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The new economics of the university: a knowledge governance approach

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Abstract University is becoming a cornerstone of the new emerging mode of governance of the generation and dissemination of knowledge as it reveals remarkable institutional advantages both in providing a solution to the knowledge trade-off and in reducing agency costs. The typical academic labor relationship emerges as an appropriate institutional device to handle the principal-agent problems when creative talents are required. The unique quasi-hierarchical setup of the academic system creates a supply of certified skills that are ready to operate on a professional basis. Such academic consultants can be paid on an ex-post per job basis matching only their variable costs. This supply leads to the creation of a specific market for research services where the demand is provided by the knowledge outsourcing of corporations. For this system to work effectively the non-exclusivity of intellectual property rights on the results of the research performed under contract is necessary. Non-exclusivity in academic employment relations should parallel non-exclusivity in knowledge ownership.

Keywords Economics of information · Economics of knowledge · Knowledge governance · Principal-agent · University · Markets for knowledge

JEL Classification O33

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1 Introduction

The organization of the production of knowledge in advanced economic systems is facing a rapid shift away from the corporate model established in the second part of the XX century in the US towards a new distributed model (Zeitlin and Herrigel 1999; Etzkowitz and Leydesdorf 2000; Etzkowitz 1998). The old model was based upon the pivotal role of the large corporation and was articulated around the key role of direct public subsidies to firms investing in research and development activities, strong public demand for goods and services incorporating high levels of knowledge intensive products and the complementary role of the academic system supported by public funding. In the new model, which is still emerging, the generation of knowledge is the result of enhanced social interactions. Transactions in the new markets for knowledge are complemented by technology sharing among firms within research consortia and technological platforms and the new venture capitalism with the emergence of new surrogate markets for knowledge intensive property rights that is the result of the merging of financial markets and the markets for knowledge (Antonelli and Teubal 2007). Corporations are performing a declining role in the performance of research and development activities while they remain active in funding the generation of new knowledge and its eventual purchase often in the form of mergers and acquisitions of new innovative small firms and research contracts assigned to the academic system. Small firms play a much bigger role in the process (Chesbrough 2003; Chesbrough et al. 2006). In this new model the academic system plays a new pivotal role. Etzkowitz (2002) proposes the successful metaphor of a triple helix where government, universities and firms are the three elements of a dynamic process of interaction and interdependence.

The academic system is emerging as a key player in the new model as it appears to be an institution, which is more adept at managing creative talents. Specifically, the university is now regarded as an institution, which has elaborated a form of quasi-hierarchical coordination based upon a set of rules and routines, articulated in a unique mix of incentives, and contracts characterized by non-exclusivity in the terms of employment that are especially efficient in the organization of the generation and dissemination of knowledge as an economic process. Such an assessment is the result of a closer analysis of the role of the academic system as an institutional device that favors the management of creative talents from a principal-agent viewpoint.

The new academic system can be regarded as a form of intermediate governance mechanism that has gradually emerged through the centuries with specific characteristics that, if properly identified and implemented, facilitate the coordination, within a quasi-hierarchy, of some levels of division of labor and exchange. So far the academic system seems to have been able to fill the wide gulf between the two extreme cases of the State, as the single provider of knowledge as a public good, and the Corporation, as the appropriate institution for the provision of knowledge as a quasi-proprietary good.

Here the characteristics of knowledge matter and applying the basic tools of information economics provides major opportunities to grasp the rationale of knowledge governance mechanisms. In this context, applying the tools of information economics to understanding the economics of knowledge and the workings of the economic institutions in the knowledge economy make it possible to explore new facets of the reasons for the increasing role of the academic system as a viable institution (Stiglitz 2000, 2002).

2 From open science to the academic management of creativity

University is a long-established institution. Since its origins, in Bologna in 1088, it has been able to survive and change, adding new facets and new aspects. The shifting identity of the academic system is the result of a process of introducing sequential and incremental steps when, at each point in time, the pressure of new forces pushed the institution to adapt to the changing context in an effort to reduce discontinuities. In so doing continuity and innovation coexist (David 2004a, b).

The University's new emerging role as a cornerstone of the new organization of the production and dissemination of knowledge leads us to try to understand the reasons for such an extraordinary story of success and adaptation from an economic viewpoint. It is, in fact, generally agreed that the academic system is an effective institution for the governance of the generation and dissemination of new knowledge, characterized by high levels of tacitness. Scientific knowledge, even when it is highly codified, has high levels of tacitness and high levels of competence need to be generated, transmitted and communicated. It is possible to find many different reasons to explain why the academic system is an effective institution. Different interpretative frameworks seem useful both to understand its vitality and to guide its evolution (Geuna 1999).

The work of Dasgupta and David (1987, 1994) has long been regarded as the most comprehensive analysis of the economic foundations of the academic system. Daguspta and David, in fact, have shown that the academic system provides a viable institutional set-up to combine the incentives to the dissemination and the generation of new knowledge. Universities facilitate the workings of open science, that is to say, the peculiar combination of incentives necessary to generate new knowledge and also to disseminate it into the economic system.

In their study, Dasgupta and David have provided a clue to the economic analysis of such a peculiar institution where knowledge-producers have a clear set of incentives to generate new knowledge and yet to give up their rights over it, via its rapid dissemination by means of publication. The open science mechanism works when an academic institution provides the necessary monetary and hierarchical rewards to scientists, according to their qualification and their reputation. A scientist's reputation is built upon publications scrutinized by peers. In open science, the production and dissemination of new knowledge signals a scientist's level of competence and skills and hence the need to make public new knowledge. However, the pursuit to publish is at the same time, an incentive because of its effects in terms of reputation and hence ultimately inclusion in the academic system. Such a mechanism works properly as long as the costs borne by the system to fund the academic system are offset by the externalities generated by the academic system. Here both the amount of knowledge actually produced and the part of it, which is effectively communicated to the rest of the system, matter. If the levels of knowledge generation are high but the levels of effective knowledge communication are low, the amount of costs borne by the economic system can become higher than the return.

Dasgupta and David's analysis is based on the Arrovian tradition of analysis of the economics of knowledge and specifically it can be regarded as an insightful elaboration of the well-known knowledge trade-off. Along the lines of the Arrovian approach in fact, knowledge, is regarded as an economic good that has many limitations and drawbacks, namely non-appropriability, non-divisibility, and non-rivalry in use (Arrow 1962, 1969). Moreover, knowledge is at the same time an output of a specific activity and yet an input, not only in the production of other goods, but also and mainly in the production of further knowledge. Hence, the knowledge trade-off between the incentives to increase

appropriability takes place. There is an appropriate stream of economic benefits for inventors, and the contrasting need to increase access to existing knowledge so as to facilitate its use in the production of new knowledge. Working within this analytical context, Dasgupta and David have made it possible to understand the original and innovative combination of incentives that can be found in the open science system. The academic system enables us to find a solution to the knowledge trade-off. It works, however, if and only if: (a) the provision of public funds makes it possible to secure a reward for the inventor, after publication—giving up the right over it—with tenure and an appropriate salary, and (b) scientific publication is an effective medium for knowledge communication.

Figure 1 provides a schematic account of the interpretative rationale elaborated by Dasgupta and David (D-D). The system is based upon a triangle where the insertion of the State makes the indirect relationship between the demand and the supply of knowledge possible. It is a relationship which the knowledge trade-off impedes. The business system accepts that it has to pay some taxes that are transferred by the State to the academic system. The latter in turn manages the open science system providing incentives for the generation and eventual dissemination of knowledge by means of chairs assigned to creative scientists. The creativity of scientists is measured by their publications. Tenured scientists are expected to teach and publish at the same time: in so doing they create and disseminate new knowledge.

The interpretative approach elaborated by Dasgupta and David highlights the facets of academia that were most consistent and coherent with the organization of the generation of knowledge in the corporate age. The changing organization of the production of knowledge has called increasing attention upon a number of limitations of this model. In so doing it has pushed towards the exploration of other facets of the academic institution and more careful examination of a number of aspects that Dasgupta and David had not considered, as they were less relevant in the corporate age.

The debate has clustered upon two main points: (a) the actual conditions for technology transfer to take place, and (b) the poor allocation mechanisms of the academic system. Let us consider them in turn.

The actual dissemination of the knowledge generated by academic institutions and hence the effective levels of knowledge externalities depend upon the levels of communication within the economic system. Knowledge communication depends upon the strength of the emission from the academic side and the levels of receptivity of the business system. In the corporate age the receptivity of large firms was very high for a variety of reasons. Corporations operated 'intramuros' large research and development laboratories where high quality scientists were employed: corporate scientists and academic scientists could communicate easily. Corporations could hire large flows of young PhDs: knowledge

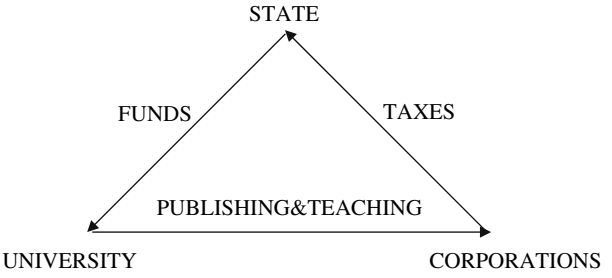

Fig. 1 The D-D flow chart of the academic system

communication was enhanced by close relationships between professors and their former students. Competent readers in the business community could easily read scientific publications outside academic circles. In the corporate model knowledge communication was quite strong because of the central role of industrial research and development.

The decline of the share of large corporations in the performance of research and development activities and in the introduction of technological innovations in the recent years and the growing role of knowledge transactions and interactions among a variety of small firms changed the context into which the Dasgupta–David model applied.[1] Within economic systems characterized by distributed processes of knowledge generation based upon constructed transactions and interactions among firms with low levels of internal research and development activities, actual knowledge communication between the academic and the business systems is much less effective. The actual receptivity of firms to the advances of generic, scientific knowledge achieved by academics, and made available by means of the traditional communication channels, based upon publications, is lower. The need for an interface able to extract dedicated solutions, hence idiosyncratic knowledge, out from such advances is much stronger. Interactions between the academic and the business community characterized by small firms require intentional efforts on both sides. The traditional mission of universities to generate knowledge as a public good becomes questionable: the risks that nobody is able to take advantage of the new advances of scientific knowledge increase. New mechanisms for the effective transmission of new knowledge to the business community including effective knowledge signaling devices are needed. The descent of academics in the new knowledge markets becomes necessary (Lawton Smith 2006).

A large part of the XX century has been characterized by a steady rate of scientific advance along well-defined directions. An acceleration of the rate of scientific advance and several changes in the directions has been taking place towards the end of the century. This discontinuity has put under stress the limitations of the previous system of resource allocation to and within the academic system. As a matter of fact the Dadgupta–David model provides poor guidance to understanding the criteria that are necessary to identify the correct amount of public resources to be provided to the academic system. Secondly, there is no indication of how to identify the criteria for the distribution of public funds within the academic system among the different academic disciplines and scientific fields. Thirdly, it provides poor guidance on how to allocate a given amount of public funds in a given discipline among the different possible academic institutions. In a pure 'open science' system a chair should be given to the best scientist with no prior identification of its discipline or location. Consequently, the amount of resources that should be transferred to the academic system should be based exclusively on the number of scientists who are actually able to raise the absolute level of scientific excellence, independently of their field of activity. This is not clearly true.

As a matter of fact a variety of spurious mechanisms are at work. Rules of thumb are used to fix the general amount of resources that the State transfers to the University. Didactic factors play a strong role. The pressure of student numbers has a strong effect, even when scientific reasons would not suggest funding the growth of some schools and some universities instead of others. Here, the typical problems of the principal-agent relationship emerge. Academic institutions may have specific internal incentives to direct the public

[1] The share of innovations introduced in biotechnology and information and communication technologies by small firms is large in absolute terms and much larger than the share of innovations introduced in mechanics, pharmaceuticals and chemistry by large corporations in the previous waves of technological change.

funding towards field A instead of field B that do not necessarily coincide with the optimization of social welfare. All attempts at technological and scientific forecasting have proved to be not very reliable. Here the risks are that hierarchical control, within the academic system, pushes towards the misallocation of funds, that is to say, away from fertile and productive new fields, in defense of tradition and established academic corporations.

The changes in the organization of the production of knowledge have exposed the 'open science' model to increasing criticisms. Both internal and external forces push the academic system towards new configurations. New facets of the academic system are emerging and some pre-existing features attract new attention and consideration. The application of the tools provided by the economics of information to analyze the economics of knowledge can be useful to understand the new directions of the university as an economic institution (Antonelli 2006).

The new academic system, characterized by the professional university, as it has been emerging in the recent years, can be considered a viable institution for the governance of the generation and dissemination of new knowledge from another viewpoint: the principal-agent approach. From this perspective the typical non-exclusivity that characterizes the terms of employment within universities and the freedom to enter the markets for professional services traditionally accepted for academics plays a crucial role. Professional rewards are now viewed as a sufficient incentive to generate and disseminate new knowledge. Academics publish to signal their competence and attract resources to fund their activities. A strong incentive compatibility between the generation of public science and research performed under contract takes place: academics cannot dismiss their reputation because it is the basic signaling mechanism to attract resources in the markets for research services. Incentive compatibility adds to efficiency compatibility stemming from qualified user-producer interactions between academics that produce knowledge and firms that use it. The quality of the research at the same time enhances the levels of the didactic activities both in terms of true content ad in terms of reputation. Substantial economics of scope between research and teaching emerge. From this viewpoint the need of public funds is much less relevant. In the extreme case, the academic system comes closer to a special form of professional order: membership in the academic system provides the basic qualifying conditions to operate in the markets for high quality knowledge intensive professional services.

The academic scientist is often also a member of the professional community for which the new knowledge is directly relevant in his daily professional work. In other words, publications are signals that are directly valuable in the adjacent professional community, overlapping with the scientific one. Hence, the close overlap between recognition within the scientific community and the professional reputation is a strict, necessary condition for the system of incentives to work. According to this approach, the academic system seems to be a much more viable institution than the corporation for the governance of the generation of knowledge characterized by high levels of uncertainty and serendipity, where the principal has little chance of properly assessing ex-ante the actual creativity of the agents, the amount of effort actually made, or the outcome of the research process both in terms of timing and specific content.

3 The comparative economics of agency costs: the university as an effective institution to solve principal-agent problems in creative work

A new interpretative model to understand the rationale of the working of the new type of university based upon the professional academic can be elaborated drawing upon the

applications of the economics of information to the economics of knowledge. It can be useful both to understand the economic mechanisms at work and as a tool to appreciate the implications for stakeholders and the needs for complementary changes in the institutional setup.

High levels of uncertainty characterize the generation of knowledge: serendipity and creativity play a crucial role. Even if the heroic assumption that the need for a specific module of knowledge can be identified, and consequently a hierarchy and a sequence of possible necessary modules of knowledge can be agreed upon and an amount of resources can be funded, it is clear that the process is still affected by basic uncertainty. Once the amount of resources has been fixed and an objective has been identified, in fact, basic unpredictability about many different aspects of the knowledge generation process emerge: *if* the new knowledge will be generated, *when* the new knowledge will become available, *where*—in which field—it will be generated and even *how*—by means of what modules of pre-existing knowledge it will be generated.

It is very difficult to organize and manage employment relations in such a context. Principals have enormous problems in assessing the actual levels of their agents' creativity and effort and to evaluate their output.

3.1 Agency costs in corporations

The costs of hierarchical coordination, articulated in agency and organization costs severely limit the size and the span of knowledge-intensive activities carried out within the boundaries of a single unit (Arrow 1974). Agency costs limit the use of hierarchical control over the activities that are necessary to generate and use technological knowledge within the boundaries of the firm for two kinds of reasons. Knowledge asymmetries also play a major role within organizations. Because serendipity and creativity play a key role in the generation of new knowledge it is difficult for principals to check on the actual content of the operations that lead to the generation of a given amount of standardized knowledge.

The management of research activities within corporations is hindered by problems associated with the identification of a correct system of incentives. This has negative consequences because of the characteristics of the distribution of creativity. Wide-ranging empirical evidence confirms that high levels of asymmetry—close to a typical Pareto distribution—characterize the distribution of actual scientific creativity among qualified and competent scientists. A small number of scientists are responsible for a large share of all publications and an even larger share of all references (Patrucco 2006). Any mistake in identifying the actual creative minds and, even worst of all, mistakes in implementing an appropriate incentive structure able to motivate the creative efforts of the few creative minds, will have major negative consequences on the output of the research activities, and hence on average costs.

As is typical in such conditions, there are two sources of possible errors:

(i) failure to identify the true creative minds. The rare skills of the true creative minds are lost because of the lack of actual incentives and mistakes in their identification, and
(ii) appointing agents who are not, in fact, truly creative. Non-creative agents can try to take opportunistic advantages of the basic information asymmetries with respect to principals regarding: (A) the expected value of the knowledge produced and (B) the actual effort and work that has been necessary to generate it.

Agency costs in the generation of knowledge within complex organizations are consequently very high also because of limitations in anticipating the outcome of a research-in progress, not only in terms of rates, but also, and mainly, in terms of directions. The outcome of a given research project can be relevant but in fields of application different from the expected ones. The traditional organization of labor in knowledge-intensive activities characterized by high levels of craftsmanship and self-employment with strong professional content is clearly explained by the high levels of agency costs incurred in monitoring effort, output and applications in the generation of knowledge (Holmstrom 1989; Garicano 2000).

Internal organizational costs also limit the number of complementary activities that can be internalized by each firm and hence the amount of knowledge that can be generated, implemented and exploited internally. Unit organizational costs are elastic not only to the size of the activities but also, and mainly, to the variety of activities that need to be internalized. The larger the rate of increase of unit organizational costs is, with respect to the number of activities, then the larger is the number of complementary activities that cannot be kept within the boundaries of the firm. Incumbents miss important opportunities because of hierarchical coordination costs. Large corporations are unable to implement all the opportunities they help to create. Coordination costs, in fact, apply both to the specific activities that are required to generate new knowledge and to the production processes that are necessary to use and exploit the knowledge generated (Arrow 1974).

In such conditions, it seems clear that the larger the uncertainty of the research projects is, then the larger is the un-predictability of the outcome and the lower is the efficiency of traditional business systems to manage the generation of new knowledge. Firms have a strong incentive to rely more and more, not only on the traditional dissemination tools of the knowledge generated by universities, i.e., publications and PhDs, but directly on academic consultants who can be hired on a professional basis, as intermediate knowledge-intensive inputs to perform a specific research activity. Intramuros research and development is substituted or strongly complemented by the services provided by the academic system. Academic patenting very much like academic publishing becomes an important signaling mechanism that helps firms to identify and locate dedicated competence and high levels of scientific creativity.

Corporations act more and more as system integrators of large research programs that are performed by a variety of academic centers. The corporation, of course, keeps control of the division of labor and manages the integration of the different modules of knowledge within an internal knowledge platform. The chief scientist in the corporation organizes the general research project, and elaborates its structure in complementary modules of knowledge. Part of the research is carried out intramuros and part is outsourced to competent academics. The identification and selection of the academic individuals and academic centers able to provide the necessary modules is crucial.

3.2 Agency costs in the academic system

Alternative institutions are necessary to manage the production of such a specific and idiosyncratic kind of good. Here the departure from the Arrovian tradition of analysis is clear. The emphasis of this analysis is no longer concentrated on the problems of allocation, but rather on the problems of generation.

By contrast, the organization of creative work within the academic system can be appreciated for its unique combination of sophisticated ex-post compensation and a

two-party incentive system. From such a viewpoint, the academic system seems to be based on the certification of creative talents. The principal rewards the creative workers by issuing a certificate that testifies to their actual levels of creativity. The qualification, in fact, is based on the reputation acquired in the open science system. The qualification, however, provides more than tenure and the resulting salary. It enables the scientific worker to enter both the markets for knowledge services and the related markets for professional services. In the former the worker can sell his/her specific research capabilities to firms that are ready to hire competent researchers to carry out specific research tasks in the fields that the scientific worker has accumulated competence and expertise. In the latter, the scientific worker can provide specific services directly where his/her competence is established.

In order to obtain such a certificate, the scientific worker has a strong incentive to establish his/her own reputation by means of publications. The actual compensation scheme however is broader than the one considered by Dasgupta and David. Hence the mechanism identified by Dasgupta and David to solve the knowledge trade-off is at work, but in a broader system of incentives and agency costs. The principal agent approach however makes it possible to explore these other aspects.

In the open science system identified by Dasgupta and David, the principal bears all the agency costs arising from the need to check the efforts and the actual creativity of the tenured workers over time. The risks of opportunistic behavior and declining creativity are high.

4 The professional university

The Professional University mechanism makes it possible to reduce the non-observability of the efforts of academics and of the actual value of their output. Principal-agent problems are much lower in assessing teaching activities. Training services can be checked better: the amount of effort in teaching, the competence of teachers and, to some extent, the output of didactic activities can be assessed better than the activities leading to the generation of new knowledge. The accountability of the research output of academics is much more difficult. Scientific reputation earned in the epistemic communities help in assessing the scientific value of the output of an experienced researcher in an established scientific field.

Relevant economies of scope in the generation and dissemination of knowledge and in monitoring costs provide the foundations for the viability of the joint production of training services and new knowledge. The university has a clear incentive to hire qualified scientists who have been able to build up a consistent reputation by means of publications because the quality of teaching and the quality of scientific competence are complementary. Moreover, the university has a strong incentive to hire qualified researchers because academic reputation based upon publications has a considerable effect on tuition fees. The levels of tuition fees are highly elastic to the reputation of the academic staff. On the top of this, it may be argued that the quality of students is also sensitive to the reputation of the academic staff. In turn, the intrinsic quality of the students prior to enrolment has a strong correlation with the quality of the students after graduation and this has a subsequent positive feedback on the ranking and reputation of the university itself.

From this viewpoint the Professional University can be considered to be a viable institution for the governance of the generation and dissemination of knowledge for two complementary and yet distinct economic reasons. First, the academic system brings together in a single and unique institutional set, the solution to the knowledge trade-off. Secondly, the academic system, articulated in a combination of didactic activities,

certification of the competence and skill of creative workers, and non-exclusivity of labor contracts, provides the institutional setting which engenders the creation of an efficient supply of certified knowledge workers to the rest of the economic system. In so doing, the academic system provides basic signals about the actual supply of creativity and competence and their distribution across fields. In other words, the university certifies the actual talent of the scientific worker and provides him/her with the opportunity to enter the markets for research and professional services.

In the Professional University the incentives for the generation and eventual dissemination of new knowledge are no longer provided exclusively by the academic system. The incentives to publication are now generated by two distinct mechanisms. The first is internal to the academic system: the scientific reputation acquired by means of scientific publications and certified by the academic system can engender some additional salaries paid by the academic system.[2] The second component however is external and it can be identified in the indirect compensation scheme for certified creative talents arising from non-exclusivity. Scientific reputation now engenders actual monetary rewards that can be earned in the markets for research and professional services.

Such rewards can be capitalized especially when the conversion of generic knowledge into highly specific and idiosyncratic applications is both necessary and not easy.[3] The second important condition for such a system to work is the high level of knowledge fungeability. Fungible knowledge can be applied to a variety of specific cases. Idiosyncratic applications cannot be imitated and replicated easily. Finally, reputation plays an important role when the opportunity cost of choosing the wrong expert is high due to the wide gaps between ex-ante and ex-post conditions. Patients praise most the reputation of their doctors when their life is at risk. Heavy investment in irreversible industrial projects suggests using the best experts available to minimize the technical and commercial risks of the undertaking and to avoid writing off huge amounts of brand new fixed capital. Spontaneous epistemic communities based on nested interactions and transactions are especially successful in academic communities and in the adjacent professional markets (David, 2004b; Antonelli 2006).

The unique institutional set-up of the Professional University makes it possible both to reduce the negative effects of the principal-agent problems when the productive process is characterized by uncertainty and basic information, actual knowledge asymmetries, and to create a supply for professional research services.

A closer analysis of the workings of the Professional University reveals three basic features that make it possible to reduce the agency costs and to bear a limited amount of the costs of scrutiny and assessment of the actual creative skills and efforts of its workers. The Professional University is in fact characterized by: (a) the non-exclusivity in the terms of employment and the related dual ladder structure of the compensation scheme, (b) the total lack of hierarchical direction in the definition of the research activities and (c) its intrinsic division into two activities and two markets: the market for education activities and the market for knowledge.

[2] In equilibrium the university should pay more to the scientific worker with a higher reputation for the increased quality of the teaching and the positive effects in terms of higher tuition fees and higher quality of students recruited by the university.

[3] This mechanism of indirect reward can also take place in a broader context: often academics become political leaders, consultants to large banks and financial corporations if not directly members of their boards, occasionally they are appointed to high level bureaucratic posts and even to parliaments and governments.

Scientific workers, after qualification and formal entry into the academic corporation, are expected to provide basic training services and to respect some generic indicators of scientific activity. The labor contract with the university includes basic teaching duties for the scientific worker, but there is almost no specification about the kind of research activity. Tenured researchers are expected to maintain some levels of research activity, documented by publications. The academic system, however, rarely expresses binding obligations about the content, the objectives and the methodologies of the research carried out by its members. Here the notion of the university as a quasi-hierarchical organization is fully confirmed: it is difficult in fact to consider the case of a fully-fledged principal who does not specify a relevant portion of the activity of its agents.

Non-exclusivity in the labor contract, typical in the academic system, means that the certified creative talent can sell his/her competence and creativity in the markets for research and professional services. Here creative minds can find a return for the marginal productivity of their competence. In some extreme cases certified, creative talents, i.e., university professors, can buy-back their teaching time, renounce all wages paid by the university and spend all their working time in the markets for research and professional services.[4] Eventually however if and when creativity slows down, professors can go back to providing teaching services and earn the salaries paid by the university.

An academic worker's output is composite as it is made up of the research output and the didactic output. The former is defined by the worker and because of the non-exclusivity clause, can be, partly, compensated by third parties.

The Professional University specifies only the content of the teaching activities and consequently pays a salary that is not expected to remunerate the full marginal productivity of academic labor, but only a part of it, that includes the component arising from the marginal productivity of the teaching activities and the social value of knowledge that is not appreciated by the price mechanism.[5]

As Fig. 2 shows, the total value of the marginal productivity of academic work (MPA) can be split into three components: (1) the marginal productivity of didactic activities (MPD), (2) the private marginal productivity of research (MPR), and the total marginal productivity of research including the social effects that are not fully reflected by the price mechanism (SMPA). In this figure the distance between MPD and MPA measures MPR. Universities pay a salary (AW) that is defined by the marginal productivity of didactic activities. Professional fees (PF), earned in the markets for knowledge, either directly as

[4] Many 'traces' in the institutional setting of the academic system reveal that salaries paid by universities are mainly related to didactic activities. In many US universities the University covers a yearly salary based upon 9 months of full paid salary. The 'buy-back' procedure enables professors to be freed from teaching paying the university a large, if not substantial, part of their wage. In Great Britain many academics have formal appointments within universities; their salaries however are paid upon the income generated by the same individuals by means of research contracts with outside parties. In Italy over 90% of top-level academics, especially in the schools of law, business and engineering, switch to part-time positions, after achieving the status of full professors with a reduction of over 40% of their academic salary and no changes in didactic burden, but full freedom of earning professional fees. They often return to full-time positions by the end of their academic career.

[5] The measurement of the total marginal product of output where the latter is knowledge cannot be based solely on the price levels. Following the well known Arrovian analysis, in fact, knowledge cannot be fully appropriated and is characterized by non-divisibility, non-rivality in use and non-exhaustibility: relevant externalities are at work. Actually the output of the open science university can be measured only in terms of the externalities that are effectively received by the system. In the case of the professional university, instead, the private marginal returns, estimated by means of the price mechanism, enter into the picture although externalities remain relevant. Figure 2 makes clear the extent to which public subsidies are necessary to compensate for the value of knowledge that is not accounted by the price mechanism.

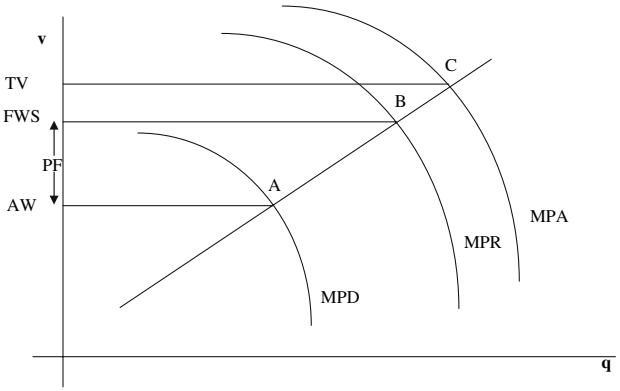

Fig. 2 The three-party compensation of academic pay

private consultants or indirectly via contractual relations between the university and the firm, pay for the private marginal productivity of research activities and, added to academic salaries, complement the salaries of scientific workers (FWS). The distance between MPR and MPA measures SMPA, the social effects of new knowledge that are not accounted by the price mechanism. The missing portion of the total value of knowledge (TV) stemming from the social benefits, non-accounted by the price mechanism, should be matched by public subsidies.[6]

In the Open University system there is no price mechanism at work and the full social value of the knowledge generated is matched by public subsidies. In the Professional University the level of subsidies instead can be reduced and partly substituted by the fees earned by academic researchers in the markets for knowledge.

4.1 The incentive complementarity between public science and contract research

A debate has been going on about the relations between public science and contract research. Some argue that in the Professional University a substitution effect may take place: scientists would be less and less active in the production of science and would dedicate most attention and efforts to securing and performing research for firms. Moreover scholars in the professional University would be less and less keen to share information with colleagues who are now seen are dangerous competitors in the markets for research services. The academic ethos would be undermined (Nelson 2004). Others stress the complementarity between the generation of public science and the performance of research under contract in terms of efficiency. The results of the investigations carried out by Mansfield (1995) suggest that the productivity of scientists was enhanced by their interactions with the business community. A specific case of user-producer interactions has been made: the producers of knowledge would take advantage of closer relations with their users.

When the basic tools of the economics of information are applied we see that an actual incentive complementarity between the generation of public science and the research under contract can be identified (Spence 1973). It is clear in fact that the scientific reputation

[6] Hence in Fig. 2 on the vertical axis we measure the value of the knowledge rather than just the price.

based upon publication is an essential ingredient of the working of the interaction mechanism between firms and the professional University. Academics need to publish so as to confirm and possibly increase their reputation. Reputation is an essential tool to signal their competence in the markets for research services and hence attract resources to fund their activities. The incentive complementarity moreover works both ways: publications are necessary to build up reputation and hence attract resources. In turn the resources provided by firms are an input into the generation of future reputation. Publication are part of a dynamic process where the scientist has a direct incentive to publish at time t1, as a way to build a reputation and hence to attract resources at time t2.

The rational scientist should be reluctant to stop publishing and switch all her energies to performing contract research without any fall-out in terms of new publications. It is clear that her reputation would quickly decay and no more firms would be interested to hire her to perform new research activities under contract. The reluctant scientist might accept to substitute her production of public science with the production of proprietary and dedicated knowledge with idiosyncratic applications only if the amount of the contract would match the long-term discounted value of her opportunity costs. This amounts to saying that the value of the contract should match the stream of her wages for a considerable amount of rime. It seems clear that such conditions could be rarely fulfilled, as they would be equivalent to an employment relation.

4.2 Non-exclusive intellectual property rights

The argument in favor of the Professional University based upon the non-exclusivity of the employment relation, and elaborated so far, holds more and better if non-exclusivity applies to intellectual property rights as well. It is clear in fact that if and when the customer of the academic services has the right to retain the exclusive property rights of the results of the research activities, the social marginal product of the professional university is seriously undermined. Because of non-divisibility, articulated in cumulability, complementarity and fungeability, and the sharp difference between production and reproduction costs, knowledge exhibits all the characteristics of an essential facility. Relevant increasing returns in the production of knowledge stem from the ensuing economies of density. Marginal costs are always below average costs. In such circumstances, as it is well known, non-exclusive property rights need to apply in order to prevent welfare losses. This condition is even stronger for knowledge as it is at the same time an output and an input for the generation of further knowledge. Exclusive intellectual property right would reduce the dynamic efficiency of the system (David 2004a; Antonelli 2007).

This is true especially upon the product of academic research conducted within the frame of professional contracts between academics and firms. The access of third parties to the result of the research conducted by academics for business firms is necessary for the working of the new system. Exclusive intellectual property right on the results of academic research, in fact, would lead to ban the dissemination of new knowledge, by means of publications. Academic personnel impeded to publish the results of their work by exclusive intellectual property rights would loose the opportunity to gain reputation. In the long run this would undermine their position in the market for professional research activities. In the short term, incumbent academics would take advantage of their existing reputation based upon previous work, conducted within the open science model. In the long run, however, the new comers could never build a scientific reputation. Clearly this process becomes quickly unsustainable: exclusive intellectual property rights upon the results of research

conducted on a contractual base would undermine the working of the full system with clear disadvantages both on the demand and the supply side and for the all the stakeholders at the system level. The elaboration of mechanisms that make the disclosure of new knowledge possible, even when it has been generated within the context of a contractual relationship between an academic and a firm, and favor publications and other dissemination devices rather than preventing them, is a necessary complement of the new model of professional university.

The fine tuning of non-exclusivity becomes necessary: it is clear that if intellectual property rights cannot command any privilege upon the new knowledge, firms would have very low incentives to outsource research activities. On the other hand it is clear that with the forms of exclusivity that feature the current intellectual property rights such as in the case of the present patent legislation, not only the new cohorts of researchers could never establish a reputation and hence enter in the markets for knowledge, but the risks of knowledge exclusion and knowledge rationing would be too high. Knowledge externalities would be drastically diminished, even below the levels associated with the traditional forms of dissemination of knowledge as a public good typical of the open science model and the new markets for knowledge would collapse.

New forms of reduced intellectual property rights seem necessary both for the dynamic efficiency of the system at large and for the working of the professional university model. Publication and appropriation of the result of outsourced research must become complementary rather than mutually exclusive (Reichman 2000; Antonelli 2007).

In a regime of non-exclusive property rights, academic patenting can become a useful signaling mechanism that helps firms to identify and locate the competence of scientific talents. The granting of a patent by qualified Patent Authorities, very much like the editorial assessment of high-ranking journals, certifies the quality of the research conducted by identifiable scholars in well-defined locations. A new complementarity between academic publications and non-exclusive intellectual property rights should take place. After a limited time window of restriction designed to secure the incentives to firm to outsource research activities scholars can choose whether to publish or to patent according to: (a) the specific content of their discovery and (b) the norms and rules practiced in their specific community. In both cases the firms that have funded the research should exert a limited control in terms of reduced ownership for a short period of time.

Only when non-exclusivity applies both to employment relationship between academics and universities on the on hand and to the intellectual property rights upon the results of the research can the model of professional university substitute successfully the open science system.

4.3 Markets for research services

The institutional ingenuity of the professional University engenders the creation of a supply for professional research services. On the supply side of this special market in fact there are academics, both as individuals and as academic centers that are certified and evaluated as to their actual levels of creativity. Moreover, the compensation schemes used in the academic system allow the supply side to operate on a variable cost basis. The fixed costs of the academics, as a matter of fact, are covered by the internal payment for their teaching activities within the academic system. The supply in this market is now characterized by high levels of signals about the actual quality of the supply and the reduced costs, as the total cost of academic supply can be shared between universities as institutions

and the customers of the research services. The position of the supply curve is much lower than it would be without the academic system.

On the demand side moreover transaction costs and specifically search and screening costs are much lower for two reasons. First, suppliers are evaluated and signaled by their academic career. This evaluation is based upon their reputation and ultimately on publications and other scientific scores based on references and the quality of journals. Secondly, suppliers are ready to work on a professional basis and accept a compensation that is clearly dependent on the actual delivery of the knowledge module. In other words, academics are not looking for a permanent employment contract with firms, but operate on a professional basis. This in turn allows ex-post payments dependent on the actual delivery of an output to be made. In so doing the academic is paid by the job.[7]

In the markets for research and professional services a firm's demand for knowledge inputs can be met by the supply of certified, part-time talented workers with a significant reduction in costs by using such markets. Qualified and certified scientific workers can earn substantial rewards by supplying their creative talents in the markets for research and professional services. In this market scientific workers can be paid by the job as professionals.

The demand side is made up of firms that are exploring external sources of knowledge, in the markets for research and professional services. Firms are ready to substitute internal research activities with scientific skills and competence that can be acquired in the market place. Outsourcing of research activities to qualified academic laboratories has become common practice. Firms are reducing their research activities with a high scientific content which they used to carry out in their own laboratories and they are increasingly turning to the competence of universities. This is especially relevant when technological knowledge is codified and composite: for in this case firms would have to be involved in a wide array of scientific fields with little chance of achieving high levels of specialization and competence in every one. The systematic access to the wide range of competence provided by universities in fact makes it possible to increase the chances for effective recombination and eventual generation of new knowledge at a much lower cost.

Firms can take advantage of the supply of scientific and creative competence of the academic system either directly, hiring individuals that operate as professionals, or indirectly when the contractor is the university itself. The latter case is typically used when teamwork is necessary to carry out the research activities. Individuals in the latter case however do retain the right to share with the university the rewards arising from their professional services. In this case the University performs the functions of an associated partnership, usual practice in the legal services and other markets for professional services.

The new emerging markets for research services provide important opportunities for small firms to take advantage of structured research activities. As it is well known, research and development activities are characterized by economies of scale, at least until a

[7] Interesting similarities can be found between the economics of open source and the new economics of the professional university. In both cases the basic mechanism consists in the complementarity between the reputation-seeking behavior of creative talents who can claim the authorship of an 'invention' and the levels of the professional fees that can be earned by 'inventors' in the markets for idiosyncratic services provided that a regime of non-exclusivity of intellectual property rights applies. Creative experts make available their advances in open source software provided that their contribution is acknowledged: the effects in terms of reputation in the markets for specific applications produce sufficient incentives to sustain the system with clear benefits in terms of the increasing returns at the aggregate level stemming from the cumulability of knowledge and the ensuing economies of density in repeated and distributed usage. More specifically it can be argued that the working of the open source community shows both how relevant is the non-exclusivity of intellectual property rights and how crucial is the identification of the expertise and ingenuity of the professional competence of intellectual workers (David 2004a; Antonelli 2006).

minimum threshold. As long as research activities could only be conducted intra-muros, small firms were not able to organize systematically the generation of knowledge and the implementation of internal learning processes. Increasing returns in the performance of research activities exerted major discriminating effects. The supply of research services by the academic system provides small firms the opportunity to fund specific and dedicated research activities that are performed by large research centres.

Universities can be selected according to their reputation and competence and a variety of contingent contracts can be activated with highly specialized laboratories. When technological knowledge is at lower levels of codification, the relations between universities and firms are typically based upon long-term broad contracts within the framework of programs that cover many different contracts and include funded chairs and bilateral transfers of personnel, as well as the systematic hiring of students who have finished a doctoral program. The more structured the fabric of contractual relations are, the lower are the risks of leakage and premature disclosure by scientists seeking visibility and extended reputation. Firms try to exert a strong control over the results of the research activities by means of intellectual property rights and specific contracts based upon timing and priority in dissemination. Scientists however need to reconfirm their reputation and hence have a strong incentive to publish. The reputation-seeking behavior of the scientists prevents dissemination from being reduced and hence favors the solution of the knowledge trade-off.

The creation of new firms, by former scientists, is often the direct result of the generation and ensuing exploitation of new knowledge, which, as such can be traded only if incorporated in knowledge-intensive-property-rights. Scientific entrepreneurs are inventors, who cannot rely on the markets for disembodied knowledge and prefer to exploit the rents associated to their knowledge by producing and selling the products that embody the new knowledge, either as a product or as a process innovation. Scientific entrepreneurship becomes a viable way of exploiting technological knowledge generated within universities, especially if and when complementary institutions such as venture-capitalism and new-dedicated markets specialized in the trade of knowledge-intensive-property-rights, such as the NASDAQ; exist in the new institutional system for the governance of knowledge. Eventually newly-created high-tech companies set up by scientific entrepreneurs with the assistance of venture-capitalists, enter the new dedicated financial markets with an initial public offering and can be acquired, via mergers and acquisitions, by large corporations. Their take-over in the stock markets substitute intramuros research and development activities as their acquisition becomes a viable mechanism to incorporate new scientific and technological knowledge into the production process of incumbents. The customers of the start-up firms can rely upon the reputation of the venture capitalists involved in the IPO and the early experience of the new company as a screening mechanism about the actual quality of the new knowledge and hence a way to reduce radical uncertainty associated with research and development activities. On the other hand venture capitalism becomes a new route for the dissemination of new knowledge. The working of the new financial markets for knowledge-intensive-property-rights complements academic publications and academic patenting as a signaling mechanism at different stages of knowledge production and exploitation (Antonelli and Teubal 2007).

4.4 The dynamics of the demand: a simple graphic exposition

The emergence of the professional University can be considered the result of the strong increase in the demand for research activities that has characterized the last decades. The

dynamic implications of the analysis conducted so far can be presented with the help of a simple figure.

It is assumed that the Principal in the economic system is able to identify the correct quantity of knowledge that is necessary to pursue the correct level of economic growth. A clear minimization problem can be set: the economic system has a strong incentive to try to minimize the institutional mechanism that makes it possible to reduce the costs of the necessary knowledge. The correct amount of knowledge that is necessary is identified in Fig. 3 as Q* on the horizontal axis. Three alternative institutional solutions for the provision of that quantity of knowledge are now considered. Respectively the Open Science (OS), the Corporation (CO) and the Professional University (PU).

The cost function of knowledge (KC) in the corporation mode is characterized by decreasing returns to scale because of the sharp effects of monitoring and screening activities. Principals are limited in their ability to evaluate the actual creative skills of their scientific workers, the levels of their efforts and even the value and the timing of their output. Formally it can be seen that the cost function of the corporate mode has a positive slope with a positive second derivative:

$$\mathrm{KC(CO)} = a(q) \text{ with } a' > 0 \text{ and } a'' > 0. \quad (1)$$

The cost function of knowledge in the open science mode (OS) is characterized by a two-party scheme. Total costs are made up of fixed and variable costs. Fixed costs are anticipated by the principal, i.e., the public sector that acts as an intermediary between taxpayers (ultimately firms) and the salaries of scientific workers. Variable costs account for the activities of dissemination and absorption that are necessary for the knowledge produced within the academic system to be effectively passed on to the rest of the economy. Formally we see a positive slope of the variable costs:

$$\mathrm{KC\ (OS)} = T + b(q) \text{ with } b' > 0 \text{ and } b'' = 0. \quad (2)$$

Finally, the cost function of knowledge of the professional university (PU), is characterized by some fixed costs that are necessary to pay part-time scientific workers and variable costs for the actual generation of knowledge intramuros. There is the derived demand of firms which play an active role in the markets for research and professional services, firms which act as customers for intermediary inputs in the form of the production of new knowledge

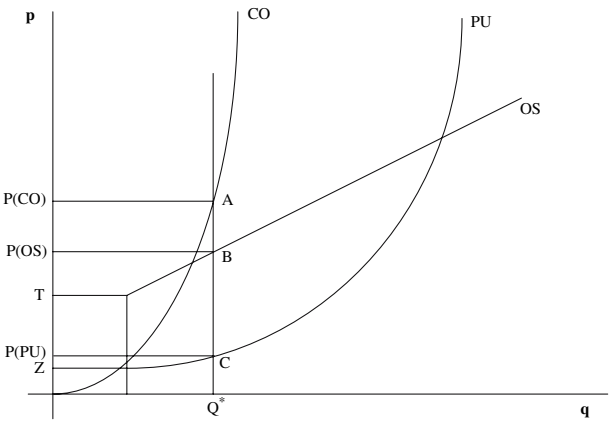

Fig. 3 Alternative institutions for knowledge generation and dissemination

provided by certified creative minds who are part-time academics. This latter component has decreasing returns to scale, but to a lesser degree than in the case of the corporate mode. The basic activity of signaling provided by the certification of the academic system and the professional type of relationship that is established between firms and academics helps to reduce screening and assessment costs and hence to minimize agency costs. Formally we get:

$$\text{KC (PU)} = Z + c(q) \text{ with } c' > 0,\ c'' > 0,\ c'' < a'',\ T > Z. \tag{3}$$

Figure 3 provides a graphic expression of the basic argument. The vertical axis shows the difference in the costs of the given quantity of knowledge that a system requires. The costs of providing the desired quantity of knowledge (Q*) are larger with the corporate mode especially if and when Q* is large. Actually with low levels of Q* the corporate mode, the case in which the generation and dissemination of new knowledge rests upon the central role of in-house research and development laboratories funded and operated by large corporations, is more effective. The pure academic mode is more effective than the corporate mode, as long as the slope of the communication costs variable is not too steep. The solution provided by the academic outsourcing mode is clearly the lowest. This reveals the competitive advantage of combining the academic provision of qualified and certified personnel who enter the markets for the provision of research and professional services on the supply side. On the demand side, firms are ready to purchase such services, on a case-by-case basis, with compensation schemes that are tied to specific performance and tasks within a freer organization of the division of scientific labor, which is still managed by corporations. The latter however having lower levels of agency costs because there is less need to check and assess the performance, effort and actual creativity of their professional inputs.

We can explore how this situation changes when the quantities of knowledge that are considered necessary for the system change. If we consider the region before Q*, it seems clear that the lower the quantity of knowledge is, the larger is the competitive advantage of the corporate solution. This can be regarded as a schematic representation of the period between the 1950 and 1990. Research and development activities funded and performed by large corporations were the main source of knowledge. University was assigned an ancillary role. Actually corporations tried to reduce the amount of public resources allocated to the academic system on the grounds that research and development activities carried out intramuros were far more efficient in terms of selecting the goals and objectives, performances and close interaction with users.

The region identified by a quantity of knowledge slightly to the left of Q* can be considered a reliable approximation of the transition towards the knowledge economy at the end of the XX century. The corporate mode was becoming increasingly less effective. The traditional academic system where research was mainly carried out within universities and knowledge communication was expected to take place via the combination of scientific publications and graduates hired by corporations gained momentum. The limits of this traditional system of knowledge communication, however, quickly emerged as the main constraint and source of inefficiency.

The region to the far right of Q* can be considered as the schematic representation of the new emerging knowledge economy where knowledge becomes an essential input for economic development especially for advanced countries specializing in providing knowledge intensive business services and high-tech products to the rest of the world economy in the XXI century. Now the limits of the corporate-based model become

evident. The fast increasing slope of the costs of knowledge produced mainly by corporations reveals all the drawbacks of the limits of organizations in managing principal-agent problems. Aging scientific personnel with declining creativity employed by corporations become a burden, as there is little scope for useful job rotation. Opportunistic behavior spreads. Firms are increasingly reluctant to fund large internal research laboratories as they have major problems in coping with low levels of predictability in the timing and content of scientific output while costs are rapidly increasing. Here the advantages of the renaissance of the university based model become apparent. Provided that there is effective interaction between the academic and the business community, the new university mode of knowledge governance is clearly superior, especially if it is implemented effectively with: (a) the systematic application of long standing traditional practices such as non-exclusivity of labor contracts, (b) active participation of academics into the markets for knowledge, (c) close interaction between research and didactic activity, particularly above college levels in graduate schools, and (d) non-exclusive intellectual property rights.

5 Conclusions and policy implications

This new assessment of the role of knowledge indivisibility and external knowledge provides new arguments in defense of universities as knowledge commons. Now, however, the argument is reversed with respect to tradition, which was based upon the notion of knowledge as a public good.

The application of the basic tools of information economics to the economics of knowledge provides an interpretative framework that is able to evaluate and highlight one aspect of the institutional economics of university that, so far, has attracted little attention. The academic system, because of its traditional characteristics, emerged through a historic process that has now lasted for over nine hundred years, since its origins in Bologna. Universities appear to possess a unique mix of incentives and rewards that makes them especially suitable to handle the deep and complex principal-agents problems that characterize the employment of creative talents at large.

A shift in the role and the organization of the university within the economic system has been taking place in the last twenty years. New aspects and facets of the academic institution emerge as key factors. The interaction between the academic and the business system is changing and new mechanisms have been implemented. The open science model articulated by Partha Dasgupta and Paul David encapsulated the key characteristics of the economics of the university at the time of the corporate economy. Since then the general organization of the production, dissemination and use of knowledge has been changing: a new model of university seems to emerge. An analysis of the academic system in the context of the principal-agent approach makes it possible to identify the factors that favor the evolution of the academic system towards a new model. More specifically, the application of the principal-agent approach provides a clue to understanding why the shift in the governance of knowledge generation and dissemination is taking place, away from the corporation based model, and towards the renaissance of an academic based model that encourages the active participation of academic workers in the markets for knowledge and the joint-provision of educational and research activities.

Clearly, adopting the principal-agent approach to understanding the advantages of the academic system provides important policy guidelines when it comes to implementing its

positive aspects. Joint production of research and didactic activities and establishing non-exclusivity both in employment relations and in intellectual property rights upon knowledge generated under contract are necessary to increase the viability of the academic system as a cornerstone of an effective organization of the generation and dissemination of scientific and technological knowledge, based upon enhanced systemic knowledge transactions and interactions.

An important implication of this approach and a strong reason for the implementation of the academic outsourcing mode of knowledge governance can be seen when the basic issue of the allocation of public funds among scientific disciplines is considered. When the principal-agent approach is applied and the academic outsourcing mechanisms is implemented, the feedback signals from the markets for research and professional services towards the academic system can be better appreciated and measured. The static and dynamic characteristics of the demand for research and professional services can be considered an important input in the identification of the scientific fields where public funds should be allocated. Although it is in a limited time frame, in fact, the directions of the demand for research services can be considered reliable signals of the relevance of some scientific fields with respect to others. The provision of public funds can now be directed taking into account such signals about the relative importance of some fields with respect to others. Of course the demand for research services provides direct funding itself. Hence the public bodies responsible for the decision-making regarding the allocation of public funds for academic research can assess whether such public funds should be used to defend minimum levels of knowledge creation in some fields and/or to further encourage the specialization of the academic system in new emerging fields where many firms are willing to purchase the professional services of certified creative scientists.

Universities and public research centers play a central role in providing minimum levels of accumulation, generation and dissemination of general knowledge. The academic system turns out to be a viable institution not only to solve the knowledge trade-off between appropriation and dissemination, but also, and mainly, because it is an effective institution for the management of creative talents. The unique blend of non-exclusivity in the labor relations and joint-production of educational and research services seems especially appropriate in implementing a two-ladder system of incentives and compensation. University has the key role of a standardization committee that certifies the quality of the scientific worker. It remunerates the didactic activities and the production of basic knowledge. Non-exclusivity in the labor contracts, implemented by creating partnerships when teamwork is necessary, helps to create a supply of research and professional services. The matching of the demand for research and professional services by the business sector provides ample opportunities for a second-tier compensation of the creative skills of certified scientific workers.

The basic function of public funding to the knowledge commons is to defend efficiency thresholds in entertaining and implementing the stocks of knowledge across the board. All eventual progress depends on the multiplicative relationship between bits of knowledge and the key role of the stock of knowledge, and it is clear that a fall in the competence and expertise in a few knowledge modules can have dramatic consequences for all the system. Minimum levels of efficiency have to be identified and presidia have to be created. Scientific presidia have to be kept both across scientific fields and across regional space.

A public university system can be funded on the solid grounds of public funds, allocated with a clear methodology based upon the notion of knowledge fungeability. The wider the fungeability of each bit of knowledge is and the wider its relevance in terms of indivisibility is likely to be and hence its multiplier role for the whole system.

The workings of the knowledge commons can be used to take advantage of the opportunities offered by the firms' demand for scientific and technological outsourcing in such a way as to use the available budget in selected areas, as long as there is a non-exclusivity clause regarding the knowledge generated and its dissemination is not prevented by obstacles created by proprietary assignment of the results of the research undertaken when there is private funding. The interaction between the public academic system and the market for knowledge intensive services should be increased also as a way of exploiting the relevant economies of scale associated to the sheer size of some research facilities and of the ubiquitous economies of density arising from the relevant fixed costs associated to the creation of dedicated skills with high levels of specialization (David 2004a, b).

In this context, universities and public research centers at large are pushed to enter the markets for knowledge on the supply side. Academic departments become suppliers of knowledge intensive business services to firms that rely more and more on the outsourcing of research intensive activities formerly carried out in their own laboratories. Knowledge generated by academic departments within the context of specific contracts with firms risks becoming subject to proprietary agreements with clear limitations on its dissemination. At the same time however, much of information economics argues that the workings of competition in a market characterized by radical knowledge asymmetries provides an important counterbalancing effect when the role of signaling is appreciated. Academic departments in fact have a strong incentive to signal to potential customers the quality of the research in progress and to disseminate information about the scientific scores. Academic publication, no longer viewed as the distinctive mission of publicly funded researchers, is now pursued as a signal to attract new potential customers for their services.

There is far less spontaneous knowledge communication than there should be. As a matter of fact when knowledge communication takes place at appropriate levels, it does so accidentally and occasionally in a few regional and institutional settings. Knowledge communication between the academic and the business community seems to be especially poor. Publications are not very effective as vectors of information about new scientific discoveries, which should be seen as possible areas of development and implementation of technological knowledge. The relationship between the top–down process of deductive 'scientific' work and the bottom-up generation of technological knowledge is often characterized as an 'uneasy alliance.' The direct association and participation of scientists and technologists in common ventures seems to be able to reduce the gaps.

Public policy can be the key component of a dynamic process which brings together universities and firms, yet respects their basic mission: respectively the production and dissemination of generic knowledge with high levels of fungeability and its application in specific and idiosyncratic contexts.

In conclusion, a closer analysis of the workings of the academic system reveals one more peculiar aspect of this old and yet evolving institution that has shaped and characterized the European economy for centuries. The university is indeed an efficient institution in solving the knowledge trade-off, that is to say, the contrasting need to increase the incentives to produce knowledge, but also to disseminate it as much as possible. The university however is also an efficient institution in managing the generation of a highly un-predictable activity such as the generation of knowledge. The rapid transition of advanced economies towards a knowledge economy suggests that the advantages of the academic institution as a quasi-hierarchical system that makes it possible to select, provide incentives for and reward creative talents should be studied carefully. Its foundations might be imitated and applied to the rest of the economic system and extended to other institutional contexts. The workings of many professional communities in fact seem

to be very similar to that of the academic system in which a process of mutual interaction between the evolution of professional orders and academic systems seems to be at work.

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