (A further 16 Norwegians are recorded as graduates of DTU over the same period.)

2.4 Trends in higher education

In a European context, the decades after World War II are typically viewed as the key period of expansion in access to higher education (Goldin and Katz 2008, 2009). However, even before this time, the number of graduates of the institutions examined in this study rose considerably. Until 1829, the annual total of graduates of the high school exam in Norway rarely exceeded 100. By 1929, over 1500 Norwegians each year graduated. The polytechnic institutes, Chalmers and DTU, also experienced growth — in particular, DTU rose from single-digit graduate totals by the 1850's to over 100 graduates a year by the 1920's.

Students came overwhelmingly from relatively high-status families. As Grane and Hørby (1993) note, the fathers of Danish graduates typically belonged to one of three groups: the educated elite (those in professions requiring higher education, such as priests), the political-administrative elite (those holding legislative and executive offices of state), or the merchant elite (traders and business owners). This accords with the patterns of student recruitment observed in the data for all the institutions considered in this dissertation.

Figure 5 draws on the grade list data used in paper I, reporting the distribution of Norwegian high school exam graduates by their fathers' occupations over the period 1813–1929. While these data reflect just one country, equivalent graphs for other graduate cohorts presented throughout this dissertation look much the same, with a heavy weighting of the groups 'Professional, technical and related workers' and 'Administrative and managerial workers'. That is, relative to figure 3, the graduates of higher education came disproportionately from households associated with 'white-collar' professions: the sons of lawyers, priests, doctors, scientists and government officials.

As noted, for much of the nineteenth century, high school was principally viewed as a stepping stone to university. However, the relationship between high school and university weakened over the course of the century. Figure 6 illustrates by high school graduating cohort the numbers of students who completed studies at the University of Oslo. The data are drawn from the University of Oslo's student register (*studentmatrikkelen*), which provides complete links between high school and university graduates up to the end of the nineteenth century. (The dataset continues beyond 1900, but no longer as a complete and representative series. Hence figure 6 focuses only on trends before 1900.)

Among the earliest cohorts of high school graduates, typically over 80 per completed studies at the university. Theology and Law were the primary fields of study, with the share of Law graduates rising relative to Theology during the 1830's. By the end of the

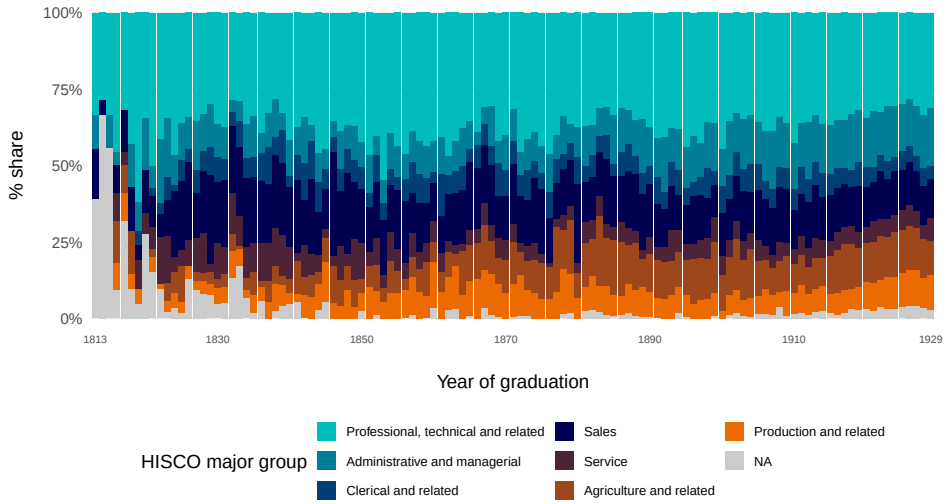

Figure 5 Occupational status of the fathers of high school exam graduates, Norway, 1813–1929

century, the share studying Law remained high, while Medicine replaced Theology as the second most popular field of study. However, almost half of all Norwegian high school graduates did not complete studies at the university.

The changing relationship between high school and university was particularly evident among female graduates. By the 1920's, females accounted for around a third of all high school graduates in both Denmark and Norway. However, they accounted for less than 10 per cent of university graduates. Their distribution across courses was also highly skewed. Between 1920 and 1929, around 23 per cent of the graduates of philosophy and the humanities at the University of Copenhagen were female, while 10 per cent of the graduates of the medical programme were female. By contrast, only four per cent of Law graduates were female, and two per cent of Theology graduates (Danmarks Statistik 1925, 1928, 1931).[5]

The decoupling of high school and university over the period — and especially the low rate of female participation in university studies — suggests a changing role of higher education in society. High school gradually became an education in its own right; part of a more diverse education system as new types of educational institutions opened. But this should not be mistaken as evidence of greater diversity in the recruitment pool for students.

[5] The specific case of theology is largely explained by the Church of Denmark's refusal to admit female priests, even though women were permitted to complete the official theology exam at the University of Copenhagen (A. L. Nielsen 2023).

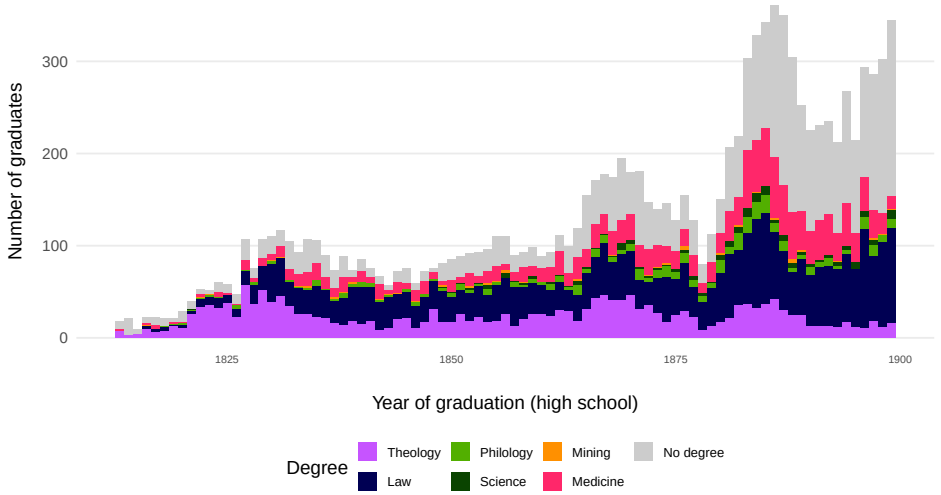

Figure 6 Degrees among Norwegian *examen artium* graduates, 1813-1899

'No degree' indicates those *artium* graduates for whom no degree is recorded in the University of Oslo's student register. An immaterially small number of graduates received two degrees, however they are recorded only once in the chart.

Source: University of Oslo (2003).

Among those who continued to university, there was a strong link between household background and what graduates studied. Using linked data from the student register for the University of Oslo, table 1 reports estimated marginal effects from probit models on the relationship between fathers' occupations and the degrees of high school exam graduates in Norway. Each column models a different degree type as the dependent variable, focusing on the three largest programmes: Theology, Law and Medicine. Occupations are grouped by HISCO major category, with a small number of minor categories that are highly represented in the data (especially those in the professional, technical and related workers major group) reported separately.

A clear pattern is evident from these results. Being the graduate son of a priest (*Workers in Religion*) is strongly correlated with studying theology. Likewise, being the graduate son of a lawyer (*Jurist*) or legislative official is strongly correlated with studying law. Being the graduate son of a doctor (*Medical, Dental, Veterinary and Related Workers*) is strongly correlated with studying medicine.

These results consider only Norwegian high school graduates, and thus do not directly say anything about the population at large. For example, from these results alone, it is not possible to conclude how likely it is that the son of a priest would himself go on to

Table 1 Probability of graduate studying course (columns) given their father's occupation (Probit marginal effects, 1813–1899)

	Theology	Law	Medicine
Professional, technical and related			
Medical, Dental, Veterinary and Related Workers	−0.078**	−0.199***	0.231**
	(0.029)	(0.031)	(0.085)
Jurists	−0.087**	0.245***	−0.111
	(0.026)	(0.033)	(0.074)
Teachers	0.102**	−0.109***	−0.047
	(0.037)	(0.033)	(0.035)
Workers in Religion	0.259***	−0.236***	−0.027
	(0.033)	(0.025)	(0.025)
Other professional, technical and related	0.108***	−0.101***	−0.022
	(0.033)	(0.029)	(0.025)
Administrative and managerial			
Legislative Officials and Government Administrators	−0.094**	0.146***	−0.040
	(0.030)	(0.041)	(0.035)
Other administrative and managerial	−0.014	0.007	−0.020
	(0.029)	(0.032)	(0.025)
Clerical and related	0.001	0.043	−0.052
	(0.030)	(0.033)	(0.036)
Sales	0.049	−0.066*	0.007
	(0.027)	(0.027)	(0.022)
Agriculture and related	0.200***	−0.123***	−0.045
	(0.035)	(0.028)	(0.032)
Production and related	0.150***	−0.135***	−0.039
	(0.035)	(0.029)	(0.030)
Year FE	Yes	Yes	Yes
Num. obs.	7391	7401	7285
Pseudo R^2	0.158	0.0889	0.082

Dependent variable: Graduate received degree given by column. Baseline HISCO major group is 'Service': all coefficients should be interpreted relative to this group. Standard errors reported in parentheses.
$^{***}p < 0.001$, $^{**}p < 0.01$, $^{*}p < 0.05$

study theology: only that a *graduate* son of a priest was quite likely to study theology. However, paper II, which links graduate records with population census data, does show that household occupational background was a key factor in influencing the probability of graduating, with the sons of priests especially likely to complete the high school exam.

3 Theory and relevant literature

Three key themes define the scope of this dissertation. The first is investment in education — a form of human capital. The second is institutional determinants of industrialisation, and the role of education in strengthening growth-enabling institutions. The third is social and educational mobility: who pursues higher education. Beyond contributing to these three areas, the individual papers additionally touch on specific topics.

3.1 Human capital and the upper-tail

The concept of 'human capital', while widespread today, had little currency prior to the 1960's. Even its earliest proponents were unsure about the term. As Schultz observed, 'the mere thought of investment in human beings is offensive to some among us. Our values and beliefs inhibit us from looking upon human beings as capital goods, except in slavery, and this we abhor' (Schultz 1961, p. 2). Similarly, G. S. Becker (1964) expressed reservations about titling his book *Human Capital* given concerns about drawing an equivalence between people and machines.

Yet the idea of human capital — investments in the skills and attributes of individuals that strengthen the productive contribution of their labour — has a long history. In *The Wealth of Nations*, Adam Smith defines capital in terms of four types: machinery, buildings, improved land and 'the acquired and useful abilities of all the inhabitants or members of the society' (Smith 1776, book 2, chapter 1). Acquired ability is something that requires an investment of time and effort. Just as with investment in equipment and property, investment in skills and talent enables the productive output of workers to be increased.

Education is just one form of human capital investment, complemented by the experience one naturally builds up in a given career — that is, on-the-job training and learning by doing (G. S. Becker 1964). Other channels by which human capital can be increased include improvements in health and longevity, as well as the transfer of skills and experience through migration.

Just as education is not the only type of human capital investment, human capital is not the only — or even necessarily the most important — means by which education influences growth and development. As Goldin and Katz (2008) describe, while the

skills provided by education have a direct effect on output, education also has an *indirect* effect through its relationship to the overall stock of ideas and knowledge in a society. That is, education also plays a role in the primary motor for long-term growth and development: technical progress.

From the perspective of Romer (1986, 1990), education facilitates the *generation* of new ideas and knowledge. In a similar but distinct vein, Nelson and Phelps (1966) posit that education supports faster *adoption* of ideas and knowledge. This latter point helps explain differences between countries in their development: while ideas and knowledge are fungible, the ability to productively harness such ideas and knowledge (whatever their origin) requires a level of technical sophistication, which education can foster.

Rosenzweig (1995) argues that the returns to education depend on the returns to learning — that is, being able to absorb and apply new ideas and knowledge. In a relatively simple world with processes and practices that people know and understand, the benefit of being able to absorb and apply new ideas is small. By contrast, as the world becomes more complex due to successive waves of technical advances that transform production processes (and perhaps especially where the pace of this progress is accelerating over time), then being able to learn and adapt has greater advantages.

In a historic context, the incentives to learn and acquire knowledge were greatest for society's elites. The lead up to industrialisation was characterised by rising interest in science and new technologies; the leading practitioners of the time were either members of the socioeconomic elite or sponsored by them (Mokyr 2018). The 'upper tail' of the human capital distribution was thus closely linked with the upper tail of the distribution of wealth and power in society.

Upper-tail human capital (as with human capital in general) is not exclusively acquired through formal education. As Mokyr (2018) sets out, many talented artisans and technicians were self taught or had a natural creative aptitude that encouraged them to question the status quo. Mokyr (2008) goes so far as to suggest that Britain's industrial advantage in the nineteenth century had little to do with formal education, but instead was at least partly a product of apprenticeships. But formal education nevertheless played a role in training innovators and critical thinkers, and generating the basic ideas and knowledge that were essential for technical advances.

Much empirical analysis of the upper tail does not consider education per se. For example, Squicciarini and Voigtländer (2015) use encyclopaedia subscriptions to measure the knowledge elite of nineteenth century France. They find that this knowledge elite mattered more for growth than average levels of human capital (measured by literacy rates). Cinnirella et al. (2022) consider the role of 'economic societies' — local groups established to improve economic conditions through, among

other things, disseminating knowledge of new technologies and promoting inventive ideas and practices. Areas of Germany with a greater number of economic society members in the eighteenth century were more innovative in the nineteenth century (measured by patent registrations). One potential mechanism is that areas with active economic societies were more likely to establish vocational training institutes.

While not explicitly examining how skills are acquired, some of the literature examines the role of specific groups of skilled workers. Mokyr, Sarid, et al. (2022) use the distribution of millwrights across pre-industrial Britain to explore how the clustering of technically specialised workers was associated with industrial development. Areas with higher concentrations of watermills and millwrights also observed greater numbers of industrial apprentices (for example, weavers and blacksmiths), whose professions benefited from the technology. Similarly, De Pleijt et al. (2020) show that the density of steam engines across English counties at the start of the nineteenth century was positively associated with the number of skilled workers, though not basic education levels (whether measured by literacy rates or primary school enrolments).

More closely related to papers III and IV in this dissertation, Hanlon (2022) examines the contribution of engineers to industrialisation, arguing that greater specialisation during the nineteenth century changed the inventive process. Engineers accounted for an increasing share of patent registrations over time, reflecting a shift from manufacturer-inventors to a distinct type of professional inventor. Maloney and Valencia Caicedo (2022) show a positive effect of the number of engineers in 1880 on present-day income levels across counties in the United States — with an additional effect from patenting levels. They suggest that while patents capture inventive activity, engineering skills may have been beneficial for adoption and adaptation. They also cite a role for lawyers in facilitating inventive activity, consistent with Cantoni and Yuchtman (2014, see below).

The relationship between upper-tail human capital and industrialisation is not uni-directional: just as human capital might support economic development, economic development might motivate additional investment in education. Diebolt, Le Chapelain, et al. (2021) examine how technical school enrolments responded to French industrialisation. While that paper focuses on intermediate-level training, they suggest two possible channels that might also have relevance to other forms and levels of education. One is that industrialisation resulted in greater household wealth, facilitating additional investment in education. The other is that the technical progress underpinning industrialisation increased the returns to education: more advanced technology motivated greater investment in skills and knowledge.

3.2 Institutions

The basic definition of institutions is 'the rules of the game in a society' (North 1990, p. 3). These rules are both formal (laws and enforcable contracts) as much as informal (social norms and customs). Collectively, well-functioning institutions reduce uncertainty in all manner of political, economic and social interactions. Specifically in the case of economic interactions, good institutions serve to lower transaction costs, facilitating market activity by building trust and committing parties to follow through on contractual undertakings.

The broad scope of institutions as a concept makes it difficult to pin down precisely what role institutions might play in industrialisation. Acemoglu and Robinson (2012) emphasise the contribution of 'inclusive institutions', which they define as institutions that do not hinder technical progress. Among these are property rights, the rule of law and individual freedoms such as being able to voluntarily enter contracts, choose one's own career, or start a new business. However, Gerschenkron (1962) notes that industrialisation took place in pre-revolutionary Russia despite institutional weaknesses (a point reinforced by more recent work, see Zhuravskaya et al. 2024). Institutions may determine the path of development, but not necessarily whether or not development occurs.

A related concept is that of state capacity: the ability of the state to carry out functions to the benefit of society and the economy. Like institutions, state capacity involves many layers. As Ogilvie (2022) notes, the most common measure of state capacity is the state's revenue base (fiscal capacity), with state expenditures also used as an alternative measure. However, these measures of themselves say little about how the state exercises its capacity. The state's legal and bureaucratic capacity, infrastructure investment and contribution to national identity are among the many channels through which the state might shape economic and social conditions (Ogilvie 2022).

Specific empirical evidence, while relatively limited, helps to explain how the state and institutions might have influenced industrialisation. North and Weingast (1989) identify how constitutional arrangements in seventeenth-century England (a product of tensions between the monarch and the parliament) supported credible property rights — though they do not explicitly define this as a causal factor for Britain's industrialisation. Acemoglu, Cantoni, et al. (2011) offer a more direct link to industrialisation, exploiting the effect of institutional reforms in French-occupied German territories during the French Revolution at the end of the eighteenth century. Among other things, these institutional reforms included a modern framework of civil law that enforced respect for property rights. They find local exposure to the French reforms was positively associated with higher urbanisation rates (a proxy for living standards) by the mid-nineteenth century, concluding that the institutional reforms paved the way for industrialisation.

Other literature examines the role of religion — a key social and cultural institution with political implications — in economic development, particularly through its influence on educational attainment. Most relevant to this dissertation (with its focus on traditionally Protestant Scandinavian countries) are studies drawing from the influential notion of a 'Protestant work ethic' (Weber 1905) helping to spur capitalism. S. O. Becker and Woessmann (2009) outline and test a theoretical mechanism in which Protestantism, with a greater emphasis on literacy, increased the marginal benefits of educational investments relative to Catholicism. Comparing predominantly Protestant and Catholic areas of Germany, they identify higher educational attainment as the key factor explaining differences in economic performance. However, Andersen et al. (2017) argue that Protestantism is not the proximate cause of these differences, with the values attributed to Protestantism by Weber (1905) stemming from an earlier Catholic order, the Cistercians, during the eleventh and twelfth centuries. Cistercian presence stimulated higher productivity, with persistent effects measurable centuries later in terms of population growth and employment. By contrast, Cantoni (2015) finds no evidence of religious differences affecting the growth rates of cities in the Holy Roman Empire — though he also acknowledges that his study focuses on urban areas, whereas S. O. Becker and Woessmann (2009) include a mix of urban and rural areas. He reconciles the two sets of results by suggesting that literacy (the key channel that S. O. Becker and Woessmann (2009) consider) had different effects in urban and rural areas. In cities, with a broad mix of economic activities, literacy had long had its advantages. By contrast, in agricultural rural areas, literacy was 'dormant capital' until industrialisation, at which point its benefits could be realised.

Just as changes to institutions might influence educational attainment and, in turn, growth, education might also be a factor relevant to how institutions are shaped and develop over time. Cantoni and Yuchtman (2014) examine the role of medieval universities in facilitating the growth of German cities between the years 1400 and 1500. While much of their analysis pertains to the location of the universities, they discuss how specifically law graduates might have enabled market activities by contributing to better local institutions and property rights enforcement. This explanation also aligns with Dittmar and Meisenzahl (2020) who note that expansion of German education during the sixteenth century was principally intended to strengthen public administration. They also show that upper-tail human capital (measured by the number of individuals who were recorded in biographies) was raised by the state provision of public goods.

Schäfer and Wulf (2014) likewise find that legal education helps explain city growth across over 200 cities of Western Europe over the period 1200 to 1600, but argue in favour of an alternative mechanism. They distinguish between the rise of Roman legal

traditions and the effect of university education in law. Their findings suggest that it was legal education rather than the law itself that drove growth. The authors argue that this owes to the scientific and rational approach embedded in legal education.

Institutional advances are not necessarily contingent on higher education. Studying the relationship between education and democracy using an international sample over the period 1870 to 2000, Murtin and Wacziarg (2014) find evidence that primary schooling matters more for the development of democratic institutions than secondary or tertiary levels of education. However, they also find little evidence that democracy on its own drives higher living standards. Two considerations are worth keeping in mind here: one, there are many different types of institutions, and there is no reason to expect that all matter equally for growth and development. Two, the period leading up to industrialisation may be qualitatively different from the period of modern growth. That is, any institutional drivers (and their connection to education, if any) may have different effects over time.

3.3 Social mobility

A key factor that is explored throughout this dissertation is the household backgrounds of graduates, including the occupations of graduates' fathers. To this end, an underlying theme in my research is social mobility: the extent to which children defy the social status of their parents — whether rising or falling in status — rather than each generation within a family following in the footsteps of previous generations.

Social status can variously be measured through changes in income, wealth or occupations (Clark 2021). My research is most closely related to occupational aspects, given that this is what my data record (especially with respect to fathers). Song et al. (2020) examine occupational mobility in the United States between 1850 and 2015, finding a long-term decline in mobility — with much of this decline observed as a consequence of industrialisation. This also accords with Long and Ferrie (2013), who compare the United States and the United Kingdom, finding that while US mobility rates were higher during the nineteenth century, the difference between the two countries with respect to mobility had evaporated by 1950. Fonseca and Guimarães (2009) consider occupational mobility in Portugal between 1860 and 1960. Despite notable regional variation, they conclude that industrialisation was associated with an increase in mobility, though slowing during the twentieth century.

In a Scandinavian context, Berger et al. (2023) examine occupational mobility across generations in Sweden in the late nineteenth and early twentieth centuries, before the rise of the welfare state. They find relatively high rates of mobility compared to other European countries, but closer to rates observed in the United States. They further identify migration as one factor which enabled higher occupational mobility. Modalsli (2017) estimates occupational mobility in Norway over the very long term,

drawing on census data to construct over 800,000 linked father–son pairs between 1865 and 2011. He finds rising social mobility over the period examined, with much of this driven by declining intergenerational persistence of non-agricultural occupations: outside of farming, sons were less likely to pursue the same occupations as their fathers. Additionally, migration between regions within Norway was also associated with higher mobility.

There is some evidence to suggest that parents' educational status may matter more for children's outcomes than occupational status or other measures of social status. In contemporary settings, Eshaghnia et al. (2022) examine Danish intergenerational mobility using modern population register data. They find that a key factor in the intergenerational transmission of social status is the correlation between parents' and children's education. This is reinforced by long-term evidence from Sweden of relative social immobility once intergenerational persistence of educational attainment is controlled for (Lindahl et al. 2015). Karlson and Landersø (2024) distinguish between levels of education, showing expansion of compulsory schooling in Denmark after World War II was associated with rising intergenerational mobility, while increased participation in university-level education has been associated with a decline in mobility.

The extent to which higher education is a help or a hindrance to social mobility is far from clear. A relevant debate from Asian economic history relates to the civil examination system in eighteenth- and nineteenth-century China and its effects on social mobility: while Hao (2013) and Shiue (2019) find persistence of elite status across generations, Campbell and Lee (2003) and Ho (1962) find greater variation in status between generations — that is, coming from a high-status family is no guarantee of attaining a high social status.

Against this backdrop, this dissertation contributes a historic perspective on understanding the development of the educated elite: the extent to which human capital was transmissible within the family during the nineteenth and early twentieth centuries, and how (it at all) this changed as access to higher education expanded.

3.4 Additional themes

The individual papers is this dissertation each have their own angles and perspectives. Paper I considers trends in higher educations over the long term, with a focus on differences between male and female students in their studies and educational performance. In historical contexts, a greater body of evidence on educational attainment focuses on differences pertaining to basic skills such as literacy and numeracy (Perrin 2020), and differences in enrolment levels in higher education (Ourliac 1988; Tournier 1973). Also related is research on occupational choice, with reputation or prestige as a motivating factor for differences between men and women

(Diebolt and Jaoul-Grammare 2024; Goldin 2014). We contribute a long-run perspective both with respect to high school academic performance (where we find no persistent differences between male and female students in terms of grades) and selection into study programmes (where we observe differences that echo contemporary enrolment trends).

Paper II touches on the role of higher education in fostering the nation state. Our results can be interpreted through the lens of Rousseau's writings: 'It is education that must give souls a national formation, and direct their opinions and tastes in such a way that they will be patriotic by inclination, by passion, by necessity' (Rousseau 1772, ch. 4). Particularly in the Norwegian context, our results tie in with discussion of the the nineteenth-century 'civil servant state' (*embetsmannsstaten*, see Myhre 2008, 2020; Rian 2020), where we discuss the role of higher education in shaping the country's ruling elite.

Paper III takes Trow (1972, 2007) as its theoretical starting point, explicitly examining the transition from elite to mass higher education using his framing. But whereas Trow describes the various elements that help define respectively elite, mass and (in the late twentieth century) universal education, I explicitly test possible interactions between these elements.

Paper IV is, of the four papers in this dissertation, closest to Mokyr's (2005) conception of upper-tail human capital, in that it focuses on higher education as a channel for supplying advanced scientific and technical skills. My work thus relates to literature on entrepreneurialism and innovation, particularly as it pertains to science and engineering. It also touches on the concept of 'academic drift', and the shift in educational focus from the practical to the theoretical (Harwood 2006, 2010).

4 Methods

My research is principally quantitative in nature, belonging to the broad family of work termed *cliometrics*: 'the application of economic theory and quantitative methods to the study of history' (Goldin 1995, p. 191). I employ regression analysis, including ordinary least squares (OLS) and probit models, to test clearly defined hypotheses. In so doing, I seek to measure the relationships between key factors, and shed light on the underlying mechanisms that explain developments over the long term.

As a workhorse model in econometrics, OLS is a tool to identify linear relationships between variables. It has the distinct advantage of providing easy-to-interpret results: given a regression of the effect of x on y, a coefficient of 0.2 on x means that a unit increase in x is associated with a 0.2 unit increase on y. The price of such simplicity is that OLS is also typically wrong — albeit wrong in a useful way. Maybe the relationship

between x and y is not exactly linear, such that an increase in x from 10 to 11 has a larger effect on y than an increase from 100 to 101. One cannot blindly plug variables in an equation; one must think about the expected relationship between the explanatory factors and the observed outcome.

The clearest example in this dissertation of where OLS would be ill-suited relates to paper II and assessing the probability of an individual in Norway graduating the high school exam after the opening of the University of Oslo in 1813. At that time, well under one per cent of the relevant youth population pursued higher education: graduation was an extreme 'tail event'. Probabilities are bounded between impossible (0) and certain (1). However, OLS has no concept of bounded outcomes. As such, when dealing with extreme tail events, it is entirely possible for OLS estimates to yield implied outcomes less than zero.

For probabilistic outcomes, I employ probit models. Probit models test binary outcomes — for example, graduate or not graduate. Whereas OLS regressions assume a linear relationship, probit models are non-linear. Instead, they rely on a cumulative distribution function of the standard normal distribution. As such, any deviation from a 50 per cent probability involves an asymmetric relationship between the explanatory factors. That is, for an event that is initially relatively unlikely, the effect of a decrease in a positively associated explanatory factor on the predicted probability will be smaller than the effect of an equivalent sized increase in the same factor. Likewise, the effect of an increase in a positively associated explanatory factor on the predicted probability will be greater if the event is initially unlikely relative to if the event is initially likely.

To assist in the interpretation of probit estimates, most papers in this dissertation report what are commonly termed 'marginal effects' (including in table 1 above). More precisely, I report the partial effect of an explanatory variable on an outcome holding all other factors at their mean values: the marginal effect at the mean. Thus, holding everything else constant at their average levels, how much does y change with a unit increase in x? In a graphical analogy, this is equivalent to calculating the slope at a point on a curve — where the placement of the point along the curve is determined by the covariate means. It gives an indication of what the *typical* effect of a unit change in x is on y, but certainly does not explain the relationship between x and y under *every* possible circumstance.

The one case where this approach fails is paper II. As graduating high school in early nineteenth-century Norway is an extreme tail event, holding variables at their mean values leads to largely meaningless estimates. The average individual had an approximately zero per cent probability of graduating before the opening of the new university, and an approximately zero per cent probability of graduating afterwards. Hence, the marginal effects associated with the change from pre-1813 to post-1813

would reveal little. Instead, we present a subset of our results in terms of the change in predicted outcome probability for representative values: specifically, we report estimates for different household occupational statuses. Individuals whose fathers were, for example, priests or lawyers were considerably more likely than the sons of farmers to graduate high school in early nineteenth-century Norway. Unpacking these differences thus gives some context to the raw probit estimates.

The precise models, outcomes and variables that I use necessarily depend on the context of the research question. More detailed, contextualised discussion can thus be found in each of the individual papers in this dissertation.

4.1 Correlation and causation

Regardless of whether OLS or probit models are employed, the elementary error in interpreting regression results is to confuse correlations between variables for a causal effect from x to y. Just because I carried an umbrella today and it rained does not mean that it rained because I carried an umbrella today.[6] Establishing causality requires careful model specification. At least in a historical context, this often involves 'natural experiments', whereby unanticipated events can be exploited to identify causal effects (for example, see Vedel 2024).

Of the research I present in this dissertation, paper II represents the most meaningful attempt at establishing causality. In that paper, my colleagues and I employ a difference-in-difference framework to compare Danish and Norwegian cohorts before and after the opening of the University of Oslo (that is, the difference between the two countries given the difference in time). On the basis that the decision to establish the university and timing of its opening were not determined by Norwegians themselves, we identify the change in graduation probability following the opening of the new university as a consequence of the new university.

Elements of causal identification are also evident in other papers. Paper I, for example, includes supplementary results that test the extent to which the higher grades received by the earliest cohorts of female students relative to their male peers were the result of male academic performance falling after the first female students arrived at their school. (We find no evidence of this.) Paper III exploits differences between the scale of curriculum reforms within individual study programmes at DTU to examine how much changes in educational quality matter for the socioeconomic composition of graduate cohorts. (Similarly, the opening of a new campus with modernised teaching facilities had differing effects across study programmes: mechanical engineering in particular had considerably better workshops, which provided the scope to teach in

[6] Both from growing up in Melbourne and now living in Copenhagen, I have had good empirical experience in testing this hypothesis.

electrical technologies.) Paper IV uses DTU as a baseline against which to examine how Chalmers' evolution into an institute of higher education influenced graduates' propensity to engage in entrepreneurial and inventive activity. But these papers, while suggesting possible causal channels, do not purport to show definitive causal effects.

While some may regard this as a limitation of my dissertation, I contend that the correlations are revealing. In particular, a key theme of this dissertation is the elite nature of higher education over the course of the nineteenth and early twentieth centuries. Despite the increase in graduate totals — whether from high school in Norway, or from technical institutes in Denmark and Sweden — there is a striking stability in the socioeconomic composition of graduate cohorts when measured by the occupations of graduates' fathers. The period I study captures both specific institutional changes, such as the admission of female students or the restructuring of courses, as well as broader societal trends, including the take-off of industrialisation in Scandinavia. Despite this, the high share of graduates who were children of fathers in relatively high-status professions was more-or-less unchanged over time. The absence of any material changes with respect to household status renders moot a search for causality: there is no effect, causal or otherwise.

4.2 A critical view

Quantitative evidence offers a robust basis for identifying patterns and trends in historical economic analysis, yet on its own is insufficient to fully explain the observed developments over time. This dissertation thus also relies on qualitative context provided by official reports, parliamentary deliberations and print media. These sources help to motivate the empirical cases examined in this dissertation: for example, the criticisms of DTU by former graduates published in an industry periodical illustrate the pressures that shaped the curriculum reforms in 1894 (paper III).

Plainly, there are risks of bias in any source. A careful examination of source material is always required to determine its value and legitimacy in a research context. As one specific example, a challenge in paper IV has been determining how much weight to place on the reports and accounts of various state committees that debated the role of Chalmers during the nineteenth and early twentieth centuries. In that context, Chalmers was typically contrasted with KTH in Stockholm and, in at least some cases, the positions expressed seemingly had more to do with defending or promoting the interests of one institution over the other (a point also implied by Björck (2004) and Torstendahl (1975) in their discussion of the sources). The findings and conclusions are not necessarily neutral assessments, but framed in a political context.

Source criticism is, in many respects, more art than science: it is ultimately a matter of judgment for the researcher as to whether a source is useful and reliable for a

given purpose. That said, one can think about source criticism in a structured and methodological way. Inspired by Scott (1990), my standard framework involves four components:

- Meaningfulness: Does a given source provide relevant information for the specific research purpose?
- Authenticity: What is the origin of the source? Is the source what it purports to be?
- Representativeness: Does the source give a complete picture, or are there omissions in coverage? If there are omissions, what biases might these introduce?
- Credibility: Is there evidence of errors or bias in the source? If so, are these systematic?

These principles apply not only to the qualitative evidence, but also the sources I use in the quantitative analysis presented in this dissertation.

5 Source material and data

I employ two sets of historical sources to map educational attainment:

- high school student records and examination grade lists for Denmark and Norway (papers I and II)
- graduate biographies for the universe of students who attended two polytechnic institutes in Denmark and Sweden (papers III and IV).

Furthermore, for paper II, historical census records for Denmark and Norway provide additional information on graduate households and trends in the wider population.

5.1 Student records and grade lists

As Ford et al. (2022) document, student records and grade lists are available for both Denmark (with published records stretching as far back as 1611) and Norway (from the establishment of the University of Oslo in 1813). These records are tied to *examen artium* — the university admissions exam, which also served as (and formally became) the high school graduation exam. As such, the grade lists provide a comprehensive record of all high school graduates in both countries through until the mid-twentieth century.

The content of the grade lists varies over time, with some differences between the Danish and Norwegian sources. In the main, the reported information includes

students' names, schools, and dates and places of birth. In most cases, the grade lists record both an overall final grade (*hovedkarakter*) and the individual examination grades for each subject.

A related source is the student register (*studentmatrikkel*) for the University of Oslo, which provides an overview of the graduates of *examen artium* up to the early twentieth century (University of Oslo 2003). On one level, the student register is less detailed than the grade lists. In particular, it does not capture individual subject grades, and does not provide full coverage of graduating cohorts after 1903. However, the student register links high school studies with university studies, such that it is possible to observe for any given graduate the full scope of their higher education career in Norway. This information can be constructed from university grade lists, but these are published separately from the *examen artium* grade lists that I employ.

The grade lists (with support from the student register) perform two functions in my analysis. First, as official records, the grade lists provide an authoritative and reliable basis for measuring who pursued higher education and what they studied. In that sense, they are superior to self-reported education levels, which can be prone to measurement error (Griliches 1977). Second, the grade lists provide detail on relative differences in educational performance within cohorts: that is, they record more than merely who was a student, but can say something about who was a 'good' student.

Grades and standardised tests have been widely used to measure educational quality and differences in educational attainment (Hanushek and Kimko 2000; Hanushek and Woessmann 2012; Hanushek and Zhang 2009). However, the context in which they are used and how they are interpreted requires some caution. In a comparison of different measures, Borghans et al. (2016) find that grades are effective in predicting later life outcomes, with the caveat that grades do not purely reflect cognitive ability but also students' personality and other innate qualities.

Most closely related to my research, Hansen and Strømme (2021) examine the performance of Norwegian law graduates over a span of two centuries, and find through much of the twentieth century a positive association between having a father with a background in law and getting a higher grade. This finding highlights a possible concern about the use of grades: that they do not exclusively reflect student ability, but can also indicate underlying structural factors that may work for or against individual students. For example, Hansen and Strømme (2021) suggest that class inequalities provided a subset of students with legal 'insider' advantages. Grades should thus not necessarily be taken at face value, but interpreted in a relevant context.

5.2 Graduate biographies

In examining polytechnic education, I draw on biographies produced in connection with the centenaries of Chalmers and DTU (Bodman 1929; Jespersen 1930). In the absence of complete enrolment records, these biographies provide a basis for measuring who pursued advanced studies in the natural sciences and engineering between 1829 and 1929. More substantially, the biographies provide details of the graduates' lives: both in terms of their backgrounds and their post-education careers.

While grade lists are official records of educational attainment, the biographies are a less authoritative source. Much of the information reported in the biographies was supplied by the graduates themselves. This necessarily introduces a degree of variability in the quality of information.

From a source critical perspective, there are two potential concerns: representativeness and accuracy. The biographies are a representative source in that they capture every graduate of Chalmers and DTU. However, they do not capture every graduate in the same degree of detail. This is particularly pronounced for the earliest cohorts of Chalmers graduates, for whom information is often limited (in a small number of cases, reporting nothing more than the student's name).[7] As I discuss in paper IV, I supplemented the Chalmers biographies with census information. However, this only partly resolves the issue. To correct for the missing data, I use a random forest model to predict the occupational status of graduates' fathers based on other observable characteristics. While imperfect, this approach means that graduates with missing household data are not simply omitted (which may otherwise bias the results). Moreover, as I show in a data appendix to paper IV, different model specifications — including purely random assignment of occupational status for the missing values — result in comparable estimates. That is, in the specific context of my analysis in that paper, the occupational status of graduates' fathers is not a key determinant of the outcomes.

With respect to accuracy, the self-reporting involved in the production of the biographies opens the door to erroneous or misleading information being included — or relevant information being excluded. Two factors mitigate this risk of bias in my analysis. First, the biographies are not solely the product of the information supplied by graduates. They also draw on official records (for example, enrolment details). Moreover, the biography editors sourced information on graduates from other

[7] For the DTU biographies, four per cent of graduates elected not to provide information to Jespersen (1930) — though most of these were recent graduates (1924–1929), who would have had little career information to report in any event.

available sources. As is evident from the analysis in paper III, there is complete background information (relating to birth, family and education) for all but one DTU graduate.[8]

Second, while the biographies do not necessarily report every job a graduate held during their careers, they provide enough information in the overwhelming majority of cases (92 per cent for Chalmers graduates, and 96 per cent for DTU) to identify at least one industry of employment. On average, I identify 1.4 industries for each Chalmers graduate and 1.5 industries for each DTU graduate, which suggests a broad comparability between the two sources.

The biographies I use in this dissertation are just a small subset of a much larger catalogue of biographical works. Among the most comprehensive of these are high school yearbooks in both Denmark and Norway, which were published in connection with reunion events, typically 25, 40 and/or 50 years after graduation from high school. The biographical information was mostly supplied by the graduates themselves, with near full coverage of the students and only limited examples of potential bias (Ford et al. 2023). Similar biographical records can be found in Sweden via the university 'nations' — student societies that students at Uppsala University and Lund University were (until 2010) required to be members of. Each nation periodically produced a detailed overview of their past members, including their careers after graduating. Further sources include commemorative volumes for individual high schools, as well as biographies over specific professions and study programmes: for example, doctors or *magister* graduates.

5.3 Data extraction

One thing is to have a rich set of source material to play with. It is quite another to convert those sources into usable data. The grade lists for Norway, used in paper I (and partly paper II), include 41,585 graduates through until 1929. (Approximately the same number of graduates again are recorded across the period 1930 to 1943, when the series of comprehensive grade lists ends.) The full set of these grade lists, including the corresponding grade lists for Denmark, are being transcribed as part of the wider HCNC project. My colleagues at the University of Southern Denmark, including Christian Møller Dahl and Christian Emil Westermann, apply machine-learning techniques to automate the transcription of printed tables (Christian M. Dahl et al. 2023). Their work is thus a core input to paper I, but also to a suite of future projects that will draw on the grade lists.

[8] The one exception relates to a graduate whose biography explicitly reports that his parents' identities cannot be disclosed as they are confidential.

Automated transcription does not mean human intervention is not required. Besides the coding involved, two manual operations are necessary. Before the transcription can proceed, the tables need to be correctly sorted into different types: for example, as subjects are added or removed from the curriculum, the table layouts of the printed grade lists change. Each change in table layout requires preparation of a new template, which instructs the model on where to find each piece of information. After the transcription is performed, a full suite of manual checks is required to test the performance of the model and correct for errors. Such errors can, for example, arise where multiple pieces of information are condensed into a single cell of the printed table, such that the model has difficulty correctly segmenting the rows.

Even once the transcription is complete, there is still a considerable amount of work required to clean the transcribed data. In particular, the Norwegian grade lists report birth dates and places in the same cell, and parents' names and fathers' occupations in the same cell. These need to be separated. I algorithmically split these combined fields using regular expression (regex) patterns: for example, given an input string for birth details of 'Bergen 1. Feb. 1834', the birthplace can be identified as the substring starting at the first character of the string and stopping before appearance of the first digit (1). To the extent that there are errors in the initial transcription, this algorithmic approach can fail, and manual editing is required.

My involvement in extracting data from the grade lists relates mostly to the manual elements of the transcription and the post-processing tasks. Research assistance with respect to quality control and data cleaning was ably provided by a small team at the University of Oslo and the University of Tromsø – The Arctic University of Norway, including Maret Grapengeter, Kristina Johansen and Trond Lien.

The biographies used in papers III and IV likewise required transcription. But whereas the grade lists are printed in a tabular format, which is naturally suited to the construction of a digitised dataset, biographies consist of passages of text. While the introductory sections of the biographies are well-structured, such that key information can be extracted through regex matching, the biography content relating to career information is considerably more varied.

I automate the process of extracting and summarising career information through the use of large language models (LLMs). Similar to asking an AI chatbot (such as ChatGPT) to condense a passage of text into key points, I feed each biography individually into a LLM and prompt it to:

- categorise the industries in which a graduate worked
- within each industry, identify each job the graduate held.

The LLM returns the summarised career information in a JavaScript Object Notation (JSON) format, which is structured for easy conversion to a dataset. For the 7279 graduates of Chalmers and DTU between 1829 and 1929, I record over 29,000 individual jobs.

During the time I have worked on this dissertation, the range and quality of open-source AI tools has improved markedly. Even smaller models that can be run on a reasonably equipped consumer-grade laptop produce reliable results. Nevertheless, no LLM performs flawlessly. I manually review the output data, and correct for errors and omissions. In the specific context of my research question, I also filter out irrelevant information that has been categorised: for example, voluntary positions that the model has classed as employment.

A more detailed description of how I transcribed the biographies is included in a technical appendix to paper IV.

5.4 Limitations

While providing rich information on the graduates of higher education, my source material is not without its limitations. The biggest challenge for the data used in this dissertation can be found in paper II, in which student records are linked to the 1801 censuses in Denmark and Norway. First and foremost, linking to the 1801 census imposes an upper bound on which graduates we can include: beyond 1818, very few graduates were born before 1801 (and therefore recorded in the census). The next full count Norwegian census was in 1865, which is too late to be useful for the purposes of our analysis.

The more significant problem is in the linking itself. For records of the high school exam held at the University of Copenhagen, the information recorded on graduates consisted only of name, birth date and (in most cases) high school. That provides a limited basis on which to match individuals, especially with relatively common names (Jens Jensen) that might have been recorded multiple times in the same birth year. Moreover, in many cases, it was not clear from the student records whether a student came from Denmark, Norway or somewhere else. Graduates also came from other parts of the Dano-Norwegian empire (for example, Schleswig-Holstein and Iceland), which were not captured in the 1801 censuses. Even those who went to high school in Denmark might have been born in Norway or elsewhere. That is, while linking rates would inevitably be less than 100 per cent in many years (as not every graduate would have been in either Denmark or Norway in 1801), we had no definitive basis to estimate what the best possible linking rate should be.

A data appendix to paper II outlines in more detail our approach to linking, and our judgment on the quality of those links. But it is sufficient to note here that linking

between the student records and the censuses was far from a straightforward exercise. Automatic algorithm-based linking helped, but was not enough on its own. Much of my time setting up the data for paper II was spent on manual linking, based on finding additional information in biographies and other genealogical references to validate links.[9] A similar, though far less intensive, process was also required for completing missing data on Chalmers graduates in paper IV.

The data have also posed difficulties with respect to standardisation of place names and job titles. The older (mostly Danish and Norwegian) sources have a tendency to record birthplaces with respect to parishes. This presents two immediate problems. One, not all parishes have unique names. For example, several Danish cities have a *Vor Frue Sogn* (Our Lady's Parish); parishes named after saints (for example, *Sankt Johannes* or *Sankt Peder*) also appear multiple times. Additional information, such as a city name or diocese, can help to clarify the correct location. But in a small number of cases, such ambiguity can only be resolved by way of a best guess as to the likely location — for example, the parish closest to a graduate's recorded high school.

Two, parish boundaries change over time, which complicates the identification of geographic parameters (for example, measuring distance to an educational institution). While municipal and other administrative boundaries also change over time, there is a gap with respect to historic Norwegian parishes and congregations (*prestegjeld* and *sogne*). Sveen and Marthinsen (2022) have produced a useful map of *prestegjeld* boundaries in 1801 (which I use in paper II), but equivalent high quality maps for later years are not available for Norway — in contrast to both Denmark (Agency for Data Supply and Infrastructure 2013) and Sweden (Junkka 2023). On the flipside, the Norwegian Agency for Shared Services in Education and Research (Sikt 2024) hosts historic data from multiple sources (including Statistics Norway), which are linked to different sets of municipal boundaries from 1769 to the present day. As such, data from one year can be converted to the municipal boundaries for another year. Paper I draws on this resource (*kommunedatabasen*) to map Norwegian graduates to population distributions over time, linked to contemporary municipal and country borders, for which mapping data are available.

[9] One of our research assistants, Trond Lien, provided valuable support in this task.

6 Summary of papers

This dissertation consists of four papers that explore different implications of the expansion of higher education in Scandinavia during the nineteenth century. The first two papers take the opening of the University of Oslo as their starting point: paper I, *Breaking barriers*, looks at student performance across a period spanning 1813 (when the first admissions exam for the University of Oslo was held) to 1929. The timespan allows for a detailed examination of long-term trends, with a particular focus on differences between male and female students. Paper II, *Lessons from Oslo*, compares the initial cohorts of the University of Oslo to those at the University of Copenhagen, and assesses how the establishment of the Norwegian university influenced educational attainment in Norway. Paper III, *The engineering classes*, similarly considers the effect of a new institution on patterns of educational attainment. But rather than a classical university, the institution in question is Denmark's polytechnic institute, DTU. Paper IV, *Students of technology, captains of industry?*, considers the outcomes of higher education with respect to industrialisation. Specifically, I analyse the entrepreneurial and inventive activity of the graduates of polytechnic education, based on data for Chalmers in Gothenburg and DTU in Copenhagen.

Two additional papers, which document some of the source material I use, also provide helpful context (Ford et al. 2022, 2023). However, while related works, these two papers are not included in the dissertation.

6.1 Paper I: Breaking barriers

In contemporary settings, gender disparities in high school performance are a persistent trend. Boys tend to drop out more frequently and achieve lower grades on average compared to girls. Furthermore, male and female students tend to study different subjects, resulting in entrenched occupational differences.

The first paper in this dissertation serves two purposes. First, it introduces a detailed dataset of individual-level educational attainment over a period spanning more than a century. The data record Norwegian high school exam graduates between 1813 and 1929, including their grades across individual subjects and their final aggregate grade. Second, it analyses differences between male and female graduates. To what extent did female students outperform their male counterparts after gaining access to high school exams in 1882? How did the academic performance of male and female students converge or diverge over time?

While the earliest female students on average received higher grades than their male peers, this relative advantage dissipated as the overall number of female students rose. By around 1910, we find no significant difference in grades between men and women. We also establish that this pattern — both the initial high female grades, and the

convergence with male grades — is not the result of a decline in average male grades upon the entry of female students to high schools. Rather, our results suggest that the first cohorts of female students were particularly talented and motivated, but that as overall female student numbers increased, their performance across the grade distribution increasingly resembled that of their male peers.

By contrast, we find a persistent difference in what male and female students studied. The first female students mostly graduated from the natural-scientific *Real* study programme rather than the classical humanities-oriented *Latin* programme. This changed in 1903 with the introduction of a new *English* study programme (a variant of the *Latin* programme focused instead on modern languages, without the requirement to study Latin). The *English* programme (and eventually also the *Latin* programme) became the preferred fields among female students, while male students to a far greater extent pursued studies in the natural sciences.

In the context of my dissertation, this paper provides evidence on long-term patterns of educational attainment. In particular, it examines the relationship between, on the one hand, access and enrolment and, on the other hand, student performance as measured by grades. The period we examine (1813–1929) captures significant changes in higher education in Norway: a rising number of high schools, changes in the courses offered, an increase in graduates totals, and the expansion of access to female students. Despite all of these factors, the distribution of graduates by household background (fathers' occupations) is relatively stable. Across the full series, employment in professional or technical work constitutes the largest single occupational group for the fathers of graduates. That is, while graduate totals increased, and female students were granted access, we see no evidence that higher education became materially less elite in the period we examine.

This paper is coauthored with Christian Møller Dahl, Kristin Ranestad, Paul Sharp and Christian Emil Westermann. My primary role for this paper has been the quantitative analysis: examining trends in the data, and designing and performing the regressions we report in the paper. Additionally, I assisted with the construction of the dataset, and contributed to the drafting of the paper. My contribution amounts to over half the total workload for the paper.

6.2 Paper II: Lessons from Oslo

Universities, and educational systems more broadly, are key institutions in the process of nation building and shaping national identities (Douglass 2021). This study examines the impact of the University of Oslo, which admitted its first students in 1813, on higher educational attainment in Norway. Prior to this time, Norwegian students would travel to Copenhagen in order to sit the high school exam, *examen artium*. With the new university, they could complete studies in Norway.

Borrowing from the literature on higher education in the twentieth century, we use distance to a university as an expression of the costs of educational access (Doyle and Skinner 2016; Knutsen et al. 2020; Suhonen and Karhunen 2019). This is especially relevant in a Norwegian context: 'the large distances in Norway ... and not least the journey to Copenhagen to take *artium* and study further made it both difficult and expensive for Norwegians to study' (Grane and Hørby 1993, p. 158). Even in Denmark — a smaller (and flatter) territory than Norway — there were significant differences in enrolment rates between youth from Copenhagen and its surrounds, and youth from Jutland in the west of the country.

Our study tests whether the new university had a national effect on higher educational attainment, or whether effects were principally concentrated in and around Oslo. To what extent did the opening of the University of Oslo influence higher educational attainment beyond what might be expected due to the reduction in access costs brought about by having a university close by?

Methodologically, we employ a difference-in-differences strategy, estimating the probability of an individual graduating before and after 1813, including individual and household-level controls. Our data come from student records for *examen artium* held at both the University of Copenhagen and University of Oslo. We link these records to the 1801 censuses for Denmark and Norway, allowing us to compare Danish and Norwegian cohorts in the years immediately before and after the opening of the new university (specifically, 1807 to 1818).

Relative to their Danish peers, we find that Norwegians experienced an increase in their chances of graduating between 1813–18 compared to 1807–12. Among those individuals from households associated with the professional and technical occupations, the predicted graduation probability increased by around 70 per cent after 1813.

Our results point primarily to a national effect rather than a geographically localised effect. In raw numbers, the greatest increase in graduate numbers came from areas further away from Oslo. Our estimates for the change-in-distance treatment imply that the penalty of distance declined after 1813.

As a mechanism for the geographic distribution of the increased probability of graduating, we test the effect of underlying interest in higher education. In support of the new university, Norwegians were encouraged to make donations. We use data on the location of these donors to construct a donor support measure. Those areas most exposed to donors recorded a greater increase in graduates after 1813: that is, areas with greater pre-existing demand benefited disproportionately from the establishment of the new university.

In terms of implications, we discuss the role of the University of Oslo in supporting the rise of the Norwegian nation state. We reflect on the 'civil servant state' (*embetsmannsstaten*), and the role of the educated, political elite in ruling Norway through the nineteenth century (Myhre 2008, 2020). Thus, paper II offers insights as to the contribution of upper-tail human capital to institutional quality and state capacity.

This paper is joint work with Trygve Andersen, Kristin Ranestad and Paul Sharp. I have had responsibility for the quantitative analysis, which has also required considerable effort in ensuring the consistency of data between the Danish and Norwegian source material. A technical appendix (appendix A) to the paper outlines in detail the work involved here, including (for my part) additional manual linking of sources. Beyond the data, I also contributed to the background research on the historical context, and was actively involved in the framing and drafting of the paper. My contribution amounts to over half the total workload for the paper.

6.3 Paper III: The engineering classes

Higher education evolved significantly during the twentieth century, shifting from an elite institution to a channel for mass education. This transition encompassed multiple features, including changes in purpose, curriculum structure, student motivations, and admissions criteria (Trow 1973, 2007). While the features of elite and mass education systems vary, less explored is the relationship between these features, and whether changes in one dimension trigger changes in another.

This paper examines the growth of DTU during the nineteenth and early twentieth centuries, exploring whether its expansion contributed to increased access to higher education beyond elite families. It focuses on two key changes during the 1890's: the opening of a new campus (which provided modern teaching equipment and facilities and expanded overall capacity), and the reorganisation of courses (in response to the rising demand for engineering skills). How did increased capacity and improved educational quality at DTU during the 1890's influence access to education and the academic performance of graduates?

My study is enabled by a comprehensive dataset of the 3879 graduates of DTU between 1832 and 1929. The data are sourced from graduates biographies (Jespersen 1930), which were produced in connection with DTU's first centenary in 1929. The data capture information on graduates' backgrounds (when and where they were born, and who their parents were), their educational pathways, and their final examination grades at DTU.

Despite a significant increase in graduate numbers, combined with a rising demand for technical skills in the context of industrialisation, I find that DTU remained a largely elite institution over the full period I examine. The opening of the new campus and the reorganisation of courses were associated with shifts in relative enrolments between study programmes, but did not lead to a more diverse student body.

Furthermore, graduates' academic performance was not significantly affected by their household background: differences between graduates in terms of their fathers' occupational status were not reflected in differences in grades (either before or after the 1890's changes). However, those who enrolled at a later age performed relatively better after the course reorganisation than before. Enrolment age can be viewed as an indicator of access to education, as those who commenced their studies at an older age were more likely to have worked for a period (including to raise money for tuition). Older students at enrolment recorded on average lower grades at graduation, but this relative disadvantage reduced after the course reorganisation. This provides some limited evidence that the effect of socioeconomic disparities within cohorts on academic performance may have lessened over time, without cohorts themselves becoming more diverse.

Neither the new campus nor the course reorganisation were specifically intended to boost participation in higher education across the socioeconomic distribution. In that light, these results might not seem surprising. However, the central finding is that even with some features characteristic of the transition to mass education — including a rapid increase in graduate totals and a greater focus on instruction in applicable skills rather than broadly cultivating an educated elite — the shift towards a more inclusive education system does not automatically follow.

My research fills a gap in the existing literature on the transition from elite to mass higher education, providing an individual-level analysis of students and their studies during a period of rapid expansion in graduate totals. By employing rich, quantitative data, I contribute a detailed examination of the students themselves: who they were, what they studied, and how they performed in those studies. In the context of the dissertation as a whole, paper III sheds light on the socioeconomic composition of graduate cohorts within technical (as opposed to classical) higher education, and shows that cohort composition did not materially change over time — either in trend terms, or in response to specific policy changes.

6.4 Paper IV: Students of technology, captains of industry?

The final paper in this dissertation examines the contribution of technical higher education to entrepreneurial innovation. While entrepreneurship and inventive capacity are widely recognised as key drivers of economic growth, the empirical evidence on the effectiveness of formal education in fostering entrepreneurial and inventive activity is far from conclusive.

This study is a comparative analysis of the two polytechnic institutes, DTU and Chalmers. While DTU was a university-level institute from inception, Chalmers initially started as a 'craft school' (*slöjdskola*), but progressed over time to become an institute of higher education. Chalmers' evolution is characteristic of academic drift — the tendency for professional and technical education to gradually move focus away from the practical to the theoretical (Harwood 2010).

Exploiting the convergence between Chalmers and DTU over the course of a century, I test the effect of differences in technical education on entrepreneurial innovation. To what extent did the graduates of Chalmers and DTU differ in their propensity to engage in entrepreneurial and inventive activity? How much did scientific, theoretical education support industrial innovation?

As described in section 5, this analysis relies on the biographies of 7279 polytechnic and engineering graduates between 1829 and 1929 (Bodman 1929; Jespersen 1930). I extract data on the background of graduates, as well as their employment profiles. Using AI tools, I classify graduates' careers into industries and identify both entrepreneurial and inventive activities: in the case of the former, whether a graduate established or owned a business; in the case of the latter, whether a graduate registered a patent or was otherwise described as an inventor.

My results reveal little difference between Chalmers and DTU graduates across the full period in their propensity to engage in either entrepreneurial or inventive activity. Among the earliest cohorts, DTU graduates were perhaps slightly more likely to establish or own a business than their peers from Chalmers. Likewise, DTU graduates in the mid- to late-nineteenth century were more likely to engage in inventive activity than Chalmers graduates. However, by the end of the nineteenth century, any differences between the two institutions had disappeared. This captures the bulk of the graduate cohorts: those who graduated between 1900 and 1929 account for two-thirds of the overall total for 1829–1929.

Controlling for industry sector employment has only a limited bearing on these results. The largest sectors for graduate employment were manufacturing and construction. Compared to DTU graduates, a larger share of Chalmers graduates recorded employment in the manufacturing sector; the reverse is true for the construction sector. However, both manufacturing and construction sector

employment were positively associated with entrepreneurship (with comparable magnitudes of effect). By contrast, of the two sectors, only manufacturing employment was correlated with inventive activity. This implies that the graduates of Chalmers had a lower baseline probability of inventive activity compared to their DTU peers.

My findings suggest that scientifically grounded, theoretical higher education may be a more effective channel for entrepreneurship and innovation than applied technical education. That is, academic drift was not unhelpful in fostering technical advances.

Paper IV is principally focused on answering the second part of this dissertation's overarching research question: the role of higher education in Scandinavia's industrialisation. Of the four papers, it has the closest alignment with Mokyr's concept of upper-tail human capital: the 'highly skilled mechanics and engineers in the upper tail of the distribution' (Mokyr and Voth 2010, p. 29). My results contribute to the literature on the role of higher education in fostering entrepreneurial innovation and supporting industrialisation.

7 Concluding discussion

This dissertation sets out to answer two linked research questions: To what extent did changes in the provision of higher education increase access to education beyond a small elite in society? How did changes in the provision of and access to higher education influence Scandinavia's development in the lead-up to and during industrialisation? Or, borrowing from Mokyr (2002): who were 'the few' who knew, and what did they do with their knowledge?

Deviating from Mokyr (2005), but in line with Dittmar and Meisenzahl (2020), I adopt an expanded definition of upper-tail human capital. Beyond scientific and technical skills with industrial applications, I also consider professional administrative skills as relevant to industrialisation through their effect on the quality of growth-enabling institutions. I focus on the role of higher education as a channel for the accumulation and application of this upper-tail human capital.

I address the research questions through quantitative analysis drawing on rich, individual-level source material. This dissertation draws on datasets constructed using a mix of manual and automated approaches — the later including machine-learning and AI-based techniques. Beyond my results, part of the contribution of this dissertation is the proof of concept around using sophisticated tools (many of which had not even been developed before I started this project) to construct data from large passages of text (specifically, graduate biographies).

7.1 Findings

Taking the Scandinavian countries as empirical cases, my results confirm the following stylised facts:

1. Through until 1929, higher education was an elite pursuit. Moreover, it did not become substantially less elite over the period.
2. From the latter part of the nineteenth century onwards, the demand for technical higher education increased, as is evident from rising graduate totals.
3. Higher education supplied skills that both supported institutional development and fostered technical progress.

The elite status of higher education during the nineteenth and early twentieth centuries is not of itself surprising. In a European context, expansion of access to high school and university-level education is typically associated with the period after World War II (Goldin and Katz 2008, 2009). However, graduate totals did rise rapidly over time, with acceleration from the late nineteenth century onwards. This is evident both from paper I (with respect to Norwegian high schools) and papers III and IV (graduates from Chalmers and especially DTU).

Changes in higher education during the period contributed to the increase in graduate totals. As is clear from paper II, access to higher education in Norway was limited until 1813, when the University of Oslo opened. At that time, Norway had just four high schools (in contrast to around 25 in Denmark, which had a similar youth population size). As paper I shows, the number of high schools grew, reaching over 50 in Norway by 1929. From the low double digits in the first years after the University of Oslo opened, annual high school graduate totals first reached 100 by the late 1820's, and 200 by the 1880's. Thereafter, expansion was rapid: by the late 1920's, the annual number of graduates exceeded 1500. Furthermore, Norwegian female students were permitted to sit the high school graduation exam from 1882; by 1929, female graduates accounted for around a third of each annual cohort.

A similar pattern of expansion is evident from the graduates of Chalmers and DTU. Until the 1870's, the combined total of graduates from the two institutions did not exceed 50 per year. DTU in particular rarely reached a double-digit total of graduates until the late 1870's. By the 1920's, the two institutions combined produced well over 200 graduates each year. DTU's growth from a low base was especially pronounced: rising from around 20 a year in the early 1890's to over 150 by the 1920's.

Despite this pattern of expansion in the raw numbers, the socioeconomic distribution of graduate cohorts was largely unchanged over the period. A comparable share of Norwegian high school graduates came from relatively high-status households: around one half of graduates in the 1820's had a father engaged in either a professional or

technical occupation or administrative and managerial occupation, and this share was virtually the same in the 1920's. Among the fathers of DTU graduates, a similar share of these occupational groups is also evident — albeit with greater noise among the earliest cohorts, given how few graduates there were. In short, the student base increased in size, but not in diversity.

One change, however, is what graduates studied. As section 2 illustrates, graduates who completed degrees at the University of Oslo became relatively less likely to study theology and more likely to study medicine and law. Similarly, the share of graduates studying medicine at the University of Copenhagen increased through the nineteenth century — though theology remained the largest single programme by 1900 (Grane and Hørby 1993). More notably with respect to Copenhagen, and as discussed in paper III, is the relative distribution of graduates between the University of Copenhagen and DTU. By the 1890's, the annual total of DTU graduates was only around 10 per cent of the number of graduates from the University of Copenhagen. During the 1920's, DTU's graduate total was around 40–50 per cent of the University of Copenhagen's (though tapering off slightly at the end of the decade).

Also at the high school level, studies in mathematics and natural sciences attracted a rising share of students. As presented in paper I, the scientific *Real* study programme was introduced in the Norwegian high school system in 1875: by the 1880's, around a third of graduates completed the *Real* programme. During the early twentieth century, the *Real* programme gained further ground, accounting for around 40–50 per cent of graduates by the 1920's. Differences in study programmes become even more stark when comparing the sexes: the *Real* programme recruited around 55–60 per cent of all male students during the 1920's, but just 10–15 per cent of all female students. This is despite the fact that among the earliest female cohorts (1882–1902), the overwhelming majority of female students studied the *Real* programme.

What did all of this mean for Scandinavia's development during the nineteenth and early twentieth centuries? The implications of higher education feature most strongly in papers II and IV. Paper II discusses the contribution of the University of Oslo to the development of the Norwegian nation state: that is, the institutional arm of upper-tail human capital. The rise of the 'civil servant state' in Norway is closely linked to the rise of the University of Oslo: it was the university which educated those who would go on to form Norway's ruling class during the nineteenth century. But even prior to this, Norway's educated elite played a role in driving the establishment of a Norwegian university. The Norwegian Society (*Norske Selskab*) — established in the late eighteenth century by a group of Norwegian students in Copenhagen — was one of the active proponents for the new university, and became a forum for fostering Norwegian cultural identity.

Paper IV points to the role of scientists and engineers with advanced technical skills: the standard Mokyrian explanation of upper-tail human capital. I concentrate on the entrepreneurial and inventive activities of graduates. While DTU had been criticised during the nineteenth century for not equipping its students with sufficiently practical skills relevant to industry (see, for example, Wagner 1999), my results show that DTU's graduates were active in industry, and contributed to Denmark's technical progress by establishing and owning businesses, and developing new ideas and products that many secured patents for.

Moreover, if it were true that DTU's academic approach was largely not useful for industry, then the comparison with Chalmers — initially a craft school, but progressing over time to a comparable institute of higher education — should reveal that DTU's graduates underperformed in entrepreneurial and inventive activity relative to their peers from Chalmers. Yet if anything, the opposite is true. Among the earliest cohorts, DTU's graduates demonstrated a (somewhat) greater propensity for entrepreneurial innovation.

Overall, while higher education became no less elite during the nineteenth and early twentieth centuries, it nevertheless played a role in Scandinavia's development. That is, higher education was a meaningful channel for the accumulation of upper-tail human capital.

7.2 Future work

To say that this dissertation scratches the surface of higher education's role in industrialisation is an overstatement. The richness of the primary source material I use — along with a suite of other similar sources from across Denmark, Norway, Sweden and elsewhere — offers enormous potential, the range of which is only hinted at in the work I present here. Happily, this dissertation is less a full stop than a comma.

My research contributes to the wider HCNC project, which is currently digitising the full set of Danish and Norwegian grade lists as well as high school graduate biographies (Ford et al. 2022, 2023). Planned future stages of the project include incorporating sources from additional countries — for example, Sweden. Collectively, these sources will document the accumulation of upper-tail human capital through higher education, including details of student backgrounds, academic performance (grades) and employment outcomes (biographical information).

There are natural extensions and related questions to each of the four papers in this dissertation. Paper I captures Norwegian graduates between 1813 and 1929, but there are additional years of graduates up to World War II which are also being transcribed.

Additionally, with comparable grade lists from Denmark, there is potential for detailed comparative analysis of trends in higher education between the two countries — in a longer-run perspective than the specific context examined in paper II.

Paper II opens the door to an examination of the long-term consequences of the opening of the University of Oslo. To what extent did the Norwegian graduates who continued their studies at the University of Oslo select into different courses than those who studied at the University of Copenhagen? To the extent that graduates' course selection between the two universities differed, how did this influence Norway's development during the nineteenth century? Such a longer-term analysis would allow for quantification of the new university's influence on the 'civil servant state' and institutional quality in Norway.

Paper III exploits differences between the study programmes offered by DTU. But as noted in section 2, DTU was not the only source of technical education in Denmark. As new types of intermediate-level technical institutes and schools opened during the nineteenth and early twentieth centuries, these also supplied skilled labour. While source material on the graduates of these intermediate institutes is less complete, some summary biographies are available (for example, Bek et al. 1931). How did the backgrounds of technical institute graduates differ from DTU's? To what extent did these intermediate institutes complement or substitute for DTU?

Paper IV compares Chalmers and DTU, relying on the convergence between the two institutions during the nineteenth century. From different starting points, the two institutions became leading institutes of higher technical education. However, one factor that has not been possible to control for is the effect within Sweden of KTH in Stockholm. While a comprehensive set of biographies for KTH on par with those available for Chalmers does not exist for the full period I examine, for graduates later in the nineteenth and certainly in the twentieth century, biographies of the engineers who were members of the Swedish Association of Skilled Technicians (*Svenska Teknologföreningen*, see Indebetou and Hylander 1937a,b) may provide sufficient coverage to enable a comparison between Chalmers and KTH.

Unlocking the full value of data on higher education requires linking graduates with population-wide data — for example, census records. Only paper II in this dissertation uses census-linked data — a substantial undertaking given the use of two separate sets of census data (Danish and Norwegian). As part of the HCNC project, linkage of all Danish and Norwegian graduates to historic censuses is currently underway. This will better enable measurement of the gains to higher education in a historic context: a 'holy grail' for assessing the effect of education on industrialisation and long-run development.

References

Abramovitz, Moses (1986). 'Catching Up, Forging Ahead, and Falling Behind'. In: *The Journal of Economic History* 46.2, pp. 385–406.

Acemoglu, Daron, Davide Cantoni, Simon Johnson, and James A. Robinson (2011). 'The consequences of radical reform: The French revolution'. In: *American Economic Review* 101.7, pp. 3286–3307.

Acemoglu, Daron and James A. Robinson (2012). *Why nations fail: The origins of power, prosperity, and poverty*. London: Profile Books.

Agency for Data Supply and Infrastructure (2013). *Digitalt atlas over Danmarks historisk-administrative geografi*. URL: https://dataforsyningen.dk/data/3967.

Allen, Robert C. (2003). 'Progress and poverty in early modern Europe'. In: *The Economic History Review* 56.3, pp. 403–443.

Andersen, Thomas Barnebeck, Jeanet Bentzen, Carl Johan Dalgaard, and Paul Sharp (2017). 'Pre-reformation Roots of the Protestant Ethic'. In: *The Economic Journal* 127.604, pp. 1756–1793.

Arkivverket, Norwegian Historical Data Centre, and Minnesota Population Center (2008a). *National Sample of the 1865 Census of Norway, Version 2.0*. Minneapolis: IPUMS.

– (2008b). *National Sample of the 1900 Census of Norway, Version 2.0*. Minneapolis: IPUMS.

– (2011). *National Sample of the 1910 Census of Norway, Version 1.0*. Minneapolis: IPUMS.

Arkivverket, University of Bergen, and Minnesota Population Center (2011). *Census of Norway 1801, Version 1.0*. Minneapolis: IPUMS.

Barro, Robert J. (1991). 'Economic growth in a cross section of countries'. In: *The Quarterly Journal of Economics*. NBER Working Paper Series 106.2, pp. 407–443.

Becker, Gary S. (1964). *Human Capital: A Theoretical and Empirical Analysis with Special Reference to Education*. 3rd edition. University of Chicago Press.

Becker, Sascha O. and Ludger Woessmann (2009). 'Was Weber wrong? A human capital theory of protestant economic history'. In: *Quarterly Journal of Economics* 124.2, pp. 531–596.

Bek, Steen, Knud Jørgensen, and Will. Hansen (1931). *Danske Teknika og deres Dimittender gennem 50 Aar: Ingeniør- og Konstruktørsammenslutningen gennem 35 Aar*. København: J. Jørgensen & Co.

Berger, Thor, Per Engzell, Björn Eriksson, and Jakob Molinder (2023). 'Social Mobility in Sweden before the Welfare State'. In: *The Journal of Economic History* 83.2, pp. 431–463.

Bergman, Malin (2001). 'När lagen mötte verkligheten: kvinnors tillträde till akademiska studier och högre statliga tjänster, 1870-1930'. PhD thesis. Lund: Lunds universitet.

Björck, Henrik (2004). *Staten, Chalmers och vetenskapen: Forskningspolitisk formering och sociala ingenjörer under Sveriges politiska industrialisering 1890-1945*. Nora: Nya Doxa.

Bodman, Gösta (1929). *Chalmers Tekniska Institut: Matrikel, 1829-1929*. Gothenburg.

Boje, Per (2014). *Vejen til velstand – marked, stat og utopi: Om dansk kapitalismes mange former gennem 300 år (Tiden 1730-1850)*. Vol. 1. Odense: Syddansk Universitetsforlag.

– (2020). *Vejen til velstand – marked, stat og utopi: Hvorfor blev Danmark rigt – og ikke rigere? (Tiden 1850-1930)*. Vol. 2. Odense: Syddansk Universitetsforlag.

Borghans, Lex, Bart H.H. Golsteyn, James J. Heckman, and John Eric Humphries (2016). 'What grades and achievement tests measure'. In: *Proceedings of the National Academy of Sciences* 113.47, pp. 13354–13359.

Campbell, Cameron and James Lee (2003). 'Social Mobility from a Kinship Perspective: Rural Liaoning, 1789-1909'. In: *International Review of Social History* 48.1, pp. 1–26.

Cantoni, Davide (2015). 'The economic effects of the protestant reformation: Testing the Weber hypothesis in the German lands'. In: *Journal of the European Economic Association* 13.4, pp. 561–598.

Cantoni, Davide and Noam Yuchtman (2014). 'Medieval universities, legal institutions, and the Commercial Revolution'. In: *The Quarterly Journal of Economics* 129.2, pp. 823–887.

Cinnirella, Francesco, Erik Hornung, and Julius Koschnick (2022). 'Flow of Ideas: Economic Societies and the Rise of Useful Knowledge Flow of Ideas: Economic Societies and the Rise of Useful Knowledge'.

Clark, Gregory (2005). 'The Condition of the Working Class in England, 1209–2004'. In: *Journal of Political Economy* 113.6, pp. 1307–1340.

– (2021). 'Social mobility in historical economics'. In: *The Handbook of Historical Economics*. Ed. by Alberto Bisin and Giovanni Federico. London: Academic Press. Chap. 23, pp. 719–748.

Clausen, Nanna Floor and Rigsarkivet (2000). *1801 Census of Denmark, Version 1.0*. Minneapolis: IPUMS.

Collett, John Peter (1999). *Historien om Universitetet i Oslo*. Oslo: Universitetsforlaget.

Dahl, Christian M., Torben S.D. Johansen, Emil N. Sørensen, Christian E. Westermann, and Simon Wittrock (2023). 'Applications of machine learning in tabular document digitisation'. In: *Historical Methods: A Journal of Quantitative and Interdisciplinary History* 56.1, pp. 34–48.

Dahl, Christian Møller, Torben Johansen, and Christian Vedel (2024). 'Breaking the HISCO Barrier: Automatic Occupational Standardization with OccCANINE'. URL: https://arxiv.org/abs/2402.13604v1.

Danmarks Statistik (1925). *Statistisk Årbog 1925*.

– (1928). *Statistisk Årbog 1928*.

– (1931). *Statistisk Årbog 1931*.

De Pleijt, Alexandra, Alessandro Nuvolari, and Jacob Weisdorf (2020). 'Human Capital Formation during the First Industrial Revolution: Evidence from the use of Steam Engines'. In: *Journal of the European Economic Association* 18.2, pp. 829–889.
Diebolt, Claude and Magali Jaoul-Grammare (2024). 'Gendered Study Choice and Prestige of Professions: France in the Long 20th Century'.
Diebolt, Claude, Charlotte Le Chapelain, and Audrey Rose Menard (2021). 'Neither the elite, nor the mass: The rise of intermediate human capital during the French industrialization process'. In: *Cliometrica* 15.1, pp. 167–202.
Dittmar, Jeremiah E. and Ralf R. Meisenzahl (2020). 'Public Goods Institutions, Human Capital, and Growth: Evidence from German History'. In: *The Review of Economic Studies* 87.2, pp. 959–996.
Douglass, John Aubrey (2021). *Neo-nationalism and Universities: Populists, Autocrats, and the Future of Higher Education*. Baltimore: Johns Hopkins University Press.
Doyle, William R. and Benjamin T. Skinner (2016). 'Estimating the education-earnings equation using geographic variation'. In: *Economics of Education Review* 53, pp. 254–267.
Eriksson, Bo (2018). 'Unionsupplösningen – Norges kamp för självständighet'. In: *Populär historia*.
Eshaghnia, Sadegh S.M., James J. Heckman, Rasmus Landersø, and Rafeh Qureshi (2022). 'Intergenerational Transmission of Family Influence'. Copenhagen.
Feldbæk, Ole (1990). 'Den lange fred. 1700-1800'. In: *Gyldendal og Politikens Danmarkshistorie*. Ed. by O. Olsen and O. Feldbæk. København: Gyldendals Bogklubber.
Feldbaek, Ole (2016). 'Denmark in the Napoleonic Wars, 1807–14'. In: *The Cambridge History of Scandinavia* 2, pp. 674–682.
Fink, Jørgen (2020). 'Genforeningen 1920'. In: *danmarkshistorien.dk*.
Fonseca, Helder Adegar and Paulo Edurdo Guimarães (2009). 'Social mobility in Portugal (1860–1960): operative issues and trends'. In: *Continuity and Change* 24.3, pp. 513–546.
Ford, Nicholas, Kristin Ranestad, and Paul Sharp (2022). 'Leaving Their Mark: Using Danish Student Grade Lists to Construct a More Detailed Measure of Historical Human Capital'. In: *Rivista di storia economica* 38.1, pp. 29–56.
– (2023). 'Not the Best Fillers in of Forms? The Danish and Norwegian Graduate Biographies and "Upper Tail Knowledge"'.
Galor, Oded (2011). 'Inequality, Human Capital Formation, and the Process of Development'. In: *Handbook of the Economics of Education* 4.6328, pp. 441–493.
Gerschenkron, Alexander (1962). *Economic Backwardness in Historical Perspective. A book of essays*. Cambridge MA: Belknap Press of Harvard University Press.
Gjerløff, Anne Katrine and Anette Faye Jacobsen (2014). *Da skolen blev sat i system: 1850-1920*. Aarhus N: Aarhus Universitetsforlag.

Goldin, Claudia (1995). 'Cliometrics and the Nobel'. In: *Journal of Economic Perspectives* 9.2, pp. 191–208.
– (2014). 'A Pollution Theory of Discrimination: Male and Female Differences in Occupations and Earnings'. In: *Human Capital in History: The American Record.* Chicago, IL: University of Chicago Press, pp. 313–348.
Goldin, Claudia and Lawrence F. Katz (2008). *The Race between Education and Technology*. Harvard University Press.
– (2009). 'Why the United States Led in Education: Lessons from Secondary School Expansion, 1910 to 1940'. In: *Human Capital and Institutions*. Ed. by David Eltis, Frank D. Lewis, and Kenneth L. Sokoloff. Cambridge University Press.
Grane, Leif and Kai Hørby (1993). *Københavns Universitet 1479-1979, Bind 2: Almindelig historie 1788-1936*. Vol. 2. København: Gad, p. 605.
Griliches, Zvi (1970). 'Notes on the role of education in production functions and growth accounting'. In: *Education, Income, and Human Capital*. Ed. by W. Lee Hansen. Vol. I. National Bureau of Economic Research, pp. 71–128.
– (1977). 'Estimating the Returns to Schooling: Some Econometric Problems'. In: *Econometrica* 45.1, p. 1.
Grytten, Ola Honningdal (2015). 'Norwegian Gross Domestic Product by industry 1830-1930'. Oslo.
– (2022). 'Revising growth history: new estimates of GDP for Norway, 1816–2019'. In: *The Economic History Review* 75.1, pp. 181–202.
Hanlon, W. Walker (2022). 'The Rise of the Engineer: Inventing the Professional Inventor During the Industrial Revolution'. Cambridge MA.
Hansen, Marianne Nordli and Thea Bertnes Strømme (2021). 'Historical change in an elite profession — Class origins and grades among law graduates over 200 years'. In: *The British Journal of Sociology* 72.3, pp. 651–671.
Hanushek, Eric A. and Dennis D. Kimko (2000). 'Schooling, labor-force quality, and the growth of nations'. In: *American Economic Review* 90.5, pp. 1184–1208.
Hanushek, Eric A. and Ludger Woessmann (2012). 'Do better schools lead to more growth? Cognitive skills, economic outcomes, and causation'. In: *Journal of Economic Growth* 17, pp. 267–321.
Hanushek, Eric A. and Lei Zhang (2009). 'Quality-Consistent Estimates of International Schooling and Skill Gradients'. In: *Journal of Human Capital* 3.2.
Hao, Yu (2013). 'Social Mobility under Three Regimes, China, 1645–2012'. PhD thesis. University of California, Davis.
Hårdstedt, Martin (2010). *Omvälvningarnas tid: Norden och Europa under revolutions- och Napoleonkrigen*. Stockholm: Norstedts.
Harwood, Jonathan (2006). 'Engineering Education between Science and Practice: Rethinking the Historiography'. In: *History and Technology* 22.1, pp. 53–79.
– (2010). 'Understanding Academic Drift: On the Institutional Dynamics of Higher Technical and Professional Education'. In: *Minerva* 48.4, pp. 413–427.

Henriksen, Ingrid, Markus Lampe, and Paul Sharp (2011). 'The role of technology and institutions for growth: Danish creameries in the late nineteenth century'. In: *European Review of Economic History* 15.3, pp. 475–493.

Hildebrand, Karl-Gustaf (1978). 'Labour and Capital in the Scandinavian Countries in the Nineteenth and Twentieth Centuries'. In: *The Cambridge Economic History of Europe, Volume 7: The Industrial Economies: Capital, Labour and Enterprise*. Ed. by Peter Mathias and M. M. Postan. Cambridge: Cambridge University Press. Chap. 9, pp. 590–628.

Ho, Ping-ti (1962). *The Ladder of Success in Imperial China: Aspects of Social Mobility, 1368-1911*. New York: Columbia University Press.

Hodne, Fritz (1981). *Norges økonomiske historie, 1815–1970*. Oslo: J. W. Cappelens Forlag.

Holberg, Ludvig (1871). 'Erasmus Montanus: An Old Danish Comedy'. Trans. by Peter Toft. In: *Fraser's Magazine* 84, pp. 69–96.

Indebetou, Govert and Erik Hylander (1937a). *Svenska teknologföreningen 1861-1936: biografier. D. 1 Födelseåren 1811-1884*. Vol. 1. Stockholm: Svenska teknologföreningen.

– (1937b). *Svenska teknologföreningen 1861-1936: biografier. D. 2 Födelseåren 1885-1914*. Vol. 2. Stockholm: Svenska teknologföreningen.

Jespersen, Rodewald (1930). *Biografiske oplysninger angaaende den polytekniske læreanstalts kandidater: 1829-1929*. 3rd ed. Copenhagen: Dansk Ingeniørforening.

Johansen, Hans Christian (1985). *Dansk historisk statistik 1814-1980*. Vol. 9. København: Gyldendal.

Junkka, Johan (2023). *histmaps: R package to generate Swedish historical administrative boundaries*. URL: https://github.com/junkka/histmaps.

Karlson, Kristian B. and Rasmus Landersø (2024). 'The making and unmaking of opportunity: educational mobility in 20th-century Denmark'. In: *The Scandinavian Journal of Economics*.

Knutsen, Tora K., Jørgen Heibø Modalsli, and Marte Rønning (2020). 'Distance and choice of field: Evidence from a Norwegian college expansion reform'.

Krantz, Olle and Lennart Schön (2007). 'Swedish Historical National Accounts 1800-2000'. Lund.

Larsen, Christian (2010a). *Realskolen gennem 200 år: Kundskaber og erhvervsforberedelse*. Vol. 1. København: Danmarks Privatskoleforening.

– (2010b). *Realskolen gennem 200 år: Kundskaber og erhvervsforberedelse*. Vol. 2. København: Danmarks Privatskoleforening.

Larsen, Christian, Erik Nørr, and Pernille Sonne (2013). *Da skolen tog form: 1780-1850*. Aarhus N: Aarhus Universitetsforlag.

Leeuwen, Marco H.D. van and Ineke Maas (2011). *HISCLASS: A Historical International Social Class Scheme*. Louvain: Leuven University Press.

Leeuwen, Marco H.D. van, Ineke Maas, and Andrew Miles (2002). *HISCO: Historical International Standard Classification of Occupations*. Louvain: Leuven University Press.

Lesaffer, Randall (2024). *1864*. URL: https://opil.ouplaw.com/page/545.
Lindahl, Mikael, Mårten Palme, Sofia Sandgren Massih, and Anna Sjögren (2015). 'Long-Term Intergenerational Persistence of Human Capital: An Empirical Analysis of Four Generations'. In: *The Journal of Human Resources* 50.1, pp. 1–33.
Ljungberg, Jonas (2002). 'About the role of education in Swedish economic growth, 1867-1995'. In: *Historical Social Research* 27.4, pp. 125–139.
Ljungberg, Jonas and Lennart Schön (2013). 'Domestic markets and international integration: paths to industrialisation in the Nordic countries'. In: *Scandinavian Economic History Review* 61.2, pp. 101–121.
Long, Jason and Joseph Ferrie (2013). 'Intergenerational Occupational Mobility in Great Britain and the United States Since 1850'. In: *The American Economic Review* 103.4, pp. 1109–1137.
Maloney, William F. and Felipe Valencia Caicedo (2022). 'Engineering Growth'. In: *Journal of the European Economic Association* 20.4, pp. 1554–1594.
Mathiesen, Nicolai Rask, Olivia Robinson, Asbjørn Romvig Thomsen, and Barbara Revuelta-Eugercios (2022). *Link-Lives Data v.1.2.1*. Copenhagen: Danish National Archives/University of Copenhagen.
Mitch, David (1999). 'The Role of Education and Skill in the British Industrial Revolution'. In: *The British Industrial Revolution*. Ed. by Joel Mokyr. Routledge, pp. 241–279.
Modalsli, Jørgen (2017). 'Intergenerational Mobility in Norway, 1865–2011'. In: *Scandinavian Journal of Economics* 119.1, pp. 34–71.
Mokyr, Joel (2002). *The Gifts of Athena: Historical Origins of the Knowledge Economy*. 1st pbk. Princeton and Oxford: Princeton University Press.
– (2005). 'Long-Term Economic Growth and the History of Technology'. In: *Handbook of Economic Growth* 1.SUPPL. PART B, pp. 1113–1180.
– (2008). 'The Institutional Origins of the Industrial Revolution'. In: *Institutions and Economic Performance*. Ed. by Elhanan Helpman. Cambridge MA: Harvard University Press, pp. 64–119.
– (2018). 'Bottom-up or top-down? The origins of the Industrial Revolution'. In: *Journal of Institutional Economics* 14.6, pp. 1003–1024.
Mokyr, Joel, Assaf Sarid, and Karine van der Beek (2022). 'The Wheels of Change: Technology Adoption, Millwrights and the Persistence in Britain's Industrialisation'. In: *The Economic Journal* 132.645, pp. 1894–1926.
Mokyr, Joel and Hans-Joachim Voth (2010). 'Aggregate growth and cycles'. In: *The Cambridge Economic History of Modern Europe: Volume 1: 1700–1870*. Ed. by Stephen Broadberry and Kevin H O'Rourke. Vol. 1. The Cambridge Economic History of Modern Europe. Cambridge: Cambridge University Press, pp. 7–42.
Murtin, Fabrice and Romain Wacziarg (2014). 'The democratic transition'. In: *Journal of Economic Growth* 19.2, pp. 141–181.

Myhre, Jan Eivind (2008). 'Academics as the Ruling Elite in 19th Century Norway'. In: *Historical Social Research / Historische Sozialforschung* 33.2, pp. 21–41.
– (2020). *Embetsmennenes stat*. URL: https://www.norgeshistorie.no/bygging-av-stat-og-nasjon/1409-embetsmennenes-stat.html.
Nelson, Richard and Edmund Phelps (1966). 'Investment in Humans, Technology Diffusion and Economic Growth'. In: *The American Economic Review* 56.1, pp. 69–75.
Nielsen, Andreas Lindbjerg (2023). *Da kvinderne trådte ind, blev kirken hel*. URL: https://www.folkekirken.dk/om-folkekirken/hvem-arbejder-i-kirken/praesten/da-kvinderne-traadte-ind-blev-kirken-hel.
Nielsen, Gritt Bykærholm and Nathalia Brichet (2007). 'Det Frie Universitet: Forestillinger om universitetets 'frihed' og 'nytte' fra 1479 til 2003'. In: *Årbog for dansk skolehistorie* 41, pp. 65–86.
North, Douglass C. (1990). *Institutions, institutional change and economic performance*. Cambridge: Cambridge University Press.
North, Douglass C. and Barry R. Weingast (1989). 'Constitutions and Commitment: The Evolution of Institutions Governing Public Choice in Seventeenth-Century England'. In: *The Journal of Economic History* 49.4, pp. 803–832.
Norwegian Historical Data Centre and Minnesota Population Center (2008). *National Sample of the 1875 Census of Norway, Version 2.0*. Minneapolis: IPUMS.
Ogilvie, Sheilagh (2022). 'State capacity and economic growth: Cautionary tales from history'. In: *National Institute Economic Review* 262, pp. 28–50.
Østergård, Uffe (2008). 'De skandinaviske staters udvikling'. In: *Politica* 40.4, pp. 442–456.
Ourliac, Guy (1988). 'The Feminisation of Higher Education in France: Its History, Characteristics and Effects on Employment'. In: *European Journal of Education* 23.3, pp. 281–292.
Paludan, Julius (1885). *Det høiere Skolevæsen i Danmark, Norge og Sverig. En sammenlignende historisk Fremstilling, udarbeidet efter Opfordring af Bestyrelsen for det Letterstedtske Fond*. Kjøbenhavn: Wilhelm Priors Hof-Boghandel.
Perrin, Faustine (2020). 'Gender Gap in Numeracy and the Role of Marital Status: Evidence from 19th century France'. In: *Revue d'économie politique* 130.1, pp. 51–76.
Rian, Øystein (2020). *Embetskjøpmennene i Norge på 1600-tallet*. URL: https://www.norgeshistorie.no/kirkestat/1120-embetskjopmennene-i-norge-pa-1600-tallet.html.
Riksarkivet and Minnesota Population Center (2016). *National Sample of the 1910 Census of Sweden, Version 1.0*. Minneapolis: IPUMS.
Riksarkivet, Umeå University, and Minnesota Population Center (2011a). *National Sample of the 1890 Census of Sweden, Version 2.0*. Minneapolis: IPUMS.
– (2011b). *National Sample of the 1900 Census of Sweden, Version 3.0*. Minneapolis: IPUMS.
– (2014). *National Sample of the 1880 Census of Sweden, Version 2.0*. Minneapolis: IPUMS.

Romer, Paul M (1986). 'Increasing Returns and Long-Run Growth'. In: *Journal of Political Economy* 94.5, pp. 1002–1037.
– (1990). 'Endogenous Technological Change'. In: *Journal of Political Economy* 98.5.
Rosenzweig, Mark R. (1995). 'Why Are There Returns to Schooling?' In: *The American Economic Review* 85.2, pp. 153–158.
Rousseau, Jean-Jacques (1772). *Considerations on the Government of Poland and on its Proposed Reformation*. Trans. by The Constitution Society.
Ruggles, Steven, Lara Cleveland, Rodrigo Lovaton, Sula Sarkar, Matthew Sobek, Derek Burk, Dan Ehrlich, Quinn Heimann, and Jane Lee (2024). *Integrated Public Use Microdata Series, International: Version 7.5*. Minneapolis, MN: IPUMS.
Sandberg, Lars G. (1979). 'The Case of the Impoverished Sophisticate: Human Capital and Swedish Economic Growth before World War I'. In: *The Journal of Economic History* 39.1, pp. 225–241.
SCB (1969). *Historisk statistik för Sverige: Del 1. Befolkning 1720–1967*. Tech. rep. Stockholm: Statistiska centralbyrån.
Schäfer, Hans Bernd and Alexander J. Wulf (2014). 'Jurists, Clerics, and Merchants: The Rise of Learned Law in Medieval Europe and its Impact on Economic Growth'. In: *Journal of Empirical Legal Studies* 11.2, pp. 266–300.
Schön, Lennart (2012). *An Economic History of Modern Sweden*. Abingdon: Routledge.
Schön, Lennart and Olle Krantz (2015). 'New Swedish Historical National Accounts since the 16th Century in Constant and Current Prices'.
Schultz, Theodore W. (1961). 'Investment in Human Capital'. In: *American Economic Review* 51.5, pp. 1035–1039.
Scott, John (1990). *A Matter of Record: Documentary Sources in Social Research*. Wiley.
Shiue, Carol Hua (2019). 'Social Mobility in the Long Run: A Temporal Analysis of China from 1300 to 1900'.
Sikt (2024). *Kommunedatabasen*. URL: https://kommunedatabasen.sikt.no/.
Smith, Adam (1776). *An Inquiry into the Nature and Causes of the Wealth of Nations*.
Song, Xi, Catherine G. Massey, Karen A. Rolf, Joseph P. Ferrie, Jonathan L. Rothbaum, and Yu Xie (2020). 'Long-term decline in intergenerational mobility in the United States since the 1850s'. In: *Proceedings of the National Academy of Sciences of the United States of America* 117.1, pp. 251–258.
Squicciarini, Mara P. and Nico Voigtländer (2015). 'Human Capital and Industrialization: Evidence from the Age of Enlightenment'. In: *The Quarterly Journal of Economics* 130.4, pp. 1825–1883.
Staaf, Björn Magnusson and Fredrik Tersmeden (2016). *Lund University over 350 years: history and stories*. Ed. by Petra Francke. Lund: Lund University, p. 264.
Suhonen, T. and H. Karhunen (2019). 'The intergenerational effects of parental higher education: Evidence from changes in university accessibility'. In: *Journal of Public Economics* 176, pp. 195–217.

Sveen, Atle F. and Jørgen H. Marthinsen (2022). *Norske Prestegjeld 1801 (Norwegian Parishes 1801)*. URL: https://github.com/atlefren/norske_prestegjeld.

Torstendahl, Rolf (1975). *Teknologins nytta: Motiveringar för det svenska tekniska utbildningsväsendets framväxt framförda av riksdagsmän och utbildningsadministratörer 1810–1870*. Uppsala: Almqvist & Wicksell International.

Tournier, Michele (1973). 'Women and Access to University in France and Germany (1861-1967)'. In: *Comparative Education* 9.3, pp. 107–117.

Trow, Martin (1972). 'The Expansion and Transformation of Higher Education'. In: *International Review of Education / Internationale Zeitschrift für Erziehungswissenschaft / Revue Internationale de l'Education* 18.1, pp. 61–84.

– (1973). 'Problems in the Transition from Elite to Mass Higher Education'. Berkeley, CA.

– (2007). 'Reflections on the Transition from Elite to Mass to Universal Access: Forms and Phases of Higher Education in Modern Societies since WWII'. In: *Springer International Handbooks of Education* 18, pp. 243–280.

University of Oslo (2003). *Studentmatrikkelen*. URL: https://www.muv.uio.no/samlinger/studentmatrikkelen/.

Vedel, Christian (2024). 'A Perfect Storm: First-Nature Geography and Economic Development'.

Wagner, Michael F. (1999). *Det polytekniske gennembrud: Romantikkens teknologiske konstruktion 1780–1850*. Aarhus: Aarhus Universitetsforlag.

Weber, Max (1905). *The Protestant Ethic and the Spirit of Capitalism*. Trans. by Talcott Parsons and Anthony Giddens. 1930th ed. London: Unwin Hyman.

Zhuravskaya, Ekaterina, Sergei Guriev, and Andrei Markevich (2024). 'New Russian Economic History'. In: *Journal of Economic Literature* 62.1, pp. 47–114.

Papers

Author contributions

Co-authors are abbreviated as follows:
Trygve Andersen (TA), Christian Møller Dahl (CMD), Kristin Ranestad (KR), Paul Sharp (PS), Christian Emil Westermann (CEW)

Paper I: Breaking barriers

I was principally responsible for data management and econometric analysis. I also assisted with data cleaning and quality control. I drafted the manuscript with input from KR and PS.

KR identified the source material and coordinated construction of the dataset. CMD and CEW led and executed the transcription of the source material using machine learning techniques. PS advised on the analytical framing.

Paper II: Lessons from Oslo

I was responsible for the econometric analysis, including data management and cleaning. I drafted the manuscript with input from KR and PS.

KR and PS identified the source material and coordinated its manual transcription. KR provided much of the historical background. PS advised on the analytical framing. TA, with colleagues at the Norwegian Historical Data Centre, led the linking process between the transcribed source material and the Norwegian census records. Linking with the Danish census records was outsourced to the Link-Lives project at the Danish National Archives. I supplemented with additional manual linking.

Paper III: The engineering classes

I was entirely responsible for the production of this paper, including transcription, data management and cleaning, econometric analysis and drafting.

Paper IV: Students of technology, captains of industry?

I was entirely responsible for the production of this paper, including transcription, data management and cleaning, econometric analysis and drafting.

Lund Studies in Economic History

115 Ford, Nicholas Martin
Origins of the knowledge economy: Higher education and Scandinavia's development ca. 1800–1929, 2025.

114 Melles, Bertus Markus
Transforming Foundations: Structural Change and Development Dynamics in Sub-Saharan Africa (1960-2024), 2024.

113 Zhao, Liang
International Capital Flow Monetary Policy and Banking Instability: Lessons from Sweden 1877-1939, 2024.

112 Castillo, Marcos
Roots Across the Atlantic: Social Networks and Economic Outcomes from the Swedish Mass Migration to the United States 1880–1920, 2024.

111 Lukkari, Valeria
Economic disparities in colonial Kenya: income inequality and wage differentiation, 2024.

110 Ostermeyer, Vinzent Leon
Why Firms Grow: The Roles of Institutions Trade and Technology during Swedish Industrialization, 2023.

109 Bergvall, Martin
Untying the knot: Studies of the Swedish divorce transition 1900-2020, 2022.

108 Dalman, Elien
Patterns of Persistence: Intergenerational mobility and Sweden's social structure 1865-2015, 2022.

107 Labbas, Elisa
Squeezed in Midlife: Studies of unpaid caregiving among working-age men and women across Europe, 2022.

106 Miladinovic, Luka
Us and Them: Economic Consequences of Ethno-confessional Diversity, 2022.

105 Baumert, Nicolai
For God's Sake – The Work and Long-Term Impact of Christian Missionaries in Cameroon 1844-2018, 2022.

104 Chanda Chiseni, Michael
Here I am Send Me: The Historical and Long-Term Impact of Christian Missionaries in Zambia 1924-2018, 2022.

103 Johansson, Tony
Sverige och den västeuropeiska arbetslösheten 1970-1990, 2021.

102 Gülsunar, Emrah
The State Parliamentary Legislation and Economic Policy during the Structural Transformation of British Economy 1700-1850, 2021.

101 Klocke, Sascha
Land Labour Legacies: Long-term Trends in Inequality and Living Standards in Tanzania c. 1920-2020, 2021.

100 Önnerfors, Martin
Water for the Many: Health neighbourhood change and equality of access during the expansion of Swedish urban water networks, 2021.

99 Rohne, Till Emelie
Agriculture for Development in the 21st Century: Evidence from Ethiopia, 2021.

98 Serratos-Sotelo, Luis
Disease Death and Displacement: The long-term effects of early-life conditions on income education and health in Sweden 1937-2011, 2021.

97 Martins, Igor
Collateral Effect: Slavery and Wealth in the Cape Colony, 2020.

96 Debiasi, Enrico
The Historical Origins of the Mortality Gradient: Socioeconomic inequalities in adult mortality over two centuries in Sweden, 2020.

95 Fibæk, Maria
Rural Income Diversification Employment and Differentiation in Kenya and Implications for Rural Change, 2020.

94 Aboagye, Prince Young
Inequality and Uneven Development in Ghana, 2020.

93 Probst, Julius
Growth Factor Shares and Factor Prices, 2019.

92 Kulionis, Viktoras
Energy Embodied in Trade 1970-2014, 2019.

91 Gary, Kathryn E.
Work Wages and Income: Remuneration and Labor Patterns in Southern Sweden 1500–1850, 2018.

90 Chen, Zeyuan
Getting Old in a Changing World: Sons Pensions and the Wellbeing of the Elderly in Contemporary China, 2018.

89 Jenkin, Samuel
Foreign Investment in Agricultural Development: The Past of the Present in Zambia, 2018.

88 Karlsson, Omar
Growth and Survival: Child Health Disparities and Early Life Adversity in Sub-Saharan Africa, 2018.

87 Lennard, Jason
Economic Fluctuations in the United Kingdom 1750-1938, 2018.

86 Andersson, Jens
State Capacity and Development in Francophone West Africa, 2018.

85 Aradhya, Siddartha
Diversity of Legacy: The Experience of Immigrants and their Descendants in Sweden, 2018.

84 Elwert, Annika
Will You Intermarry Me? Determinants and Consequences of Immigrant-Native Intermarriage in Contemporary Nordic Settings, 2018.

83 Lazuka, Volha
Defeating Disease: Lasting Effects of Public Health and Medical Breakthroughs Between 1880 and 1945 on Health and Income in Sweden, 2017.

82 Sztern, Sylvia
Russia on the Move: The Railroads and the Exodus from Compulsory Collectivism 1861–1914, 2017.

81 Tegunimataka, Anna
Trajectories of Integration: Naturalization Intermarriage and Education in Denmark 1980-2015, 2017.

80 Zheng, Yannu
How Immigrants Invent: Evidence from Sweden, 2017.

79 Nielsen, Hana
Coal commerce and communism: Empirical studies on energy history in the Czech Republic, 2017.

78 Berger, Thor
Engines of Growth: Essays in Swedish Economic History, 2016.

77 Kenny, Seán
Empirical Studies in Money and Debt in Northern Europe 1840-2015, 2016.

76 Neilson, Jeffrey
Converging Times: Parenthood Time Allocation and the Gender Division of Labor in Sweden 1990-2010, 2016.

75 Qi, Haodong
Live Longer Work Longer? Evidence from Sweden's Ageing Population, 2016.

74 Lindström, Martin
All that's mine I carry with me: Early life disease and adult health in Sweden during 250 years, 2015.

73 Molitoris, Joseph
Life and Death in the City: Demography and living standards during Stockholm's industrialization, 2015.

72 Eriksson, Björn
Dynamic Decades: A micro perspective on late nineteenth century Sweden, 2015.

71 Persson, Mats R
In good times and in bad: Immigrants Self-employment and Social Insurance, 2015.

70 Borowiecki, Karol Jan
"Mournful and yet grand is the destiny of the artist." Some Economic History of Music Composers and their Creativity, 2015.

69 López Jerez, Montserrat
Deltas Apart: Factor Endowments Colonial Extraction and Pathways of Agricultural Development in Vietnam, 2014.

68 Xiao, Jing
Entrepreneurial Dynamics and Acquisitions of New Technology-Based Firms, 2014.

67 Taalbi, Josef
Innovation as Creative Response: Determinants of Innovation in the Swedish Manufacturing Industry 1970-2007, 2014.

66 Bergenfeldt, Fredrik
Roads to Market: Transport and Agricultural Change – the case of southern Sweden 1750-1850, 2014.

65 Sjöö, Karolin
Innovation and Transformation in the Swedish Manufacturing Sector 1970-2007, 2014.

64 Lind, Daniel
Value Creation and Structural Change During the Third Industrial Revolution: The Swedish Economy from a Vertical Perspective, 2014.

63 Silva, Ernesto
Essays on Income and Fertility: Sweden 1968-2009, 2014.

62 Dekhtyar, Serhiy
Early Life Origins of Health and Well-Being in Modern Sweden, 2013.

61 Holmberg, Kajsa
Behind the Counter: Female Inroads Obstacles and Careers in the Swedish Commercial Bank Sector 1885-1937, 2013.

60 Palacio, Andrés
Mind the Gap: Inequalities in Infant and Child Mortality: the Case of Colombia 1967-2010, 2013.

59 Quaranta, Luciana
Scarred for Life: How conditions in early life affect socioeconomic status reproduction and mortality in southern Sweden 1813-1968, 2013.

58 Hannemann, Tina
It Breaks a Man's Heart: Socioeconomic Differences in the Onset of Cardiovascular Disease in Contemporary Sweden, 2012.

57 Faran, Turaj S.
The Industrialization Process in the Chinese Mirror: Continuity and change in transition from collective agriculture to market economy in China, 2011.

56 Weisdorf, Jacob L.
Malthusian Progress, 2011.

55 Håkansson, Peter
Ungdomsarbetslösheten – om övergångsregimer institutionell förändring och socialt kapital (Youth unemployment – transition regimes institutional change and social capital), 2011.

54 Henriques, Sofia Teives
Energy Transitions Economic Growth and Structural Change: Portugal in a Long-run Comparative Perspective, 2011.

53 Helgertz, Jonas
Immigrant Careers – Why Country of Origin Matters, 2010.

52 Bohman, Magnus
Bonden bygden och bördigheten: Produktionsmönster och utvecklingsvägar under jordbruksomvandlingen i Skåne ca 1700-1870 (Peasants production patterns and paths of development during the agricultural transformation in Southern Sweden (Scania) ca 1700-1870), 2010.

51 Waldenström, Daniel
Lifting All Boats? The Evolution of Income and Wealth Inequality over the Path of Development, 2009.

50 Roubert, Carl-Johan
Småländsk världsindustri: en studie om entreprenörer och kluster 1950-2002, 2009.

49 Örnberg, Lena
Bondens val: System samspel och stödjande strukturer under moderniseringsprocessen i norra Thailand (Farmer's Choice: Systems interaction and supporting structures during the modernisation process in Northern Thailand), 2008.

48 Rönnqvist, Sofia
Från diversity management till mångfaldsplaner? Om mångfaldsidéns spridning i Sverige och Malmö (From Diversity Management to Diversity Plans? On the Spread of the Diversity Idea in Sweden and Malmö), 2008.

47 Karlsson, Tobias
Downsizing: Personnel Reductions at the Swedish Tobacco Monopoly 1915-1939, 2008.

46 Enflo, Kerstin
Regional and Industrial Growth Patterns in 20th Century Western Europe, 2008.

45 Axelsson, Tobias
Peasants and Policymakers: Agricultural Transformation in Java under Suharto, 2008.

44 Gustafsson, Fredrik
The Visible Palm: Market Failures Industrial Policy and the Malaysian Palm Oil Industry, 2007.

43 Forsberg, Le Thanh
Defining Strong Ownership: Institutional Determinants and Stakeholder Interests in Vietnamese Development Planning, 2007.

42 Andera, Jan
Driving under the Influence: Strategic Trade Policy and Market Integration in the European Car Industry, 2007.

41 Krantz, Olle & Schön, Lennart
Swedish Historical National Accounts 1800–2000, 2007.

40 Lundh Nilsson, Fay
Lönande lärande: Teknologisk förändring yrkesskicklighet och lön i svensk verkstadsindustri omkring 1900 (Profitable Learning – Technological Change Skills and Wages in the Swedish Engineering Industry around 1900), 2007.

39 Abou-Zeinab, Ali
Commercial Banking and Economic Development: The Lebanese Experience 1856–1974, 2006.

38 Jönsson, Per Ingvar
Chaebolföretagen – en "omöjlig" konfiguration i den sydkoreanska industrialiseringsprocessen (The Chaebol Conglomerate – An "Impossible" Configuration in the South Korean Industrialization Process), 2006.

37 Josephson, Camilla
Growth and Business Cycles: Swedish Manufacturing Industry 1952-2001, 2005.

36 Appelquist, Joakim
Informationsteknik och organisatorisk förändring: Teknik organisation och produktivitet i svensk banksektor 1975–2003 (Information Technology and Organizational Change: Technology Organization and Productivity in Swedish Banking Sector 1975–2003), 2005.

35 Green, Erik
Peasant Production and Limits to Labour: Thyolo and Mzimba Districts in Malawi mid-1930s to late-1970s, 2005.

34 Saarinen, Jani
Innovations and Industrial Performance in Finland 1945–1998, 2005.

33 Lindgren, Mattias
Does Schooling Make Sense? A Household Perspective on the Returns to Schooling for Self-employed Farmers and Employees in Egypt, 2005.

32 Lundh, Christer, Jonas Olofsson, Lennart Schön & Lars Svensson (eds.)
Wage Formation Labour Market Institutions and Economic Transformation in Sweden 1860-2000, 2004.

31 Rytkönen, Paulina
Fruits of Capitalism: Modernisation of Chilean Agriculture 1950-2000, 2004.

30 Johansson, Kent
Child Mortality during the Demographic Transition: A Longitudinal Analysis of a Rural Population in Southern Sweden 1766-1894, 2004.

29 Holmquist, Svante
Kapitalbildning i svensk industri 1870-1930 (Capital Formation in Swedish Industry 1870-1930), 2004.

28 Carlsson, Ellen
To Have and to Hold: Continuity and Change in Property Rights Governing Water Resources Among the Meru of Tanzania and the BaKgatla of Botswana 1925-2000, 2003.

27 Abdulsomad, Kamaruding
Building Technological Capabilities of Local Auto Parts Firms under Contrasting Industrial Policies: A Comparative Study of Malaysia and Thailand 1960-2000, 2003.

26 Bengtsson, Henrik
Ålder och ekonomisk omvandling: Sveriges tillväxthistoria i ett demografiskt perspektiv 1890-1995 (Age and Economic Transformation: Sweden's History of Economic Growth in a Demographic Perspective 1890-1995), 2003.

25 Andersson, Martin
Bending the Kuznets Curve: Wrenching and Levelling Forces during Agricultural Transformation in Taiwan and Chile, 2003.

24 Sandal, Jan-U.
Jakten på Entreprenøren: Kan Joseph A. Schumpeters teori benyttes til å identifisere og differensiere entreprenører i det 21. århundrede? (In Search of the Entrepreneur: Can Joseph A. Schumpeter's Theory be used to Identify and Differentiate Between Entrepreneurs in the 21st Century?), 2003.

23 Öberg, Klas
Pharmacy Regulation in Sweden: A New Institutional Economic Perspective, 2003.

22 Stanfors, Maria
Education Labor Force Participation and Changing Fertility Patterns: A Study of Women and Socioeconomic Change in Twentieth Century Sweden, 2003.

21 Klinthäll, Martin
Return Migration from Sweden 1968-1996, 2003.

20 Olsson, Mats
Storgodsdrift: Godsekonomi och arbetsorganisation i Skåne från dansk tid till mitten av 1800-talet (Manorial Economy and Corvée Labour in Early Modern Scania), 2002.

19 Kander, Astrid
Economic Growth Energy Consumption and CO2 Emissions in Sweden 1800-2000, 2002.

18 Rauhut, Daniel
Fattigvård socialbidrag och synen på fattigdom i Sverige 1918-1997 (Poor Relief Social Assistance and the View on Poverty in Sweden 1918-1997), 2002.

17 Schånberg, Ingela
Genus och utbildning: Ekonomisk-historiska studier i kvinnors utbildning ca 1870-1970 (Gender and Education: Economic History Studies in Women's Education ca. 1870 to 1970), 2002.

16 Svensson, Patrick
Agrara entreprenörer: Böndernas roll i omvandlingen av jordbruket i Skåne ca 1800-1870 (Agrarian Entrepreneurs: The Role of the Peasants in the Transformation of Agriculture in Scania 1800-1870), 2001.

15 Bevelander, Pieter
Immigrant Employment Integration and Structural Change in Sweden 1970–1995, 2000.

14 Lobell, Håkan
Växelkurspolitik och marknadsintegration: De utländska växelkurserna i Sverige 1834–1880 (Exchange Rate Policy and Market Integration: Foreign Exchange Rates in Sweden 1834-1880), 2000.

13 Dribe, Martin
Leaving Home in a Peasant Society: Economic Fluctuations Household Dynamics and Youth Migration in Southern Sweden 1829-1866, 2000.

12 Thorburn, Thomas
Economic of Transport: The Swedish Case 1780-1980, 2000.

11 Ankarloo, Daniel
"Institutions": What Is In a Word? A Critique of the New Institutional Economics, 1999.

10 Iglesias, Edgar
Welfare Security and the Level of Fertility: A Global Analysis 1985 and 1995, 1999.

9 Scott, Kirk
The Immigrant Experience: Changing Employment and Income Patterns in Sweden 1970–1993, 1999.

8 Siriprachai, Somboon
Control and Rent-Seeking: The Role of the State in the Thai Cassava Industry, 1998.

7 Pei, Xiaolin
The Institutional Root of China's Rural Industry and Gradual Reform, 1998.

6 Olofsson, Jonas
Arbetslöshetsfrågan i historisk belysning: En diskussion om arbetslöshet och social politik i Sverige 1830-1920 (The Unemployment Question in Historical Perspective: A Discussion on Unemployment and Social Policy in Sweden 1830-1920), 1996.

5 Ahlström, Göran
Technological Development and Industrial Exhibitions 1850-1914: Sweden in an International Perspective, 1995.

4 Arlebäck, Sven Olof
Från ägarmakt under ansvar till företagsledarmakt upa: En studie över maktförskjutningen i tre svenska verkstadsaktiebolag (The Transition of Power from Shareholders to Top-Management: A Study of Three Swedish Engineering Firms), 1995.

3 Staffansson, Jan-Åke
Svenskt smör: Produktion konsumtion och utrikeshandel 1861-1913 (Swedish Butter: Productivity Consumption and Foreign Trade 1861-1913), 1995.

2 Bergström, Asta
Åtstramning och Expansion: Den ekonomiska politiken i Sverige 1971-1982 (Retrenchment and Expansion: Swedish Economic Policy 1971-1982), 1995.

1 Lundh, Christer (ed.)
Population Economy and Welfare: Scandinavian Population Studies vol 10, 1995.

0 Ahlström, Göran
Technological Development and Industrial Exhibitions 1850-1914: Sweden in an International Perspective, 1995.

Origins of the knowledge economy

High school and university-level education was long an elite pursuit. However, with economic growth and rising technical complexity, the need for specialised knowledge and skills increased. In the run-up to and during industrialisation, higher education systems admitted a growing number of students and diversified across an increasing range of courses and types of educational institutions.

Denmark, Norway and Sweden provide rich case studies for examining the growth of higher education during the nineteenth and early twentieth centuries. I examine higher education through two lenses: To what extent did changes in the provision of higher education increase access to education beyond a small elite in society? How did changes in the provision of and access to higher education influence Scandinavia's development in the lead-up to and during industrialisation?

This dissertation comprises four papers that explore key developments in Scandinavian higher education including:

- the admission of female students
- the opening of Norway's first university
- the introduction and expansion of polytechnic education
- the growth in demand for highly trained engineers.

Using detailed individual-level data on the graduates of higher education, my results offer new insights into social mobility and economic development during a critical period of history.

Printed by Media-Tryck, Lund 2024 NORDIC SWAN ECOLABEL 3041 0903

Department of Economic History
School of Economics and Management

Lund Studies in Economic History 115
ISBN 978-91-9896-414-1
ISSN 1400-4860