Research Proposal [Part B2]

Section a. State-of-the-Art and Objectives

Have elites played a major role in economic development? For a long time, history was devoted to the analysis and description of the elite's achievements - the great battles won by generals, the miracles of Saints, the conquests and weaknesses of kings and emperors, and the transformative inventions of geniuses. This view of the world started to change with the Enlightenment. Voltaire, in his *Histoire universelle*, followed the chronological succession of the dynasties as a guide, not a purpose. He did not want the reader to be so unfortunate as to read a book about the year a prince unworthy of being known succeeded a barbarous sovereign. Later on, in the nineteenth century, especially with the rise of Socialism, the attention shifted towards the achievements of the masses. Today, the weight which should be given to the role of the masses versus that of the elite remains actively contested in both science and politics (think for example of the success of anti-elite views in 2016 in the developed world).

An exemplary application of this tension concerns the role of human capital and, in particular, of upper-tail human capital (hereafter referred to as UTHC), in the emergence of the West through the scientific and industrial revolutions. According to one extreme view, innovations were driven entirely by the UTHC – scientists and mathematicians pushing the envelope of propositional knowledge, which was then applied in the agricultural and industrial revolutions of the late eighteenth and nineteenth centuries. For example, for Mokyr (2002), a small group of a few thousand people were the main actors, paving the way for the Industrial Revolution. The other extreme view sees technical innovations as driven entirely by the evolutionary development of artisanal knowledge, which is improved over time through learning-by-doing and the diffusion of improvements that were discovered largely by chance. From this perspective, formal and codified knowledge played no role in these advances (Epstein, 2013).

Strategic Objective

This important debate on the weight and significance of the UTHC in generating the take-off to modern growth has so far been mostly qualitative and largely focused on specific places and sectors. **There are currently no global quantitative analyses of the issue simply because data are not available at the European level.** The strategic objective of this project is to take the debate to a new level by conducting research in a more systematic and quantitative way. I propose to build and exploit a new database covering a large sample of university professors and members of scientific academies across Europe from the Middle Ages to the Industrial Revolution. This new database will be used to support the development of new empirics and theory, to then tackle the outstanding questions identified below.

With such a tool, it will become possible to address questions which could not be addressed before, and **to investigate the role of scholars in opening the path to modern growth and how they interacted with artisans' knowledge and institution improvements in doing so.** This can be achieved by exploiting the variations in the data along the various dimensions recorded in the database to investigate the link between elite knowledge and economic development through time and space, and by field of study and quality of institutions. Before detailing what I intend to do, let me first describe the current state-of-the-art knowledge in terms of existing theories and available data.

A priori, there can be four different types of answers to my research question.
(1) Elites generated the new scientific knowledge (Science), which, when applied, triggered the Industrial Revolution. For Jacob (2014), the marriage of industrial culture to scientific knowledge and technology was key. Musson and Robinson (1969) argued in favor of a central place for Science in the development of the Industrial Revolution, in particular in engineering and chemistry. Wootton (2015) describes how the discoveries of Brahe, Newton, Toricelli, and others caused the Industrial Revolution and transformed the world. In terms of economic models, this view resembles innovation-driven endogenous growth models (Romer (1990) and Aghion and Howitt (1992)), but with doubtful applicability to the pre-industrial era, since legal protections for intellectual property (which are at the core of this class of models) became widespread only recently.
(2) Elite knowledge triggered a major cultural change in the period 1500-1700, which prepared the population, or at least part of it, for the modern world. This is the thesis defended in the recent book by Mokyr (2016). He suggests that the Enlightenment in the eighteenth century was pivotal in driving the economic growth in the nineteenth century, but that it was not a mass phenomenon. *"It was an Elite phenomenon, confined to intellectuals, scholars, ..."* This thesis on the culture of growth resembles the theoretical approach based on threshold externalities (see

Azariadis and Drazen (1990)), but in which the key variable triggering a change of regime would be the UTHC and not general human capital. Alternatively, the cultural change model of Bisin and Verdier (2001) can be used to think about this channel, if the UTHC plays a role in socializing the youth to the culture of the Enlightenment.
(3) Elite knowledge, by writing books, educating the population, and producing good citizens, made labor more open to the adoption of new techniques (Cipolla, 1969). Indeed, the economic take-off was preceded and accompanied by a rise in literacy (see Cressy (1980) for England). Allen (2009) also stresses that even though great inventors were not so frequently in contact with scientists, they were all very well educated and literate. In the growth/development literature, human capital accumulation is often perceived as central, in particular with the emergence of endogenous growth models (see Lucas (1988), Boucekkine, de la Croix, and Peeters (2007)) and unified growth theory (Galor and Weil (2000), Cervelatti and Sunde (2005), Galor (2011)). Its distribution and its upper tail, however, were not the focus of specific attention (except in Strulik and Werner (2014) and Squicciarini and Voigtlaender (2015), see below).
(4) Elite knowledge was just a luxury good, which played no role in the take-off to modern growth. Or science was only useful to defend industrialization and capitalism against the workers who opposed machinery.

Beyond these four approaches, there is the view that the UTHC was a necessary yet not sufficient condition. Allen (2011) writes: "Scientific discoveries were known across Europe, and upper-class enthusiasm for natural philosophy was universal. These cultural developments, therefore, cannot explain why the Industrial Revolution was British." For Allen, the Industrial Revolution is due to the cheap price of energy in Britain, so that research and development was conducted there (by British engineers). Here, Science and human capital were necessary conditions for the take-off, but they were not sufficient. For Ferguson (2011), Science was one of the key components of the Rise of the West, but trade and competition mattered as much.

I thus propose to develop a new quantitative approach to determine which of these alternatives is paramount. The specific objectives of this project are [1] to develop a **new integrated database** on the elements necessary to the study of the role of upper-tail human capital (scholars, universities, academies, and books); [2] to conduct an empirical analysis of the **weight and significance of the UTHC in paving the way towards the first industrial revolution, either directly or through culture and literacy;** [3] to unravel the corresponding **mechanisms which** contributed to the take-off to modern growth; [4] to develop new theories of **the interface between elite knowledge and the adoption of better techniques and institutions**, helping to establish a greater understanding of the key mechanisms behind these complementarities and how UTHC affected development by promoting a **culture of growth**.

A further consequence of this project could be to give a fresh start to the theory of growth and development, a theory in which individuals play a central role.

The Mechanisms Involved

If elites had an impact on development, either directly through technical progress, or indirectly through changing the culture and / or educating the population, different mechanisms were involved. The most obvious is through an increase in density (number of scholars per inhabitant) and the concentration of upper tail-human capital in key "crucible regions." Places and periods with more actively engaged scholars are expected to have higher outcomes in terms of their economic development, technical progress (such as the adoption of the printing press, the steam engine, etc.), and the growth of cities. They might also display an improvement in the quality of governance and legal institutions, and in democratization. This positive view of the role of the UTHC for economic and social development is in line with the two existing studies of the question at the country level: Squicciarini and Voigtländer (2015) show that the number of subscribers to the Encyclopédie predicts the rate of economic development one century later (in France, the unit of observation is the *département*); Dittmar and Meisenzahl (2016) show that cities that established public goods institutions in the 1500s generated more UTHC and grew faster (in Germany, the unit of observation is the city).

The composition of the UTHC in terms of field is also important. Some fields may be reservoirs of rent-seekers, who tend to hamper institutional innovation. Since the seminal paper of Murphy, Schleifer, and Vishny (1991) in favor of more engineers and fewer lawyers in developing countries, the case of law has been particularly controversial (see also Maloney and Caicado (2016) on the role of engineers in America). Economic development requires not being too far from the efficient allocation of talents across relevant fields.

However, the composition and density of upper-tail human capital are not the whole story. Another, more subtle channel linking elites to positive development outcomes is the *contact time effect*. In a world where face-to-face communication was essential for both knowledge transmission and enhancement, the length of the elite's productive life was important to determining the extent of their impact on their cultural and economic environments. A formal link between productivity growth and longevity is implicitly provided by Lucas (2009). In his model, people pick up ideas from those they meet. The more people they meet, the better and more influential they become. If they live long, they have much greater chances of becoming excellent at what they do, and they also give far more opportunities to other people to learn from them. This effect of longevity on growth might quantitatively be important, and this is why several authors have tried to assess changes in the elite's longevity before the Industrial Revolution (Cummins (2014), de la Croix and Licandro (2015), see below).

A last mechanism whereby elites influenced development is both their national and international mobility. Mokyr (2005) measures the mobility of 1,185 "creative people" in Europe over the period 1450–1750, and shows that it was large, with 3.72 mean moves per person. Mobility promotes the diffusion of ideas, and also demonstrates the relative freedom of knowledge elites with respect to their king or government.

The Limitations of Current Theories

One of the key questions that must be tackled is that of the complementarity between elite human capital and other potentially significant inputs, such as artisan knowledge. **Most of the existing literature on human capital and education is of little use here as it cannot be directly applied to pre-industrial societies**. First, because masses are viewed as educated through formal schooling, while, in fact, most of the knowledge that they gained was tacit. It was embodied in people rather than written in books. Elite knowledge (books, universities, and science) was not taught to the masses. Instead, it interacted in a more subtle way with artisanal knowledge, which was itself transmitted from person to person through apprenticeships. A few models have addressed this issue. In Strulik and Werner (2016), there are scientists and workers, both endowed with human capital, which improves through learning-by-doing. In their model, there is also a pre-industrial R&D sector in which only scientists intervene. Their model is useful in that it distinguishes between elite education and mass education, including cases in which elite education mostly concerns the low-ability elite. It provides a first step towards understanding the complementarities between education and economic growth during and after the Industrial Revolution, and the interactions between R&D and learning-by-doing. However, it does not really address the issue of the complementarity between both types of knowledge, science and techniques, in pre-industrial times.

In Squicciarini and Voigtländer (2015), there is an illustrative model showing the link between the knowledge of entrepreneurs and technical progress (science). The latter grows exogenously. Yet the technical and operational knowledge of entrepreneurs helps them stay at the frontier. Their model does not enter into the detailed channels through which this operates, but it illustrates that *"First, more scientifically savvy entrepreneurs were more likely to know about the existence of new technologies, which reduced their search costs and raised the likelihood of adoption. Second, they could operate modern technology more efficiently because of having a better understanding of the underlying processes."*

Finally, de la Croix, Doepke, and Mokyr (2017) examine the role of apprenticeship institutions in stimulating economic growth in the pre-industrial era. They build a model of technological progress that emphasizes the person-to-person transmission of tacit knowledge from the old to the young (as in Lucas (2009) and Lucas and Moll (2014)). This makes it possible to go beyond the simplified representations of technological progress used in the models of pre-industrial growth, such as the two described above. Their model is mostly about the exploitation of practical knowledge, which is represented as the efficiency with which craftsmen perform tasks. While there is some scope for new innovation, the main engine of technological progress is in effect the transmission of productive knowledge from old to young workers. Young workers learn from their elders through a form of apprenticeship. There is a dissemination of acquired knowledge (or productivity) across workers, and when young workers learn from multiple old workers, they can adopt the best technique to which they have been exposed. The limitation in this explanation lies in the modelling of new knowledge, which applies an exogenous rate to the actual state of knowledge.

To conclude, although some advances have been made to model elite human capital as a distinct feature, and to account for the tacit nature of productive knowledge, **there is as of yet no theory that provides an understanding**

of how the two interact, either in terms of new knowledge creation or for the diffusion of current best techniques.

The Limitations of Existing Databases

Several authors have built databases in order to analyze the key characteristics of the elite, such as increased longevity and mobility. In a sense, economists and economic historians are now reviving the old tradition of prosopography, which collects and analyzes large quantities of biographical data about a well-defined group of individuals (in the elites in most cases) in order to reveal connections between them, and to draw the contours of a representative person (a survey of the state of this literature in France and Germany is provided by Joly (2008)). To better understand the strengths and additional capabilities of the proposed database that we intend to build to address the core research question, it is useful to compare its merits with the limitations of past attempts.

Cummins (2014) analyzes the longevity of European nobility and its link with the 'Rise of the West'. It is based on data collected by the Church of Jesus Christ of Latter-day Saints which has been expanded by several independent genealogists. It therefore extends the existing demographic studies of Europe's aristocracy considerably. All observations (>100k) of birth and death are geo-coded. The empirical challenge was to extract the major time and spatial trends in the nobles' lifespans from the noisy data, while controlling for the changing selectivity and composition of the sample. The main result of this paper is to show that the areas of North-West Europe where the Industrial Revolution took place had achieved greater longevity than the rest of Europe by 1000 CE, thus suggesting that the `Rise of the West' originated before the Black Death. **The main weakness of this analysis is that it relies on the study of noble families, which might not be the prime holders of upper-tail human capital.**

The paper by de la Croix and Licandro (2015) pursues the same aim, but based on a different database built from the ***Index Bio-bibliographicus Notorum Hominum (***IBN), which contains entries on famous people from about 3,000 dictionaries and encyclopedias. It also contains information on multiple individual characteristics, including their place of birth and death, occupation, and nationality. De la Croix and Licandro (2015) document that there was no trend in adult longevity until the second half of the seventeenth century, with the typical longevity of famous people being at about 60 years during this period. This finding is important as it provides a reliable confirmation of conjectures that life expectancy was rather stable for most of human history, and establishes the existence of a Malthusian epoch. They also show that permanent improvements in longevity preceded the Industrial Revolution by at least a century. The longevity of famous people started to increase steadily for the generations born during the 1640-9 decade, reaching a total gain of around nine years over the following two centuries. The increase in longevity among the educated segment of society hence preceded industrialization, **lending credence to the hypothesis that upper tail human capital may have played a significant role in the process of industrialization and the take-off to modern growth.** Finally, using information about locations and occupations available in the database, they also find that the increase in longevity did not occur only in the leading countries of the seventeenth-eighteenth centuries, but almost everywhere in Europe, and was not dominated by mortality reduction in any particular occupation. Compared to Cummins (2014), this study has the advantage of covering a broader swath of population than just the nobility, as it includes all the professions that can be thought to have played a role in the transition to modern economic/industrial growth: e.g. scientists, professors, writers, merchants, etc. Their study however suffers from two main weaknesses that the present proposal will be immune from. The selection into the sample is based on choices made by others (the IBN), hence it is impossible to know whether it was really a random sample drawn from the set of all famous people. Second, the age at which famous people became famous cannot be controlled for (for some of them, it might even be post-mortem), making impossible to compute properly a population at risk and a life expectancy.

With the expansion of electronic resources, it has now become feasible to gather information on the web to study the place and role of notable people in history. Gergaud, Laouenan, and Wasmer (2016) build a database of people recorded in ***FreeBase*** and ***Wikipedia***. The essential contribution of this approach is to link every individual to all the places mentioned in the corresponding Wikipedia entry. The final product comprises over one million people and seven million locations, but only thirty thousand among them have an occupation related to education. Their research is probably less relevant for the UTHC than the previous one, as a large part of the data come from athletes and singers, but their approach of geocoding the birth to death trajectories of people has inspired me to record similar information for European scholars. Indeed, their mobility was crucial to the dissemination of new knowledge and practices.

Beyond these efforts to build global databases, there are some country level initiatives focused on UTHC. For Britain, Dowey (2016) studies quantitatively 'Knowledge Access Institutions' – learned societies, mechanics institutes, Masonic lodges, and public libraries – which reduced the cost of access to useful knowledge over the course of the eighteenth and early nineteenth centuries. For France, Roche (1978) gathers and analyzes a large database of academies and their members over the period 1680-1789. For Germany, the project "*Repertorium Academicum Germanicum* - The Graduated Scholars of the Holy Roman Empire between 1250 and 1550" focuses on universities located on the territory of the Holy Roman Empire from 1250 to 1550. Compared to those, our project is truly European, allowing to consider cross-border interactions at the continental level.

In addition to the "famous people" literature, there is one paper which looks quantitatively at the effect of universities on pre-industrial society. Cantoni and Yuchtman (2014) show that university training in Roman law played an important role in the establishment of markets during the "Commercial Revolution" in medieval Europe. To establish this result, Cantoni and Yuchtman determine the enrollment rates of German students in the universities of Bologna, Paris, Padua, Orléans, Prague, Heidelberg, Cologne, and Erfurt. This data was collected from a variety of sources, most of them books published in the nineteenth century.

Beyond establishing a new database covering thousands of scholars and literati, the specific objective of this project compared to the literature is to link these data to universities and academies, to books published, and to a range of key fields. Creating these links is **essential to step towards determining the nature and extent of the role of upper-tail human capital (UTHC) in the Rise of the West and the emergence of the Industrial Revolution.**

Section b. Methodology

Let me now describe the proposed methodology in more detail, from the construction of the new database, its subsequent exploitation, to showing how it will open up new horizons and opportunities for research.

The Key Features of the Proposed Core Database

Over the period 1500-1800, the number of universities in Europe rose from around eighty medieval universities to nearly two hundred (Frijhoff, 1996). This still highlights the ambition of the project, as it is hard to tell how much time will be needed to gather a significant amount of data on at least half of these universities. The aim will be to achieve sufficient coverage to enable us to establish significant variability across places, time, and fields, and to identify mobility patterns. The value and interest of the UTHC database to economists, economic historians, and other researchers on cultural change will be significant.

Figure 1 represents the 188 universities which confer doctoral degrees at some point before 1800 (from Frijhof 1996). We propose to limit the coverage of the new database to them and to include all professors in these universities active before 1800. Later on, we may extend the database to the universities created in the nineteenth century, but the problem of reverse causality becomes more acute then, as universities might have been created to meet the demand of the industrial sector rather than being the triggers for its development.

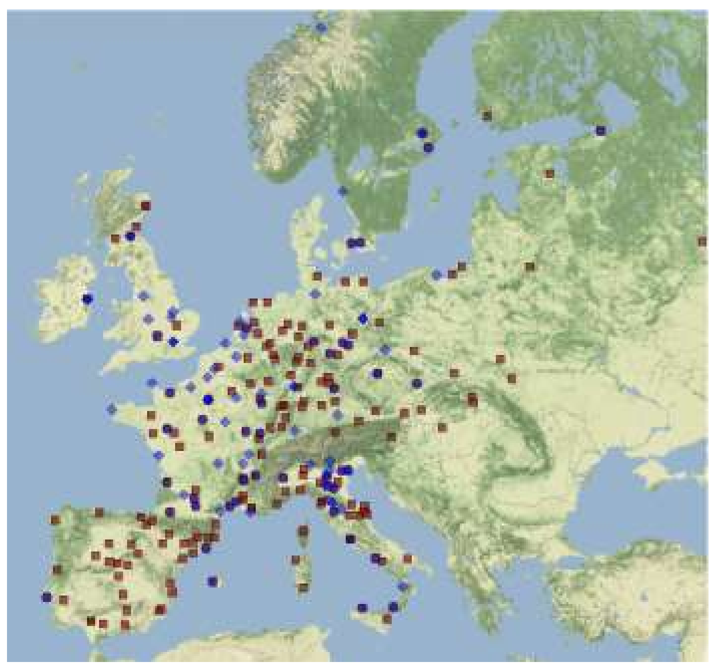


Figure 1: universities (red) and scientific societies of some importance (blue) active in Europe at some point before 1800. Source: Frijhof (1996) for universities, Mc Cleland III (1985) for scientific societies.

In addition to universities, we will incorporate data for the members of scientific societies (academies). Initiated in Florence, the movement for national academies gained momentum in Northern Europe with the creation of the Académie des Sciences (1666), the Royal Society of London (1662), and the Academia Leopoldina (1677). Including academies implies high gains in terms of the quality of the picture of the scientific elite. The 100 important scientific societies (as listed in Mc Clelland III, 1985), both official and private, are represented in blue on the map.

At this stage, we have given on the map identical weight to all institutions which gives the impression that a large part of Europe is quite well covered. The project will allow to give weights to each of these institutions, based on their quality, measured, as explained later, by the publications of their members, their mobility, and the diversity of their scholars. These weights will allow to determine the exposure of each region to UTHC.

For universities, building a comprehensive list of professors with the relevant supporting information (at least: name, birth, nomination year, field, and death or retirement) will not be as easy. We will essentially proceed in six steps. (a) Establish the list of universities to be prioritized, their activity period, a short history notice, and their GPS coordinates. In this step, we all also pay attention to their degree of autonomy with respect to religious or political authorities. (b) For each university, we will check whether there is an online historical database of professors. If there is, we will import the contents of the database. (c) For universities without such a database, we will check whether there are books of biographies of their professors. If there are, we will encode the contents of these books. (d) For the remaining universities, we will check whether *matricula* (people registered at a given university) and *chartularia* (containing transcriptions of original documents related to the historical events of a university) exist. We will build a sample of professors from the information therein. (e) When the sample built is small, we will get in touch with the university's archive department, ask for an inventory of the archives; and identify those with potential professor names. We will request their digitalization, or go personally to the archives. (f) For each professor, we will check national biographies and other databases to complete the information needed.

I now detail these steps with a few examples. For some universities, such as Groningen University, the list of professors has already been established. The *Catalogus Professorum Academiae Groninganae* includes all full professors from 1614 onwards (see the website at http://hoogleraren.ub.rug.nl/). The website is still under development, but it shows the interest of universities themselves in looking at their past in a more systematic way. This highlights that the proposed project could lead not only to the production of scientific knowledge, but could also serve a societal purpose by gathering information on the long history of European universities, and making it publicly available in an accessible format.

Some universities have not established a list of their professors, but some authors published biographies of them in the nineteenth or early twentieth centuries. This is, for example, the case for the University of Jena (Günther, 1858). Here too, it is highly feasible to code the information. For the scholars listed in the book but still alive in 1858, the relevant information can be added from the *Deutsche-biographie*. This allows solving the problem of right censoring (the fact that everyone is not observed until the end of their activity period). This shows the benefit of combining databases. Similar compendia exist for Oxford (Emden 1957) and Cambridge (Emden 1963). A third category of universities has neither a ready-to-use website nor a published biography of their professors. However, books have been written on their history. Here, we will need to build our database from this information and find a way to assess the completeness of the resulting list. Notice that, for professors in exercise during the late Middle Ages and the Renaissance, information can be retrieved from two recent projects, both aiming at collecting biographical and social data on those who graduated from medieval universities. The project "*Repertorium Academicum Germanicum* - The Graduated Scholars of the Holy Roman Empire between 1250 and 1550" mentionned above. The project "*Studium*" pursues a similar aim for the University of Paris from the twelfth century to the Renaissance. The database is accessible online at: http://lamop-vs3.univ-paris1.fr/studium/faces/find.xhtml. Both projects are currently under development.

The main difficulty arises from those universities where nothing has been done to record past professors. All universities know their "prominent" professors, but do not have lists of all their professors. This is apparently the case for the forerunner of my own university (*Universitas Lovaniensis*), which was active from 1425 to 1797. Louvain is a "bad case example," as its archives were dispersed in 1797. Yet, even in such a case, a large sample of its professors can still be built. First, there is a *matriculum* with the list of all those involved in the university. The list itself is of little use as the quality of these people is not recorded (students, professors, etc…), but it follows the chronological succession of rectors, whose names are provided. As rectors were nominated every six months, their names give a good coverage of the universe of professors there (with some selection bias). Moreover, from the inventory of the archives, item # 118 is a list of nominations of professors to courses (for the period 1557-1773) that could be considered should the previous steps lead to insufficient coverage. In any case, the list of names will be matched with other sources (books on the history of the university, Wikipedia, IBN, and national biography) in order to complete the information about them. On the whole, it will be highly feasible to obtain good coverage of Louvain with a few weeks of well-focused effort.

For academies, the situation is simpler, as the list of members was often kept by the academies themselves (and the notion of membership is also more clearly defined). In some cases, it will be necessary to do more research to match the names with their vital dates, using other sources. For example, the ***Nationale Akademie der Wissenschaften*** does not report the vital dates, but they can be found in the ***Deutsche biographie*** (http://www.deutsche-biographie.de/).

The starting point for data collection will be Northern rather than Southern Europe. Indeed, many universities were created in Spain and Italy during the Middle Ages, but unlike the wealth of information which exists for England and Germany, biographies on their professors are very scarce (hopefully Bologna seems well covered in Mazzetti (1847), and Alcala in Guttiérez Torrecilla et al. (2013)). It would then be necessary to rely on archives from the beginning, without being sure that we can gather a sufficient amount of information (see the introduction of Verger 1988). Starting with Northern Europe, we can quickly establish a list of 10,000 professors without relying on any in-depth additional work (for example, the French academies already include 2,300 names, Groningen University has about 400 names in the relevant period, the University of Utrecht, which also available online, has 450, Rostock has 790 names online, Greifswald has c. 600, Jena has 450 (from the book mentioned above), Leipzig has 900, etc). 10k should represent about 5% or 10% of the target group. Once this intermediary goal has been achieved, we will then proceed in two directions: [1] completing the database with further work, and [2] enriching it by matching it with other existing sources. Having reached this key intermediate stage may also require that we make adjustments to the project planning, by broadening or reducing the geographical scope of the project. **The risk is mitigated by the scalability of the project.**

An important feature of the core database will be the inclusion of the field of study. When the first universities emerged, there were normally only four faculties, arts, law (canon and Roman law), medicine (including pharmacy and surgery), and theology, each serving a particular sector of society. Later on, when the needs of society increased, some universities expanded the realm of their expertise, while others did not, thus becoming more and more obsolete. Humanism, directly followed by Protestantism, induced an expansion of the faculty of arts. For example, when the new university of Marburg was created in 1529, it included ten chairs in arts: rhetoric (2), Greek, Hebrew, dialectics, grammar, poetry, history, physics, and mathematics, including astronomy (Pedersen, 1996). Faculties of arts, however, were very slow to cope with subsequent needs, such as cartography and astronomy, leading major scientists to quit the university before the end of their career (Copernicus, Kepler, or Galileo). Encoding the field of scholars will allow us to quantify and map these changes in a very precise way, also identifying the capability of universities to adjust to the needs of the changing world around them. Another consequence of the humanist revolution was the creation of national or specialist sectoral academies. Adding the members of these societies to the database and paying special attention to their field of research is indispensable to capturing the shifts in focus in universities following the humanistic revolution.

Another promising feature of the database is being able, for each institution, to compute the birthplace diversity of its members (following Alesina, Harnoss, and Rapoport 2016). The hypothesis is that the quality of the institution is positively correlated with the diversity of its members. Birthplace diversity indexes can help identify the best places in each period, and also how institutions rose and declined over time.

Enrichment of the Core Database

The core database we build will be enriched by several important elements. We plan to [1] identify nobles in the sample, [2] measure the quantity and quality of the output of scholars, and [3] establish their mobility patterns.

There is no large literature on the social origins of university professors in pre-modern Europe (Vandermeersch, 1996). Vandermeersch claims that most of them came from the intellectual bourgeoisie (which he calls lower-middle class), although some came from the nobility. He mentions a study on French professors in law over the period 1681-1793, in which twenty-four out of fifty-nine were noblemen. He also reports that in some universities, like Cracow, professors were ennobled after twenty years of service. It would clearly be an advance if we could identify in our database those professors of noble origin. This can be achieved either from the record itself, by using biographical dictionaries, and/or matching our database with nobility genealogical data such as the database in

Cummins (2014) described above. In the same vein, identifying priests among professors would be a way of measuring their decreasing influence and the progressive secularization of higher education.

We propose to **measure the quality of scholars and their impact within their respective fields by their book production**. Data on books (titles and editions) have been collected and used by Buringh and van Zanden (2009) from various sources. They also consider books produced before the adoption of the printing press (data sources are available on the "global historical bibliometrics" website at http://www.iisg.nl/bibliometrics/). According to their panel data regression on the per capita production of manuscript books, the latter is correlated with the presence of universities and monasteries, and the degree of urbanization. Baten and van Zanden (2008) use the same data on book production as a proxy for upper-tail human capital. They show that human capital formation of this type had a strong, robust, and positive effect on economic performance in the centuries before 1800.

In addition to these data, there is the *Universal Short Title Catalogue (USTC)* database of St. Andrews (2012), which is designed as a universal catalogue of all known books printed in Europe between 1450 and 1600. This catalogue has been used recently by Dittmar and Seabold (2016), who measure the importance of religious ideas in these books. We aim to use it to measure the importance of scientific ideas over this period, when many existing assumptions were being challenged.

The mobility of students and professors has been a key aspect of universities since their foundation. Until the seventeenth century, all universities taught in Latin, which facilitated *peregrinatio academica*, the academic pilgrimage (Rydder-Symoens, 1992). With our database, we can identify the patterns of migration for professors, far beyond what is currently only known for the most famous scholars (for example, Desiderius Erasmus tutored in Paris, Louvain, and Cambridge, before moving to Italy). For each individual, we will build a geo-localized migration track from place of birth to first and following appointments, to place of death. **Establishing these patterns matters for understanding and monitoring the diffusion of knowledge.**

Correlation Analysis

Once the database has been established, we will exploit the variation in the composition, density, and quality of the UTHC across time, space, fields, and the variation in longevity and migration of the UTHC to measure the correlation between the UTHC and different scientific, economic, and social outcomes. The unit of analysis will be either the city or the region. Several important works have used the city as a unit of analysis, but for our purpose it needs to be completed by a broader geographical unit (indeed, the development of the cities of Oxford and Cambridge will not tell us much about the English take-off, unless taken within a broader area, where their students were distributed). **A key strength of our analytical approach will be the capability to observe where the scholars actually worked**, which is not possible when you only know the places of birth and death. The studied outcomes will include the adoption of new techniques (such as the printing press and the steam engine), the establishment of better institutions, and the development of cities and regions. To measure these outcomes, we will utilize existing databases such as: Bairoch, Batou, and Chèvre (1988) and Bosker and Buringh (2013) who build a database of city population for almost all cities in Europe reaching 5k inhabitants before 1850. City growth is often used as the primary indicator of economic vitality. Dittmar (2011) compiles information from three different sources on the adoption of the printing press during its infancy (1450-1500). DeLong and Shleifer (1993) build an indicator on whether cities were free or subject to a prince's will. To measure regional development in terms of broad human capital, we can rely on numeracy indexes based on age heaping measures, as suggested by A'Hearn, Baten, and Crayen (2009). Literacy in the pre-industrial period can be measured by signatures on marriage registers; such data are available for many countries at a regional level (see Maggiolo's survey for France in Fleury and Valmary, 1957). Measures of income such as height are also available at this level of disaggregation (see for example the variation in height across French regions during the seventeenth century in Komlos, Hau, and Bourginat, 2003).

Having linked scholars to institutions and to their output in terms of published books opens up the possibility of looking at **peer effects**. Along the lines suggested by Borowiecki (2013) for music composers, we aim to study whether individual productivity depended on whether other scholars in the same field were located in the same university (or in nearby universities). We can also challenge the external validity of Waldinger's (2012) result, who found no evidence of such effects in twentieth century data, using the dismissal of scientists by the Nazi government in 1933 as a source of exogenous variation in the peer group of scientists who stayed in Germany.

Demographic Analysis

First, following Schich et al. (2014), we will apply new methods (in economics) to identify the characteristic statistical patterns of the migration of scholars. Taking inspiration from tools of network and complexity theory to describe the mobility of artists over the span of human history, we will provide **a macroscopic view of the history of scholars and universities in part of Europe, and document historical trends in the primacy of knowledge centers beyond the scope of specific events or the narrow time intervals that historians usually provide.**

Second, given the large number of observations, as well as the knowledge of the age at which each scholar entered the population at risk (their age at nomination), we will be able to properly compute the life expectancy of scholars and also measure its standard error (for example by implementing Monte Carlo simulations to the life table, see Andreev and Shkolnikov (2010)). This significantly improves on the large existing literature in historical demography computing the life expectancy of small groups of people (noble families, cardinals, knights of the Golden Fleece, etc. See references in de la Croix and Licandro 2015). Dupâquier (2000) applies this approach to the members of the French Academy. Given the low number of observations, the population at risk at young ages is extremely small, and the estimated life expectancy is not robustly estimated. With large samples, life expectancy can also be computed for different regions and time periods precisely, and correlated to outcome variables. This would make it possible to further test the implications of the contact time model (see above) according to which knowledge transmission is eased when people live longer.

Causal Inference

In exploiting the new database empirically, we need to be able to directly address the question of the exogeneity of the localization of human capital that many other researchers have faced before us. A correlation between the UTHC and development is not necessarily indicative of a causal effect. For example, if we believe that the presence of coal was key for the take-off to modern growth (as Pomeranz (2009) does), the UTHC might have been concentrated in the coal regions to meet a demand for education as a luxury good, leading to the false impression that the UTHC was key for the take-off. The current literature has adopted several strategies to deal with this issue. One is to use instrumental variable techniques to isolate causal links. For example, distance to Wittenberg has been used as an instrument to predict Protestantism (Becker and Woessmann 2009), distance to the first adoption of the steam engine has been used to predict further adoptions (Franck and Galor 2015), distance from Mainz has been used to predict the adoption of the printing press (Dittmar 2011) etc. This **distance instrument** might not be the best in our case though, as universities were not created in concentric circles around Bologna, Paris, or Oxford. Yet this may be true for each country separately. The exclusion restriction in this case would imply that being close to Oxford affected outcomes only through the creation and/or development of universities. This may hold in countries where university towns did not have any importance beyond hosting a university, which may be true for Oxford or Louvain, but not for a city like Paris.

Beyond the distance instrument, we will investigate the power of an instrument based on the impact of plagues. Jedwad, Johnson, and Koyama (2016) show convincingly that the urban level mortality rate following the Black Death (1347-1352) is exogenous and mattered for subsequent growth, by stimulating urban development in areas which were previously less developed. However, whether the Black Death stimulated university creation in those areas remains to be shown. And here too, it is necessary to think carefully about the exclusion restriction which requires that there be no effect of plagues on development through an unobserved variable. Dittmar and Meisenzahl (2016) use major plague outbreaks as reported by Biraben (1975), who provides quantitative data to characterize the frequency, duration, and variations in incidence of the plague in European history. They assume that (exogenous) plagues affected the quality of institutions, which themselves attracted the UTHC who fostered development later on.

A last instrumentation method that we will implement is catered to our particular problem. The aim is to measure the effect of the size of a group of peers on the output of a particular person, and hence on the society around. To tackle the fact that the location choice of scholars is endogenous, the centrality of birth – that is, the average distance between a scholar's place of birth and the birthplace of his peers – can be used as an instrument. It is more likely that scholars born closer to the birthplace of their peers experienced a greater number of peers during their working life. A scholar's influence must depend on peer group size, and the centrality-of-birth measure impacts the scholar's output only through its impact on the number of peers. This strategy has been used with success by Borowiecki (2013) in his study of the productivity of music composers.

An alternative to instrumentation methods is finding a source of random variation, which modified the allocation of the UTHC without altering other unobserved variables. **The creation of universities itself can be seen in some cases as a natural experiment**. Why there was no university in London until the nineteenth century, and why universities were sometimes founded later in more important cities such as Brussels, Amsterdam, or Stockholm remains a mystery for historians (Rüegg, 1992). Looking in detail into the history of each university will provide valuable information for the identification of the possible sources of exogenous variations. Persecution by the authorities is an important ingredient in the foundation of some universities. This is what happened in Cambridge, with masters and students fleeing Oxford following the execution of a few students on the orders of the mayor and the king (Verger, 1992). The same pattern was repeated in Paris in 1229-31, leading to the creation of universities in Orléans and Angers. The great Schism between the Pope and the Emperor is considered as having played a major role in the creation of universities, and is treated as a natural experiment by Cantoni and Yuchtman (2014). One task in the project is accordingly to examine the history of each university looking for quasi-natural experiments, and to use them as a source of variation in the UTHC.

Beyond the creation of universities, political turmoil and the **persecution of minorities provide opportunities to observe exogenous variations in the allocation of the UTHC**. A convincing (and inspiring) modern example is provided by Waldingen (2010). He shows how the rise of Nazism in pre-World War II Germany led to the dismissal of many Jewish and "politically unreliable" professors in mathematics. Combining a doctoral-student-level data set with data on all German mathematics professors, including their publication and citation records, Waldingen was able to assess how the loss in university quality impacted future student outcomes. Coming back to our time frame, the religious conflicts between Catholics and Protestants also led to significant changes in the European university landscape. Scoville (1953) describes two large waves of emigration: the first resulted from the expulsion of Protestants from the Low Countries in the latter part of the sixteenth century, while the second followed the revocation of the Edict of Nantes in the latter half of the seventeenth century. Scoville is essentially interested in how these migrations led to the diffusion of new techniques (for example in the textile industry), but they certainly also affected universities. For example, the decline of Louvain and the rise of Leiden in the Netherlands might have been witness to a brain drain fleeing the Spanish Low Countries (a quick inspection of the list of their full professors, at http://hoogleraren.leidenuniv.nl/, shows some of this.). A famous example is Justus Lipsius (whom the building of the European Parliament is named after), who fled because of the war. The second wave of migration described by Scoville, the Huguenot diaspora and their migration to Prussia after the revocation of the Edict of Nantes, is a natural experiment used in the literature (Hornung, 2014). Finally, one can also notice that several members of the French academies left after this revocation, while still maintaining written exchanges with their former colleagues (see Pederson (1996)). Our challenge will be to identify migrations between universities and academies. A second challenge will be to separate the effect of the UTHC migration from that related to the migration of skilled craftsmen.

We will also investigate whether it is possible to exploit exogenous variations in the activity of the Inquisition that affected the dynamism and orientation of universities. For Spain, Vidal-Robert (2011) shows that the Inquisition had significant and long-lasting negative effects on local economic development, in particular through the delayed adoption of new technologies (as measured by the number of patents by region). More generally, for many authors, **the Inquisition was an important factor behind the waning of innovation in Southern Europe and the displacement of the center of the Scientific Revolution toward Western and Northern Europe** (Young 2009). The feasibility of such an identification strategy will depend on the availability of data on Inquisition trials in the part of Europe that we intend to cover, and on whether the observed spatial variations can be seen as exogenous. If this is possible, we will have much better, direct measures of outcome variables (publications of each scholar, migration, and fields covered by the university) than those used in the literature.

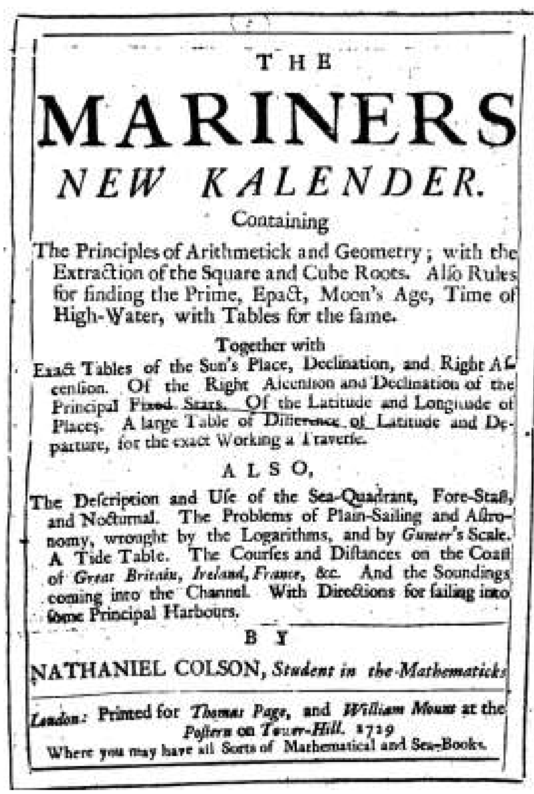
Finally, there is a source of variation often used in the literature, which we will not be able to exploit: the expulsion of Jews and their persecution. Indeed, although they represent a minority with strong human capital, Jews were usually banned from attending and teaching at universities, with the exception of Padua and Leiden (Collins 2013).

The Extent of the Complementarity between Elites and Artisans

Guided by the information gathered while building the database, we will develop two new theoretical frameworks: a growth model of the trickle down of the scientific revolution in which elite knowledge and artisanal techniques are complements; and a model of the competition between tradition and modernity within universities, and its effect on the adoption of enlightened institutions.

Concerning the first mechanism, the economic literature reviewed above usually assumes substitutability between artisans and elites. For example, in de la Croix, Doepke, and Mokyr (2017), apprentices acquire ideas from their masters, but also acquire new ideas exogenously (maybe from contacts with the elite), and they implement the best of the two. New ideas are then diffused by master-apprentice relationships. An example is the invention of the spiral-spring balance in watches in the seventeenth century. No similar macro-invention occurred over the subsequent century, yet the real price of watches fell by an average of 1.3 percent per year between 1685 and 1810 (Kelly and Ó Gráda (2016)), reflecting the slow diffusion of efficiency gains made possible by the new idea.

The literature in the history of science, however, shows that the interface between upper-tail human capital and practical knowledge is more complex than just slowly adopting a new idea obtained randomly for free. More elaborate modelling is required to understand the incentives that underlie a fast adoption and diffusion; **we will accordingly model this interface by considering three layers. The first layer is theoretical knowledge, *sciencia*, mostly developed by intellectuals and generally codified in books. The second layer is codified practical knowledge, often in collections of recipes. The third layer is *ars*, the knowledge of master craftsmen, which is mostly uncodified and acquired through apprenticeship.** As an example of the different layers interacting, consider advances in beer brewing, especially those concerning hygiene and sterilization (from Leong (2017)). The *sciencia* layer corresponds to philosophers and physicians developing realistic views of the human body and ways to preserve health by regulating food and drink. An example for the second layer (codified practical knowledge) is Sir John Tracey's (died 1648) recipe for making ale, including the particular step of boiling water for three hours before adding malt. The inclusion of the boiling step reflects advancing theoretical views about health and water quality. The third practical layer in this example consists of brewers, whose knowledge was mostly tacit, but also influenced by recipe collections, and hence indirectly by science.


THE
MARINERS
NEW KALENDER.
Containing
The Principles of Arithmetick and Geometry; with the Extraction of the Square and Cube Roots. Also Rules for finding the Prime, Epact, Moon's Age, Time of High-Water, with Tables for the same.
Together with
Exact Tables of the Sun's Place, Declination, and Right Ascension. Of the Right Ascension and Declination of the Principal Fixed Stars. Of the Latitude and Longitude of Places. A large Table of Difference of Latitude and Departure, for the exact Working a Traverse.
ALSO,
The Description and Use of the Sea-Quadrant, Fore-Staff, and Nocturnal. The Problems of Plain-Sailing and Astronomy, wrought by the Logarithms, and by *Gunter's* Scale. A Tide Table. The Courses and Distances on the Coast of *Great Britain, Ireland, France, &c.* And the Soundings coming into the Channel. With Directions for sailing into some Principal Harbours.
BY
NATHANIEL COLSON, *Student in the Mathematicks*
London: Printed for *Thomas Page*, and *William Mount* at the *Postern* on *Tower-Hill*. 1729
Where you may have all Sorts of Mathematical and Sea-Books.

To guide modelling, another example of science trickling down to practice is provided by almanacs. Science here is astronomy (from Omodeo (2017) and Kremer (2017)). The practical realms benefitting from astronomy included navigation, agriculture, and time measurement. Early examples of practical codified knowledge influenced by astronomy are the incunable almanacs, which served as working handbooks for everyone working in "trading zones." These trading zones included arsenals, workshops, and large construction sites and places where artisans and learned men met (Long 2011). These almanacs benefitted progressively from the development in science. The "Mariners new Kalender" is a powerful example (see left panel). It was written by a "theoretician," student in mathematics Nathanael Colson, printed in London in 1729, and advertised as necessary for the ingenious mariner. Notice also that Kremer (2017) looks at the most prolific authors of incunable almanacs, and finds 13 professors in the top 20 authors. According to Long (2011), the proliferation of books on technical subjects allowed the skilled to acquired learning, and also the learned to acquired skills. One key question the model will address is **determining the incentives faced by the members of the three layers under which an economy relies on codified knowledge in addition to tacit knowledge, speeding up the diffusion of ideas, or rather sticks to the traditional way of learning through interpersonal contacts**.

Such incentives likely depend on the printing technology, density of population, literacy of the population, and protection of intellectual property. Patents and copyrights did not apply over the period we consider, since intellectual property was not formally protected (the first sign of modern copyright for authors is The Statute of Anne passed by the English Parliament in 1709, see Moore (2013)). **We thus need to consider mechanisms of innovation without monopoly rents**. The following structure will allow for preserving incentives to write and print books. The process of production and reading of applied books involves three distinct stages. First, at some cost, authors (literate craftsmen, upper-tail human capital, and former students) can write a "recipe" with their knowledge, coming either from practice, or from implications of science. Second, "editors and publishers" buy these recipes. They compare many recipes and find the best one among them. This comparison is useful for new knowledge to replace old knowledge over time (technically, if the distribution of knowledge satisfies the maximum stability postulate, the dynamics of knowledge in which the best is retained can be determined analytically). In the third step, publishers produce recipe collections and almanachs in the form of printed books which can then be sold to readers. We assume that the final stage of production involves a very low marginal cost, i.e. increasing the number of book copies is almost free. This implies that books have a public good characteristic, as the use of books by different readers is non-rival. The negligible cost of book production is subject to a caveat: after a book has been first assembled, there is a period during which only a limited number of copies is available. Subsequently, every reader is free to make additional copies of the book. The initial delay in book production is crucial to generate scarcity rents from book production (as in Boldrin and Levine (2008)), which provides incentives to produce books even in an environment without copyright protection.

The theoretical framework developed in the proposed research should allow the three layers of knowledge to interact in more than one way. Essential ingredients include the fact that recipe codification is always inferior to the knowledge acquired by practice as far as acquiring knowledge is concerned. Epstein (2013, p52) notes that "Written manuals were incomplete and sometimes misleading (…) they left out crucial practising tricks." Yet codification remains unmatched as far as sharing knowledge is concerned. Still, the "technology" to write recipes can be subject to improvements over time. For example, one way to make recipes more useful is codifying what not to do (named "the codification of error" by Dupré (2017), with an application to glass making).

Our theory will thus feature two differences between tacit and codified ways of transmitting knowledge. First, the speed of reproduction is different: ideas can spread only to a few people every period through apprenticeship, but they can reach every worker in an economy (after the initial delay) through book production. For example, with our model, one can measure the productivity lost over time by banning printing, what the Ottoman Empire did for 250 years (Rubin (2017)). The second difference is the location of knowledge: whereas, in the case of apprenticeship, knowledge is not codified and resides only in the brains of workers, in the case of books, there is an external storage site for ideas. In that case, the contact time mechanism described above matters most.

The objective of this formal analysis is identifying channels through which economic conditions affect the choice and intensity of the mode of knowledge transmission and the overall rate of technological progress. Having explicit transmission technologies will allow identifying the underlying mechanisms behind some of the reduced-form relationships suggested by data on long-run economic progress. The explicit structure of the model will yield testable implications directly regarding, for example, the relationship between upper-tail human capital, general literacy, book-production rates, and technological progress.

Complementarity between Elites and Enlightened Institutions

Before analyzing the relation between elites and the adoption of enlightened institutions, we should assess why universities were created in the first place. We will start from the idea that the dominance of the nuclear family in Europe created a need early on for organizations that cut across family lines. Universities were such institutions; monasteries, guilds, and independent cities were others. Indeed, in contrast to the rest of the world, the nuclear family came to dominate in Europe. By 1500, extended families or clans had become less visible there, especially in the Western part (Shorter 1975, p. 284). Hence, earlier institutional developments may have made the establishment of universities in Europe much more attractive compared to clan-based societies (see Greif and Tabellini (2012) for a similar argument about corporations in Europe. According to Haskins (1923) and Charle and Verger (2012), universities indeed emerged as corporations of masters and students, *universitas societas magistrorum discipulorumque*). A test of this idea can be performed by matching our database with Todd (1985 and subsequent work) to a measure of family structure. In Todd, each European region falls into three categories: nuclear, stem, and extended family (to simplify). With our data, we can determine whether universities had a higher probability of emerging in a nuclear family region, and, more importantly, whether their professors were more likely to be born in nuclear family regions.

Once universities were in place, they influenced the society around them, including the "Prince" or the oligarchy in charge of the city. To guide modelling, let me first stress that history shows cases in which universities fought against novelty: according to Cantoni (2012), "Ziegler (2008) hypothesises that the German territories with universities had a more conservative attitude towards the Reformation, both because they had advanced further in the creation of a state bureaucracy trained in formal law (which thus had a vested interest in the status quo), and because they were naturally skeptical of the new theological teaching coming from the most recent of all universities, Wittenberg." However, Cantoni did not find any significant effect of universities on the adoption of Protestantism in his regression. A theoretical way to model Ziegler's insight is proposed by Acemoglu (2008). In his model, an oligarchic institution may initially enjoy a high rate of growth, but oligarchies also tend to extract rents and establish barriers to entry. Over time, innovation inevitably moves from one location to the next, so that members of a sitting oligarchy do not remain at the frontier, leading to the prediction that oligarchies will eventually stagnate. Acemoglu's prediction has been tested on a sample of 169 European cities by Stasavage (2013), who finds strong support in favor of the theory.

In other cases, universities and academies favored modernity. When Kepler (1571-1630), a professor at Graz University, advised the Emperor, or when Euler (1707-1783), a member of the Academy in Berlin, taught philosophy and physics to Frederik II's niece, he plead in favor of freedom and enlightenment. On the whole, there was competition within universities between conservative forces (leading to raising barriers to entry) and modernity forces. The influence on society depended critically on which of the two was winning. In some cases, progress was achieved by the emergence of new universities (like Halle and Göttingen, which allowed for the foundation of *Wissenschaft* – the empirical approach to knowledge – in the eighteenth century Holy Roman Empire; see Ashby (1963)). The debate on the merits and drawbacks of universities resembled the one on medieval guilds. Traditionally relegated by an earlier literature to a set of conservative, rent-seeking clubs, a revisionist literature has tried to rehabilitate craft guilds as agents of progress and technological innovation (Epstein (2013)). The same trend can be observed in the literature on the role of universities in the Scientific Revolution (Porter (1996)).

An essential ingredient of our model of universities will be **viewing them as multiproduct firms, producing a variety of goods (new knowledge - fields)**. Each good requires specific human capital (scholars) to be developed and transferred to society. Investing in a new product line (like introducing Newtonian physics) helps the university remain at the frontier, but hurts the vested interests of its scholars, as they will lose their investment in their old field and/or cannot themselves switch to this new field. Unlike the approach of Bénabou, Ticchi, and Vindigni (2015), who model the interaction between science and religion and in which the government may censor innovations, the resistance to change comes from inside universities, which seems more appropriate to us, at least as far as Northern Europe is concerned. A second ingredient of the proposed new model consists in describing the influence of adopting new fields on the society around them. The state of the society will be described by a stock of modernity, which may represent the share in the population of people with an enlightened view of the world (or their share among the Prince's advisors). The last essential ingredient consists in identifying the way a more modern society helps universities more easily expand the variety of products they offer, by adopting new fields of research**.** Describing such a new model of the dynamic interactions between conservative and modern forces within universities and learned societies would enable us **to derive the conditions under which one of the two forces prevailed, and to use the richness of our database to examine where and when it did so.**

Further Dissemination

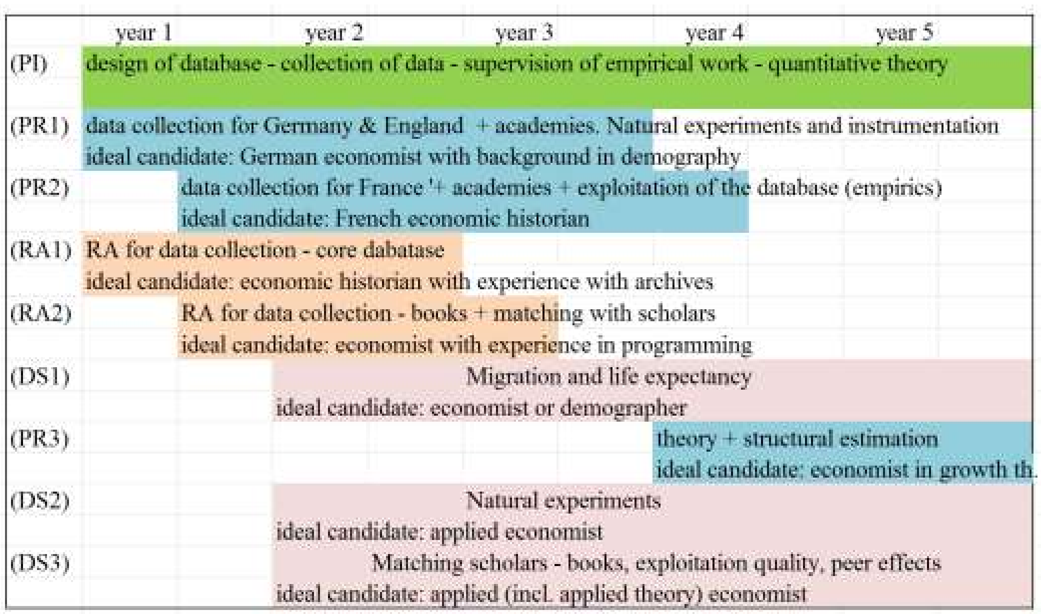
Many more theoretical and empirical issues can benefit from the establishment of the proposed new database. Its main strength lies in linking people to the places where they worked and to the outputs that they produced. The wide coverage of the database allows us to think about the external validity of studies based on more restricted areas or time frames. Once completed, our database will be open for use in a variety of ways by the scientific communities in economics, demography, and prosopography.

The database will be made available online for use by the civil society. Indeed, there is a large interest in many European universities in more systematically recording the history of the university, as attested to by many university websites. Regarding ownership rights, although UCLouvain would keep the ownership of the structure of the database according to the law in force, it remains my academic choice to make it available online for free to other researchers, as well as to a wider audience.

Section c. Resources (Including Project Costs)

The PI will assemble a **research team** composed of 3 postdoctoral researchers, hereafter denoted PR1, PR2, and PR3, and 3 doctoral students, hereafter denoted DS1, DS2, and DS3. The team will therefore consist of:

- David de la Croix is the principal investigator (PI) and leader of the team. He will supervise the work of the post-docs and doctoral students throughout the project, and cooperate with them in implementing its different parts. He will spend 70% of his total working time on the project: 40% will be supported by UCL and 30% by the ERC.
- Two postdoctoral fellows (PR1 and PR2) will each be hired for three years, at the beginning of the project. The post-docs, with the PI, will determine the structure of the database to be built. They will look for university-specific data, and encode the corresponding contents with the help of the assistants. They will carry out the empirical analysis, and with the PI and one doctoral student, they will identify the natural experiments to be exploited. One of these post-docs will ideally know German well, while the other needs to know French. One will be knowledgeable in demographic techniques, to lead the study of life expectancy and migration with the PI. The French speaking post-doc should ideally have been trained in economic history, to help with the collection of data on French universities for which the availability of data is not as good as in the Netherlands, Germany and the United Kingdom.
- PR3 will be hired for two years, in the middle of the project. He/she should have been trained in growth theory and development, and will collaborate with the development of the two new theoretical models described above.
- Three doctoral students (DS1, DS2, and DS3) will each be hired for 4 years, during the first year of the project. DS1 will be either a demographer or an economist, and will work on life expectancy and migration. DS2 will be an empirical economist and will work on the design and implementation of natural experiments. DS3, with a background in economics and economics geography, will focus on matching scholars with their publication, and will study agglomeration externalities and peer effects. All three doctoral students will also collaborate to encode data at the beginning of the project.
- To help with data encoding and management, we will also hire two research assistants (RA1 and RA2) each for two years. One (RA1) should have a master's in economic history, and one (RA2) should be competent in programming, as matching books with people will essentially be a programming issue. Both will be hired from the beginning for the database to reach a critical mass as soon as possible.
- The research team will be assisted by an administrative staff member hired from the beginning of the project and constituted by one person working part-time (15% of a full time) to back the team on aspects such as the organization of the monthly seminar and annual workshop, and the maintenance of the project website. The administrative staff costs are in direct relation with the project. See "Other" in the cost category "Personnel."



The PI will supervise the work of the team and will cooperate with its members in order to overcome any problems related to data collection and analysis. The doctoral students will benefit from the experience of participating in the project, both because they will acquire specific competences in historical, empirical, and theoretical economics, and because the set of interactions offered by the project will be unique. Similarly, the postdoctoral researchers will benefit from the project, not least because they will have the possibility of working with experts in this domain and of being supported and evaluated by them in a positive and informal context.

The research activities of the team will be scheduled in order to approximately fit the timeline shown in the above figure. The direct cost related to the doctoral students and postdoctoral researchers is shown in the Table Cost Category under “Students” and “Postdocs.” The other direct costs are:

Equipment: Each team member will require a laptop computer for personal work (encoding and code development). One powerful computer will be shared in a network between the team members for increased efficiency of use. These laptops and powerful computer will be dedicated to the project.

Consumables: This category covers software and books. We intend to use Access for database management, R (freeware) for data work, and Mathematica for modelling. Book acquisition will include some rare used books on the history of universities and the prosopography of their professors.

Travel: Instead of organizing a large final conference and/or a summer school, we will organize one small workshop per year. The objective of the workshop is to invite people working in the field (J. Voth, S. Becker, J. Mokyr, D. Cantoni etc.) to come to Louvain-la-Neuve and present their work together with the members of our team. This will lead to cross fertilization, and, from the point of view of the doctoral students, it is the best way to get acquainted with the new ideas people develop in this field. Regular seminars will also be organized during the project (once a month). We need 7 intercontinental and 10 intra-European travels per year for these activities. In addition, 8 intercontinental and 34 intra-European travels will be needed per year for the members of the team for data collection and participation in international conferences and workshops. The costs shown in the table cover travel, accommodation, and stays related to participants to the project and invited researchers.

Publications: This includes the costs for the open access fees of high impact journals.

Other: The costs of workshops and seminars beyond travel, accommodation, and stays of invited researchers (in the category “travel”) are included in this category. The cost of the final financial audit is also included here.

Subcontracting: Two thirds of subcontracting will be devoted to the digitalization of archive material by foreign universities. These universities are those for which no book on professors is available, and for which one thus needs some in-depth research. This research implies either going to their archives directly (travel) or getting the key documents digitalized by their archive service (subcontracting). One third is devoted to the creation and maintenance of an interactive database interface (IT services). This interface will bridge our database with our website, which gives external visibility to the activities of the research team, and contains all of the information that will be generated over time.

Cost Category	Costs	Euro
Direct Costs:	Personnel	
	PI	224,000
	Postdocs (3 postdocs each for 3 years)	455,850
	Ph.D. Students (2 for 4 years)	539,993
	Other (2 RAs for 2 years + 15% admin)	292,121
	Total Personnel	1,511,964
	Other Direct Costs:	
	Equipment	37,000
	Consumables	50,000
	Travel	236,000
	Publications	20,000
	Other: workshops and seminars + audit	21,000
	Total Other Direct Costs	364,000
	Total Direct Costs	1,875,964
	25% of Direct Costs	468,991
Subcontract Costs:	(No overheads)	150,000
Total Costs of project:		2,494,955

Project Duration in months	60
% of the PI's total time that will be dedicated to this project	70%
% of the PI's total time that will be spent in the EU/ERA	90%

The other IT services (website maintenance…) will be provided internally by the team.

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