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THE CLIOMETRICS OF ACADEMIC CHAIRS. SCIENTIFIC KNOWLEDGE AND ECONOMIC GROWTH: THE EVIDENCE ACROSS THE ITALIAN REGIONS 1900-1959

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THE CLIOMETRICS OF ACADEMIC CHAIRS. SCIENTIFIC KNOWLEDGE AND ECONOMIC GROWTH: THE EVIDENCE ACROSS THE ITALIAN REGIONS 1900-1959[1]

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ABSTRACT. The analysis of the evolution of the academic chairs of an academic system is a promising area of investigation. The exploration of the evolution of the size and the disciplinary composition of the stock of academic chairs in Italy in the years 1900-1959 provides an opportunity to understand the contribution of scientific knowledge to economic growth. The basic assumption is that knowledge is not a homogeneous activity, but rather a bundle of highly differentiated disciplines that have different characteristics both in terms of generation and exploitation that bear a differentiated impact on economic growth. Advances in scientific knowledge are likely to have a direct, positive effect on economic growth according to their fungibility, appropriability and complementarity with other sources of technological knowledge and hence exploitation conditions. Advances in scientific knowledge that can be converted into technological knowledge with high levels of fungibility, appropriability and complementarity have a higher chance to affect economic growth. The econometric analysis confirms that advances in engineering and chemistry, as proxied by the number of chairs, had much a stronger effect on economic growth than in other scientific fields. These results have important implications for research policy as they highlight the differences in the economic effects of academic disciplines.

KEY WORDS: ACADEMIC CHAIRS, TYPES OF KNOWLEDGE, KNOWLEDGE FUNGIBILITY, KNOWLEDGE EXPLOITATION, KNOWLEDGE EXTERNALITIES OF KNOWLEDGE TYPES.

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1. INTRODUCTION

There is a large consensus that scientific knowledge contributes economic growth. Advances in scientific knowledge make available to the economic system new ideas that can be applied to the production of economic goods. The application of scientific knowledge to economic activity leads to the introduction of technological and organizational innovations that consist in new products, new processes, new intermediary inputs, new business methods and new markets.

Not all the advances of scientific knowledge can be easily converted into technological knowledge and eventually in innovations. The application of advances in scientific knowledge to economic activities requires dedicated activities that in turn require a specific set of complementary conditions. Some advances in scientific knowledge can be better implemented, so as to feed the introduction of innovations, than others.

This paper investigates the relationships between the advances of scientific knowledge and economic growth in Italy in the period 1900-1959 exploring the evolution of chairs in the Italian academic system. The analysis of the evolution of the academic chairs of an academic system is a promising area of investigation. The exploration of the evolution of the size and the disciplinary composition of the academic chairs in Italy in the years 1900-1959 provides an opportunity to understand the contribution of scientific knowledge to economic growth. The basic assumption is that academic chairs be a reliable indicator of the build up of scientific knowledge.

The analysis of their changing disciplinary mix provides a unique opportunity to assess whether all kinds of scientific knowledge are equally useful to support economic growth and enables the identification of the disciplines that are more likely to support the introduction of innovations and hence eventually economic growth. The analysis of the stock of academic chairs provides the opportunity to test the hypothesis that knowledge is not a homogeneous activity, but rather a bundle of highly differentiated disciplines that have a differentiated impact on economic growth.

The paper articulates and tests the hypothesis that advances in scientific knowledge provide the system with important knowledge externalities that vary according to the characteristics of knowledge. Knowledge is intrinsically heterogeneous and its different components have a differentiated impact of economic growth. Only when their fungibility with the recombination process that is at the origins of technological knowledge within firms is high and their exploitation conditions in terms of appropriability and cumulability are positive they can be actually used for economic purposes.

The rest of the paper is structured as it follows. Section 2 elaborates with the tools of the economics of knowledge the main hypothesis that the intrinsic heterogeneity of knowledge and the different exploitation conditions of scientific advances play a crucial role for their actual conversion into technological knowledge and hence in technological innovations. Section 3 presents the empirical evidence based upon the construction of an original database of all the chairs in service in the Italian economic system in the years 1900-1959, distinguished by scientific fields and the main regions. This section illustrates the empirical evidence on the evolution of the Italian academic system based on the distribution of chairs in the main Italian regions in the context of the historic and institutional changes that paralleled the economic exploitation of some specific scientific disciplines rather than others in the first part of the XX century. To do so it relies also on the results of the analysis of the available entries of the Biographical Dictionary of Italian Entrepreneurs (BDIE), with a special regard to the sources of technological knowledge that had been at the origin of the key technological innovations introduced in such a time period.

Section 4 presents the results of the different econometric tests aimed at identifying the differentiated economic effects spilling from the different scientific fields. The conclusions summarize the main results, stress the methodological novelties of the analysis and highlight the implications for research policy.

2. TYPES OF KNOWLEDGE AND ECONOMIC GROWTH

Economic history has provided large evidence on the role of scientific knowledge in economic growth and has highlighted the complexity of the relationships between scientific advances, their actual transformation into technological knowledge and the final utilization to support the introduction of technological innovations. Economic history has also shown that different technologies played a central role at different times and in different locations. Not all scientific advances have been alike at all times, from the viewpoint of their effects on economic growth (Mokyr, 1990, 2002, 2003).

The contribution of scientific and technological knowledge to economic growth cannot be analyzed in isolation. Since the first pathbreaking studies on economic growth of Moses Abramovitz it is clear that the role of the specific conditions into which knowledge is generated and used can be appreciated only when the institutional conditions into which they are embedded is fully recognized and the key elements of knowledge as an economic activity are identified and qualified. Because knowledge exhibits elements of sheer complexity, from an economic viewpoint, a major effort is necessary to grasp the conditions that make actually possible not only its generation but also its effective exploitation and use for economic purposes (Abramovitz, 1956 and 1989).

The economics of knowledge has made important progress in the recent years and has provided new tools to understand knowledge as an economic activity enabling to grasp the incentives to the generation and use of knowledge. As it is well known since the arrovian path-breaking analysis, knowledge is characterized by intrinsic non-appropriability and information asymmetries that reduces the incentives to its generation and limit the possibility for transactions in the market place and the provision of finance with the well-known consequences in terms of undersupply. The public support to the academic system, together with others tools such as public subsidies to firms performing R&D activities, public procurement and intellectual property rights, are seen as tools that should possibly contrast the lack of incentives and provide a remedy (Nelson, 1959; Arrow, 1962, 1969).

In this analytical frame the economics of university becomes an interesting field of investigation. It is in fact important to see whether the provision of public subsidies to the academic system is actually an effective tool to contrast the undersupply of knowledge. In the arrovian tradition of analysis universities receive public subsidies from the business sector, channeled by the state, to create incentives to talented people to specialize in the generation and publication of knowledge products. Academic chairs are the incentive to specialize in the generation and publication of knowledge. Scholars are willing to disseminate their knowledge by means of publications in order to get a chair. This elegant system design is functional as long as the loss of revenue by the business sector, in terms of levies paid to the state, is compensated by the amount of knowledge made available by means of publications and dissemination of human capital, including doctors able to support the dissemination and use of scientific advances by the business sector. Firms can access the advances of scientific knowledge made possible by the incentive mechanism called ‘university’ and use them to introduce innovations (Geuna, 1999; Geuna Salter Steinmueller, 2003.)

The university becomes a triangular mechanism that integrates and in extreme cases substitutes the missing markets for knowledge. The mechanism can work as long as the basic functions of the market place in terms of selection of less efficient producers and allocation of activities across producers is efficiently mimicked. The incentive mechanism is functional as long as two conditions are fulfilled. First, the academic system is able to transform efficiently the resources transferred by the state into advances of scientific knowledge. The academic system in other words is able to repeal any degeneration that might reduce the pressure to use efficiently the resources made available by the taxpayer. Second, and most important, the bundle of knowledge activities that are performed by the academic system matches the needs of the business sector. As soon as we realize that knowledge can no longer be regarded as a homogeneous activity, but rather as a bundle of differentiated types of knowledge activities and specific knowledge items with highly idiosyncratic and peculiar characteristics, the problem of the matching becomes relevant (Antonelli, 1999, 2005, 2008).

The analysis of the exploitation conditions of scientific knowledge is crucial to grasp the problem of the matching between types of scientific knowledge and needs of the business sector in terms of inputs into the generation of technological knowledge. Next to the generation of knowledge, in fact, there is the relevant issue of its fungibility and appropriability as conditioning factors that qualify, and often limit its possible economic exploitation.

The analysis of the relationship between knowledge generation and knowledge exploitation enables to explore in a novel way the field of analysis often referred to as the relationship between scientific and technological knowledge. Technological knowledge can be considered as scientific knowledge exploited for economic purposes. Scientific and technological knowledge can coincide from the content viewpoint, and actually the former can even anticipate the latter. The distinction is based on the purpose for which the knowledge has been generated. New knowledge generated for economic purposes, and as such technological knowledge, can become or feed scientific advances when its generalization is generated for the sake of scientific progress. Viceversa, new scientific knowledge can become technological after appropriate efforts of specification and application are made for the purpose of making a profit (Dasgupta and David, 1987, 1994; David, 1993).

The generation of technological knowledge often differs from the generation of scientific knowledge as the latter relies more systematically on deductive processes while the former is often the result of inductive processes. Yet both kinds of knowledge are interchangeable from the content viewpoint provided they consist of general laws that apply to a variety of different contexts and are validated by rigorous scrutiny. The exploitation conditions of scientific knowledge become central to assess its possible economic impact. In order for scientific knowledge to feed the actual generation of new technological knowledge and hence affect economic growth, the conditions of its fungibility, appropriability and exploitability play a crucial role (Von Tunzelman, 2000).

Scientific knowledge cannot be directly used as such for economic purposes: it requires dedicated efforts to obtain specific applications that yield an actual transformation. Technological knowledge consists in the application of scientific knowledge to economic purposes. The transformation of scientific knowledge into technological knowledge requires dedicated resources and entails costs. Profit-seeking agents are willing to bear the costs of the transformation of scientific knowledge into technological knowledge only if and when its exploitation conditions are viable (Mansfield, 1991, 1995; Mansfield and Lee, 1996).

The transformation of scientific knowledge into technological knowledge is all the more difficult when the locus of generation differs from the locus of application. Scientific knowledge generated within R&D laboratories of a corporation can be transformed into technological knowledge more directly. As a matter of fact technological knowledge generated for economic purposes reveals scientific contents as it consists of general laws that are valid also in other contexts different from the original ones. The transformation of scientific knowledge into technological knowledge useful for economic purposes is more complicated when the latter is generated for the sake of scientific advances in academia. A crucial issue of communication and interaction emerges. The costs of the resources that are necessary to transform the new scientific knowledge into technological one are subject to scrutiny and attentive examination by firms. As a consequence not all knowledge generated for the sake of scientific progress, spilling in the atmosphere, is actually perceived, appreciated and actually transformed by firms into technological knowledge. The notion of absorption costs plays once more a crucial role and acts as a strategic interface that must be taken into account when considering the possible effects of scientific knowledge upon economic progress (Cohen and Levinthal, 1989 and 1990; Von Tunzelman, 2000).

The generation of knowledge within firms is based upon recombination processes that are able to combine internal sources of knowledge with external ones, as well as codified knowledge with tacit competence acquired by means of learning processes. The acquisition of external knowledge from other firms entails absorption costs. The access and use of scientific knowledge generated by universities entails exploitation costs. Scientific knowledge engenders actual pecuniary knowledge externalities only when it is characterized by high levels of fungibility and its exploitation is viable. Knowledge externalities consist in the access to knowledge sources at costs that are below equilibrium levels: as such knowledge externalities are pecuniary rather than pure (Antonelli, 2006; Antonelli and Fassio, 2012).

When advances of scientific knowledge are characterized by low levels of fungibility with the recombination processes internal to firms and exhibit poor conditions for economic exploitation, and the economic incentives to perform the necessary transformation into technological knowledge are low, their economic effects are small. A major invention can have poor economic effects if its fungibility is low and the conditions for its economic exploitation are not satisfactory. A minor invention can have major economic effects if it is characterized by high levels of fungibility and good exploitation conditions. When these two conditions apply the incentives for its transformation into technological knowledge by profit-seeking agents are large. A divergence emerges here between the intrinsic value (user value) of a scientific progress and its economic value (exchange value) (Meisenzahl and Mokyr, 2012).

The detailed analysis of the characteristics of knowledge as an economic activity enables to articulate a fine-grained exploration of the conditions that are necessary for advances in scientific knowledge to actually have a positive effect on economic growth via their contribution to the generation of technological knowledge. The bottom-line exploitation of scientific knowledge depends upon its levels of fungibility, stickiness, cumulability, appropriability and patentability, complementarity with competence based upon learning processes (Antonelli, 2006, Stephan, 1999 and 2011).

The fungibility of scientific knowledge to economic purposes and its exploitability play a central role in affecting the likelihood of its transformation into technological knowledge, and vary significantly across academic disciplines. A first clue about the differentiated role of the scientific disciplines is provided by the BDIE (Biographical Dictionary of Italian Entrepreneurs), a multivolume work launched in 2001 by Enciclopedia Italiana and coordinated by members of the Economic History Institute at Bocconi University (Amatori, 2011). The volume provides a detailed analysis of the sources of technological knowledge that enabled the introduction of the key innovations in the first part of the XX century in Italy[2]. Next to detailed economic information for each innovative company and its innovative founder, the evidence collected for each case study includes important elements to assess the sources of technological knowledge that made possible the introduction of the key innovation

[2] The project was intended to carry entries for about a thousand entrepreneurs who were active from the middle of the nineteenth century to the beginning of the new millennium, but for budgetary reasons it was suspended to the letter N. However, using also other sources of information it has been possible to have a quite comprehensive picture of the most relevant technological innovations that have characterized the Italian economic growth in the first part of the XX century.

considered. The case study evidence provided by the BDIE allows to appreciating the centrality of engineering and chemical sciences. A large majority of the key innovations relied upon advances in scientific knowledge generated in engineering.

The reason for the importance of these two types of disciplines lies precisely in the clear benefits that entrepreneurs could gain from the access to the fungible scientific discoveries generated by the academic system. Such advances in scientific knowledge allowed the implementation of a wide array of basic technologies including automobiles and engines at large, helicopters, machinery of various kinds, electrical power. Chemistry also played a major role supporting the introduction of major innovations in the emerging rubber industry and in the dying processes that were central for the textile industry and the fashion industries at large. Such scientific advances were characterized by a large scope of application, high levels of complementarity with other sources of technological knowledge, including tacit knowledge embedded in organizations, high levels of consequent stickiness that increased considerably natural and institutional appropriability also because of high levels of patentability.

It is hence clear that since different scientific disciplines have different levels of such knowledge characteristics, also the incentives for their transformation into technological knowledge will differ substantially. Table (1) provides a tentative match between the general features of knowledge and their declination in each single disciplinary field. Engineering and chemistry rank very high in terms of all the conditions for knowledge exploitation. Knowledge fungibility plays a central role as it defines the scope of application of scientific knowledge to economic purposes. Firms have clear and strong incentives to bear the costs of the transformation of new scientific knowledge into technological knowledge so as to introduce innovations when the levels of knowledge appropriability based upon relevant knowledge stickiness and intrinsic complementarity between abstract and codified knowledge and tacit knowledge in its application to economic activities are high. Learning by doing and learning by using provide solid ground for the application of scientific knowledge to economic purposes. Technological knowledge in chemistry and engineering can be easily patented with further positive effects in terms of actual appropriability. Finally technological knowledge in engineering and chemistry exhibits high levels of intrinsic cumulability of the new flows of knowledge into the stock of knowledge of each economic agent.

Scientific advances in engineering and chemistry exhibit high levels of fungibility, stickiness, patentability and hence appropriability, as well as high levels of cumulability and complementarity with internal other sources of knowledge, hence are characterized by high levels of exploitation conditions and as such are likely to be swiftly transformed into technological knowledge and eventually into innovations that increase economic growth. Scientific advances in humanities, social sciences and other natural sciences (mathematics, physics, early biology and medicine), especially in the first part of the XX century had much lower levels of fungibility, appropriability and potential complementarity with other sources of technological knowledge, hence much lower chances to be easily converted into technological knowledge and hence innovations.

According to these general features of knowledge, it becomes clear that, for what concerns the years 1900-1959, small scientific advances in engineering and chemistry were likely to have major and clear effects on economic growth. Major breakthroughs in other scientific disciplines instead were more likely to have little or no impact on economic growth. In these disciplines the working of the mechanism design implemented by the academic system made possible, at the societal level, the generation of scientific knowledge that the market system could not support. The functional role of the academic system has been fulfilled with positive effects that go beyond economics. From a strict economic viewpoint however it is clear that the support of these academic activities could not be advocated in economic terms (Lawton Smith, 2006).

The general features of the different types of knowledge allow to understanding the likelihood of the exploitation of each disciplinary field by economic agents.

TABLE 1. THE CONDITIONS FOR THE ECONOMIC EXPLOITATION OF KNOWLEDGE ACROSS ACADEMIC DISCIPLINES IN ITALY IN THE YEARS 1900-1959.

CONDITIONS FOR KNOWLEDGE EXPLOITATION	ENGINEERING, CHEMISTRY AND OTHER APPLIED SCIENCES (AS)	HUMAN SCIENCES (HU)	SOCIAL SCIENCES (SS)	NATURAL SCIENCES (NS) MATHEMATICS (MATH) AND MEDICAL SCIENCES (MS)
STICKINESS	HIGH	LOW	LOW	MEDIUM
APPROPRIABILITY	HIGH	LOW	MEDIUM	MEDIUM
PATENTABILITY	HIGH	LOW	LOW	LOW
FUNGIBILITY	HIGH	LOW	MEDIUM	LOW
CUMULABILITY	HIGH	MEDIUM	MEDIUM	HIGH
IMPLEMENTABILITY WITH LEARNING	HIGH	LOW	LOW	LOW

Building upon these premises we can spell out our hypothesis and elaborate our research strategy. Advances in scientific fields that are qualified by exploitation conditions qualified by high levels of fungibility, appropriability, patentability, stickiness, cumulability and complementarity with learning processes are likely to be applied to economic activities and hence transformed in technological knowledge that supports the introduction of innovations. In Italy, in the period 1900-1959, exploitation conditions appeared to be very high in engineering and chemistry and quite low in humanities, social sciences and other natural sciences. We expect that scientific advances in engineering and chemistry could yield major effects on economic growth. This is not the case for the other academic disciplines where the transformation of scientific advances into technological changes was contrasted by lower exploitation conditions. The economic and historic analysis of the relations between scientific knowledge and economic growth requires more and more to go beyond aggregate indicators of scientific activity at large and to investigate the composition of the disciplinary fields of activity and their specific effects on economic growth (Meisenzahl, Mokyr, 2012).

In order to measure the scientific advances of the different academic disciplines we have selected the new and promising field of empirical investigation provided by the cliometrics of academic chairs. We have built an original data set collecting the chairs by discipline opened in each Italian university in the years 1900-1959. We have subsequently aggregated the chairs in five macro-fields.

We assume that the creation of an academic chair meets the basic requirements of internal efficiency. We assume in other words that professors have been selected according to their scientific skills, talent and creativity. Next we assume that the allocation of chairs reflects the correct appreciation of the scientific needs in terms of knowledge indivisibility. Finally we assume that the allocation of chairs across disciplines meets the demand for human capital expressed by the social and economic system. Building upon these assumptions we can claim that the stock of academic chairs is a relevant unit of analysis to assess the effects of scientific knowledge upon economic growth. Academic chairs can become a relevant indicator that, as much as patents or R&D expenditures can be used to investigate the relationship between technological knowledge and economic growth, yet providing additional and reliable information on the types of scientific knowledge at work (Adams, 1990).

The number of academic chairs in a system, their evolution through time and their changing distribution across disciplines is a fundamental characteristic of a national innovation system. Chairs are a relevant unit of analysis because they represent an original measure of the kind of scientific activity going on in a system. Their number can be considered a reliable measure of the amount of knowledge externalities that spill in an innovation system. Knowledge externalities spilling from academic chairs are transferred to the economic system with a variety of means including the number of students, both graduate and undergraduate, their publications and their personal and professional interactions with the rest of the system. The inclusion of academic chairs in the list of institutional factors that qualify an innovation system with the possibility to implement cross-sectional and longitudinal studies would greatly implement the analysis of national innovation systems (Nelson, 1993).

With respect to other indicators, such as R&D expenditures of the academic system, chairs enable to study more carefully the distribution of scientific activities by academic disciplines. This enables to better specify the analysis of their economic effects according to their fields of activity.

From a historic viewpoint, the cliometrics of academic chairs enables to investigate how and if the specific disciplinary flows of scientific knowledge generated efficiently – we assume- by the different components of academic system had actually positive effects on the economic growth of a given system. The exploitation conditions that are intrinsic to the various scientific fields should play a key role.

3. THE EMPIRICAL EVIDENCE ON THE EVOLUTION OF CHAIRS

3.1. THE DATA AND THE LONG TERM EVIDENCE ACROSS DISCIPLINES AND REGIONS

The data used in this paper are drawn from an original and dedicated database, built through the collection of the official national bulletins on education published by the Italian Ministry of Education[3]. The data collection comprehends the overall number and type of University chairs for each of the Italian Universities for the years going from 1901 to 1959. According to the type of discipline corresponding to each chair we were able to aggregate the overall number of chairs (considering only full and associate professors) in 5 broad disciplinary fields classified as: applied sciences (AS - including chairs in chemistry and engineering), social sciences (SS - sociology, economics and law), human sciences (HUM - arts and humanities), other natural sciences (ONS - biology, physics and mathematics) and medical sciences (MS). Afterwards, according to the University to which each chair belonged, we aggregated all the chairs, distinguished by disciplinary field, in 5 macro-regions.[4]

As it is well known Italy is a highly differentiated economic system with major disparities and differences across regions. As a matter of fact the historic, economic,

[3] The Italian National Statistical Office (ISTAT) and the Ministry of Education, University and Research (MIUR) do not provide a coherent database containing historical data on the number of chairs in the Italian University: the only accessible sources are the published yearbooks of the Ministry of Education. The database used in this paper is the result of the first attempt to harmonize such data and it has been created through a careful collection of all the data concerning the number and type of chairs in each Italian university and in each faculty during the years 1901-1959. The sources of the data are the Yearbooks of the Ministry of Public Education (Annuario del Ministero della Pubblica Istruzione, Roma, Tipografia Elzeveriana) for the years 1894-1929 and 1953-1959, and the Yearbooks of the Ministry of National Education (Annuario del Ministero dell'Educazione Nazionale, Roma, Provveditorato generale dello Stato) for the years 1930-1943.

[4] The choice to use 5 macro-regions instead of each of the 20 Italian regions was motivated by the fact that in the first half of the 20th century not all of the Italian regions had one or more universities inside their territory. Since our aim was to build a balanced panel, we preferred having less individuals, but more complete time series.

and social differences across regions were –and still are- so relevant and their integration into a single national state so recent that they can be considered five economic systems on their own. The identification of the following five macro-regions, based upon the regional composition of the old pre-unitary states, seem to provide a suitable level of aggregation[5]:

1 - Piedmont and Liguria, (i.e. the former Savoy Kingdom),

2 – Lombardy, (part of the Habsburg Empires for a few centuries),

3 - the North East (including Veneto, Trentino and Friuli-Venezia Giulia, i.e. the former Republic of Venice),

4 - the Central Regions (including Abruzzo, Emilia-Romagna, Lazio, Marche, Tuscany and Umbria, i.e. the so-called Papal States)

5 - the Southern Regions (which include Apulia, Basilicata, Calabria, Campania, Sardinia and Sicily, i.e. the Kingdom of Sicily).

In such a way we have been able to track the evolution, within and across the five economic sub-systems represented by the (macro) regional aggregations, of the number of professors at the overall academic level and in each of the disciplines that we had identified.

In order to understand the evolution of each regional university system we decided to focus on some measures able to inform us about the features of each system. First of all we computed a density measure: the regional ratio of chairs per capita. In order to do so we combined our data with the data provided by the Italian National Statistical Office (ISTAT) on the overall population in each Italian region, as measured by the censuses that were implemented every ten years, starting with the data on 1901[6]. In Table (2) the total number of chairs, in each of the five Italian economic sub-systems, represented by the macro-regions in some specific years, and the number of chairs per capita (i.e. the ratio of chairs to the overall population) are reported.

INSERT TABLE 2 ABOUT HERE

[5] As a matter of fact Sardinia was a peripheral part of the Savoy Kingdom and Tuscany was never part of the Papal States. Yet the aggregation in these five macro-regions provides a set of quite homogeneous sub-systems.

[6] In order to obtain a yearly measure of the population in each of the macro-regions we assumed a constant rate of growth between each of the census' measurements.

Our aim is to track both the evolution of the university across the macro-regions and that of the Italian economic sub-systems: in particular we are interested in the overall process of economic growth at the regional level. The most recent and reliable data available is provided by Daniele and Malanima (2007, 2011), who computed the regional differentials in income per capita[7] for each year for the time-spam we are interested in, using the latest revisions of the time-series of the growth of Italian Gross Domestic Product in the first half of the 20th century[8], and combining these data with those related with the sectoral distribution of the regional labour force[9].

Finally in order to have the levels of income per capita for each of the 5 macro-regions we applied the regional differentials provided by Daniele and Malanima (2007, 2011) to the recent revision of the time-series of Italian GDP per capita provided by Banca d'Italia-ISTAT-Università di Roma Tor Vergata research group (Baffigi 2011)[10]. Furthermore we checked the robustness of our results by using also the time series of Italian GDP per capita elaborated by Daniele and Malanima (2007, 2011). Figure (1) presents the two time-series of (log) income per capita in each of the macro-regions: the red line represents the regional series of (log) income per capita obtained by multiplying the differentials by the GDP series of Baffigi (2011), while the blue line is obtained applying the differentials to the series of GDP per capita by Daniele and Malanima (2007, 2011). As it is evident in the plots the two series are very similar although they maintain small differences: we will therefore check whether our results are robust to both types of measures. Table (3) reports for some specific years the levels and the rates of growth of income per capita in the period 1901-1959 in each of the 5 macro-regions.

INSERT FIGURE 1 AND TABLE 3 ABOUT HERE

In order to test the differentiated impact of different types of academic knowledge on the Italian economic system(s), however, it is necessary to control for the processes that led the growth of income per capita in these years, in order to avoid spurious correlations between the "academic" variables and the growth of wealth. The historical literature is quite unanimous in identifying the main source of growth of the Italian economy in the process of industrialization that took place at the beginning of the century (Fenoaltea, 2003; Williamson, 2011). Ideally the levels of capital stock at

[7] The levels of GDP per worker, that is of labour productivity, instead, are not available for this period of time at the regional level, nor through the National Statistical Office (ISTAT), nor through other sources.
[8] See also Maddison (1991), Malanima and Zamagni (2010), Fenoaltea (2005).
[9] The data related with the sectoral composition of the labour force are provided by ISTAT and recently collected by Daniele and Malanima (2011)
[10] Since Daniele and Malanima provide the regional differentials for each Italian region, in order to obtain the differentials for the 5 macro-regions we took the average differential of the regions included in each macro-region.

the regional level would provide the obvious control for the increased capitalistic intensity of the economic activities: these measures are available for the Italian regions only from 1951 onwards[11]. Therefore we decided to use the data provided by ISTAT on the total number of person employed in the secondary sector as a proxy of the process of industrialization of each macro-region[12]. This measure is useful not only in order to control for the process of capital accumulation and modernization that, on its turn, should influence the growth of income per capita, but also allow to understand the relation between the growth of the industrial economy and the development of the academic knowledge in some specific disciplines such as technical or business-related ones. Table (4) presents the data concerning the regional level of employment in the secondary sector in each region.

INSERT TABLE 4 ABOUT HERE

The last point concerns the missing observations: our database of university chairs does not include data for the years related to the First and Second World War, specifically we miss the observations for the years between 1916 and 1921 and those between 1943 and 1952. Furthermore since in 1914, 1915, 1940, 1941 and 1942 the levels of income per capita in each region had already started a steep decline (because of the start of the First and Second World War), we decided to exclude from our econometric analyses also these years, which would result in outliers that might affect our estimates. We hence ended up with 37 years of observation for each region and 185 observations overall.

The absolute number of chairs per capita describes the general level of development of the university system in each macro-region. A preliminary analysis of the overall trends, at the overall academic level and with respect to the main disciplinary groups considered, of the evolution of the five macro-regional systems enables to identify four sub-periods that are relatively more homogeneous. The first 15 years (1901-1915) cover the period from the beginning of the century until the beginning of the First World War, the second time-span covers the whole 20’s until the Great Depression (1916-1930). The third period includes the 30’s and the Second World War (1931-1945), while the last period relates to the post-war period and all the 50’s (1946-1959). In Tables (5) and (6) we show the number of chairs in each disciplines

[11] See Paci and Saba (1997)
[12] Again our data proceed from those of Daniele and Malanima (2012)

and their shares on the overall number of chairs at the beginning of each of these time-periods.

INSERT TABLES 5 AND 6 ABOUT HERE

3.2 THE EVIDENCE IN THE FOUR KEY PHASES

3.2.1. INDUSTRIALIZATION AND THE GROWING ROLE OF APPLIED SCIENCES: 1901-1915.

A first glance at the number of chairs per capita in Table (2) shows that at the beginning of the 20th century the Central Regions displayed the highest density of university chairs, followed by Piedmont and Liguria and by the Southern Regions; Lombardy displayed a lower ratio of chairs to population, while the North East lagged behind.

These disparities in terms of density are partly explained by the number of universities in each of the macro-regions. Specifically in 1901 in the 6 regions (Abruzzo, Emilia-Romagna, Lazio, Marche, Tuscany and Umbria) that we grouped together as Central Regions, 12 universities were already existing (in Bologna, Camerino, Macerata, Florence, Modena, Parma, Pisa, Rome, Siena, Ferrara, Perugia and Urbino), in most cases with a long and established tradition. In Piedmont and Liguria there were the two universities of Turin and Genoa, while in the 6 Southern Regions there were 6 universities (in Catania, Cagliari, Messina, Napoli, Palermo and Sassari). In Lombardy the universities of Milan and Pavia already existed, while in the North East Padua was single university. The disparities in the densities therefore are explained mostly by the number of universities per capita: in 1901 in the Central Regions there was one university every 900 thousand inhabitants, in the Southern Regions one every 1,5 million, in Piedmont and Lombardy one every 2 million and in the North East one every 4 million people[13].

In Table (5) the last column, which reports the total number of chairs in each region, tells us that in this period Lombardy and the North East experienced the highest growth rate of the total number of chairs. In Lombardy this growth was mainly due to

[13] When instead we consider the average number of chairs per university in each of the 5 macro-regions we notice that the ratios are very similar (an average of 50 chairs per university in the Central Regions, 48,5 in the Southern Regions, 48 in Lombardy) with a slight exception in the case of Piedmont and Liguria (76) and the North East (68).

the newly born Bocconi University (established in 1902), in the North East instead it was due to the enlargement of the University of Padua.

The analysis of the distribution of the chairs across the different disciplines in 1901 (see Table 6) reveals some important differences among the five macro-regions. While the Central and Southern Regions were more specialized in Medical and Social Sciences (the latter consisting mainly in chairs in law), Lombardy and Piedmont instead displayed a higher share of chairs in Chemical and Engineering Sciences[14]. For what concerns the chairs in Theoretical and Natural Sciences, instead, there were not significant differences among the regions.

It is worth underlining that the comparison of the relative academic specialization of the regions with the data concerning the share of industrial employment shown in Table (4), confirms that the regions that had already reached in 1901 a higher level of industrialization (Piedmont, Liguria and Lombardy) were also those in which the percentage of chairs in Chemical and Engineering Sciences was higher. Furthermore Table (3) shows that the level of industrialization seems also to parallel quite effectively the levels of income per capita in each of the macro-regions: again Piedmont with Liguria and Lombardy display the highest values, while the other three regions show an income per capita that is on average 20% lower than the two most industrialized ones.

Specifically at the beginning of the century, during the so-called “Giolittian age”, Italy experienced an early phase of industrialization due to, among other factors, the state intervention and a greater openness towards the world economy, testified by the growth of imports and exports of new raw materials and industrial goods (Amatori 2011). At the regional level during the first 15 years of the 20th century we observe a steep growth of industrial employment in all of the macro-regions, as shown in Table (4), with the exception of the Southern Regions (where instead it declined). In Table (3) we notice that especially in the Northern Regions these dynamics positively influenced also the growth of income per capita.

When we analyze the growth of chairs in these 15 years and we distinguish between each specific discipline we notice that the process of industrialization of the economy was mirrored in the three Northern Regions (Piedmont and Liguria, Lombardy and North East) by a general increase of the number of chairs in Chemical and Engineering Sciences. Also in the Southern Regions the number of chairs in Chemical and Engineering Sciences grew, due to the increase in size of the Royal

[14] In both cases this was mainly due to the size of the Royal Technical Institute (Reale Istituto Tecnico Superiore) in Milan and of the Royal Training School for Engineers (Reale Scuola di Applicazione per Ingegneri) in Turin.

Schools for Engineers in Palermo and Naples, even if the corresponding process of industrialization in these regions was slow.

In Lombardy the foundation of Bocconi University led also to an increase of the chairs in Social Sciences, in particular through the growth of the chairs in disciplines such as management and economics. In the Central Regions instead Social and Human Sciences grew substantially because of the increase of the number of chairs within the faculties of, respectively, Law and Humanities. Another relevant fact occurring in these years was a generalized decrease not only of the shares but also of the actual number of chairs in Theoretical and Natural Sciences in almost all of the macro-regions.

Summing up, the first 15 years of our data show a generalized decrease of the chairs in Theoretical and Natural Sciences. In Lombardy we observe a first growth of the chairs in economic and business-related disciplines (hence of social sciences), while the Central Regions, experienced only a moderate increase of the chairs in social sciences, related mostly to the growth of chairs in law, rather than in business and economics. Overall these years display a widespread growth of the chairs in applied sciences such as Chemistry and Engineering, especially in the northern regions (such as Piedmont, Liguria and Lombardy), which was mirrored by the growth of the industrial sector. In the Southern regions the same increase of the chairs in applied sciences occurred but such a growth was not associated with a corresponding growth of the employment in the secondary sector and hence of the process of industrialization.

We can hence assume that the large industrial growth in the Northern Regions probably fostered and was favored by the supply of technical and managerial skills provided by the university system. It must be stressed that in Italy the matching between the supply of scientific knowledge provided by the academia with the needs of profit-seeking agents willing to improve their technologies of production consisted –and still consists (Bodas-Freitas, Geuna, Rossi, 2011)– for a large part of personal relations between professors and entrepreneurs.

A confirmation of the importance of such a mode of knowledge transfer between Italian firms and the university departments proceeds from the Biographical Dictionary of Italian Entrepreneurs (BDIE). The case studies provided by the volume show that personal relations between professors and entrepreneurs were central for the access and the dissemination of the new scientific knowledge and its eventual implementation into technological knowledge. The empirical evidence shows the relevance of the personal relations between the professors of engineering and chemistry and the entrepreneurs as the crucial condition for the actual exploitation of the new scientific knowledge. In this context the already mentioned schools of engineering of Torino and Milano played a central role in such a process, feeding a virtuous circle by means of which they became the platform of the interactions between the business community and the academia.

Indeed knowledge spilling from academic chairs is not sufficient to impact economic growth. Dedicated activities and systematic interactions, often based upon personal relations, are necessary to actually generate technological knowledge and finally to innovate. The mix of scientific and professional activities based upon systematic relations with former students and potential entrepreneurs searching for advice and support became the typical character of the Italian professors of engineering. Such a character became the interface between scientific knowledge and technological knowledge that favored not only the dissemination but also the active exploitation of advances in scientific knowledge and its transformation in technological knowledge building the bridges that could finally support the introduction of innovations and hence supporting economic growth.

3.2.2 THE BIRTH OF THE BUSINESS SCHOOLS: 1915-1930.

As Table (4) shows, during the 20's only in the three Northern Regions (Lombardy, Piedmont and the North East) the number of workers in the secondary sector kept on growing with high and positive rates, although lower than in the previous period; in the Central and Southern Regions instead the growth was still much more moderate. In Table (3) we also notice that instead the disparities in the growth rates of income per capita was even higher with Lombardy, Piedmont and Liguria displaying a growth rate of more than 25% and the Southern Regions even decreasing the overall level of income per person.

The analysis of the aggregate dynamics of the number of chairs in Table (5) suggests the same patterns occurred in the previous 15 years: Lombardy and the North East experienced the highest growth of chairs. Such a growth, mostly due to the newly born Cattolica University in Milan in 1921, led Lombardy to reach in 1930 almost the same level of density of chairs over population of Piedmont, reaching a higher level than the Southern Regions. North East's growth was instead due to the new University of Trieste (Università degli Studi Economici e Commerciali di Trieste) and to the Institute for Economic and Business studies in Venezia (Istituto Superiore di Scienze Economiche e Commerciali di Venezia), both established in 1930 and specialized in business studies. However when we look at the number of chairs per capita in 1930 in Table (2) it is evident that the region had not yet completed the process of catching up.

At the end of the 20's in Italy many new Institutes for Economic and Business Studies were founded or given the official status of university-level courses in several existing universities in all regions of Italy[15]. This led to a general increase of the chairs in management, economics and statistics. In Piedmont and in the North East therefore we observe the same growth of Social Sciences that had occurred in Lombardy in the previous time-span. In the Central and Southern Regions instead the growth of chairs in business and economics came together with a steep decrease of the chairs in law (whose shares had been much higher in these regions when compared to the Northern Regions), hence the overall share of Social Sciences decreased in the former case and remained constant in the latter. Finally in the Central Regions the number of chairs in Chemistry and Engineering increased in this period.

Overall between 1915 and 1930 the chairs in Chemical and Engineering Sciences in the Northern Regions didn't grow as much as in the previous fifteen years, as did the process of industrialization. Instead in these regions the centrality of Social Sciences grew as a consequence of the establishment of the new Institutes for Economic and Business studies. Conversely the Central Regions experienced the growth of chairs in applied sciences that had already occurred in the Northern Regions before the First World War: however this growth was not mirrored by a corresponding growth of the industrial system. Finally in the Southern Regions, in which the industrialization was also lagging behind the other regions, the total number of chairs grew only marginally and there were no significant differences in the distribution of the chairs across disciplines.

3.2.3 THE SECOND WAVE OF GROWTH OF APPLIED SCIENCES: 1930-1941.

Looking at the evolution of the overall number of university chairs in each region, during the Thirties we notice a quite homogeneous rate of growth across the regions. In this framework the North East and the Southern Regions are, respectively, the upper and lower bound: such dynamics led the North East to reach almost the level of chairs per capita of the Southern Regions.

In 1930 the level of industrialization of the different macro-regions was already quite diversified, if compared to the level of the beginning of the century: while Piedmont,

[15] Specifically these business schools named "Istituti Superiori di Scienze Economiche e Commerciali" were established during the 20's in Bari, Bologna, Catania, Florence, Genoa, Naples, Rome, Turin and Venice.

Liguria and Lombardy held a ratio of respectively 17% and 22% of employment in the secondary sector over the whole population, in the North East, in the Central and Southern regions such ratio hardly exceeded 10%. The same disparities were present in the levels of income per capita: in 1930 the level of income per person in the Central Regions was more than 30% lower than that of Piedmont and Lombardy; in the case of the Southern regions such gap was even larger. Even if during the 30's the rate of increase of the share of employees in the industry declined in the two leading macro-regions, in the other regions it did not increase sufficiently to allow for a convergence of such ratio. Consequently in 1939, before the start of the Second World War the disparities among regions were still similar to those of 1930. The industrialization of the regional economies during the 30's consisted also in a progressive shift towards more technologically advanced sectors, in markets with great growth potential (such as the machinery industry, the automotive and chemical industry, the iron and steel industry, see Amatori and Colli, 2003). The growth of these sectors greatly fostered the demand for technological knowledge, to be further translated into scientific knowledge: in such a framework it was straightforward to consider the university as a major provider of this kind of knowledge, both through the formation of experts and through direct relationships with firms.

Consequently during the 30's we observe a large and generalized growth of the chairs in Chemical and Engineering Sciences (which anyway did not involved the Southern Regions). In the North East such a growth was due to the inclusion of the Faculty of Engineering within the University of Padua in 1936 and to the birth of the Royal University Institute of Architecture (Reale Istituto Universitario di Architettura) in Venice in 1933. In Lombardy the growth of these chairs was due to the enlargement of the Politecnico of Milan (the old Royal Engineering Higher Institute - Reale Istituto Superiore d'Ingegneria), which led also to an increase of its overall number of chairs. In Piedmont instead, beside the increase of the size of the Politecnico of Turin, the opening of the faculty of Engineering in the University of Genoa in 1936 led to a great increase of the number of chairs in these disciplines. In the Central Regions the number of chairs in applied technical disciplines increased as well, as it had already occurred in the previous sub-period.

The Central and Southern Regions experienced instead the growth of chairs in Social Sciences that had occurred in the Northern regions in the previous decade: however while in the case of the Southern Regions this was due to the increase of the chairs in economics and business in the Central Regions this was mainly due to the increase of chairs in law.

The data also show a generalized decrease of the number of chairs in Medicine and, in the case of Central and Southern Regions, also the decrease of the shares of chairs in Natural Sciences. Human Sciences instead increased their share in all regions except the Central ones.

These transformations led to a change in the distribution of the chairs across disciplines in all regions: in the Northern Regions Social Sciences became the discipline with the highest number of chairs. Also in the Central and Southern Regions Social Sciences gained centrality in the distribution of the disciplines, although Medicine still held a major part of the overall number of chairs. Engineering and Chemical sciences were stable on a share of the total chairs slightly lower than 20%, with the exception of the Southern Regions, in which they held a lower share.

In a decade in which the process of industrialization did not grow as in the previous periods, the increase of the size of the two Politecnici and the inclusion of the Faculties of Engineering within many existing universities led to an overall increase of the number of chairs in applied sciences. Such a process, however did not involved the Southern regions, in which the share of chairs in Chemical and Engineering Sciences remained lower than in the other regions.

Furthermore in these years the Central and especially the Southern Regions experienced the increase of the chairs in Social Sciences that had already occurred in 1902 in Lombardy (with the foundation of Bocconi business school) and later on in Piedmont, Liguria and the North East, with the establishment of the new business school in 1930.

3.2.4 THE GROWTH OF THE OVERALL UNIVERSITY SYSTEM: 1946-1959.

After the Second World War the Italian university system experienced a general expansion with high rate of growth: in almost 20 years the number of chairs grew more than 25%. In the 50's the highest growth of university chairs occurred in the Southern Regions and in the North East (with a percentage growth of more than 40% in both cases). The same high rates of growth in the university system occurred also in the economy as a whole with a large increase of the levels of income per capita and of workers employed in the secondary sector. However in both cases the homogeneous rates of growth in the different regions led to a generalized increase of wealth and of industrialization, but it did not affect the pre-existing disparities among regions, which remained almost unchanged after these 20 years.

Disaggregating the growth of chairs across disciplines and regions allows to highlight that during this period the Southern Regions eventually experienced an outstanding increase of the number of chairs in Chemical and Engineering Sciences, which led to an increase of their share on the total number of chairs. This was achieved through the creation of new faculties of Engineering in some universities such as Bari and Cagliari and through the enlargement of the already existing faculty of Engineering in Naples. The same increase of the quota occurred in Piedmont, in which the Politecnico of Turin more than doubled the number of chairs, and in the North East, where the University of Trieste increased by including a new faculty of Engineering.

In all of the Northern Regions the overall growth of the number of chairs did not involve Social Sciences, whose share decreased steadily. In the Central and Southern Regions such a process was less strong. In these years instead we observe a generalized increase of the chairs in Human Sciences, both achieved through the increase of the share of these types of chairs within the existing universities and both through the establishment of the University Teaching Institutes (Istituti Universitari di Magistero), aimed at the training of teachers, in many Italian towns. Also the chairs in Medical Sciences grew homogeneously across all regions, with the exception of the universities in the North East, in which the growth of the chairs in these disciplines was instead very moderate.

Looking at the number of chairs per capita in the different regions at the end of the 50's in Table (2) the density of the chairs in the different regions was still similar to the beginning of the century, the Central Regions displaying the highest density followed by Piedmont, Southern Regions and Lombardy, while the North East still exhibited the lowest ratio of professors per capita. However when looking at the growth of the number of chairs we notice that Lombardy and Veneto more than doubled the number of chairs that existed in 1901, while the other regions experienced a total growth ranging from 38% to 62%.

4. THE ECONOMETRIC ANALYSIS

4.1. A SIMPLE MODEL

In order to test our hypothesis on the different role of the academic disciplines in their contribution to economic growth in the Italian regions, and without data limitations, we would chose to adopt a very simple and basic framework where a production function could be estimated and the output elasticities of each of the disciplines computed so as to provide a rough proxy of their contribution to economic growth. The limitations of the economic data set however force us to use very rough proxies both for capital and actual employment. Hence our estimates cannot actually claim to measure the precise size of these elasticities, but rather to provide some clues on the differentiated effects on the growth of a region in a certain period of time of the different types of knowledge.

Ideally we would like to test our hypotheses on a dynamic Cobb-Douglas production function, expressed in (log) labour intensities, as follows:

$$\ln\frac{Y_{it}}{L_{it}} = c + \rho\ln\left(\frac{Y_{it-1}}{L_{it-1}}\right) + \alpha\ln\left(\frac{K_{it}}{L_{it}}\right) + \gamma_1\ln\left(\frac{AS_{it}}{L_{it}}\right) + \gamma_2\ln\left(\frac{SS_{it}}{L_{it}}\right) + \gamma_3\ln\left(\frac{HU_{it}}{L_{it}}\right) + \gamma_4\ln\left(\frac{MS_{it}}{L_{it}}\right) + \gamma_5\ln\left(\frac{ONS_{it}}{L_{it}}\right) \quad (1)$$

Where the indexes i and t denote respectively regions and time. Y, K and L represent, in turn, GDP, capital stock and employment. AS_{it} indicates the yearly number of chairs in applied sciences (including engineering and chemicals) in each macro-region, SS_{it} represents social sciences (law, economics, statistics and sociology), MS_{it} denotes medical sciences (medicine and veterinary), ONS_{it} stands for other natural sciences (including mathematics, physics and natural sciences) and HU_{it} for human sciences.

Given the analysis of knowledge features provided in Section (2) we would expect to verify the hypothesis that the output elasticity of the different disciplines differs and specifically that $\gamma_1>\gamma_2=\gamma_3=\gamma_4=\gamma_5=\gamma_6$.

However, as previously explained, the exact levels of employment and capital stocks at the regional level are not available for the time period and the regional disaggregation we are interested in. We only have income per capita and we can proxy the capital stock of a region's economy with the number of workers employed in the secondary sector and the number of employees with the size of the population. Therefore the equation that we can actually estimate is the following:

$$\ln\frac{Y_{it}}{P_{it}} = a + \rho\ln\left(\frac{Y_{it-1}}{P_{it-1}}\right) + \beta\ln\left(\frac{IND_{it-j}}{P_{it-j}}\right) + \gamma_1\ln\left(\frac{AS_{it-j}}{P_{it-j}}\right) + \gamma_2\ln\left(\frac{SS_{it-j}}{P_{it-j}}\right)$$

$$+ \gamma_3\ln\left(\frac{HU_{it-j}}{P_{it-j}}\right) + \gamma_4\ln\left(\frac{MS_{it-j}}{P_{it-j}}\right) + \gamma_5\ln\left(\frac{ONS_{it-j}}{P_{it-j}}\right) + \eta_t + u_i + \varepsilon_{it} \qquad (2)$$

with j=1,…,4

Where P_{it} denotes the population in each macro-region in each year and IND_{it} stands for the number of employees in the secondary sector in each region. In Table (7) the descriptive statistics are presented.

INSERT TABLE 7 ABOUT HERE

The error term is decomposed in three parts u_i, ε_{it} and η_t which correspond to region specific, idiosyncratic and common stochastic shocks. We also chose to try several specifications of equation (2) with different time lags of the independent variables (from t-1 up to t-4). Indeed we do not know ex ante with which time-lag the knowledge spilling from the academic systems might affect the economic performances of a region. Since the limited number of observation does not allow us to include contemporaneously in the same estimation all the lagged coefficients of the independent variables (as in a distributed lag model), we will try different specifications of equation (2) in which the independent variables will be introduced with a growing number of lags.

An important problem in our estimation is related with the low number of controls that we are able to introduce in order to explain the regional levels of income per capita. In other words we are worried that the growth of income per capita might be explained by a great number of factors (increase of public expenditure, fiscal shocks, lowering of tariff barriers, entrepreneurial and social capital of a region, specific industrial policies) that we cannot control for, due to the difficulty in finding appropriate proxies at the regional level for this period of Italian history. All of these factors would hence end up in the error term and create a possible problem of endogeneity with our variables of interest. Indeed if any of the "academic" variables is correlated with some of these factors our results would produce a bias in the coefficients of the academic disciplines[16]. A first way to cope with this problem is to use the within group estimator, in order to rule out time-invariant characteristics of each region (u_i), that on their turn might be correlated with the levels of the chairs in some specific discipline[17]. By the same token the introduction of the lagged dependent variable among the regressors allows to controlling for all of the heterogeneity among regions that we are not controlling and that influences the overall level of income per capita of each region.

However with dynamic panel data the violation of the assumption of strict exogeneity makes the within-group estimator inconsistent and possibly downwards biased (Nickell, 1981; Judson and Owen, 1999), therefore we need to check for the robustness of our estimates through the adoption of a GMM estimator in first-differences (Arellano and Bond 1991). The model is hence estimated in first differences (eliminating u_i and the potential sources of omitted variable bias) instrumenting the endogenous variables with suitable lags of their own levels.

4.2 THE RESULTS

Table (8) reports the results of the estimation of equation (3) with one, two and three years lags, through the within group estimator. When we look at the coefficients we notice first of all a great explaining power of the lagged dependent variable: its coefficient is always positive and significant, and lower than one. As expected also the coefficient of the share of the population employed in the industrial sector is positively associated with the levels of income per capita, disregarding the time lag with which it is introduced.

When we focus on the variables related with the number of chairs in each specific discipline, our results highlight the role of applied sciences (AS) in the overall process of growth of income per capita in the Italian regions. The coefficient of applied sciences is positive and significant and displays the highest value among all the other coefficients of the educational variables, only when the time-lag exceeds 3 years the coefficient of AS loses significance. The variables that represent the other academic disciplines are instead never significantly different from zero. Finally we

[16] This could be the case of an increase in public expenditure, that could contemporaneously increase the level of income per capita and the number of chairs in some or in all the discipline we identified.

[17] As an example the quality of the entrepreneurial capital of a region (which we are not likely to control for with the number of employed in the industry) might influence the willingness of university to increase the number of chairs in applied sciences this would hence result in an upward bias of the AS coefficient.

also introduce four time dummies corresponding to the four 15-years periods we identified in Section (3.2.) in order to control for common shocks at the country level

Table (9) exhibits the results of the test of equation (2) with the GMM Arellano-Bond estimator in first differences (Arellano, Bond, 1991). The results of the Sargan test of overidentifying restrictions show that the test on the validity of the lagged levels (up to two years-lagged) used as instruments in the first-differenced equations cannot be rejected, hence confirming our choice of instruments. Furthermore the results of the AR(1) and AR(2) tests show that the error terms (in levels) are not serially correlated. Moreover the results of these new estimates are in line with those obtained with the within-group estimator: the coefficients of the lagged dependent variable is positive and significant and smaller than in the within group estimates. Also the number of persons employed in the secondary sector (IND) significantly affects the growth of income per capita. The coefficient of applied sciences (AS) is positive and significant in all the specifications, while the other coefficients related with different types of disciplines are not significantly different from zero, a part from medical sciences (MS) and other theoretical sciences (ONS), which show a negative sign in some of the specifications. On the contrary the coefficient of social sciences (SS) increases in size as the time lags increases and it becomes positive and significant with 4-years lag.

INSERT TABLES 8 AND 9 ABOUT HERE

As a further robustness check we also present the results of these estimations when the GDP series of Malanima (2011) are used as a dependent variable. The results in Tables (10) and (11) show that the coefficient of applied sciences (AS) is the only one positive and significant when the within group estimator is implemented, while when the GMM estimator in first differences is used only applied sciences (AS) and social sciences (SS) are positive and significant (but in the case of social sciences this occurs only when at least 2 years lags are introduced).

In line with our expectations overall our results seem to confirm the positive role of the chairs in Chemical and Engineering Sciences and, to a minor extent, of Social Sciences in the regional growth of income per capita.

INSERT TABLES 10 AND 11 ABOUT HERE

Further robustness checks: the role of applied sciences

On the basis of the results so far obtained we will test another specification of equation (2), in order to directly test the relevance of the number of chairs in Chemical and Engineering Sciences. Since the chairs belonging to these disciplines are the ones that affect the most the levels of the income per capita in each region, we test the stronger hypothesis that the higher is the share of chairs in these disciplines (among all the disciplines), the higher will be the levels of income per capita. Therefore we transform equation (2) into the following:

$$\ln\frac{Y_{it}}{P_{it}} = a + \rho\ln\left(\frac{Y_{it-1}}{P_{it-1}}\right) + \beta\ln\left(\frac{IND_{it-1}}{P_{it-1}}\right) + \delta_1\left(\frac{AS_{it-1}}{TOT\_CHAIRS_{it-1}}\right) + \eta_t + u_i + \varepsilon_{it} \quad (3)$$

Where TOT_CHAIRS denotes the total number of university chairs in each region and in each year. Table (12) presents the results of this estimation, obtained through the GMM estimator in first-differences: as shown in column (1) the coefficient of Applied Sciences is positive and significant, thus providing a first confirmation of our hypothesis on the role of these disciplines in the overall economic development of the Italian regions. The coefficient of the lagged dependent variable is again positive and significant; also the number of person employed in the secondary sector is significantly positive, as in the previous specifications. Combining this first evidence with the detailed description of the different phases through which the regional university systems went through during the first fifty years of the 20th century suggest to test for the existence of differentiated effects of the share of chairs on the levels of income per capita across different time periods. Therefore we chose to interact the Applied Sciences variable with the 4 time dummies that correspond to the 4 time periods identified in Section (3.2.). The results, displayed in column (2) of Table (12), show indeed different effects of the share of chairs in applied sciences along the different time-spans. Specifically we find an increasing positive effect of the specialization of the regional universities in applied sciences on the overall levels of income per capita.

INSERT TABLE 12 ABOUT HERE

5. CONCLUSIONS

Advances in scientific knowledge are a necessary but not sufficient condition for economic growth. High levels of fungibility of scientific knowledge within the recombination process that is at the origin of technological knowledge are key to support the necessary transformation activities of profit-seeking agents. Advances in scientific fields that are characterized by high levels of fungibility and good exploitation conditions have much stronger impact on economic growth than advances in scientific knowledge with low appropriability, cumulability and fungibility conditions. Advances in scientific knowledge can feed the recombinant generation of technological knowledge and hence the eventual introduction of technological innovations only if profit-seeking firms have the opportunity to implement the new advances with internal competence based upon learning processes and can protect the economic benefits stemming from the transformation of scientific knowledge into innovations.

The detailed study of the sources of technological knowledge that led to the introduction of the most important technological innovations in the first wave of the industrialization, across Italian regions, in the first part of the XX century has shown the central role of the advances in engineering and chemistry. The other disciplines played much a weaker role. Academic knowledge is relevant for economic growth not only when firms see a new opportunity stemming from a scientific advance, but when they have a clear incentive to invest considerable resources to transform scientific knowledge into technological knowledge.

The results of the case-study evidence can be generalized with the systematic exploration of the growth of the Italian academic system and the investigation of its relationship with economic growth.

The cliometrics of academic chairs is quite a new field of empirical investigation that can yield new important opportunities for empirical research to better explore the complex questions underlying the relationship between knowledge and growth. An original data-base covering all the chairs of the Italian academic system from 1900 through 1959, divided in the 5 highly differentiated macro-regions that compose the Italian economic system, has been created. The differences across the five macro-regions were –and still are- so relevant and their integration into a single nation so recent that they can be considered five economic systems on their own. All the chairs and their fields have been identified and mapped across the five macro-regions.

The data base enabled to test the hypothesis that advances in scientific knowledge as proxied by chairs have a differentiated impact on regional economic growth according to their exploitation conditions. The econometric test across the five macro-regions fully confirms the hypothesis and supports the case-study evidence with a systematic analysis at the regional level of the Italian economic and academic system(s).

The econometric evidence confirms that growth of income per capita, across the main regional components of the Italian economic system, has been positively influenced by the evolution of chairs in chemistry and engineering and to a minor extent in social sciences. The dynamics of chairs in the other academic disciplines did not exert any significant effect on the growth of Italian regions.

Advances in scientific knowledge do deserve the support of the society for arguments that are not taken into account in this study. Advances in scientific fields with high levels of exploitability such as engineering and chemistry in the first part of the XX century, in the Italian experience, did generate major knowledge externalities that could be converted and transformed into technological knowledge with strong and positive effects on Italian economic growth.

The suitability for the economic exploitation of the different types of scientific knowledge depends partly on the historic and institutional context into which it is generated and partly on its specific features in terms of fungibility, appropriability, stickiness and cumulability. The combination of these factors can help to understand the incentives by the economic agents to invest resources in order to transform a specific kind of scientific knowledge into technological knowledge. In this paper we have shown how such a combination of factors increased the incentives for the economic exploitation of some selected types of scientific knowledge with respect to others in the different macro-regions of the Italian economy in the first half of the XX century.

The selective support of scientific fields according to their exploitation conditions can become an effective tool of science and innovation policy directing additional resources towards the implementation of scientific fields of activity with higher chances of actual transformation into technological knowledge and technological innovation. The cliometrics of chairs can become an important area of research to better explore at the national, regional and industrial levels, from both the historic and contemporary viewpoints, the relations between knowledge and growth.

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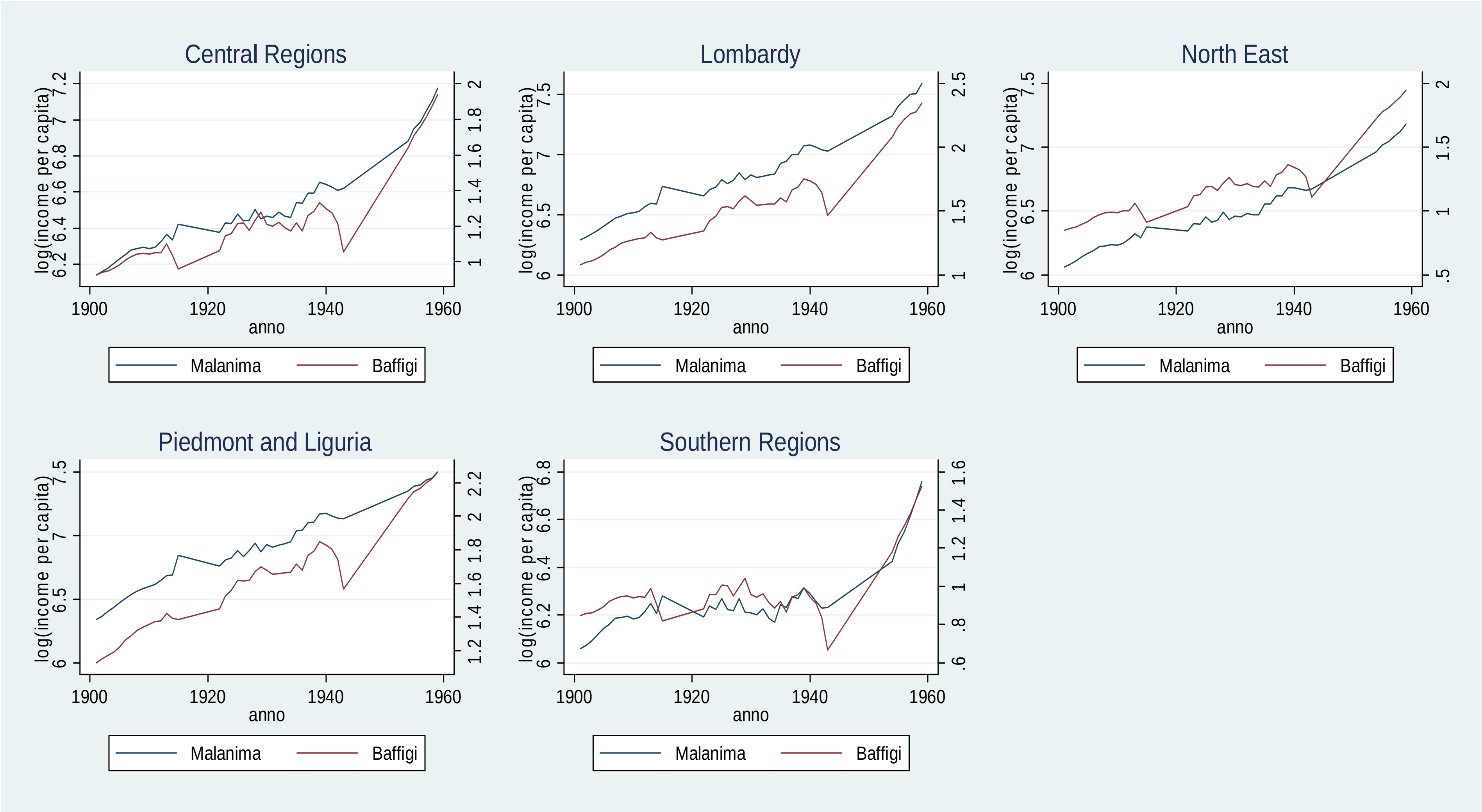
Table 2. Total number and density of university chairs in the Italian regions in different sub-periods between 1901 and 1959

	Central regions		Lombardy		North East	
Years	Total number of chairs	Density (chairs over population)	Total number of chairs	Density (chairs over population)	Total number of chairs	Density (chairs over population)
1901	551	5,72%	96	2,25%	68	1,69%
1915	587	5,61%	119	2,43%	79	1,67%
1930	568	4,81%	174	3,16%	97	1,88%
1941	644	4,98%	197	3,26%	119	2,16%
1959	754	5,28%	225	3,15%	167	2,89%

	Piedmont and Liguria		Southern regions	
Years	Total number of chairs	Density (chairs over population)	Total number of chairs	Density (chairs over population)
1901	152	3,45%	340	3,08%
1915	161	3,45%	362	3,11%
1930	176	3,59%	367	2,85%
1941	193	3,82%	386	2,69%
1959	234	4,21%	552	3,33%

Figure 1. Baffigi and Malanima estimates of income per capita, 1901-1959.



Source: Malanima series are in 1911 prices, while Baffigi series are in 2010 prices

Table 3. Income per capita in the Italian regions in different sub-periods between 1901 and 1959: levels and rates of growth

	Central regions		Lombardy		North East	
Years	Income per capita	Perc. growth of income per capita	Income per capita	Perc. growth of income per capita	Income per capita	Perc. growth of income per capita
1901	464	-	540	-	430	-
1913	581	25,07%	732	35,36%	556	29,37%
1930	642	10,47%	927	26,77%	639	14,96%
1939	775	20,75%	1.177	26,94%	801	25,24%
1959	1.307	68,65%	1.973	67,57%	1.318	64,59%

	Piedmont and Liguria		Southern regions	
Years	Income per capita	Perc. growth of income per capita	Income per capita	Perc. growth of income per capita
1901	567	-	428	-
1915	799	40,88%	518	20,86%
1930	1.023	28,02%	498	-3,82%
1941	1.300	27,03%	552	10,93%
1959	1.812	39,45%	862	56,14%

Source: Malanima (2007), values are in constant prices (1911 prices)

Table 4. Workers employed in the secondary sector in the Italian regions in different sub-periods between 1901 and 1959

	Central regions			Lombardy			North East		
Years	Employed in the secondary sector	Perc. growth in the secondary sector	Perc. of population in the secondary sector	Employed in the secondary sector	Perc. growth in the secondary sector	Perc. of population in the secondary sector	Employed in the secondary sector	Perc. growth in the secondary sector	Perc. of population in the secondary sector
1901	908.000	-	9,42%	737.000	-	17,28%	400.000	-	9,92%
1913	1.089.800	20,02%	10,42%	956.200	29,74%	19,52%	496.800	24,20%	10,49%
1930	1.157.300	6,19%	9,81%	1.217.200	27,30%	22,13%	573.600	15,46%	11,13%
1939	1.350.333	16,68%	10,44%	1.369.000	12,47%	22,66%	687.000	19,77%	12,44%
1959	1.993.000	47,59%	13,95%	1.806.600	31,96%	25,29%	954.200	38,89%	16,54%

	Piedmont and Liguria			Southern regions		
Years	Employed in the secondary sector	Perc. growth in the secondary sector	Perc. of population in the secondary sector	Employed in the secondary sector	Perc. growth in the secondary sector	Perc. of population in the secondary sector
1901	554.000	-	12,59%	1.110.000	-	10,06%
1915	717.400	29,49%	15,39%	1.061.000	-4,41%	9,13%
1930	834.700	16,35%	17,00%	1.091.600	2,88%	8,46%
1941	930.000	11,42%	18,41%	1.199.667	9,90%	8,35%
1959	1.154.400	24,13%	20,75%	1.717.800	43,19%	10,35%

Source Istat and Daniele and Malanima (2012)

Table 5. Total number of chairs

Region	Year	Medicine	Human Sciences	Chemical and Engineering Sciences	Social Sciences	Other Theoretical and Natural Sciences	Total
Central Regions	1901	168	80	68	112	123	551
	1915	182	101	64	138	102	587
	1930	154	102	84	123	105	568
	1941	153	115	123	157	96	644
	1959	183	141	129	190	111	754
Lombardy	1901	22	21	19	13	21	96
	1915	23	29	23	27	17	119
	1930	45	34	27	44	24	174
	1941	42	42	36	48	29	197
	1959	53	49	42	45	36	225
North East	1901	18	12	9	12	17	68
	1915	16	15	16	13	19	79
	1930	17	16	10	35	19	97
	1941	17	23	24	42	13	119
	1959	19	42	38	42	26	167
Piedmont and Liguria	1901	40	24	24	26	38	152
	1915	48	23	31	28	31	161
	1930	45	29	27	43	32	176
	1941	43	35	37	44	34	193
	1959	55	42	52	45	40	234
Southern Regions	1901	107	48	42	74	69	340
	1915	120	44	55	77	66	362
	1930	122	48	55	77	65	367
	1941	109	67	56	95	59	386
	1959	153	102	90	125	82	552

Table 6. Share of total chairs

Region	Year	Medicine	Human Sciences	Chemical and Engineering Sciences	Social Sciences	Other Theoretical and Natural Sciences
Central Regions	1901	30%	15%	12%	20%	22%
	1915	31%	17%	11%	24%	17%
	1930	27%	18%	15%	22%	18%
	1941	24%	18%	19%	24%	15%
	1959	24%	19%	17%	25%	15%
Lombardy	1901	23%	22%	20%	14%	22%
	1915	19%	24%	19%	23%	14%
	1930	26%	20%	16%	25%	14%
	1941	21%	21%	18%	24%	15%
	1959	24%	22%	19%	20%	16%
North east	1901	26%	18%	13%	18%	25%
	1915	20%	19%	20%	16%	24%
	1930	18%	16%	10%	36%	20%
	1941	14%	19%	20%	35%	11%
	1959	11%	25%	23%	25%	16%
Piedmont and Liguria	1901	26%	16%	16%	17%	25%
	1915	30%	14%	19%	17%	19%
	1930	26%	16%	15%	24%	18%
	1941	22%	18%	19%	23%	18%
	1959	24%	18%	22%	19%	17%
Southern Regions	1901	31%	14%	12%	22%	20%
	1915	33%	12%	15%	21%	18%
	1930	33%	13%	15%	21%	18%
	1941	28%	17%	15%	25%	15%
	1959	28%	18%	16%	23%	15%

Table 7. Descriptive statistics

Variable	mean	std. dev.	min	max	observations	id	time
$\ln(Y_{it}/P_{it})$	1.322	0.366	0.846	2.350	185	5	37
$\ln(IND_{it}/P_{it})$	-2.038	0.330	-2.492	-1.374	185	5	37
$\ln(AS_{it}/P_{it})$	-5.301	0.369	-6.245	-4.634	185	5	37
$\ln(SS_{it}/P_{it})$	-5.037	0.425	-5.958	-4.292	185	5	37
$\ln(HU_{it}/P_{it})$	-5.184	0.353	-5.888	-4.563	185	5	37
$\ln(MS_{it}/P_{it})$	-4.885	0.506	-6.040	-4.008	185	5	37
$\ln(ONS_{it}/P_{it})$	-5.216	0.395	-6.207	-4.259	185	5	37
AS_{it-1}/TOT_{it-1}	0.165	0.031	0.103	0.251	185	5	37

Table 8. Within group estimator.

VARIABLES	(1) j=1	(2) j=2	(3) j=3	(4) j=4
$\ln(Y_{t-1}/P_{t-1})$	0.822***	0.844***	0.821***	0.799***
	(0.043)	(0.053)	(0.064)	(0.077)
$\ln(IND_{it-j}/P_{it-j})$	0.171**	0.132*	0.145*	0.163*
	(0.067)	(0.074)	(0.085)	(0.094)
$\ln(AS_{it-j}/P_{it-j})$	0.048***	0.035*	0.037*	0.026
	(0.018)	(0.019)	(0.022)	(0.024)
$\ln(SS_{it-j}/P_{it-j})$	-0.006	-0.002	0.001	0.021
	(0.017)	(0.018)	(0.019)	(0.020)
$\ln(HU_{it-j}/P_{it-j})$	-0.032	-0.014	-0.007	-0.018
	(0.021)	(0.022)	(0.025)	(0.027)
$\ln(MS_{it-j}/P_{it-j})$	0.000	0.019	0.006	-0.018
	(0.020)	(0.021)	(0.024)	(0.026)
$\ln(ONS_{it-j}/P_{it-j})$	-0.011	-0.025	-0.009	-0.003
	(0.019)	(0.021)	(0.024)	(0.026)
reference period (1901-1915)				
1915-1930	0.033***	0.023*	0.029*	0.022
	(0.011)	(0.013)	(0.015)	(0.019)
1930-1945	0.026**	0.021	0.027*	0.025
	(0.012)	(0.013)	(0.015)	(0.016)
1945-1959	0.121***	0.113***	0.129***	0.145***
	(0.025)	(0.032)	(0.040)	(0.049)
Constant	0.576***	0.535**	0.670***	0.644**
	(0.181)	(0.206)	(0.237)	(0.288)
Observations	170	155	140	125
Number of id	5	5	5	5
R-squared	0.989	0.988	0.986	0.983

All models are estimated through the within-group estimator. The dependent variable is $\ln(Y_{it}/P_{it})$ income per capita (GDP per capita series from Baffigi, 2011) for all models. The j index represents the time lag. In column (1) the variables are one year lagged (t-1), in column (2) the time lag is 2 (t-2), in column (3) the lag is 3 (t-3) and in column (4) the time lag is 4 (t-4). Standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1

Table 9. First differences GMM estimator

VARIABLES	(1) j=1	(2) j=2	(3) j=3	(4) j=4
$\ln(Y_{t-1}/P_{t-1})$	0.679***	0.712***	0.704***	0.666***
	(0.039)	(0.051)	(0.074)	(0.081)
$\ln(IND_{it-j}/P_{it-j})$	0.351***	0.280***	0.282***	0.362***
	(0.050)	(0.059)	(0.045)	(0.052)
$\ln(AS_{it-j}/P_{it-j})$	0.056***	0.051***	0.059***	0.048**
	(0.003)	(0.012)	(0.008)	(0.021)
$\ln(SS_{it-j}/P_{it-j})$	-0.013	0.000	0.006	0.039***
	(0.010)	(0.015)	(0.014)	(0.014)
$\ln(HU_{it-j}/P_{it-j})$	0.024	0.017	0.023	-0.009
	(0.028)	(0.028)	(0.031)	(0.020)
$\ln(MS_{it-j}/P_{it-j})$	-0.062**	0.002	-0.026	-0.061***
	(0.026)	(0.025)	(0.028)	(0.023)
$\ln(ONS_{it-j}/P_{it-j})$	-0.026*	-0.038**	-0.010	0.011
	(0.015)	(0.018)	(0.026)	(0.043)
Observations	155	140	125	110
Number of id	5	5	5	5
Sargan test	148.1	134.3	123.9	109.7
Sargan p-value	0.481	0.451	0.337	0.307
Wald p-value	0.000	0.000	0.000	0.000
AR(1)	-2.194	-2.225	-2.200	-2.217
p-value	0.0282	0.0261	0.0278	0.0266
AR(2)	0.319	-1.264	0.0278	1.256
p-value	0.750	0.206	0.978	0.209

The dependent variable is ln(Yit/Pit) income per capita (GDP per capita series from Baffigi, 2011) for all models. The j index represents the time lag. The instruments used in each equation are the levels of the lagged dependent variable and the “academic” variables (for all of these variables only 1 and 2-year lags were included). Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1

Table 10. Within group estimator, Malanima GDP series.

VARIABLES	(1) j=1	(2) j=2	(3) j=3	(4) j=4
$\ln(Y_{t-1}/P_{t-1})$	0.893***	0.900***	0.898***	0.901***
	(0.040)	(0.047)	(0.054)	(0.065)
$\ln(IND_{it-j}/P_{it-j})$	0.094	0.071	0.070	0.072
	(0.064)	(0.068)	(0.075)	(0.083)
$\ln(AS_{it-j}/P_{it-j})$	0.043**	0.028	0.044**	-0.018
	(0.017)	(0.019)	(0.021)	(0.024)
$\ln(SS_{it-j}/P_{it-j})$	-0.008	0.004	0.000	0.029
	(0.017)	(0.017)	(0.018)	(0.019)
$\ln(HU_{it-j}/P_{it-j})$	-0.015	-0.014	0.002	-0.008
	(0.020)	(0.022)	(0.024)	(0.027)
$\ln(MS_{it-j}/P_{it-j})$	0.002	0.019	-0.007	-0.016
	(0.020)	(0.021)	(0.023)	(0.025)
$\ln(ONS_{it-j}/P_{it-j})$	-0.014	-0.015	-0.005	-0.002
	(0.019)	(0.020)	(0.023)	(0.025)
reference period (1901-1915)				
1915-1930	0.011	0.006	0.008	-0.002
	(0.010)	(0.012)	(0.014)	(0.016)
1930-1945	0.023*	0.021	0.022	0.017
	(0.013)	(0.014)	(0.015)	(0.017)
1945-1959	0.077***	0.079***	0.077**	0.090**
	(0.023)	(0.028)	(0.034)	(0.041)
Constant	0.949***	0.919**	1.009**	0.728
	(0.354)	(0.409)	(0.471)	(0.579)
Observations	170	155	140	125
Number of id	5	5	5	5
R-squared	0.990	0.989	0.987	0.984

All models are estimated through the within-group estimator. The dependent variable is $\ln(Y_{it}/P_{it})$ income per capita (GDP per capita series from Daniele, Malanima, 2007) for all models. The j index represents the time lag. In column (1) the variables are one year lagged (t-1), in column (2) the time lag is 2 (t-2), in column (3) the lag is 3 (t-3) and in column (4) the time lag is 4 (t-4). Standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1

Table 11. First differences GMM (Arellano and Bond), Malanima GDP series.

VARIABLES	(1) j=1	(2) j=2	(3) j=3	(4) j=4
$\ln(Y_{t-1}/P_{t-1})$	0.790***	0.830***	0.789***	0.776***
	(0.054)	(0.069)	(0.081)	(0.061)
$\ln(IND_{it-j}/P_{it-j})$	0.262***	0.220**	0.289***	0.389***
	(0.072)	(0.093)	(0.082)	(0.110)
$\ln(AS_{it-j}/P_{it-j})$	0.070***	0.050***	0.077***	0.004
	(0.005)	(0.010)	(0.020)	(0.023)
$\ln(SS_{it-j}/P_{it-j})$	0.013	0.033*	0.032**	0.068***
	(0.010)	(0.019)	(0.014)	(0.016)
$\ln(HU_{it-j}/P_{it-j})$	0.028	-0.008	0.036*	-0.018
	(0.019)	(0.029)	(0.020)	(0.024)
$\ln(MS_{it-j}/P_{it-j})$	-0.052***	0.020	-0.061**	-0.022
	(0.016)	(0.032)	(0.028)	(0.019)
$\ln(ONS_{it-j}/P_{it-j})$	-0.008	-0.004	0.016	0.021
	(0.019)	(0.024)	(0.030)	(0.040)
Observations	155	140	125	110
Number of id	5	5	5	5
Sargan test	121.3	108.1	102.9	92.80
Sargan p-value	0.947	0.945	0.837	0.754
Wald p-value	0.000	0.000	0.000	0.000
AR(1)	-2.214	-2.211	-2.154	-2.218
p-value	0.0268	0.0270	0.0312	0.0266
AR(2)	2.153	2.123	1.774	2.205
p-value	0.0313	0.0337	0.0760	0.0274

The dependent variable is ln(Yit/Pit) income per capita (GDP per capita series from Daniele, Malanima, 2007) for all models. The j index represents the time lag. The instruments used in each equation are the levels of the lagged dependent variable and of the "academic" variables (for all of these variables only 1 and 2-year lags were included). Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1

Table 12 Share of Applied Sciences, GMM first differences.

VARIABLES	(1)	(2)
$\ln(Y_{it-1}/P_{it-1})$	0.664***	0.654***
	(0.034)	(0.038)
$\ln(IND_{it-1}/P_{it-1})$	0.423***	0.510***
	(0.077)	(0.075)
AS_{it-1}/TOT_{it-1}	0.624***	
	(0.122)	
(AS_{it-1}/TOT_{it-1}) *1901-1915		0.263
		(0.257)
(AS_{it-1}/TOT_{it-1}) *1915-1930		0.690***
		(0.158)
(AS_{it-1}/TOT_{it-1})* 1930-1945		0.623***
		(0.151)
(AS_{it-1}/TOT_{it-1})* 1945-1959		1.105**
		(0.447)
Observations	170	170
Number of id	5	5
Sargan test	133.6	131.0
Sargan p-value	0.126	0.118
Wald p-value		
AR(1)	-2.209	-2.202
p-value	0.0271	0.0277
AR(2)	0.276	0.237
p-value	0.783	0.813

The dependent variable is ln(Yit/Pit) income per capita (GDP per capita series from Baffigi 2011) for all models. The instruments used in each equation are the levels of the lagged dependent variable, the share of chemical and engineering chairs over the total number of chairs and the interaction terms (for all of these variables only 1 and 2-year lags were included). Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1