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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 paper elaborates and tests two hypotheses. First, 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 that can be converted into technological knowledge with high levels of fungibility, appropriability, cumulability and complementarity have a higher chance to affect economic growth. Second, that academic chairs are a reliable indicator of the amount and types of knowledge being generated by the academic system. Hence the analysis of the evolution of the academic chairs of an academic system is a promising area of investigation. In this paper the exploration of the evolution of the size and the disciplinary composition of the stock of academic chairs in five Italian macro-regions in the years 1900-1959 provides an opportunity to understand the contribution of scientific knowledge to economic growth in each regional system. The econometric analysis confirms that advances in engineering and chemistry, as proxied by the number of chairs, had much a stronger effect on the regional economic growth than advances in other scientific fields. These results have important implications for research policy, as they highlight the differences in the economic effects of academic disciplines, and for the economics of science, as they support the hypothesis that academic chairs can be used as reliable indicators of on-going research activities in the different types of scientific knowledge.

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.

Because of the idiosyncratic characteristics of knowledge as a good and an economic activity the governance of the generation of scientific knowledge and its utilization and exploitation for economic activities require a specific set of institutional conditions (Arrow, 1969). As Schumpeter (1942) remarked the corporation, introduced in the US in the first part of the XX century, has been the institutional innovation that made possible the innovative governance of the generation of scientific knowledge, its transformation into technological knowledge and its exploitation with the introduction of innovations. The advantage of the corporation lied in the unique combination of internal competence and financial resources that made it possible respectively to select different research projects and fund them internally (Chandler, 2002; Chandler, Hagstrom and Solvell, 1998).

The corporation was able to provide a better set of knowledge governance mechanisms than the knowledge governance mode based upon the academic mode of knowledge generation. The academic mode of knowledge governance, combined with the entrepreneurial exploitation based upon the banking credit provided by the 'innovative banker', was indeed already in place in Europe and in the US since the first wave of industrialization in the XIX century (Schumpeter, 1934). The corporation as an innovative mechanism of knowledge governance diffused in the rest of the world and was widely adopted in Europe only in the second part of the XX century (Chandler, 1962, 1977, 1990).

Since the end of the XX century the open innovation mode of knowledge governance has been replacing the corporation. The open innovation mode is based on the academic generation of scientific knowledge, its transformation by knowledge intensive startups, supported by venture capitalism, and its eventual exploitation by global corporations after take-over on financial markets, de-listing and vertical integration (Chesbrough, 2003). The new open innovation mode of knowledge governance puts the university back to the center stage of the knowledge generation process, yet in a more articulated framework that substitutes the innovative banker with venture capitalism and financial markets and integrates the global corporation as the ultimate player of the exploitation phase.

In this new context, the working of the academic mode of knowledge generation plays, again, a central role. As such it deserves careful analysis and scrutiny not only to assess its internal efficiency, defined in terms of the relationship between the amount of economic resources invested and the actual amount of knowledge being generated, but also in terms of external efficiency, measured in terms of the relationship between the amount of resources invested and the actual effects on the efficiency of the economic system.

If all scientific knowledge were alike internal and external efficiency would coincide. When instead some advances in scientific knowledge can be better exploited (so as to generate technological knowledge and eventually innovations) than others, external and internal efficiency diverge. The conditions of external efficiency and the determinants of the capability of the academic system to allocate the resources, mainly public, invested into more effective mix of types of knowledge, at least from an economic viewpoint, comes under scrutiny. According to our first hypothesis knowledge cannot be any longer regarded as an undifferentiated bundle: there are different types of knowledge according to their levels of fungibility to supporting economic growth.

From this viewpoint the investigation of the external efficiency of the academic mode of knowledge governance before the adoption of the corporation can provide important insight about the actual fungibility of scientific knowledge to economic growth exploring in detail whether all scientific disciplines can contribute it.

The analysis of the relationship between the types of scientific knowledge and the actual amount of local knowledge spillovers able to support the generation of technological knowledge and the eventual introduction of innovations can be implemented with the second key hypothesis that academic chairs can be considered as a reliable proxy of the amount of knowledge generating activities.

Finally we acknowledge the strong local dimension of knowledge dissemination, according to which the benefits stemming from knowledge generated within the academia require dedicated efforts and close interactions with the industrial and entrepreneurial local system in order to be fruitfully transferred. Since the effects of knowledge spillovers are more likely to occur locally in our analysis we will adopt a regional perspective.

In order to test these hypotheses this paper investigates the relationships between the advances of scientific knowledge and economic growth in five Italian macro-regions in the period 1900-1959 exploring the evolution of chairs in the regional academic systems. At that time the corporate mode of knowledge governance had not yet been adopted by the Italian economic system. In this context 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 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 rest of the paper is structured as it follows. Section 2 elaborates, with the tools of the economics of knowledge, the two hypotheses that: i) 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 and ii) chairs can be used as a reliable indicator of the different types of knowledge being generated by the academic system. Section 3 presents the empirical evidence based upon the construction of an original database of all the chairs in service in five Italian macro-regions in the years 1900-1959, distinguished by 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

Recent advances in the economics of knowledge make it possible to grasp that knowledge cannot any longer be regarded as a homogenous bundle of activities. Knowledge instead is highly heterogeneous from many different viewpoints as it exhibits different levels of non-appropriability, cumulability, complementarity and fungibility into technological knowledge and ultimately in innovations. With specific respect to this latter point it is more and more evident that not all the advances of scientific knowledge can be converted into technological knowledge and eventually in innovations at the same conditions.

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.

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).

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).

Here the historic evidence and the fine-grained analysis of the scientific base of the main technological innovations introduced in a given country in a given time provide useful information. Large case study evidence allows to appreciating the centrality of engineering and chemical sciences in Italy especially through the XX century. A large majority of the key innovations introduced in Italy in the first part of the XX century relied upon advances in scientific knowledge generated in engineering (Amatori, 2011; Amatori and Colli, 2003)[2].

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.

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 well 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 analysis of the working of the academic system enables to articulate the second hypothesis of this paper. According to the new economics of knowledge the provision of public subsidies to the academic system is actually a governance tool implemented to contrast the undersupply of knowledge engendered by its idiosyncratic characteristics (Arrow, 1969; Geuna, 1999). In this approach 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 nothing else but 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. The levies paid to the state by the business sector are compensated by the knowledge spillover made available by means of publications and

[2] A major clue about the differentiated role of the scientific disciplines with respect to economic growth in Italy is provided by the BDIE (Biographical Dictionary of Italian Entrepreneurs), a large project launched in 2001 by Enciclopedia Italiana and coordinated by members of the Economic History Institute at Bocconi University (Amatori, 2011). 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. The BDIE 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. 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 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.

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, Salter, Steinmueller, 2003)

The university becomes a triangular mechanism that integrates and in extreme cases substitutes the missing markets for knowledge. In this context, and especially at a time when no research and development activities –typical of the corporate mode of knowledge governance- were yet conducted, the number of academic chairs in a system, their evolution through time and their changing distribution across disciplines can and should be considered 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).

Even after the diffusion of the corporate mode of knowledge governance, and especially to-day along with the diffusion of the open innovation, the use of academic chairs as a reliable indicator 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.

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).

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.

Different ideas and different academic fields are most likely to affect the levels of economic output and economic efficiency at different times and with different time lags between their generation and their application. For the time being we miss all information about the lag with which academic knowledge is likely to affect the levels of economic activity within a region. Our own emphasis upon the differences among academic fields stresses the importance of this variance and has strong implications on the methodological strategy of the empirical analysis pushing to focus the econometric estimates on the long-run effects of the different chairs on income per capita.

Finally, from a methodological perspective, it must be stressed that, as the literature on the linkages between university and industry has highlighted, (Jaffe, 1989; Anselin, Varga and Acs, 1996; Mansfield and Lee, 1996; D'Este, Iammarino, 2010) knowledge spilling from academic chairs is not sufficient to impact economic growth. Dedicated activities and systematic interactions, often based upon personal relations, are necessary in order to actually transfer fungible scientific knowledge into applied technological knowledge and eventually innovate. The fruitful transmission of scientific knowledge outside academia, i.e. the level of external efficiency, is likely to have a strong local content, since personal interactions and actual collaborations between academics and economic actors are often a necessary condition for the transmission of knowledge. In this perspective the Italian historical example confirms such patterns and the anecdotal evidence provided by the Biographical Dictionary of Italian Entrepreneurs (BDIE) highlights the importance of the systematic relations between professors (especially in the faculties of engineering) with former students and potential entrepreneurs searching for advice and support. These features of the mechanism of scientific knowledge transfer imply the need to adopt a local (or regional) perspective when analyzing the external efficiency of an academic system. Indeed the spillovers proceeding from the academia will have a strongly localized economic effect, which is better captured by analyses that appreciate the local perspective.

3. THE EMPIRICAL EVIDENCE

3.1. THE DATA

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 and we have subsequently aggregated the chairs in five macro-fields according to their levels of fungibility to economic growth. The choice of this specific time period is due first of all to the fact that in this period knowledge governance in Italy was fully based upon the academic mode of knowledge governance, since the corporate model started its diffusion only in the second part of the century. The first half of the XX century is hence a perfect historical example of an academic mode of knowledge governance. Moreover only in this period the Italian university system reached a sufficient level of development, in terms of number of chairs and of establishment of clear scientific fields, in order to allow a quantitative analysis of its effects on the economic system.

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, with some gaps in correspondence of the two World Wars. 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). At the beginning of the XX century some of the Italian regions did not have any university inside their territory, some of them had very few specialized schools and only in the following years these institutions would expand and become real universities.[4] Therefore, in order to have a sufficient number of chairs for each discipline in each region, we chose to aggregate all the chairs, distinguished by disciplinary field, in 5 macro-regions: in this way we were able to build a balanced panel with complete time series and a sufficient number of chairs in each observation.

The choice on the specific macro-regions was motivated on economic and historical grounds. 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, 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:

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). [5]

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[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] Another problem with the use of individual regions as the unit of analysis was due to the fact that some regions like Trentino Alto-Adige and Friuli Venezia Giulia only became part of the Italian territory after the First World War, hence during the time span that we chose for our analysis.

[5] Although Sardinia was a peripheral part of the Savoy Kingdom, it was never part of the Papal States, hence we believe that the aggregation in these five macro-regions provides a set of quite homogeneous sub-systems.

Through this process 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 the Figures (1 to 5) we report the time series of the number of chairs for each discipline in the five macro-regions.

Our aim is to track both the evolution of the university across the macro-regions and that of the Italian regional economic systems: in particular we are interested in the overall process of economic growth at the regional level. The most recent and reliable data available on this topic is provided by Daniele and Malanima (2007, 2011), who computed the regional differentials in income per capita 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, and combining these data with those related with the sectoral distribution of the regional labour force.[6]

In order to obtain 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 their reconstructed time-series of Italian GDP per capita in constant terms (for the details see the Appendix A).

In order to test the differentiated impact of different types of academic knowledge on the Italian regional economic systems, 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 the regional level would provide the typical control for the increased capitalistic intensity of the economic activities: however these measures are available for the Italian regions only from 1951 onwards.[7] Therefore we decided to use the data provided by ISTAT and aggregated by Daniele and Malanima (2012) on the total number of persons employed in the manufacturing sector as a proxy of the process of industrialization of each macro-region. 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 allows 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. Hence we shall use the share of employees in the manufacturing sector on total employment, as a proxy for the missing data on capital intensity.

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, since in those years the yearbooks from the Italian Ministry of Education do not provide data on the number of academic chairs.[8] Indeed the years corresponding to the two World Wars present problematic issues: on one hand the economic data display great discontinuities with respect to the prior and following years and hence, as typical outliers, do not tell us much about the long run relationship between academic and economic variables. On the other hand the academic activity during the years of war was quite

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[6] The levels of GDP per worker, that is of labour productivity, are not available for this period of time at the regional level, nor through the National Statistical Office (ISTAT), nor through other sources; see also Maddison (1991), Malanima and Zamagni (2010), Fenoaltea (2005). The data related with the sectoral composition of the labour force are provided by ISTAT and recently collected by Daniele and Malanima (2011)

[7] See Paci and Saba (1997)

limited (sometimes null), so that even if data on university chairs were available, these would be imprecise and not very reliable. Therefore our dataset does not include all the years corresponding to the two World Wars and the immediate post-war periods, which means that we have two periods of missing data for the years 1914-1921 and for the time-span 1940-1953.[9] Our database hence consists of 37 years of observations for each macro-region and hence 185 observations overall.

3.2 THE LONG TERM EVIDENCE ACROSS DISCIPLINES AND REGIONS

The evolution of the chairs of each discipline in the different macro-regions –see Table (1) and Figures from (1) to (6) – allows to appreciate the heterogeneous paths through which the regional university systems have developed across time. Indeed in the first half of the XX century the Italian university system was far from homogenous and every macro-region held a idiosyncratic specialization in some disciplines, proceeding from the inheritance of its pre-unitary history. During the first 50 years of the century the university underwent a gradual process of renovation which also had to do with the contemporary industrialization of the country: however also in this case the regional paths were not uniform across the years and only in the 50's a generalized homogenization of the university policy at the country level took place. In what follows we will present some stylized facts for each single macro-regional academic system.

Piedmont and Liguria

At the beginning of the century the macro-region of Piedmont and Liguria, with the universities of Turin and Genoa, already displayed a high number of chairs per inhabitant (only the Central Regions had a higher ratio) and specifically it exhibited a strong specialization in Applied Sciences.[10] Across the years this specialization was confirmed through the constant increase of the size of the Politecnico of Turin and the birth of the Faculty of Engineering in Genoa in 1936. During the 20's instead the birth of the business schools of Turin and Genoa led also to the growth of chairs in Social Sciences, mainly in Business and Economics. The academic specialization in Applied Sciences paralleled the contemporary high rate of industrialization that involved the region all through these years.

Lombardy

In 1901 in Lombardia the university was present in Milan and Pavia, with a high share of chairs in Chemistry and Engineering, due to the existence of the Royal Technical Institute in Milan. However across the years the region will also display a strong specialization in Social Sciences – and especially in economics and business– testified by the birth of the Bocconi Business School already in 1902. The region experienced one of the highest generalized increase of chairs across the years, due also to the birth of the new Cattolica University in Milan in 1921. Also in this region the

[9] More precisely we have missing data on academic chairs for the period 1916-1921 and for the period 1944-1953. Furthermore in order to consistently exclude the war periods from our analysis we decided to additionally drop from our database all the years belonging to the period of the two World Wars for which we had data on the number of chairs (i.e. the years 1914, 1915, 1940, 1941, 1942 and 1943), since in those years the levels of income per capita in each region had already started a steep decline due to the war.

[10] The chairs in Engineering and Chemistry belonged mainly to the "Scuola d'Applicazione per gli Ingegneri" (Royal Training School for Engineers) in Turin.

importance and size of the Politecnico paralleled the great industrial development occurred in the first half of the XX century.

The North East

In 1901 the North Eastern regions were those with the lowest density of chairs per inhabitant (about half of that of Piedmont): indeed Padua was the only existing university in the macro-region. At the same time also the level of industrialization was quite lower than in the other northern regions. In the following years, and especially during the fascist period, the region will increase the number of chairs in Social and Applied Sciences, through, respectively the birth of the new Institutes for Economic and Business studies in Trieste and Venice and the birth of the Royal University Institute of Architecture in Venice in 1933.[11] Finally during the 50's the North East experienced a generalized increase of the number of chairs, which involved specifically Other Natural Sciences, Humanities and Applied Sciences.

The Central Regions

The long academic tradition of these regions was well described at the beginning of the century by the high number of universities, with one university every 900 thousand inhabitants (in the North East in 1901 there was one university every 4 million people).[12] The specialization of the local universities in the Central Regions was mainly focused on Medical and Social Sciences (consisting mainly in chairs in law). This specialization remained quite constant across the years, along with a level of industrialization that did not increase steadily, and the growth of chairs in Applied Sciences and Economics occurred quite late, during the 30's.[13] Conversely during the 50's the growth of chairs involved all disciplines and increased the overall number of chairs per capita.

The Southern Regions

In the first years of the century also the Southern Regions displayed a specialization mainly centered on Medical Sciences and Law. The increase in size of the Royal Schools for Engineers in Palermo and Naples in the years 1901-1915 partially shifted the academic specialization towards Applied Sciences, however this change was not paralleled by a contemporary increase of industrial development. After the first world conflict the general number of chairs per capita decreased considerably and only at the end of the 20's the overall number of chairs in these regions reached the pre-war levels, without any significant difference in the distribution of the chairs across disciplines. Only during the 30's the regions experienced a substantial increase of the number of chairs in Social Sciences, due to the birth of the business schools in Bari, Catania and Naples.

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[11] The new Institutes for Economic and Business studies in Trieste ("Università degli Studi Economici e Commerciali") and in Venice ("Istituto Superiore di Scienze Economiche e Commerciali") were both established in 1930, they specialized in business studies. The growth of the number of chairs in Applied Sciences instead was due to the birth of the Royal University Institute of Architecture ("Reale Istituto Universitario di Architettura") in Venice in 1933 and to the inclusion of the Faculty of Engineering within the University of Padua in 1936.

[12] Twelve 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.

[13] At the end of the 20's the establishment of the Institutes for Agrarian Studies in Bologna, Firenze, Perugia and Pisa instead increased the share of chairs in Applied and Other Natural Sciences. In the 30's the birth of new business schools in Roma, Florence and Bologna allowed the increase of the chairs in social sciences also in these regions.

Finally after the Second World War, and in line with the other Italian regions, a generalized increase of the number of chairs per inhabitant occurred, involving all disciplines.

3.3. THE ECONOMETRIC ANALYSIS

In order to test our hypothesis on the different role of the academic disciplines in their contribution to economic growth in the different Italian regions we choose to adopt a very simple and basic framework, where a production function at the regional level is estimated and the output elasticities of each of the disciplines are computed, so as to provide a proxy of their contribution to economic growth. We adopt a Cobb-Douglas specification that allows to consider the different inputs as partially (but not perfectly) substitutable:

$$Y_{it} = A_{it} K_{it}^{\alpha} L_{it}^{\beta} AS_{it}^{\gamma_1} SS_{it}^{\gamma_2} ONS_{it}^{\gamma_3} HU_{it}^{\gamma_4} MS_{it}^{\gamma_5} \qquad (1)$$

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

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 $\gamma_1 > \gamma_2 = \gamma_3 = \gamma_4 = \gamma_5 = \gamma_6$. In order to estimate equation (1) we take logs and divide both sides by L, transforming it in labour intensities and we decompose A_{it} into a region specific fixed effect a_i and a common time effect b_t:

$$\ln\frac{Y_{it}}{L_{it}} = a_i + b_t + \alpha \ln\left(\frac{K_{it}}{L_{it}}\right) + \gamma_1 \ln\left(\frac{AS_{it}}{L_{it}}\right) + \gamma_2 \ln\left(\frac{SS_{it}}{L_{it}}\right) + \gamma_3 \ln\left(\frac{ONS_{it}}{L_{it}}\right)$$
$$+ \gamma_4 \ln\left(\frac{HU_{it}}{L_{it}}\right) + \gamma_5 \ln\left(\frac{MS_{it}}{L_{it}}\right) \qquad (2)$$

However, as explained in the data section, the capital stocks at the regional level are not available for the time period we are interested in. Furthermore the data by Daniele and Malanima (2011) do not provide us with the levels of labour productivity, but rather with income per capita. Therefore the equation that we can actually estimate is the following:

$$\ln\frac{Y_{it}}{P_{it}} = a_i + b_t + \beta\ln\left(\frac{IND_{it}}{P_{it}}\right) + \gamma_1\ln\left(\frac{AS_{it}}{P_{it}}\right) + \gamma_2\ln\left(\frac{SS_{it}}{P_{it}}\right) + \gamma_3\ln\left(\frac{HU_{it}}{P_{it}}\right) + \gamma_4\ln\left(\frac{MS_{it}}{P_{it}}\right) + \gamma_5\ln\left(\frac{ONS_{it}}{P_{it}}\right) + \varepsilon_{it} \quad (3)$$

Where P_{it} denotes the population in each macro-region in each year. We hence compute our production function substituting employment levels with population levels. Also the academic variables are computed as number of chairs per capita. IND_{it} , instead, stands for the number of employees in the manufacturing sector in each region: since we do not have the regional capital stocks we chose to proxy it with the share of population active in the industry, assuming that a higher number of persons employed in the manufacturing sector also corresponds to a higher level of invested capital. Besides the region and time fixed effects (respectively a_i and b_t), ε_{it} indicates region-specific idiosyncratic shocks. In Table (2) the descriptive statistics of the variables are presented.

INSERT TABLE 2 ABOUT HERE

The estimation of equation (3) presents a number of econometric issues that need to be addressed in order to provide reliable results. The time series of income per capita, as well as those of the share of employment in the industry and the number of chairs per capita are very likely to be strongly persistent along time and hence violate one of the assumptions of many panel-data estimators, i.e. the assumption of stationarity of the variables. Moreover the limited number of observations of the database does not allow to exploiting many of the advantages provided by a large cross-sectional dimension. We hence cannot use the family of GMM-based estimators developed specifically for panel data with large N and small T (Arellano, Bond, 1991; Blundell, Bond, 1998).

Another important issue is related with the fact that, as already noted, we don't exactly know the lag with which knowledge produced in the academia will affect the overall level of economic activity within a region. It is likely that ideas and competences produced in the academia will spill into the regional economic system with very heterogeneous lags and hence it might be not useful to investigate the effect only on some specific lags, because we might be catching only some effects and disregarding some others. We hence prefer to obtain an estimate of the long-run effect of the different chairs on income per capita, rather than a (possibly) mis-measured short-run effect.

Finally we are worried about the possible endogeneity of our main variables of interest, i.e. the academic chairs. More specifically we expect that the regional level of income per capita will depend by a great number of factors (increase of public expenditure, fiscal shocks, lowering of tariff barriers, specific industrial policies) that we cannot control for, since the data at the regional level about these variables are lacking. 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.

All of these issues suggest us that panel cointegration techniques should be the ideal solution for the estimation of equation (3). This choice allows to exploit the temporal dimension of our dataset, it accounts for the non-stationarity of our variables, it provides us with a measure of the long-run effects of the independent variables on income per capita and, as we will show, it also allows to account for the possible endogeneity problems.

If a cointegrating relationship is confirmed by the usual tests implemented in the literature (see Appendix C), then the final step consists in the estimation of the long run effect of the explanatory variables in equation (3) on regional income per capita. In this respect Kao and Chen (1995) have shown that panel ordinary least squares (OLS) may result in a biased and non-normal distribution of the residuals, a problem that may be further amplified by the dynamic heterogeneity of the panel setting. Therefore in the related literature two of the most common alternatives are the fully modified OLS (FMOLS) proposed by Pedroni (2000) and the within dimension panel dynamic ordinary squares (DOLS) estimator, presented by Kao and Chiang (2000). Relying on Monte Carlo evidence Kao and Chiang (2000) have shown that both the OLS and the FMOLS may display a non-negligible bias in finite samples, a problem that instead does not affect the DOLS estimator. Since our sample is quite small, consisting of a limited number of individuals (the macro-regions), we are worried about the possibility of small sample bias and we hence choose to use the DOLS estimator. A further advantage of this estimator is that it is asymptotically unbiased and normally distributed, also in the presence of endogenous regressors (Stock and Watson, 1993) and it is robust to the omission of variables that do not form part of the cointegrating relationship.

The DOLS estimator is based on the decomposition of the error term ε_{it} of equation (3) into the following components:

$$\varepsilon_{it} = \sum_{j=-\infty}^{\infty} \varphi_j \Delta X_{it-j} + u_{it} \tag{4}$$

where ΔX_{it} includes the first-differences of the set of the non-stationary I(1) explanatory variables and u_{it} is an error term that must be orthogonal to all leads and lags of ΔX_{it}. In practice, the infinite sums of leads and lags of the first differences will be truncated at some small numbers due to the finite sample properties of the dataset (see Breitung and Pesaran, 2008). This procedure corrects for the possible endogeneity of the regressors. Following this decomposition of the error term, the final specification of our model, in which we indicate as *y* the dependent variable and as *X* the set of independent variables of the model, will be:

$$y_{it} = c_i + b_t + X_{it}^{'}\beta + \sum_{j=-k}^{k} \varphi_j \Delta X_{it-j} + u_{it} \tag{5}$$

The dependent variable in equation (5) is the log of regional income per capita (i.e. $\ln(Y_{it}/P_{it})$). X is the set of explanatory variables including the number of chairs per capita in each different discipline and the share of population employed in the secondary sector, region fixed effects are denoted by c_i, b_t accounts for common time trends and u_i indicates idiosyncratic white noise errors.

3.4 THE RESULTS

Since the preliminary tests displayed in Appendix B confirm that our variables of interest are integrated of order one and that there is a cointegrating relationship among them, in Table (3) we present the results of the DOLS estimation procedure. A first step of the estimation consists in the choice of the proper number of lags and leads included in the regression. A possible problem related with this choice is that the use of different lags can sometimes produce quite heterogeneous results. In our case it must be stressed that since our dataset is quite small including too many lags would result in a substantial loss of observations available for the estimation. We hence decide to start with a parsimonious specification with only one lead and one lag and to subsequently add more of them.

INSERT TABLE 3 ABOUT HERE

In the first column of Table (3) are presented the results obtained with the within dimension DOLS estimator with one lead and one lag: the results show a large positive and significant coefficient for the share of workers employed in the manufacturing sector, a negative and significant sign for the coefficient of chairs per capita in humanities (HU) and social sciences (SS) and a positive and significant sign for the number of chairs per capita in applied sciences (AS). These results provide a first confirmation about our hypothesis concerning the role of the faculties of chemistry and engineering in the overall economic development of Italian regions. Given the great importance of the process of increasing industrialization occurring in Italy in the first half of the XX century, it seems also natural to find a positive coefficient for the share of workers in the industry. Finally as for the social sciences we suspect that their negative sign depends strongly on the impossibility to distinguish between management/ business chairs and law chairs.

As a further check of the robustness of our findings we present in the second column of Table (3) the results obtained through the inclusion of two lags and two leads: as it is evident this choice substantially decreases the number of observation used in the estimation. However the results basically confirm our first findings, with larger coefficients for the applied sciences (AS), while the only relevant difference consists in a greater standard error for the chairs in humanities (HU) whose coefficient remains negative but not significant anymore.

Even if the issue of heterogeneity should not be a big problem in our estimation, since the individuals are regions belonging to the same region which should present quite similar characteristics in terms of institutional settings, we still want to try and check whether allowing for the possible heterogeneity of the slope coefficients would change considerably our results. We hence use the between-dimension, group-mean panel DOLS estimator suggested by Pedroni

(2001).[14] The results in column (3) of Table (3) show that only the coefficient of applied sciences and that of the share of people employed in the industry are still significant, thus providing a strong confirmation that the long-run relationship between these two variables and the level of income per capita is robust.

3.5. ROBUSTNESS CHECKS

The results from Table (3) show that there is a strong positive relationship between the levels of chairs in applied sciences per capita and the levels of income per capita. However we know that two possible shortcomings of our methodology are related respectively with the problem of the measurement of capital in the regional production function, due to the lack of regional data on investments, and with the possible endogeneity problems due to omitted variables. These two problems could affect our estimates since also the tangible investments that we cannot control for with the share of population employed in the industry might enter as omitted variables. We know that the DOLS estimator is robust to the omission of variables that are not included in the cointegrating relationship: however there might be omitted variables that actually enter the cointegrating relationship and whose omission could lead to biased results. As we said before we are worried about possible factors that are contemporaneously correlated both with the regional level of income per capita and with the number of chairs in a specific region.[15] One of these variable is public expenditure: an increase in public expenditure within a region might increase both the level of income per capita and the number of chairs in some or in all the discipline we identified. Indeed it is likely that an increase in public spending would affect the general level of expenditures in public administration, and university is to be considered as an important part of it.

Since expenditures in public administration at the regional level for those years are not available we include in our specification the overall level of expenditures in public works between 1901 and 1959 in each of the 5 macro-regions (see Appendix A for a detailed description of these data): this measure should provide a proxy of the expenditures and investments made by the Italian central state in each of the region, particularly it will give us a measure of the volatile propensity of the state to expand public expenditure, adding a regional perspective. We then create a new variable consisting of the ratio of the expenditures in public works per capita in each macro-region.

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[14] The group-mean panel DOLS consists in estimating separate DOLS regressions for each of the regions of the dataset and then simply averaging the long-run coefficients as follows: $\hat{b} = N^{-1}\sum_{n}\hat{b}_i$. The t statistic for the average consists of the sum of the individual t statistics divided by the root of the number of cross-sectional units as follows: $t_{\hat{b}} = \sum_{n} t_{\hat{b}_i} \Big/ \sqrt{N}$

[15] Among the possible control variables it would be useful to include in our specification also the private-firm R&D expenditures: however besides the impossibility to find any source of data concerning R&D for the time period considered, it must be stressed that the paper insists precisely on the fact that R&D expenditures are a typical feature of the corporate model of knowledge, that was yet to come in Italy in the first half of the XX century. Hence it is likely that the private investments in technology by private firms in these years do not constitute a relevant omitted variable that could possibly affect our estimates

In Appendix B – see Table (3B) – we check whether a cointegrating relationship exists between the variables introduced in equation (3) with the further inclusion of public expenditures. The results of Kao (1999) and Pedroni (1999) tests show, also in this case, that a cointegrating relationship exists and hence we proceed to the inclusion of public expenditures in the DOLS estimating procedure.

In Table (4) we present the results: the coefficient of public expenditure is, as expected, positive and significant, but what matters the most is how its inclusion affects the other variables. The coefficient of the chairs in humanities and social sciences loses its significance, while that of applied sciences and of the share of person employed in the industry remains large and significant. These results are also robust to the inclusion of one or two lags and leads and basically confirm and provide further robustness to our preliminary findings about the importance of applied sciences in the development of Italian economy.

INSERT TABLE 4 ABOUT HERE

3.6. THE ROLE OF APPLIED SCIENCES

On the basis of the results so far obtained we will test one final specification of equation (3), 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 income per capita in each macro-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 (3) into the following:

$$\ln\frac{Y_{it}}{P_{it}} = c_i + b_t + \alpha\ln\frac{IND_{it}}{P_{it}} + \beta\ln\frac{AS_{it}}{TC_{it}} + \sum_{j=-k}^{k}\varphi_j\Delta\ln\frac{IND_{it-j}}{P_{it-j}} + \sum_{j=-k}^{k}\varphi_j\Delta\ln\frac{AS_{it-j}}{TC_{it-j}} + u_{it} \qquad (6)$$

Where TC denotes the total number of university chairs in each macro-region and in each year. Table (5) presents the results of this estimation, obtained as usual through the DOLS estimator with one and two lags and leads: 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. Also the number of person employed in the manufacturing sectors is positive and significant as in the previous specifications. Finally we check whether the inclusion of the level of public expenditures per capita substantially changes this long-run relationship. However the results in column (3) show that the coefficients are robust also to the inclusion of this further variable.

INSERT TABLE 5 ABOUT HERE

4. CONCLUSIONS

The paper has elaborated and tested two hypotheses. First, that academic chairs can be used as a reliable indicator of the amount and types of knowledge being generated by the academic system. Second, 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 that can be converted into technological knowledge with high levels of fungibility, appropriability, cumulability 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. The results of the case-study evidence, available in the literature, has been confirmed and generalized with the systematic exploration of the growth of the regional Italian academic systems and the investigation of its relationship with economic growth.

An original regional 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 paper implements a panel cointegration econometric approach not only because of the particular features of the data base, but also and primarily because of the lack of reliable information on the lag with which knowledge produced in the academia affects the overall level of economic activity within a region. Very little is known about the dissemination lags of academic knowledge and even less about the difference among the different types of academic knowledge that have been analyzed. Moreover, due to the well documented localized nature of the spillovers from academic sources, the panel regional perspective seems a well suited level of analysis for a detailed investigation of such effects. The cointegration approach has made it possible to provide convincing evidence on the strong differences in the long run dynamic relationship between the different types of chairs and income per capita.

The econometric evidence confirms that growth of income per capita, across the main regional components of the Italian economic system, has significantly paralleled the evolution of chairs in chemistry and engineering. The dynamics of chairs in the other academic disciplines did not exhibit any significant dynamic association with the growth of Italian regions.

These results are important for many reasons. First they confirm that knowledge cannot be any longer regarded as a homogeneous bundle. Knowledge is highly differentiated as it comprises different types of knowledge with respect to its levels of appropriability, cumulability, complementarity, exhaustibility and economic fungibility.

High levels of fungibility of scientific 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. Advances in scientific knowledge are a necessary but not sufficient condition for economic growth. 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.

Advances in scientific knowledge do deserve the support of the society for arguments that are not taken into account in this study, however, as far as public support for the university is advocated on the basis of its positive effect on economic growth, it is clear that in Italy in the first part of the XX century only academic fields with high levels of exploitability such as engineering and chemistry did generate major knowledge externalities that could be converted and transformed into technological knowledge with strong and positive effects on 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.

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 results of the analysis of the evolution of the academic chairs of an academic system and of their economic effects confirm that the exploration of the evolution of the size and the disciplinary composition of the stock of academic provided useful insights on the contribution of the different types of scientific knowledge to economic growth. As soon as knowledge is finally appreciated as a highly heterogeneous bundle of activities, the cliometrics of academic chairs can become a fertile field of empirical investigation that can yield new important opportunities for empirical research to better explore the complex questions underlying the relationship between the different scientific disciplines and economic growth. 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 types of scientific knowledge, generated by the academic system, and growth.

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