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 achievements of the elite - 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, focused on the manners of the nations. He followed the chronological succession of the dynasties as a guide, not as a purpose. He did not want the reader to be so unfortunate to read a book about in what year a prince unworthy of being known, succeeded a barbarous sovereign. Later on, in the nineteenth century, especially with the rise of socialism, attention shifted towards the achievements of the masses. Today, the weight to give to role of masses versus that of the elite remains actively contested question in both science and in politics (think for example to the successes 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 industrial revolution. One extreme side views innovations as being driven entirely by UTHC – the scientists and mathematicians, who pushed the envelope of propositional knowledge which was then applied in the agricultural and industrial revolutions of the late 18th and 19th centuries. For example, for Mokyr (2002) a small group of a few thousand people were the main actors, who opened the way for the Industrial Revolution. For Jacob (2014), it is the marriage of industrial culture to scientific knowledge and technology, which 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.

The other extreme view sees innovations as being driven entirely by the evolutionary development of artisanal knowledge, which is improved over time through learning by doing and by the diffusion of improvements that were discovered largely by chance. From their perspective formal and codified knowledge played no role in these advances (Epstein, 2013). An even more extreme view is the one proposed by Berg (1982). For him, the connection between science and industrial technology not only hardly ever existed, but science was used to defend industrialization and capitalism against the workers who opposed machinery.

Strategic Objective

This important debate on the weight and significance of UTHC in the generation of the first industrial revolution has so far been very much qualitative based and largely focused on specific places and industries. **There are currently no global quantitative analyses of the question simply because the data are not available at the European level.** The strategic objective of this project is to push 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 Northern and Western Europe from the Middle-Ages through to the Industrial Revolution. This new database will be used to support the development of new empirics and theory, to then validate these advances and to address the outstanding questions identified below.

Endowed with such a tool, it will become possible to address questions, which could not have been addressed before, and **to investigate the role of scholars in opening the path to modern-growth and how they interacted with artisans' knowledge in doing so.** This can be achieved by exploiting the variability of the data along the various dimensions recorded the database to investigate the link between elite knowledge and economic development through geographical, temporal, by field of study and by quality of output. Quality can be measured by matching the new database with the one on published books, and other measures of achievement. Before describing in detail what I intend to do, and how I intend to exploit the variation in the density and quality of UTHC in the database to measure the extent of the correlation and the causality between UTHC and the adoption of new techniques and better institutions, and to highlight some key mechanisms behind this relation, let me describe the current state of the art knowledge in terms of ex-

isting theories and the available data.

A priori, the potential answers to our research question can be of four different types. (1) Elites generated the new scientific knowledge (Science), which, when applied, triggered the industrial revolution. (2) Elite knowledge triggered a major cultural change in the period 1500-1700, which made the population, or at least part of it, ready to invent the modern world. This is the thesis, defended in the recent book by Mokyr (2016), 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, ..."* (3) Elite knowledge was not important for the first industrial revolution, but by educating the population and producing good citizens, it made labor more open to the adoption of the new techniques, which were primarily developed by entrepreneurs. (4) Elite knowledge was just a luxury good, which played no role in the take off to modern industrial growth. I propose to develop a new quantitative approach to determining, which of these alternatives is paramount.

The specific objectives of this project are [1] to develop a **new integrated database** on the elements necessary for the study of the role of upper tail human capital (scholars, universities, academies, books); [2] to conduct empirical analysis of the **weight and significance of UTHC in paving the way towards the first industrial revolution;** [3] to unravel the corresponding **mechanisms** contributing to the take-off to modern growth; [4] to develop a new theory of **the complementarity between elite knowledge and artisanal techniques**, helping us to establish a greater understanding of the key mechanisms behind this complementarity; [5] to model the interaction between conservative and modern forces within institutions, contributing to determine the conditions under which UTHC affects development by promoting a **culture of growth**.

The mechanisms involved

If elites had an impact on development, either directly through technical progress, or indirectly through changing culture and / or educating the population, different mechanisms were involved. The most obvious is through increases 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 show higher outcomes in terms of their economic development, technical progress (such as adoption of the printing press, the steam engine etc.), and in 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 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 UTHC in terms of fields 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 is 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 through the *contact time effect*. In a world where face-to-face communication was essential for both knowledge transmission and enhancement, the length of the productive life of the elite is important to determining the extent of their impact on their cultural and economic environments. A formal link between productivity growth and longevity has been implicitly provided by Lucas (2009). In his model, people pick up ideas from the other people that they meet. The more people they meet, the better and more influential they become. If they live long, they have many more chances to become excellent at what they do and they also give many 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 longevity of the elite before the industrial revolution

(Cummins, 2014, de la Croix and Licandro, 2015, see below).

A last mechanism whereby elites influence development is through both their national and international mobility. Mokyr (2005) measured the mobility of 1185 "creative people" in Europe over the period 1450–1750 and showed that it was large, with 3.72 mean moves per person. Mobility both 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 we will have to deal with is the one of the complementarity between elite human capital and the 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 it views masses as being 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, science) was not taught to the masses. Instead, it interacted in a more subtle way with artisanal knowledge, which was itself being 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 gets better through learning-by-doing. In their model, there is also a pre-industrial R&D sector where only scientists intervene. Their model is useful in its distinction between elite education and mass education, including cases where elite education mostly concerns 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 of the two 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. But the technical and operational knowledge of entrepreneurs helps them to 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 (2016) examine the role of apprenticeship institutions in stimulating economic growth in the pre-industrial era. They have built 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). This makes 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 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 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 analyses 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 was 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) analyses the longevity of European nobility and its link with the 'Rise of the West'. It was based on data collected by the Church of Jesus Christ of Latter-day Saints and has been expanded by several independent genealogists. It therefore extended the existing demographic studies of Europe's aristocracy considerably. All observations (>100k) of birth and death were geo-coded. The empirical challenge was to extract the major time and spatial trends in the nobles' lifespans from the noisy data, while at the same time controlling for the changing selectivity and composition of the sample. The main result of this paper was to show that the areas of North-West Europe, which later witnessed the Industrial Revolution, had achieved greater longevity than the rest of Europe even by 1000 CE, thus suggesting that the `Rise of the West' originates 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 17th 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 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 found that the increase in longevity did not occur only in the leading countries of the 17th-18th century, 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 population than just the nobility, as it includes all the professions that could 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 we do not know whether it was really a random sample drawn from the set of all famous people. Second, we cannot control for the age at which famous people became famous (for some of them, it might even be post mortem).

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

In addition to the "famous people" literature, there is one paper looking quantitatively at the effect of universities on the 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 determined 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 being 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 those 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 emergence of the industrial revolution.**

Section b. Methodology

Let me now describe in more detail the proposed methodology, from the construction of the new database, its subsequent exploitation and 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 existence in Europe rose from around eighty medieval universities to nearly two hundred (Frijhoff, 1996). Limiting the coverage to Northern and Western Europe, this number goes below one hundred. This still highlights the ambition of the project, as we do not know how much time will be needed to gather a significant amount of data on at least half of those universities. The aim will be to achieve a sufficient coverage to enable us to establish significant variability across places, times 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 large.

We propose to limit the coverage of the new database to universities active at some point in the period 1400-1800 and the database will include all professors in these universities born before 1800. Later on, we will 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.

We will start with Northern Europe defined as the space above a line going from Nantes to Cracow. Doing the contrary, starting with Southern Europe, would be a mistake. 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 either very scarce or non-existent. We would then be forced to rely on archives from the beginning, without being sure of being able to gather a sufficient amount of information (see the introduction of Verger 1988). At a later stage of the project, we will integrate Bologna and Padua in the analysis, as their connections with the rest of Europe are clear and of great importance (Cantoni and Yuchtman 2014).

In addition to universities, we will incorporate data for the members of national academies to gain a more complete picture of upper tail human capital. Initiated in Florence, the movement for national academies gained momentum in Northern Europe with the creation of the Académie Française (1635) and the Académie des Sciences (1666), the Royal Society of London (1662), and the Academia Leopoldina (1677). Obtaining information on all the members of these academies since their inception is likely to be an intensive but low risk task as the information in readily available from the web. It will, however, be high gain in terms of the quality of the picture of the scientific elite. 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*** (http://www.leopoldina.org/en/ members/list-of-members/) does not report the vital dates, but we can find them in the ***Deutsche biographie***. (http://www.deutsche-biographie.de/)

For universities, building up a comprehensive list of professors with the relevant supporting information (at least: name, birth, nomination year, field, death or retirement) will not be as easy. We will essentially pro-

ceed in six steps. (a) Establish the list of universities to be prioritized, their activity period, a short history notice, their gps coordinates. In this step, we all also pay attention to their degree of autonomy with respect to religious or political autorities. (b) For each university check whether there is an online historical database of professors. In case of positive answer, import the content of the database. (c) For the universities without such a database, check whether there are books of biographies of their professors. In case of positive answer, encode the content of these books. (d) For the remaining universities, check the existence of *matricula* (persons registered at a given university) and *chartularia* (containing transcriptions of original documents related to the historical events of a university). Build up a sample of professors from the information therein. (e) When the sample built is small, get in touch with the archive department of the university and ask for an inventory of the archives and identify those with potentially names of professors. Ask for digitalization or go personally to the archives. (f) For each professor, check the national biographies and other databases to complete the information needed.

We now detail these steps with some examples. For some universities, such as Groningen University, the list of professors is already established. *Catalogus Professorum Academiae Groninganae* and 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 the 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 have published biographies of them in the 19th or early 20th centuries. This is, for example, the case for the University of Jena (Günther, 1858). Here too is it highly feasible to code the information. For the scholars listed in the book, but still alive in 1858 we can add the relevant information from the Deutsche-biographie. This allows to solve the problem of right censoring (the fact we do not observe everyone until the end of his activity period). This shows the benefit of combining the 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. But books have been written on their history. Here, we will need to build up 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" focuses on universities located on the territory of the Holy Roman Empire from 1250 to 1550. The information is entered into a prosopographic database available at: http://www.rag-online.org/en/database.html. The project "*Studium*" pursues a similar aim for the university of Paris from the XIIth 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 in which nothing has been done to record their professors of the past. All universities know their "prominent" professors, but do not have lists of all their professors. This is apparently the case for the ancestor 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. But, even in such a case, we will still be able to build a large sample of its professors. First, there is a matriculum with the list of all persons involved in the university. The list itself is of little use as the quality of the persons is not recorded (students, professors, etc…), but the list follows the chronological succession of rectors, whose names are indicated. As rectors were nominated every six months, their names give already a good coverage of the universe of professors there (with some selection bias). Moreover, there is an inventory of the available archives. Item # 118 is a list of the nominations of professors to courses (for the period 1557-1773) that we may need to consider in case the previous steps lead to insufficient level of coverage. In any case, the list of names will be matched with other sources (books on history of university, Wikipedia, IBN,

national biography) in order to complete the information about them. On the whole it will be very feasible to obtain a good coverage of Louvain in a few weeks of well focused effort.

Starting with Northern Europe, we will quickly be able to establish a list of 10,000 professors without relying on any in depth additional work (for example, the French academies already include 2300 names, Groningen University has about 400 names in the relevant period, University of Utrecht, also available on the web, has 450, Rostock has 790 names on the web, 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 is achieved, we will then proceed in two directions: [1] completing the database with further work, and [2] enriching the database by matching it with other existing sources. Having reached this key intermediate stage may also require us to make adjustments to the project planning, by enlarging or reducing the space/geographical spread to be covered by 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 the society. Later on, when the needs of the society increased, some universities expanded the realm of their expertise, while others did not and became 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, 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 the 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 into the database and giving special attention to their field of research (those persons hardly had any teaching), is indispensable to capturing the shifts in focus in universities following the humanistic revolution.

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 migration pattern/mobility.

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 (that he called lower-middle class), although some came from the nobility. He mentions a study on French professors in Law over the period 1681-1793, where 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 can identify in our database those professors of noble origin. This can be achieved either from the record itself, or by using biographical dictionaries, and/or matching our database with nobility genealogical data such as the database of Cummins (2014) described above. In the same vein, identifying priests among the professors would be an important way to measure the both reduction in their 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 per capita production of manuscript books, the latter is correlated with the presence of universities, 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 provides the universe of books over a sub-period and 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 in them during this period, when many existing assumptions were being challenged.

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

Correlation analysis

Once the database is established, we will exploit the variation in the composition, density and quality of UTHC across time, space, fields, and the variation in longevity and migration of UTHC to measure the correlation between UTHC and different scientific, economic and social outcomes. The unit of analysis will be that of the city. **A key strength of our analytical approach will be the capability to observe where the scholars have actually worked**, which is not possible when you only know the place of birth and the place of 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. To measure these outcomes, we will utilize existing databases such as, for example: Bairoch, Batou and Chèvre (1988) and Bosker and Buringh (2013) who built a database of city population for almost all the cities in Europe that had reached 5k inhabitants before 1850. City growth is often used as the primary indicator of economic vitality. Dittmar (2011) compiled information from three different sources on the adoption of the printing press during its infancy period (1450-1500). DeLong and Shleifer (1993) built an indicator on whether cities were free or subject to the will of the prince.

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 line suggested by Borowiecki (2013) for music composers, we aim to study whether individual productivity depends on whether other scholars in the same field are located in the same university (or in nearby universities). We can also challenge the external validity of Waldinger (2012) result, who found no evidence of such effects in 20th 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 staying in Germany.

Demographic analysis

First, following Schich et al. (2014), we will apply new methods (in economics), to identify characteristic statistical patterns of the migration of scholars. Taking inspiration from who use the 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 of knowledge centres primacy 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 enters the population at risk (their age at nomination), we will will be able to compute properly the life expectancy of scholars and also measure its standard error. (There are different ways of computing standard errors of life expectancy. One is to assume that the number of death at each age is distributed binomially

(this is called the scheme of Bernoulli trials). This can be implemented applying Monte Carlo simulations to the life table, see Andreev and Shkolnikov (2010)). This seems to be a detail, but it is not. There is a large literature in historical demography computing 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 (say 25) is extremely small, in particular because nomination in these groups comes usually late in life. A shock killing one young person (e.g. the French Revolution) has large impact on the estimated life expectancy, because it may switch some age-specific death rates from 0 to, say, 50%. This emphasises the need to use large population groups for the proper computation of the uncertainty surrounding the estimates. 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 for us to test further the implications of the contact time model (see above) according to which knowledge transmission is eased if people live longer.

Causal inference

In exploiting the new database empirically, we be able to directly address the question of 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 does Pomeranz 2009), 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 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 with 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 adoption of the printing press (Dittmar 2011) etc. This distance instrument might not be the best in our case though, as we do not see universities being created in concentric circles around Bologna or Oxford. But this may be true for each country separately. The exclusion restriction in this case would imply that the fact of being close to Oxford affects outcomes only through the creation and/or development of universities. This may hold in countries, where university towns do not have any importance beyond the fact of hosting a university, which may be true for towns like Oxford, but not for cities 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. It remains to be shown however, that the Black Death stimulated university creation in those areas. And here too we need to think carefully about the exclusion restriction which requires that there is 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 the (exogenous) plagues affect the quality of institutions which themselves attract UTHC who foster development later on.

A last instrumentation method that we will implement consists in the following. To tackle the fact that the location choice of scholars is endogenous too, 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. 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 to find a source of random variation, which modified the allocation of UTHC without altering other important 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, Stockholm remains a mystery for the historians (Rüegg, 1992). Looking in details 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 of foundation of some new universities. This is what happened in Cambridge, with masters and students fleeing from Oxford following the execution of a few students upon the order of the mayor and the king (Verger, 1992). The same pattern 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). Finally, competition between universities might have been important as well; e.g. Rinteln (1619-1810) lost its importance once Göttingen was founded in 1734. 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 UTHC.

Beyond the creation of universities, political turmoil and the persecution of minorities provide opportunities to observe exogenous variations in the allocation of UTHC. A convincing (and inspiring) modern example is provided by Waldingen (2010). He has shown how the rise of Nazism in pre-WWII Germany led to the dismissal of many Jewish and "politically unreliable" professors in Mathematics. Combining PhD 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 emigrations: the first resulted from the expulsion of Protestants from the Low Countries in the latter part of the sixteenth century, and 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 be the witness of 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 it.). A famous example is Justus Lipsius (who gave his name to the building of the European Parliament) 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 (but where still allowed to maintain 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 the one 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 universities dynamism and orientation. For Spain, Vidal-Robert (2011) has shown 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 regions). 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. But if we can, we would have much better and direct measures of outcome variables (publications of each scholar, migration, fields covered by university) than has been used in the literature.

Finally, there is a source of variation often used in the literature, which we will not be able to exploit. It is the expulsions of and the persecutions against the Jews. Indeed, despite the fact that they represent of 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

In parallel to this work, we will develop **a new theory of the complementarity between elite knowledge and artisanal techniques, in order to identify some of the key mechanisms behind this complementarity**. We will then do the same for the complementarity between elites and the adoption of enlightened institutions.

Concerning the first mechanism, the literature reviewed above usually assumes a sort of substitutability between artisans and elites. For example, in my recent paper with Doepke and Mokyr, we assume that apprentices acquire ideas from their masters, but also acquire exogenously new ideas (may be from contacts with elite), and that they then implement the best of the two. The powerful example of the British watch industry in the eighteenth century shows that this complementarity is much more subtle. "Watchmaking was a high-level skill, originally regulated by a guild but by 1700 more or less free of guild restrictions. Training occurred exclusively through master-apprentice relations. In the seventeenth century, the industry experienced a major technological shock by the invention of the spiral-spring balance in watches by two of the best minds of the seventeenth century, Christiaan Huygens and Robert Hooke (ca. 1675). No similar macro-invention occurred over the subsequent century, yet the real price of watches fell by an average of 1.3 percent a year between 1685 and 1810 (Kelly and Ó Gráda 2016)." (de la Croix, Doepke and Mokyr, 2016). As Kelly and Ó Gráda note, *"Once this conceptual breakthrough occurred, England's extensive tradition of metal working and the relative absence of restrictions on hiring apprentices, along with an extensive market of affluent consumers, allowed its watch industry to expand rapidly"*(p. 5). **To understand the various complementarities between the dissemination of the creation of knowledge, we need to start from a model of person-to-person exchanges of ideas.** We will accordingly extend the Lucas and Moll (2014) model to allow for two types of knowledge, with their own specificities. Artisans' knowledge has immediate consequences on productivity, but is subject to a ceiling: one can improve horses equipment as much as possible, it will never make the horse fly. In contrast, while scientific knowledge has little impact in the short-run it is able to push the ceiling far further in the long-run.

Our key contribution will be **to develop a new model of the "encounter" of artisanal and scientific knowledge (like spiral-spring balance meets watchmakers), and its implications for the consecutive dynamics of technical progress.** In order to model the outcome of the "encounter" in terms of higher productivity, we will need to consider different alternative formulations based on production theory, matching models, or unconventional production function, such as the o-ring, and analyze whether their implications are relevant with respect to the history of science in general and some examples such as the one on watchmakers in particular. Our chosen formulation will have consequences for the design of an efficient allocation of talents and resources between the two activities. Actual institutions will be more or less close to the efficient point, depending on characteristics to be identified.

The last step will be to match the model with data, combining information from our newly build database with available micro data, such as the ones on the prices of watches in England. One interest in using structural models is to create the capability to generate predictions from counterfactual experiments and "what if" scenarii.

This approach is related to the modeling of technological progress in unified growth models such as Galor and Weil (2000), and more generally to models of productivity growth over the very long run such as Kremer (1993) and Jones (2001). In these papers, productivity growth is partly shaped through aggregate externalities that relate the size and/or growth rate of the population to productivity growth. In contrast, we will use a new explicit model of the person-to-person exchange of ideas, with two types of persons; population density of both types is once again important because it partly determines what knowledge can be acquired. In a sense, we will open the black box of population driven technical progress by making knowledge diffusion explicit.

Complementarity between Elites and Enlightened Institutions

Before analyzing the complementarity 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 one of these, 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 in Europe, and 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 – universities indeed emerged as corporations of masters and students). A test of this model 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 in three categories: nuclear, stem family, extended family (to make it simple). With our data, we can determine whether universities have a higher probability to emerge in a nuclear family region, and, more importantly, whether their professors are more likely to be born in nuclear family regions.

Once universities are in place, they influence the society around them, including the "Prince" or the oligarchy in charge of the city. History shows cases where 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 university 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), professor at Graz University, advises the Emperor, or when Euler (1707-1783), member of the Academy in Berlin, teaches philosophy and physics to the exquisite princess of Anhalt-Dessau, the niece of de Frederik II, he pleads in favor of freedom and enlightenments. On the whole, there is competition within universities between conservative forces (leading to raising barrier to entry) and modernity forces. The influence on the society depends critically on which of the two is winning. The debate on the merits and drawbacks of universities resembles the one on medieval guilds. Traditionally relegated by an earlier literature to be a set of conservative, rent-seeking clubs (see the review by Ogilvie 2016), a revisionist literature has tried to rehabilitate craft guilds as agents of progress and technological innovation (Epstein 2013). We observe the same trend in the literature on the role of universities in the Scientific Revolution (Porter 1996).

A first ingredient of the new model will be **to view universities as multiproduct firms, producing a variety of goods (new knowledge - fields)**. Each good requires specific human capital (scholars) to be developed and transferred to the society. Investing in a new product line (like introducing Newtonian physics) helps the university to remain at the frontier, but hurts the vested interest of its scholars, as they would 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 would come from inside the universities, which seems more appropriate to us, at least 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 having the enlightened view of the world (or the share among the Prince advisors).

The last essential ingredient consists of identifying the way a more modern society helps universities to expand more easily 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.** Moreover, using the city level information described above, we will be able **to gain insights about the indirect effect scholarly elites may have had on economic development, through affecting culture**.

Further dissemination

Many more theoretical and empirical issues can benefit from the establishment of the proposed new database. Its main strength relies in linking people to places where they worked and to the outputs that they produced. The wide coverage of database will allow us to think about the external validity of many 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. It can be matched with other databases to deliver new insights.

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

Section c. Resources (including project costs)

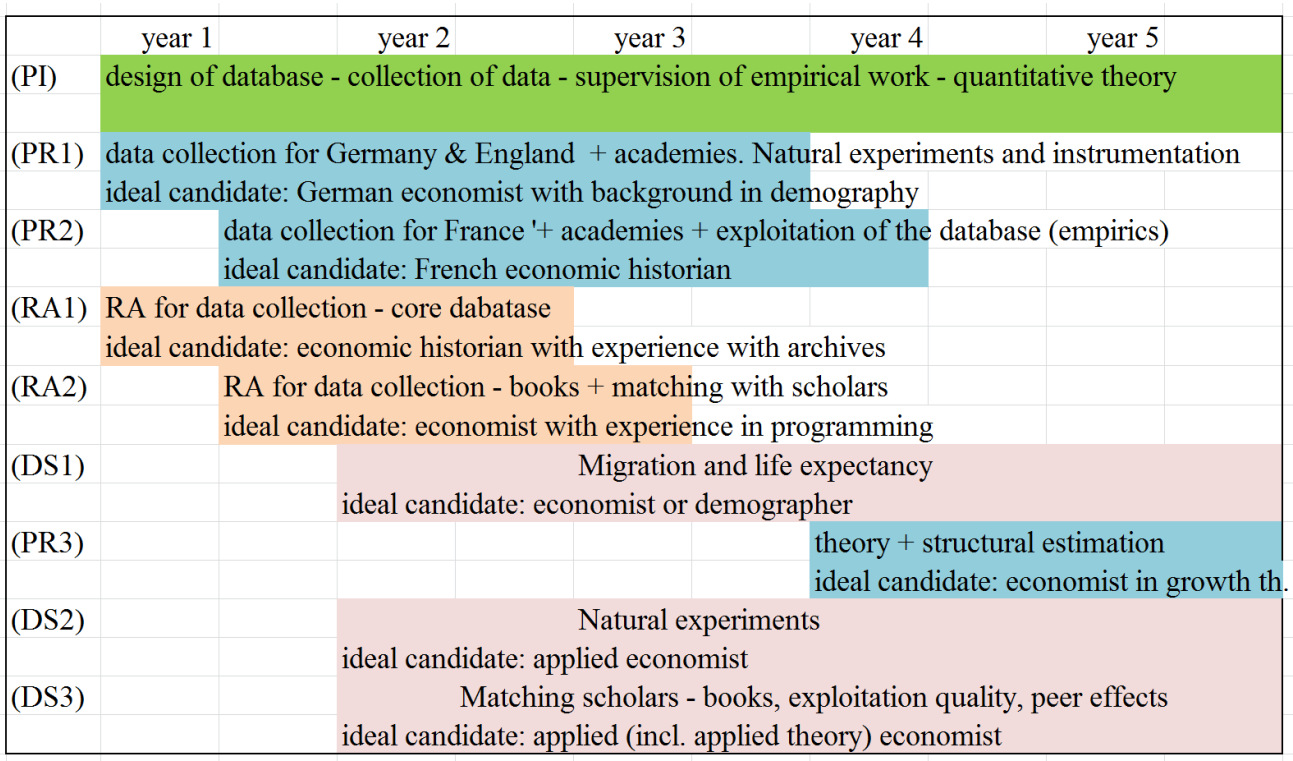
The PI will assemble a **research team** constituted by 3 postdoctoral researchers, hereafter denoted as PR1, PR2, and PR3 and 3 doctoral students, hereafter denoted as DS1, DS2, and DS3. The team will therefore consist of:

- David de la Croix is the principal investigator (PI) and leader of the team. He will supervise the work of the postdocs and doctoral students throughout the project, and cooperate with them in implementing the different parts of the project. He will spend 65% of his total working time on the project: 35% will be supported by UCL and 30% by the ERC project.
- Two postdoctoral fellows (PR1 and PR2) will each be hired for three years, at the beginning of the project. The post-docs will determine with the PI 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 on the empirical analysis, and design with the PI and one doctoral student the natural experiments to be carried. One of these post-docs will ideally know German very well, while the other needs to know French. One will be knowledgeable in demographic techniques, to lead with the PI the study of life expectancy and migration. 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 and the United Kingdom.
- PR3 will be hired for two years, in the middle of the project. This person should have been trained in growth theory and development, and will collaborate with the development of the two new theoretical models described above, as well as to the structural estimation of them.
- Three doctoral students (DS1, DS2 and DS3) will each be hired 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 the agglomeration externalities and peer effects. All three doctoral students will also collaborate to encode data at the beginning of the project.

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 greatly 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, also the postdoctoral researchers will benefit from participating in the project, not least because they will have the possibilities to work together with experts in this domain and being supported and evaluated by them in a positive and informal context. The direct cost related to the doctoral students and postdoctoral researchers is shown in the table Cost Category under "Students" and "Postdocs".

- To help with data encoding and management, we will also hire two research assistants (RA1 and RA2) each one for two years. One (RA1) should have a masters in economic history, and one (RA2) should be competent in programming, as matching books with persons will be essentially 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 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 website of the project. The administrative staff costs are in direct relation with the project. This is in accordance with the Université catholique de Louvain usual management and accounting practice. See "Other" in the cost category "Personnel".



The research activities of the team will be scheduled in order to fit approximately the timeline shown in the above figure.

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. This is in accordance with the UCL usual accountancy practices.

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 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, G. Clark, D. Cantoni, J. van Zanden 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 to the new ideas people develop in this field. Regular seminars will also be organised during the project (once a month). The organisation of these activities will not be subcontracted. 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 to international conferences and workshops. The costs shown in the table cover travel, accommodation, and stay related to members of the unit and invited researchers (workshop participants and seminars).

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 stay of invited researchers (in the category "travel") are included in this category. The cost of the final financial audit is also included in this category.

Subcontracting: Two thirds of subcontracting will be devoted to the digitalization of key archive material by foreign universities. These universities are those for which no historical information on their professors is available, and for which one thus need some in depth research. This research implies either going in 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 give external visibility to the activities of the research team and contain the whole information that will be generated over time. The other IT services (repository server, website maintenance…) will be provided internally by the team.

Cost Category	Costs	Euro
Direct Costs:	Personnel	
	PI	200,000
	Post docs (3 postdocs each for 3 years)	455,850
	PhD Students (2 for 4 years)	539,993
	Other (2 RAs for 2 years + 15% admin)	292,121
	Total Personnel	1,487,943
	Other Direct Costs:	
	Equipment	37,000
	Consumables	50,000
	Travel	260,000
	Publications	20,000
	Other: workshops and seminars + audit	21,000
	Total Other Direct Costs	388,000
	Total Direct Costs	1,875,964
	25% of Direct Costs	468,991
Indirect Costs	(No overheads)	150,000
Subcontract Costs:		2,494,955
Total Costs of project:		2,494,955
Requested Grant		

Project Duration in months	60
The % of the PI's total time that will be dedicated to this project	65%
The % of the PI's total time that will be spent in the EU/ERA	90%

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