Origins of the knowledge economy

Higher education and Scandinavia's economic development

Project plan

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Project on a page

- ***Research question*: How did changes in the supply of and demand for different types of higher education contribute to Scandinavia's economic development from the nineteenth century onwards?**
- While there is much theoretical and empirical literature examining the role of education in long-term growth, less understood is how different types of education — and the specialisation of skills implicit in higher education — shape development.
- The twin purposes of this project are to:
  - examine the role of higher education in Scandinavia's industrialisation and long-term economic development from the nineteenth century onwards
  - develop and apply new techniques for the measurement of human capital (education) and the analysis of its effects.
- I employ two sets of novel Scandinavian source material: grade lists, which track student performance in high school and university; and graduate biographies, which provide details of students' background, education and post-study careers.
- My dissertation will comprise a collection of four articles which build and apply a new skills-based measure of human capital to examine different aspects of the role of higher education in Scandinavian industrialisation.
- *Supervisors*: Kristin Ranestad (primary), Mats Olsson, Paul Sharp (University of Southern Denmark).
- *Indicative timeframe*: September 2020 – August 2024.

> 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, 291)

The Scandinavian countries — Denmark, Norway and Sweden — have a long history of higher education. The Academy of Lund — a medieval forerunner to Sweden's Lund University — was established in 1425. The University of Copenhagen and Uppsala University (Sweden) both opened later in the fifteenth century. Further institutions were established during the seventeenth century in then-Swedish territories: the University of Tartu (Estonia) and the Royal Academy of Turku (Finland). Lund University was likewise founded during this time, in 1666. (For simplicity, I refer to all universities in this project plan by their contemporary names.)

It was in the nineteenth century that higher education began to take flight. More institutions opened, including the University of Oslo (Norway's first university), the Technical University of Denmark, and Chalmers University of Technology in Sweden. The range of courses expanded, including the introduction and expansion of higher education in engineering. The number of students also began to increase, a trend that accelerated in the early twentieth century. For example, the number of graduates of the University of Copenhagen and the Technical University of Denmark rose from around 100 in 1830 to approximately 300 in 1900, and further to over 500 by 1930 (Undervisningsministeriet 1998; Danmarks Statistik 1900; 1930).

There is a rich literature on the role of education in industrialisation and development (G. S. Becker 1964; S. O. Becker, Hornung, and Woessmann 2011; Galor 2005; Goldin and Katz 2008; Ljungberg and Nilsson 2009). However, there is relatively little evidence on the role of specifically *higher* education (that is, formal education beyond high school) in the process of industrialisation. In a recent paper, Diebolt et al. (2021) venture down this path, by exploring the contribution of 'intermediate' skills — knowledge of the sciences, of languages, of law and commerce — to French industrialisation during the nineteenth century. Their analysis draws on enrolment levels in selected education institutions to explore aggregate trends in skill acquisition and technical progress.

My research project employs previously untapped source material to construct a comprehensive individual-level database of Scandinavian graduates during the nineteenth and early twentieth centuries. The source material includes biographical entries on virtually all high school graduates across Denmark, Norway and Sweden over more than a century. The data available include details of each graduate's background (where and when they were born, and to whom), high school grades, higher education qualifications, and careers (including migration). In short, the database charts the life course of graduates: before, during and after education. It offers the potential for novel analysis of the contribution of higher education to individual life outcomes and, by extension, Scandinavia's long-term development.

This project plan outlines some of the proposed applications of the database, which will comprise my dissertation. The project described here sits within a wider research programme — mapping the Human Capital of the Nordic Countries (HCNC) — involving researchers across multiple universities (Lund University, the University of Southern Denmark and the University of Tromsø), with a suite of related research tasks and outputs.

1 About the project

The central question that this project explores is: **How did changes in the supply of and demand for different types of higher education contribute to Scandinavia's economic development from the nineteenth century onwards?** Embedded within this construct are a series of subordinate themes and ideas:

- When did different types of higher education (that is, courses) emerge? What motivated their establishment? Were there differences in the expansion of higher education offerings across the Scandinavian countries?
- Who pursued higher education? What motivated their enrolment — in education generally and in particular courses? How did this change over time?
- What types of skills did employers seek? What motivated employers to choose educated graduates rather than train candidates on the job?
- How did higher education drive Scandinavian economic development and the growth of specific industries/sector? How did economic development and sectoral growth drive the rise of higher education?

The overarching purposes of this project are twofold:

1) to examine the role of higher education in Scandinavia's industrialisation and long-term economic development from the nineteenth century onwards
2) to develop and apply new techniques for the measurement of human capital (education) and the analysis of its effects.

These purposes are not independent of one another. Plainly, any examination of human capital rests on the methods and assumptions underpinning its measurement. Moreover, the conceptual and methodological techniques for this project can be applied precisely because the Scandinavian countries offer sufficiently rich data in a historical context.

Relationship to the HCNC programme

My dissertation contributes to a broader body of work examining different aspects of human capital accumulation across the Nordic countries (in this context, Denmark, Finland, Norway and Sweden). The HCNC programme is structured as a natural sequence of work packages. The first step lays the foundations for analysis: the construction of an individual-level database of human capital, drawing on official records (from high schools, technical institutes and universities) and comprehensive biographies of graduates. The new database will support a richer measure of human capital, which takes account of education quality and the heterogeneity of skills acquired by individuals. A key task in association with the creation of the database is critical examination of the source materials — rigorously testing their credibility and accuracy.

The subsequent work packages contemplate the market for graduates:

- on the supply side, who received an education? How did the profile of graduates change as access to education expanded? Put another way, what was the effect of education on employment outcomes and social mobility?
- on the demand side, what motivated employers' choice of formally trained graduates rather than 'raw' labour that could be trained on the job? What did the increase in skilled labour mean for productivity at the firm- or industry-level?

The unique contribution of my dissertation to the HCNC programme encompasses principally three elements.

1) Constructing a new measure of human capital: that is, determining how best to make use of our data to build a more meaningful measure of acquired skills through higher education than simple 'years of schooling' metrics (see below).
2) Deepening the theoretical understanding of supply of and demand for higher education: specifically, in the context of industrialisation and changes in types of education offered, explaining what motivates the shift from 'on-the-job' training to formal instruction.
3) Examining the contribution of human capital to productivity growth: that is, separate from the direct effect of improvements in labour force quality through higher levels of skills acquisition, accounting for the indirect effect of human capital accumulation (via higher education) in accelerating the technical progress essential to long-term economic growth.

2 The relevance of human capital

As a piece of economic jargon, 'human capital' is a useful shorthand for a range of personal qualities and competencies — our skills, our longevity, our instincts and cultural biases, our habits and behaviours — and how these relate to the supply of labour in the production process. In that sense, 'human capital' is not synonymous with 'workers' or 'people'. Rather, it reflects endowments and investment pertaining to the attributes of individuals, enhancing their productive capacity. Put another way, human capital is not who we are, but how we develop and apply ourselves over the course of our working lives.

While human capital is a broad concept, a significant component of it is related to education. Education — whether through formal instruction in schools and other institutions, or informally through our upbringing and work experiences — is a key ingredient in the development of our skills. Thus, education has direct relevance to workers' productive capacity: a twelfth century peasant and a twenty-first century office worker are both units of labour, but the qualitative difference between them is (among other things) based on education and skills.

The concept of human capital has its origins (at least in part) in Smith (1776). In *The Wealth of Nations*, 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). Ability does not (by and large) descend upon us from the sky; it 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.

Nevertheless, the contribution of this human capital to output was largely unexplored until the twentieth century. Analysis of the drivers and origins of economic growth yielded a fundamental question: if one assumes diminishing marginal returns to capital and (raw) labour then why, in the developed world, do we observe steady growth in output per capita over time? The answer provided by Solow (1956) and Swan (1956) is technical progress: that we discover better ways of using scarce resources to produce output. We become more productive — getting more output per unit of input (holding quality constant).

The problem with the Solow–Swan analysis is that this productivity growth factor is treated as an exogenous parameter. Moreover, in a growth accounting sense, we cannot measure technical progress directly. Rather, it is observed as a residual: as we can measure inputs and output, the unexplained difference between the two over time must reflect technical progress. This is unsatisfying for many reasons, least of all because it also captures any deficiencies in the measurement of inputs and output. More specifically, if we do not account for improvements in the *quality* of labour services supplied — improvements in skills and capabilities — then we overstate the role of technical progress. Understanding the role of human capital is thus key to understanding economic development.

Theory of human capital

It is simplistic to say there exists any human capital *theory*. Rather, human capital is a variable which can play a role in various aspects of economic theory. The twentieth century revival of human capital as a subject of analysis related principally to microeconomics: the incentives for firms and individuals to invest in education. Those incentives both influence and are influenced by human capital's macroeconomic role: how education contributes to long-term growth.

Microeconomic effects

The starting point for Becker (1964) is not schooling but on-the-job training: that is, why do firms invest in training their workforce? In broad terms, any firm's incentive to invest in training is related to the risk of that investment benefiting other firms if and when trained workers switch jobs. Just as property rights provide some incentive for physical investment (for example, patents that guarantee exclusive rights to use particular innovations), a given firm is more inclined to invest in human capital that the firm itself enjoys the benefit of. As workers take their human capital with them wherever they go — and workers generally cannot be forced to remain in the employment of a particular firm — this encourages firms to invest in training for skills specific to a particular job or firm rather than generally applicable skills.

General skills — in perhaps the most extreme form, basic literacy — are more likely to be acquired by households at their own initiative and expense, through schools and other educational institutions. Aside from any direct user costs of education (for example, tuition fees), the major cost borne by individuals is an opportunity cost: the time spent in the classroom is time spent not working and therefore not earning an income. Individuals forgo earnings today in the expectation of obtaining higher earnings in the future. In theoretical terms, this is a household optimisation problem (G. S. Becker 1965).

One can conceive of this broadly as a question of choice: how much (and what type of) education do households and individuals choose? However, one should also be cognisant that there is not always a real choice in the real world: some level of education might be compulsory; somebody might wish to pursue education but be blocked due to non-economic, social factors (for example, girls have — or are — not always been permitted to attend school).

Macroeconomic effects

That individuals and firms make choices pertaining to skills and education (the above caveat notwithstanding) has consequences beyond earnings. Goldin and Katz (2008) distinguish between two different sets of macroeconomic effects. One set relates to the direct contribution of workers' skills on output: that is, how improved labour quality. The other set represents an indirect, but by no means insignificant, channel: the effect of education on technical progress. Education supports knowledge creation and application, such that the capacity for introducing new goods, markets, tools and techniques increases. Education facilitates the technical advances that in turn underpin economic growth.

While the distinction is useful as an analytical framework, disaggregating these direct and indirect channel effects is complex in practice. As Mokyr writes:

> It is undeniable that technological progress during the Industrial Revolution was an elite phenomenon, carried not by a dozen or two of big names who made it to the National Dictionary of Biography, but by the thousands of trained engineers, capable mechanics, and dexterous craftsmen on whose shoulders the inventors could stand. (Mokyr 2005, 301)

In this narrative, new innovations emerge (technical progress) — but those innovations have no practical value without a sufficiently skilled workforce (human capital) to enable production. How should the output gain here be allocated to technical progress versus human capital? Indeed, differences in human capital may be a relevant factor in understanding differences in technical progress across countries: ideas might freely cross borders, but without the right skills in the labour force, the ability to adopt and apply those ideas is constrained.

As Goldin and Katz (2008) note, growth is not an automatic consequence of investment in education. Poor countries in the world today are not necessarily poor because of insufficient investment in education. Rather, realising the potential economic gains from education relies on other conditions. There is an intrinsic relationship between technical progress and education — as an economy becomes technically more advanced, the demand for higher skills (and thus the return from education) increases; investment in education in turn spurs a higher rate of technical progress, which raises economic growth.

A more formal exposition of this idea is offered by Galor (2005; 2011). His Unified Growth Theory is a compelling attempt to explain the transition from a Malthusian regime (whereby relative gains in prosperity translated to higher population growth, while output per capita remained broadly constant over time) to the modern growth era (where output per capita rises over the long term). The fundamental insight of this theory is that there is a threshold level of technical progress, beyond which investment in human capital (rather than simply having more children) becomes advantageous. This transition is the story of industrialisation — a story in which education plays a starring role.

Existing measures

The most common measures of education relate to school enrolment rates and years of schooling. While the two concepts are related, it is necessary to emphasise the distinction. At a point in time, school enrolment rates point to what share of the child population is (or was) in school, while average years of schooling across a working age cohort reveals how much schooling the existing labour force attained prior to entering the workforce. Taking as given a positive effect of human capital on production, an increase in education does not deliver an immediate, direct boost to economic output. It is only once students enter the workforce that the investment in their human capital starts to pay off in terms of measurable output effects.

The key advantage of enrolment rates and schooling levels is that data are straightforward to compute and readily available. For example, Barro and Lee (2013) offer a comprehensive international dataset on educational attainment from 1950 onwards, including enrolment rates in primary, secondary and tertiary education as well as average years of schooling. An extended version of the dataset for 111 countries stretches back to 1820 (Lee and Lee 2016). The Penn World Tables (Feenstra, Inklaar, and Timmer 2015) includes an index of human capital based on years of schooling — with this data derived partly from Barro and Lee, as well as Cohen and Leker (2014). Similar, though typically smaller scale and no longer current, efforts have also been advanced by Kyriacou (1991) and Psacharopoulos and Arriagada (1986). Such databases have been employed in widely cited human capital research by, among other, Benhabib and Spiegel (1994) and Bils and Klenow (2000).

In some countries, rich detail on enrolment and schooling can also be found at a sub-national level over long timespans. Goldin (1998) uses state-level high school enrolment and graduation rates across in an examination of US human capital accumulation from the late nineteenth century into the twentieth century. She argues that 'advances in secondary schooling may provide the single most important measurable reason for per capita income growth for much of this century' (Goldin 1998, 347). Becker, Hornung and Woessmann (2011) use county-level data on school enrolment rates and average years of schooling (as well as adult literacy rates — see below) as measures of human capital in nineteenth century Prussia. Similarly, Cinnirella and Hornung (2016) use Prussian school enrolment rates in their analysis of the effect of land ownership on human capital accumulation. Ljungberg and Nilsson (2009) use school enrolment rates from 1812, combined with demographic data on the size and age distribution of the population, to construct a long-term data series of Sweden's human capital stock — from 1870 to 2000.

Aggregate measures of schooling (whether in years or enrolment rates) are attractive on simplicity grounds, but cannot capture the full picture of education acquisition. Two challenges arise here. First, differences in educational quality matter as much as quantity; two countries with equivalent years of schooling will not necessarily observe the same educational or economic outcomes given, for example, differences in teaching and curricula. Second, aggregate measures of schooling are only a partial proxy for what we are typically interested in when it comes to human capital: that is, what are the skills and attributes that the (potential/prospective) labour force acquires through education.

A more promising line for human capital measurement is to focus on learning rather than schooling: that is, a focus on outcomes rather than inputs. Most directly, this means using test results to measure student performance and knowledge acquisition. Hanushek and Kimko (2000) demonstrate how internationally comparable tests (in mathematics and science) can be used to refine human capital estimates by accounting for education quality. Their results show a strong correlation — and probable causal relationship — between higher average test performance and economic growth.

The learning-outcome approach has been central to a new human capital index produced by the World Bank (Angrist et al. 2019; Kraay 2018). The index measures human capital in 164 countries from 2000 onwards using, among other things, international student assessments to qualitatively adjust data on years of schooling. Specifically, the index draws on results from three worldwide programmes: the Trends in International Maths and Science Study (TIMSS), the Progress in International Reading Literacy Study (PIRLS), the Programme for International Student Assessment (PISA) and Early Grade Reading Assessments (EGRA). These results are supplemented by regional tests: the Southern and Eastern Africa Consortium for Monitoring Educational Quality (SACMEQ), the Program of Analysis of Education Systems (PASEC), and the Latin American Laboratory for Assessment of the Quality of Education (LLECE). Results across the different testing regimes are harmonised to maximise comparability of countries.

One downside to this learning-outcome approach to measuring human capital is that it is difficult to apply such techniques to long-run analysis. International tests such as TIMSS and PISA are relatively recent innovations in education policy — such testing cannot be retrospectively performed on cohorts prior to their introduction.

An alternative measure sometimes applied in studies of economic history is literacy rates. For example, Hanushek (1992) uses reading comprehension and vocabulary test scores from Iowa in the 1970's to examine the quantity–quality tradeoff. Nilsson (1999) considers literacy rates in rural southern Sweden during the nineteenth century — though different measures yield substantially different results, with aggregate population literacy rates ranging from as little as 8–10 per cent up to 85–90 per cent, depending on the measure used. That is, how one defines and measures literacy has a material effect on the observed outcome.

As Nilsson (1999) explains, historical studies of literacy include a mix of direct and indirect measures, including subscription records for newspapers and publishing volumes for books. One standard measure is marriage registry signatures: the logic being that if one is unable to sign their own name, that they cannot read or write anything. While undoubtedly a simple and comparable measure, a signature is at most only evidence of total illiteracy (and even then not necessarily a perfect measure of that). It offers nothing more than a binary 'yes/no' response to the question of literacy, and offers no insight into different *levels* of literacy. Moreover, any literacy measure can only be a very partial measure of human capital: the range of skills that might be relevant in a production process extends well beyond reading and writing.

3 A database of Scandinavian human capital

While there are certain deficiencies in existing measures of education and human capital, the history of record keeping in the Scandinavian countries provides rich potential to construct more precise measures. Two broad categories of improvement are:

1) a greater focus on quality, rather than merely quantity, of students' learning
2) disaggregation of education by skills acquired.

This section outlines the data sources that are available for Scandinavia in the nineteenth and early twentieth centuries, and describes the process of converting these printed records into a usable database.

Source material

The principal data sources that are being used in the construction of the Scandinavian human capital database are high school and university grade lists, and graduate biographies contained in anniversary yearbooks and similar historical volumes. These two sources are described in further detail below. In addition, these student-level records are being linked with historical census data, with two purposes in mind: one, providing further information on graduate households; two, allowing us to compare graduates' outcomes with those of the rest of the population.

The grade lists

As discussed above, the use of test results in analysis of student performance and skills acquisition has been enabled in recent years by the introduction of international testing regimes. A novel opportunity exists to apply similar techniques in a historical context thanks to the publication of comprehensive grade lists in Scandinavia.

We have located grade lists for both Danish and Norwegian students. As Ford et al. (2021) document, grades are available for university students from 1837 to the mid-twentieth century. Danish high school grades are also available from 1805 to 1915, with individual subject grades up to 1884. Comparable records are also available for Norway: both university and high school grades are available from 1813 through to the twentieth century. The availability of Swedish grade lists is currently unclear; we are still examining what possibilities exist for tracking Swedish student performance over the relevant timeframe.

Having access to grades from both high school and university allows us to (at least in approximate terms) identify the specific contribution of tertiary education. That is, high school grades provide an indication of a student's baseline ability prior to university. We can thus measure the improvement of a student's human capital during university by controlling for their pre-university human capital.

The usefulness of the grades relies on the consistency across a given cohort. The high school marks were in connection with university admission exams and/or national high school graduation exams. Likewise, all university students in a given course and year were assessed on the same basis. This provides for comparability of results within a cohort. There is nevertheless a potential issue with changes over time — whether due to changes in curriculum, changes in teachers, and perhaps due to changes in marking standards (for example, what might have earned a top grade in one year might have merited a mere pass twenty years later). One approach to address this is to compare the relative ranking of students in each cohort rather than compare the absolute value of their marks.

The graduate biographies

A novel tradition in the Scandinavian countries was the publication of graduate yearbooks, providing biographical profiles of virtually all university graduates. In Denmark and Norway, the yearbooks were published in connection with high school reunions, typically 25, 40 and/or 50 years after graduation from high school. In Denmark, the yearbooks cover cohorts that graduated from 1812 to 1923; in Norway, 1831 to 1943. Though there is variation from year to year, the yearbook biographies commonly include graduates' birthdate and place, their family background, their high school and any university studies, and a summary of their careers and other key professional achievements. The biographical information was mostly supplied by the graduates themselves, and our preliminary analysis suggests a high level of reliability with only limited examples of potential bias.

The Swedish biographical records have a different origin: the university ‘nations’, which are student societies that can (very loosely) be compared to fraternities and sororities in the North American university tradition. The tradition of nations at both Uppsala and Lund universities dates back to the seventeenth century. Until 2010, students at those two universities were required to be members of a nation. Each nation periodically produced a historical overview of their past members — that is, unlike the Danish and Norwegian yearbooks, each nation’s historical overviews included multiple cohorts. Elsewhere, university publications include biographical material: for example, Chalmers University of Technology produced a commemorative volume to mark its centenary (1829–1929), which includes biographies of graduates over the institution’s first 100 years.

We have not yet catalogued and examined the range of Swedish historical volumes available. But from the selection of records we have seen, the information contained in the Swedish biographies is broadly equivalent to that of the Danish and Norwegian yearbooks.

In addition to the Danish and Norwegian yearbooks and the Swedish nation and university records, other graduate-focused biographical volumes exist in the form of profession-based compendia (for example, doctors or engineers) and geographically defined compendia (for example, Danish students from Schleswig, a historically contested border region between Denmark and Germany). Though they are not the focus of this project, such supplementary material can play a useful role in, for example, verifying the validity of our principal sources.

From information to data

The source materials are printed records, which are currently being digitised. Once we have electronic copies of the grade lists and biographies, the next step is to extract the key data and use these to construct a database that tracks the education and life outcomes of individuals. The grade lists (and census records) are table based, and largely numeric. Converting these tables to a database is relatively simple. The more challenging task is to convert biographical text into variables in a database.

To this end, HCNC colleagues are applying machine learning techniques. In broad terms, this involves using sophisticated models that can read and interpret text, identify the relationships between different elements in the text, and convert these to variables. To illustrate, consider the following (translated) excerpt from one biographical entry:

> Madvig, Johan Nicolai Agathon. Borgerdydskolen (school) in Christianshavn. Born in Copenhagen, 27 February 33. Son of Professor PhD Johan Nicolai Madvig and Elisabeth Agathe Helene Nielsine (neé Bjerring). Philosophical exam 51, first class with honours. Beneficiary of stipends from Moltke and Hurtigkarl. 13 June 57, Law exam, first class. 54–55 Sessional teacher in geography at Metropolitanskolen.
> (Class of 1850 Denmark yearbook, 1875, p. 3)

There are several variables of interest in this short passage, which a machine learning model must be designed to identify: name, birthdate and place, parents, studies and job. There are also key relationships between these elements that must be correctly identified. For example, the graduate is Johan Madvig — but two other names are also referenced in the text, Madvig's father (of almost the same name) and mother. Dates must also be interpreted: 27 February 1833 is Madvig's date of birth, 13 June 1857 is when he graduated from university. The model must understand the differences between similar-looking elements, making sense of the context in which they are presented (much as humans do when reading).

Teaching a computer model to read text in this way is far from a straightforward task — but not an impossible task. Technical advances over recent years now make machine learning a viable option for extracting data from large volumes of non-digital source material, which opens significant new possibilities for researchers in economic history and other fields (Gutmann, Merchant, and Roberts 2018).

Efforts on digitisation and database construction are currently focused on the Norwegian and Danish records, enabling quantitative analysis using these records to commence from late 2021. The Swedish records will follow later, with expected completion by the end of 2022.

4 Structure of the dissertation

My dissertation consists of four articles, which apply a blend of theoretical and empirical analysis, using quantitative and qualitative methods (table 1). While the four articles stand naturally on their own, the narrative intent of the dissertation (to be reflected in the dissertation's introductory *kappa*) is to build from identified deficiencies in conventional measures of human capital, introduce a new measure that employs the richer data available for the Scandinavian countries, and demonstrate how this new measure is better placed to answer key questions relating to human capital and its role in economic development.

The four articles, outlined in detail below (with reference to the underlined short titles), are:

1) A new measure of human capital: Estimating the returns to skills and specialisation
2) Lessons from Oslo: Examining social mobility after the establishment of Norway's first university
3) In the footsteps of Chalmers and Ørsted: Engineering education in Sweden and Denmark, 1820–1920
4) Education, research and the pursuit of knowledge: The indirect effects of higher education on Scandinavian productivity during industrialisation.

This package builds from the rich data available on historic Scandinavian education to explore how human capital contributes to economic development. Three explanatory pathways are explored: who gets an education (article 2); what skills people get an education in (article 3); and how education drives technical progress and, by extension, long-term growth (article 4).

In addition to the articles discussed here, I will also contribute to several other articles as part of the HCNC programme. Foundational elements that are relevant here are papers relating to the Scandinavian graduate database and its source materials — in particular, critical analysis of the grade lists and graduate biographies (for example, Ford, Ranestad, and Sharp 2021).

Table 1: Brief overview of articles

Short title	Focus	Method
1. A new measure	Estimating returns to higher education	Theoretical/quantitative
2. Lessons from Oslo	Supply of skills (social mobility)	Quantitative (diff-in-diff)
3. Chalmers and Ørsted	Demand for skills (engineering)	Qualitative/quantitative
4. The pursuit of knowledge	Long-term effects of education via technical progress	Qualitative/quantitative

1) A new measure

The main contribution of this 'chapter 1' of the dissertation is a theoretical framework for improving the measurement of human capital with respect to education. As a proof of concept, the paper will also include an application using the data available from Denmark — grade lists, biographies and data on individuals' wage income (from census records).

As explained in section 3 of this project plan, existing measures of human capital lack sufficient detail of what skills students acquire. An improved measure should account for qualitative differences: what do students study, and how well do they perform in their studies? These questions can be answered using the unique source material we have access to for nineteenth and early-twentieth century Scandinavia.

An appropriate starting point for designing a new measure of human capital is the existing workhorse model for estimating the returns to human capital: the Mincerian earnings function (Mincer 1974; Card 1999). Conventional applications of Mincer consider years of schooling (perhaps disaggregated by level: primary, secondary and tertiary). The principle can be extended to account for different types of tertiary education or defined categories of skills (Psacharopoulos 1994).

An additional twist on the standard approach is to use student grades to quality-adjust for years of education. One simple approach: years multiplied by a grade score normalised to between zero and one (where a student who graduates with top marks earns one). While these are ideas rather than conclusions, for illustrative purposes, an extended earnings function could look something like:

$$\ln y = \beta_0 + \beta_1 S_1 + \beta_2 \sigma S_2 + \sum_{i=1}^{u} \beta_{3,i} \tau_i U_i + \beta_4 W + \beta_5 W^2 + e$$

Where the log of earnings (y) is a function of:

- years of primary school (S_1)
- years of secondary school (S_2), quality adjusted by school graduation mark normalised to between 0 and 1 (σ)
- years studying a given field (i) at university (U_i), quality adjusted by subject graduation mark normalised to between 0 and 1 (τ_i). There are u fields at university; each field enters the estimation separately ($i \in [1, u]$), such that returns are disaggregated
- years in the workforce (W), which enters the equation as a quadratic function (consistent with the standard observation that wages rise with age, plateau, then fall towards retirement). One could also consider disaggregating different types of work here, for example by sector.

The β values are the regression coefficients and e is the customary error term.

The model is intended to be flexible, with the degree of detail depending on what data is available. If student grades are not available, for example, then the quality-adjustment aspect can be dropped. Even with less information, the model should still be both usable and useful — albeit less precise.

A known drawback of the Mincerian approach is that it only estimates the private returns to education: it focuses on the income of workers given their education and skills. However, there are also spillover benefits to the rest of society — for example, increased productivity induced by new knowledge and ideas owing to education. Measurement of these social returns is challenging. The benefits to society can be difficult to conceptualise and quantify, while the full costs of education are not necessarily clear cut (Patrinos 2016). Nevertheless, to understand the effect of human capital accumulation on economic development and growth, one cannot ignore the social returns.

In proposing a new measure, it is useful to compare it to existing measures of human capital. The 1916 Danish census includes, unusually, data on individuals' income and wealth. Given this, one can compare a standard Mincerian earnings function (based on years of schooling) with the new measure (taking account of field of study and grades). How well does the new measure perform relative to the standard measure? What insights does the new measure reveal (particularly with respect to differences across fields of study), which the standard measure cannot?

2) Lessons from Oslo

The purpose of this paper is to consider what early effects were observable in terms of the supply of university-educated labour in Norway following the opening of the country's first university in 1811. With the costs of accessing tertiary education instantaneously lowered, which groups in Norwegian society (after 1811) now went to university who previously did not?

Unlocking access to education is a central part of the story of achieving the economic gains from human capital. Scandinavia entered the industrial age with already high levels of literacy — a trend that started with Lutheran church teachings, and was subsequently reinforced by public primary schooling. In Denmark and Norway, compulsory primary school was introduced in 1739 (Feldbæk 1990). In Sweden, compulsory schooling was first introduced in 1842 — but there had been a high level of domestic education prior to this (Ljungberg 2002). It is in (non-compulsory) secondary and tertiary education that differences in Scandinavians' human capital acquisition are more apparent. Thus, understanding who went to high school and university — and the factors that contributed to changes in the cohort profile over time — is relevant to the exploring the role of human capital in Scandinavia's development.

Norway provides a unique case study for examination. First, the late establishment of a national university (relative to Denmark and Sweden) provides an advantage in terms of the data available. Second, Norway did not itself choose the timing of the new university. For centuries, Norway was ruled in union with Denmark (as well as with Sweden under the period of the Kalmar Union). The Danish — and by extension, Norwegian — king was required to approve a new university; Danish officials resisted the idea for decades out of fears that it would fuel Norwegian separatism. Third, the establishment of the University of Oslo coincided with (though was not a direct consequence of) Norway's separation from Denmark in 1814. Thus, one would expect a greater share of Norwegian graduates from the University of Oslo to work in Norway rather than, for example, remain in Denmark after completing their studies at the University of Copenhagen.

The data sources underpinning this analysis are the grade lists and Danish and Norwegian census data from 1801. The approach is a difference-in-difference analysis, using Danish graduates as a baseline (unlikely to be affected by the University of Oslo opening) against which the Norwegian students can be compared. By linking Danish and Norwegian graduates (only in Copenhagen pre-1811, with the opportunity to study in Oslo post-1811) with their household entries in the 1801 census (that is, when the graduates were children), one can explore any differences in the socioeconomic status of Norwegian students that were triggered by the exogenous shock of Norway's first university opening.

Furthermore, the new measure of human capital can be applied to estimate the direct gains to Norway from any change in university-educated Norwegians. This includes both the increased number of Norwegian graduates, and the increased share of Norwegian graduates who then worked in Norway (rather than remaining in Denmark).

3) Chalmers and Ørsted

In examining the period of the industrial revolution, and the role of skills and education in that crucial phase of development, it is difficult to escape the contribution of engineering — both in terms of the new knowledge, tools and techniques that emerged, but also in the rise of technical education focused on applied natural sciences and the new fields of engineering. This paper proposes to examine the role of engineering and engineering studies, comparing development trends in Denmark and Sweden. How did the industrial structures of those two countries affect the demand for different types of engineering skills?

In 1829, two technical universities opened: the Technical University of Denmark (DTU), and Chalmers University of Technology (Chalmers) in the western Swedish city of Gothenburg. Notwithstanding their common origin in time, the two universities had some key differences. Institutionally, DTU was something of a spin-off from the University of Copenhagen, with the physicist Hans Christian Ørsted — a professor at Copenhagen — as its first rector (president).

Chalmers was established as a private institution financed by the estate of (and named after) William Chalmers, a business leader who died in 1811. It eventually became a state university in 1937. (Another technical institution in Sweden, KTH Royal Institute of Technology, was established in 1827 — with its roots in a mechanical laboratory established in the late seventeenth century.)

In contrast to many of the traditional fields of academic study (for example, theology, philosophy and law), engineering was perhaps the first clear example of a field of study geared towards the economic demands of the age. Chalmers' will/testament expressly stated an ambition for an industrial school; the university's first rector was a business leader. DTU restructured its educational programmes in the late nineteenth century, following criticism from industry that teaching was too theoretical, and that graduates lacked practical experience. A direct consequence was that DTU's applied natural science offerings were all repurposed as engineering courses during the 1890's.

University education is, of course, not the only means by which skills can be taught. Technical schools were also introduced during the nineteenth and twentieth centuries to expand the supply of skilled workers. More broadly, industrialisation began in the absence of formal study programmes for engineering. But the pace of industrialisation, and the advanced technologies it brought to the fore, motivated a shift from 'on-the-job' training to institutionalised education. Understanding this process, and why employers began to hire graduates rather than train apprentices or less-educated recruits, is one major theme of this paper.

This paper must account for the differences in the industrial structures of Denmark and Sweden. While engineers were in demand in both countries, the types of engineers and the work they performed necessarily hinged on local conditions. Sweden's industrialisation was driven by forestry and later mining (Hildebrand 1978). Denmark's economy, by contrast, was principally agricultural — the technical advances of the nineteenth century were based on improved techniques for food processing (especially with respect to dairy, see Lampe and Sharp 2018). Given these differences, this paper proposes to explore the interaction between employer demands for skills and the supply of skills through universities: that is, why universities offered the courses they did, and the extent to which they tailored their programmes in response to industry demands.

A large part of this task is qualitative: documenting — using public documents, archival records, news items and similar publications — the factors that shaped university-level engineering education and the employment of engineers. A basic theoretical framework to explain the shift from 'on-the-job' learning to employment of university graduates would also be relevant here. A quantitative overlay using the new human capital measure (article 1) would allow for a comparison of the direct effects of engineering education in Denmark and Sweden.

4) The pursuit of knowledge

Unlike primary and secondary schools, universities are not purely teaching institutions. Tertiary education is inextricably linked to research. Research is inextricably linked to the creation of new knowledge. And knowledge is inextricably linked to technical progress. The question this then raises is: how did Scandinavian universities — and the researchers trained at those institutions — influence the technical advances that enabled Scandinavia's growth?

The Scandinavian student records available provide information on those who progressed to research and academia. As one example, a research-oriented qualification was introduced to the Danish university system in 1848: the 'magister conference'. In contrast to other established fields with set curricula and official exams, the magister conference was tailored to the research of individual students. It afforded the University of Copenhagen flexibility in conferring academic degrees, and expanded the potential scope of research over time (University of Copenhagen 2018). The Danish grade lists include full descriptions of what each magister student studied and how they were examined.

More broadly, the graduate biographies are a valuable source for identifying those who went on to work as researchers and academics. If one starts from the stylised theoretical assumption that the stock of knowledge is a function of the amount of labour dedicated to research and development, then identifying the number of researchers is relevant in understanding technical progress. Or as Jones puts it: 'Just as more autoworkers will produce more cars, more researchers and innovators will produce more new ideas' (Jones 2021, 1).

The previous two articles focus on human capital's direct channel effects — the role of education in improving labour quality (that is, worker skills). By contrast, this article analyses the indirect channel — how education contributes to technical progress by driving the creation and application of new knowledge. The stretch goal for this final paper is to quantify the effect of higher education on Scandinavian productivity growth. A more modest ambition is to examine how researchers trained at Scandinavian universities contributed to the technical advances that drove Scandinavia's industrialisation.

Of the four articles, this paper is the least methodologically defined as this stage. One aspect is an attempt to validate theoretical models of knowledge production. A quantitative analysis in this space is complicated. Were the only data available the number of researchers, such an analysis might not reveal much. However, the data available from Scandinavia allow for an analysis based on the skills of individual researchers. Indeed, the biographical sources can help to precisely link individuals and specific technical advances (whether theoretical breakthroughs or applied inventions).

A second aspect considers productivity growth in Scandinavia (or some subset). Specifically, the area of interest is total factor productivity (TFP), where productivity growth represents efficiency improvements in the use of all inputs. The challenge here is that measurements of TFP are notoriously imprecise: a 'measure of our ignorance' (Abramovitz 1956, 11). TFP cannot be directly observed; it is calculated as a residual from what is observable. The question here is whether historical TFP estimates, though imperfect, are sufficiently reliable to be used even for analysis of approximate effects of research labour on productivity growth. An alternative line of inquiry might be to focus on technical progress within a specific industry rather than across the economy (though this narrowed scope does not necessarily make the task of estimating productivity any easier).

More precise definition of the task — including which Scandinavian country or countries and what time period are in scope — will be determined later in the project.

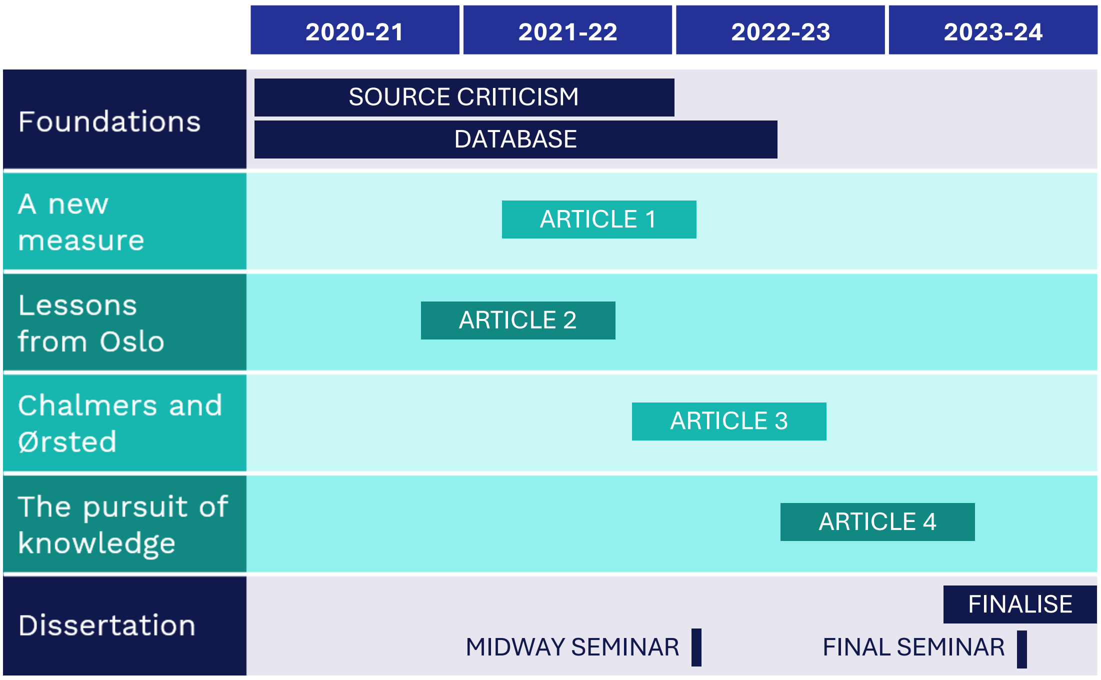
5 Timeline

The timeline for my dissertation and its constituent elements is illustrated in figure 1. The sequencing of work is not entirely consistent with the structure of the dissertation as presented in this plan. In particular, article 2 (Lessons from Oslo) is expected to be completed before article 1 (A new measure) — though work on the latter will commence in parallel with work on the former.

There are some risks and possible challenges to acknowledge with respect to timing. Plainly, the analysis proposed in this plan is contingent on the HCNC programme, and the timely completion of the Scandinavian human capital database. To the extent that work on constructing the database is delayed, or if the machine learning techniques do not prove sufficiently robust in translating biographical text to variables, this will necessitate revisions to the overall plan. This risk is not insignificant. However, progress is already well underway on the Danish and Norwegian records, and the early results are encouraging. Moreover, even in a worst-case scenario, manual entry of the data remains possible — solid, though less ambitious, analysis would still be feasible using a narrower set of student cohorts.

A related factor is that identification and digitisation of the Swedish records is still only at a preliminary stage. The covid-19 pandemic has delayed our efforts to examine available source material. This is not an immediate problem, in that the initial analysis will proceed with the Danish and Norwegian records (the two countries with the most similar records in nature and detail). Nevertheless, uncertainty about the coverage of the Swedish records — that is, how many graduates we will be able to identify — is an issue that we will need to resolve over the next year. In addition, and as noted above, we are not currently aware of any Swedish grade lists. Should we be unable to identify individual student performance in a comparable way to the Danish and Norwegian cohorts, this will partly constrain (though by no means prevent) the analysis of human capital in the Swedish context.

Figure 1: Indicative schedule of activities



References

Abramovitz, Moses. 1956. "Resource and Output Trends in the United States since 1870." National Bureau of Economic Research (NBER).

Angrist, Noam, Simeon Djankov, Pinelopi K Goldberg, and Harry Anthony Patrinos. 2019. "Measuring Human Capital." 8742. Policy Research Working Paper.

Barro, Robert J., and Jong-Wha Lee. 2013. "A New Data Set of Educational Attainment in the World, 1950-2010." *Journal of Development Economics* 104: 184–98.

Becker, Gary S. 1964. *Human Capital: A Theoretical and Empirical Analysis with Special Reference to Education*. 3rd editio. University of Chicago Press. https://doi.org/10.1093/nq/s1-IV.92.83-a.

———. 1965. "A Theory of the Allocation of Time." *The Economic Journal* 75 (299): 493. https://doi.org/10.2307/2228949.

Becker, Sascha O., Erik Hornung, and Ludger Woessmann. 2011. "Education and Catch-up in the Industrial Revolution." *American Economic Journal: Macroeconomics* 3 (3): 92–126. https://doi.org/10.1257/mac.3.3.92.

Benhabib, Jess, and Mark M Spiegel. 1994. "The Role of Human Capital in Economic Development: Evidence from Aggregate Cross-Country Data." *Journal of Monetary Economics* 34: 143–73.

Bils, Mark, and Peter J. Klenow. 2000. "Does Schooling Cause Growth?" *American Economic Review* 90 (5): 1160–83. https://doi.org/10.1257/aer.90.5.1160.

Card, David. 1999. "Chapter 30 The Causal Effect of Education on Earnings." *Handbook of Labor Economics* 3 PART (1): 1801–63. https://doi.org/10.1016/S1573-4463(99)03011-4.

Cinnirella, Francesco, and Erik Hornung. 2016. "Landownership Concentration and the Expansion of Education." *Journal of Development Economics* 121 (July): 135–52. https://doi.org/10.1016/j.jdeveco.2016.03.001.

Cohen, Daniel, and Laura Leker. 2014. "Health and Education: Another Look with the Proper Data."

Danmarks Statistik. 1900. "Statistisk Aarbog 1900." København.

———. 1930. "Statistisk Aarbog 1930." København.

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.” *Cliometrica* 15: 167–202. https://doi.org/10.1007/s11698-019-00199-6.

Feenstra, Robert C., Robert Inklaar, and Marcel P. Timmer. 2015. “The Next Generation of the Penn World Table.” *American Economic Review* 105 (10): 3150–82. www.ggdc.net/pwt.

Feldbæk, O. 1990. “Den Lange Fred. 1700-1800.” In *Gyldendal Og Politikens Danmarkshistorie*, edited by O. Olsen and O. Feldbæk. København: Gyldendals Bogklubber.

Ford, Nicholas, Kristin Ranestad, and Paul Richard Sharp. 2021. “Using Danish Student Grade Lists to Construct a More Detailed Measure of Historical Human Capital.” 207. EHES Working Paper.

Galor, Oded. 2005. “From Stagnation to Growth: Unified Growth Theory.” *Handbook of Economic Growth* 1 (SUPPL. PART A): 171–293. https://doi.org/10.1016/S1574-0684(05)01004-X.

———. 2011. *Unified Growth Theory*. Princeton University Press. https://doi.org/10.2307/j.ctvcm4h7m.8.

Goldin, Claudia. 1998. “America’s Graduation from High School: The Evolution and Spread of Secondary Schooling in the Twentieth Century.” *Journal of Economic History* 58 (2): 345–74. https://doi.org/10.1017/S0022050700020544.

Goldin, Claudia, and Lawrence F. Katz. 2008. *The Race between Education and Technology*. Harvard University Press.

Gutmann, Myron P., Emily Klancher Merchant, and Evan Roberts. 2018. “‘Big Data’ in Economic History.” *The Journal of Economic History* 78 (1): 268–99. https://doi.org/10.1017/S0022050718000177.

Hanushek, Eric A., and Dennis D. Kimko. 2000. “Schooling, Labor-Force Quality, and the Growth of Nations.” *American Economic Review* 90 (5): 1184–1208. https://doi.org/10.1257/aer.90.5.1184.

Hanushek, Eric A. 1992. “The Trade-off between Child Quantity and Quality.” *Journal of Political Economy* 100 (1): 84–117.

Hildebrand, K. G. 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*, edited by Peter Mathias and M. M.

Postan, 590–628. Cambridge: Cambridge University Press.

Jones, Charles I. 2021. "The Past and Future of Economic Growth: A Semi-Endogenous Perspective." 29126. NBER Working Paper. Cambridge, MA.

Kraay, Aart. 2018. "Methodology for a World Bank Human Capital Index." 8593. Policy Research Working Paper. http://www.worldbank.org/research.

Kyriacou, George A. 1991. "Level and Growth Effects of Human Capital: A Cross-Country Study of the Convergence Hypothesis." 91–26. *Working Papers*. Working Papers. C.V. Starr Center for Applied Economics, New York University. https://ideas.repec.org/p/cvs/starer/91-26.html.

Lampe, M., and P. Sharp. 2018. *A Land of Milk and Butter: How Elites Created the Modern Danish Dairy Industry*. University of Chicago Press.

Lee, Jong Wha, and Hanol Lee. 2016. "Human Capital in the Long Run." *Journal of Development Economics* 122 (September): 147–69. https://doi.org/10.1016/j.jdeveco.2016.05.006.

Ljungberg, Jonas. 2002. "About the Role of Education in Swedish Economic Growth, 1867-1995." *Historical Social Research* 27 (4): 125–39.

Ljungberg, Jonas, and Anders Nilsson. 2009. "Human Capital and Economic Growth: Sweden 1870-2000." *Cliometrica* 3 (1): 71–95. https://doi.org/10.1007/s11698-008-0027-7.

Mincer, Jacob A. 1974. "The Human Capital Earnings Function." In *Schooling, Experience, and Earnings*, 83–96. NBER.

Mokyr, Joel. 2002. *The Gifts of Athena: Historical Origins of the Knowledge Economy*. 1st pbk. Princeton and Oxford: Princeton University Press.

———. 2005. "The Intellectual Origins of Modern Economic Growth." *Journal of Economic History* 65 (2): 285–351.

Nilsson, Anders. 1999. "What Do Literacy Rates in the 19th Century Really Signify? -New Light on an Old Problem from Unique Swedish Data." *Paedagogica Historica* 35 (2): 274–96. https://doi.org/10.1080/0030923990350201.

Patrinos, Harry Anthony. 2016. "Estimating the Return to Schooling Using the Mincer Equation." *IZA World of Labor*, July. https://doi.org/10.15185/izawol.278.

Psacharopoulos, George. 1994. "Returns to Investment in Education: A Global Update." *World Development* 22 (9): 1325–43. https://doi.org/10.1016/0305-750X(94)90007-8.

Psacharopoulos, George, and Ana-Maria Arriagada. 1986. “The Educational Attainment of the Labor Force: An International Comparison.” EDT38. Education and Training Series: Discussion Paper.

Smith, Adam. 1776. *An Inquiry into the Nature and Causes of the Wealth of Nations*. *Readings in Economic Sociology*. https://doi.org/10.1002/9780470755679.ch1.

Solow, Robert M. 1956. “A Contribution to the Theory of Economic Growth.” *Source: The Quarterly Journal of Economics*. Vol. 70.

Swan, T. W. 1956. “Economic Growth and Capital Accumulation.” *Economic Record* 32 (2): 334–61. https://doi.org/10.1111/j.1475-4932.1956.tb00434.x.

Undervisningsministeriet. 1998. “Uddannelsessystemet i Tal Gennem 150 År, 1848-1998.” København.

University of Copenhagen. 2018. “Magisterkonferens.” Universitetshistorie. Københavns Universitet. 2018. https://universitetshistorie.ku.dk/leksikon/m/magisterkonferens/.