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THE DERIVED DEMAND FOR KNOWLEDGE

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THE DERIVED DEMAND FOR KNOWLEDGE[1]

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ABSTRACT. This paper calls attention on the effects of the economic properties of knowledge on its derived demand, an issue that has not received enough attention in the literature. The results of the analysis suggests that, because of the idiosyncratic -Arrovian- properties of knowledge, a chain of effects takes place: i) in downstream markets the price of goods that have been produced using knowledge as an intermediate good, falls, ii) consequently the derived demand in upstream knowledge markets –both within corporations and by them to knowledge intensive business services (KIBS) - has a lower position, and iii) the price of knowledge is lower than it should be were knowledge a standard good traded in competitive markets, iv) with negative consequences in terms of adverse selection of large scale high quality research projects, but v) possible compensating effects stemming from the use of knowledge spillovers to generate cheaper knowledge. Such results have important implications for economic policy discussions and decisions.

KEY WORDS: KNOWLEDGE AS AN INTERMEDIARY INPUT; DERIVED DEMAND OF KNOWLEDGE; DEMAND SIDE KNOWLEDGE POLICY.

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1. INTRODUCTION

The economics of knowledge consists in the analysis of the economic properties of knowledge[2] as an economic good, a central input into the production of all goods –including new knowledge- and the result, itself, of an intentional and dedicated production process. The pathbreaking contribution by Arrow (1962) has opened this fertile field of investigation comparing knowledge to standard goods. With respect to standard economic goods knowledge is characterized by highly idiosyncratic characteristics such as limited appropriability and non-rivarly in use[3]. So far the attention has concentrated on the consequences of the Arrovian properties on knowledge supply, and has largely disregarded their bearings on knowledge demand. For example, probably the most important reason of the remarkable diffusion of CDM approach is the role of knowledge as the "deus of machina" in the system of three central econometric relations it proposes to consider jointly: i) the extended production function; ii) the innovation or knowledge generation function; and iii) the R&D or knowledge investment function (Crepon, Duguet, Mairesse, 1998). The knowledge investment function can be viewed as both a demand equation for the units of production of firms which are producing normal economic goods and as a supply equation for the R&D units of firms producing knowledge. The integration of the augmented production function and the knowledge generation function enables the identification of the derived demand of knowledge. The derived demand of knowledge in turn enables to grasp the depreciation of knowledge as a major and specific form of market failure.

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[2] Following Arrow and the literature that impinges upon his contribution, knowledge is used here to identify a broad array of overlapping activities including research and learning, competence, experience, know-how, as well as information about scientific technological, organizational and scientific procedures that can be embodied both in tangible and intangible products ranging from capital goods to services. As such knowledge exhibits varying levels of tacit and codified contents embedded not only in protocols and routines, but also, and primarily, in skills.

[3] The literature has eventually identified other idiosyncratic characteristics of knowledge such as limited divisibility, non-exhaustibility, cumulability and complementarity, low reproduction costs.

The rest of the paper is structured as it follows. Section 2 provides a bird-eye view of the development of the economics of knowledge in the last sixty years and introduces the derived demand of knowledge. Section 3 provides a simple theoretical analysis by means of a graphical representation of knowledge derived demand equation and its shift from a theoretical situation in which knowledge would be a normal economic good. The analysis is further enriched by the integration of the analysis of the effects of the Arrovian properties on the supply of knowledge. The approach enables to single out the depreciation of knowledge and its effects, both positive and negative. Section 4 discusses the likely policy implications of this analysis. Section 5 summarizes and concludes briefly.

2. A BIRD-EYE VIEW OF THE ECONOMICS OF KNOWLEDGE

To understand our focus here on the importance of the demand for knowledge as an intermediary input is better to first discuss the issue in the perspective of the remarkable development of economics of knowledge in the last sixty years. Since Richard Nelson's pioneer contribution in 1959: "The simple economics of basic scientific research", the issue of the undersupply of knowledge has been central in the economics of knowledge. Nelson opens up the enquiry on the economic properties of knowledge as an economic good and their economic consequences. He elaborates upon the well-known Schumpeterian analysis of the limits of perfect competition: "The introduction of new methods of production and new commodities is hardly conceivable with perfect—and perfectly prompt—competition from the start. And this means that the bulk of what we call economic progress is incompatible with it. As a matter of fact, perfect competition is and always has been temporarily suspended whenever anything new is being introduced—automatically or by measures devised for the purpose—even in otherwise perfectly competitive conditions" (Schumpeter, 1942: 105).

In his analysis, Nelson (1959) articulates the distinction between social and private profit and concludes that: "when the marginal value of a ‘good’ to society exceeds the marginal value of the good to the individual who pays for it, the allocation of resources that maximizes private profits will not be optimal” (Nelson, 1959: 298).

In his 1962 famous paper: “Economic welfare and the allocation of resources for invention”, Kenneth Arrow marks an important methodological progress as it introduces explicitly the comparative analysis of ‘knowledge as a standard good’ regarded as the benchmark with respect to ‘knowledge as a special good’. The comparative approach remains at the core of the economics of knowledge and enables to identify the full range of implications and consequences of the properties of knowledge both for economics and economic policy.

The “Arrovian postulate” about the failure of the market place as the institutional mechanism for the correct allocation of resources to the generation of knowledge is set. Since then, the analysis of the supply for knowledge attracted most attention with strong economic policy implications (Antonelli and David, 2016). The literature elaborated the basic argument that policy interventions should remedy the lack of incentives to the generation of knowledge, pushing it closer to the benchmark conditions that would apply for standard economic goods. An array of tools has been consequently put in place to increase the incentives to generate new knowledge. Such tools include intellectual property rights aimed at increasing the levels of appropriability, public subsidies to research and development expenditures (R&D) aimed at compensating private investors for the missing revenues, a public research infrastructure including Universities and public research institutions aimed at generating upstream scientific knowledge that could support the downstream generation of knowledge by the business sector.

The extended production function, introduced by Zvi Griliches (1979): “Issues in assessing the contribution of research and development to productivity growth”, elaborates the Cobb-Douglas production function with the formal inclusion of knowledge, measured as a R&D capital stock (or patent or innovation indicators) regarded as an additional input that contributes explicitly to the production of output alongside "physical" capital and labor. The extended production function becomes a pillar of the applied economics of knowledge. It provides the basic framework to investigate empirically the role of knowledge in the economy (Griliches, 1984, Link and Siegel, 2007).

The inclusive and quite exhaustive review of the large body of econometric research of Hall, Mairesse and Mohnen (2010) confirms that knowledge is a key input in the long run production process. It also shows that social returns tend to be much higher than private returns, due to positive knowledge externalities, and in particular from the public research system to the business sector. Recent empirical research provides additional evidence confirming that social returns to R&D are estimated to be at least twice as high as the private returns (Wolff 2012; Bloom et al. 2013).

The analysis of knowledge as the output of a dedicated activity can be dated back to Schmookler (1966) who identified the knowledge generation process as the result of investment in capital goods and the consequent implementation of formal research activities. The specification of a full-fledged knowledge generation function was formalized by Zvi Griliches (1979), and eventually implemented by Pakes and Griliches (1984), and Jaffe (1986).

The introduction of the knowledge generation function paved the way to a rich and still increasing empirical literature in which knowledge –usually measured by patents or innovation counts- is the output of an activity that uses a variety of inputs ranging from R&D expenditures performed by each firm, their stock, as well as the levels and the stocks of R&D activities –and/or their output in terms of patents and innovation countsperformed by other firms that are located in regional, industrial, technological, cultural proximity.

The CDM approach marks a major step as it provides a systemic framework into which it is possible to analyze the simultaneous interaction of three equations (or groups of equations): the extended production function, the knowledge generation function, and a knowledge investment function (Crepon, Duguet, Mairesse, 1998). CDM specifies the extended production function as an innovation output extended production function not as an R&D extended production function like most of the literature à la Zvi Griliches. The R&D extended production function can be viewed as a "reduced form equation" of the CDM model.

In the CDM framework there is an important distinction between the observed and the latent R&D, and possibly also between the proxy for innovation output (product or process or both, etc.) and the latent innovation output. The reporting of R&D expenses is far from homogeneous across firms. Corporations have systematic reporting protocols that small firms do not apply: much research activity is informal. The same applies to the output measures: the use of patents is uneven and influenced by the characteristics of the firms, the knowledge and the type of market competition.

Taking advantage of new information on innovation provided by the emerging Community Innovation Surveys (CIS), and taking into account relevant endogeneity and selectivity econometric problems likely to significantly bias the main elasticity parameters of interest, the CDM approach has stirred a rich literature supplementing the empirical work performed on the basis of the separate analysis of the extended production and knowledge generation functions (see for example Hall and Mairesse, 2006)[4].

The CDM approach stirs a new reflection on the role of the demand for knowledge as an intermediary input. The demand for knowledge as an intermediary input is clearly the necessary interface between the knowledge generation function and the augmented production function. The CDM systemic approach induces to reconsider the early analyses of Ken Arrow and Dick Nelson so as to raise the question whether both the founders of the economics of knowledge assumed that the undersupply of knowledge was the consequence of the reduction of supply of knowledge intensive products only? To what an extent did they consider also the changes in the derived demand (and supply) of knowledge?

Building upon the tools implemented by the CDM approach –the knowledge generation function and the extended production function- it seems clear that the limited appropriability of knowledge affects not only the production of knowledge intensive products but also the demand of knowledge and –possibly- its supply.

An effort seems necessary to extend the CDM framework by appreciating the role of knowledge as an –indispensable- intermediary input and hence including the specification and estimation of the derived demand for knowledge equation (Antonelli, 2007). This seems appropriate not only from a theoretical, but also from an empirical, viewpoint. From a theoretical viewpoint it enables to understand the consequences of the Arrovian properties of knowledge in the downstream markets of the final goods -that have been produced by means of knowledge- on the upstream demand of knowledge both within and between firms. The analysis of the

[4] The CDM framework can be further enriched so as to take into account knowledge externalities explicitly. This is not straightforward since it should in principle be done at the level of each of its three layers of equations.

derived demand for knowledge within firms enables to grasp the effects of the price of the final goods on the internal shadow prices of knowledge within the boundaries of the corporation. It is clear that there is a strong positive relationship between the price of the final goods and the position of the derived demand of knowledge: the higher is the latter and the farther on the right the former. The analysis of the demand for knowledge is relevant also when it takes place between firms and KIBS in the markets for knowledge. From an empirical viewpoint in fact the study of the demand for knowledge is becoming more and more relevant because of the increasing specialization of advanced countries in knowledge intensive activities that are emerging as a full-fledged industry composed by firms that produce and sell knowledge embodied in patents and knowledge-intensive services to other firms that use them to produce other goods including both other services and other tangible goods, including new knowledge[5].

One cannot proclaim that the notion of a demand for knowledge was ignored in the early economics of knowledge, which are associated here to the ground-breaking contributions of Arrow, Griliches and Nelson. But it remained largely implicit and its importance was not stressed. A major exception is Schmookler (1966), as recognized in the illuminating analysis of Nathan Rosenberg (1974) that identifies the analytical core of Schmookler's argument in the causal relationship between the demand for

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[5] From an historical viewpoint, the new century is witnessing the progressive vertical disintegration of the generation of knowledge from the augmented production function. What used to be vertically integrated within firms (groups or corporations) is becoming the object of specialized activities (KIBS) that sell knowledge embodied in products and services in the new emerging markets for knowledge (Abramovitz and David, 1996; Arora, Fosfuri and Gambardella, 2001; Tassey, 2005; Shearmur and Doloreux, 2013). The R&D management literature has elaborated the open innovation approach that stresses the reduction of the in-house generation of knowledge and the increasing role of knowledge outsourcing (Chesbrough, 2003; Chesbrough, Vanhaverbeke and West, 2006).

a good (typically capital goods) and the consequent –derived- demand for scientific work. The increase of the demand causes an increase of profitability in the generation of the related knowledge that pulls an increase in the demand for scientists at work in that field and ultimately the increase of the amount of knowledge generated.

The following section provides a simple framework to assess the chain of effects of the Arrovian properties of knowledge on the price of innovated goods in downstream markets and consequently upon the upstream demand of knowledge as an intermediary input, both in terms of quantity and price.

3. WHAT CAN WE GATHER ABOUT THE POSITION AND SLOPE OF THE KNOWLEDGE SUPPLY AND DEMAND CURVES? A GRAPHICAL EXPOSITION

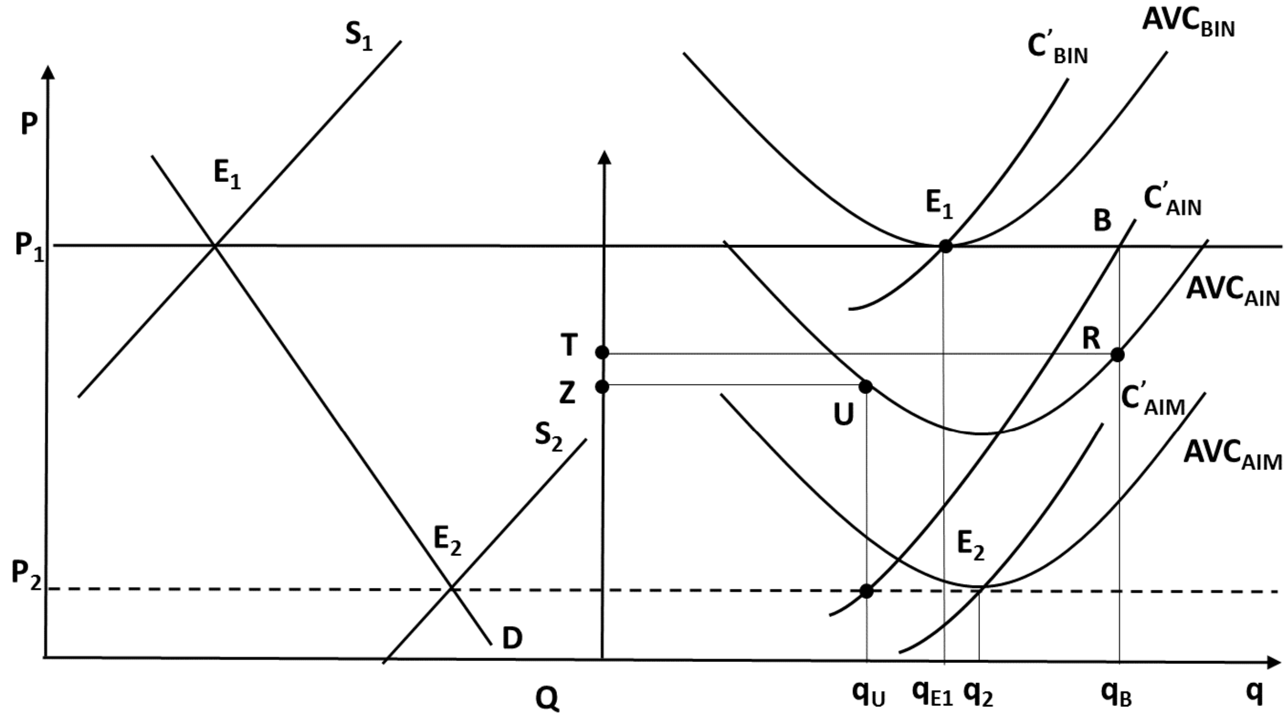
This paragraph applies the Arrovian methodology to compare the working of the market place of standard goods to the markets of knowledge when it is characterized by the Arrovian properties. Because of the limited appropriability of knowledge, the price of knowledge intensive products will be lower than it should have been, had knowledge been a standard economic good (Dasgupta and David, 1994)

The producers of knowledge intensive goods risk not only to miss the full stream of benefits that stem from the introduction of an innovation made possible by the use of knowledge, but also to fail to recover the expenses incurred to produce themselves or purchase the knowledge they need in order to implement process and/or product innovations. Because of limited appropriability, competitors can imitate and produce innovated goods without bearing the costs of knowledge. Their entry and growth will shift the supply schedule of the innovated products downward. Innovators are exposed not only to the missing profits but also to emerging losses. The price in the final markets, in fact, will be determined by the levels of the costs of imitators that do not bear the costs of research activities. It seems clear that the price of the innovated goods that use knowledge characterized by the Arrovian properties as an input is lower that it would be in benchmark product markets where all firms bear the costs of R&D.

INSERT FIGURE 1 ABOUT HERE

Figure 1 provides a simple graphical analysis of the consequences of the limited appropriability of knowledge in the downstream markets for goods produced with knowledge as an input. Let us start with the equilibrium condition E_1 in the industry before the introduction of innovation (BeforeINnovation). In the equilibrium condition firms produce q_{E1} the quantity where marginal costs C'_{BIN} equal AVC_{BIN} . Let us now assume that a firm is able to use knowledge as an input to introduce an innovation. Its marginal cost C'_{AIN} and average cost AVC_{AIN} after innovation fall (AfterINnovation). The firm that can appropriate the benefits of the innovation, would fix prices in B, sell the quantity q_B and earn extraprofits identified by the surface of the rectangle P_1BTR. If and when appropriability is not possible, however, other firms can benefit of the knowledge costs incurred by the innovator. They can imitate the innovation. Their average and marginal costs, after imitation, C'_{AIM} and AVC_{AIM}, are actually lower than the costs of the innovator (AfterIMitation). For them the cost of knowledge is 0. If everybody can imitate the innovation the supply schedule of the industry S_1 shifts to the right towards S_2 where the new equilibrium price P_2 equals marginal and average costs of imitators. The cost of the innovator is now above the new equilibrium level. The innovator will sell the quantity q_U at a cost that is actually larger then the new equilibrium price P_2 incurring losses defined by the rectangle $ZP_2U\ q_U$. The innovator is not able to earn any profit (lucrum cessans) but incurs actual losses (damnum emergens).

FIGURE 1 APPROPRIABILITY AND IMITATION: *LUCRUM CESSANS* AND *DAMNUM EMERGENS*



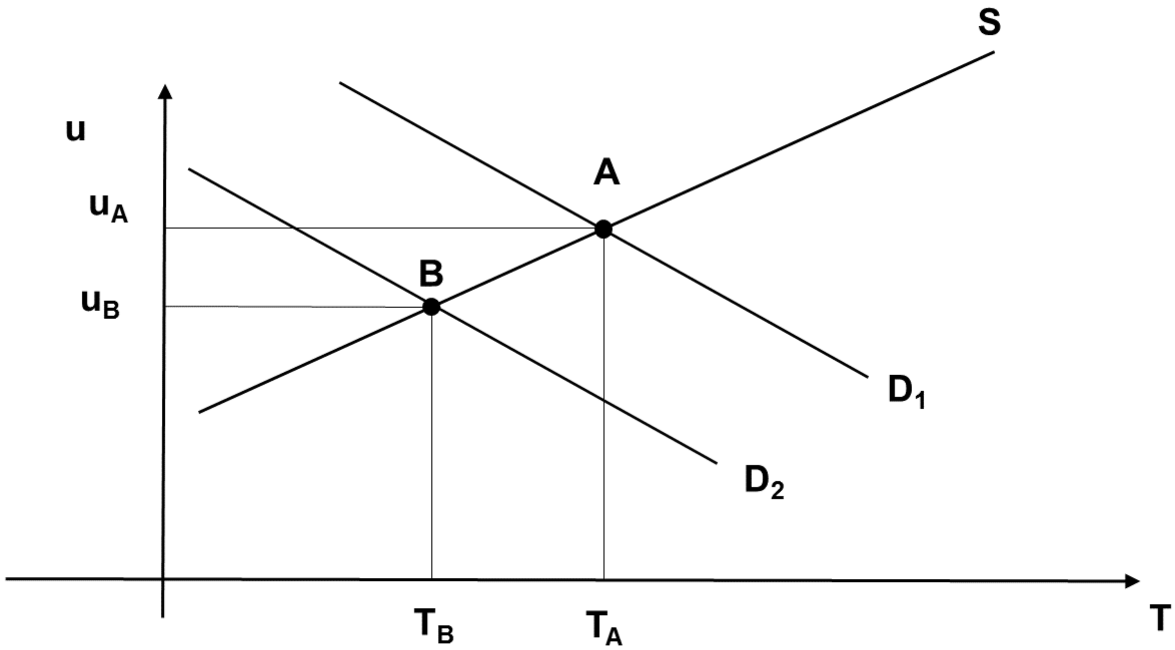
As a consequence, the derived demand for knowledge (i.e. the marginal product of knowledge as an input in the extended production function in value) expressed by downstream activities to specialized upstream knowledge producers –both within vertically integrated firms that perform intramural R&D activities and in the markets for knowledge, between downstream knowledge users and upstream knowledge producers (KIBS)- will be lower than it would have been, had knowledge been a standard economic good.

The position of the derived demand of knowledge depends upon the actual levels of knowledge appropriability: it will be lowest when appropriability in the downstream markets is zero. With higher levels of appropriability in the downstream markets, the position of the derived demand schedule of knowledge will shift upward. When there is full appropriability in the downstream markets the position of the derived demand of knowledge will overlap with the benchmark i.e. that of knowledge as a perfect economic good.

As Figure 2 shows, the derived demand curve of knowledge, as an input in the augmented production function, with its actual “Arrovian” economic properties, D_2, lies below D_1 the benchmark demand curve for knowledge as a standard input, next to S the benchmark supply curve for knowledge.

INSERT FIGURE 2. ABOUT HERE

FIGURE 2. THE SHIFT OF THE DERIVED DEMAND OF ARROVIAN KNOWLEDGE WITH RESPECT TO THE BENCHMARK DEMAND OF A STANDARD GOOD



With a given knowledge supply schedule (S), the derived demand of knowledge -characterized by its Arrovian properties- leads to the reduction of both the quantity (T) and the price of knowledge (u).

The Arrovian postulate about the markets failure is confirmed and actually enriched. The standard Arrovian market failure consists in the undersupply of knowledge ($T_A > T_B$). The analysis implemented so far enables to appreciate a second aspect of the market failure: the depreciation of knowledge ($u_A > u_B$).

The depreciation of knowledge stemming from the downward shift of the demand curve, determined by its limited appropriability and the consequent fall of the price of goods produced using it as an input, is itself a cause of a specific and new type of market failure. It engenders, in fact, the exclusion of high productivity and large scale projects that cannot be any longer afforded. The fall of the price of knowledge is the cause of an additional market failure: the excess and adverse selection of research projects. The system is able to implementing minor research projects that are likely to yield incremental innovations. Large scale and high quality research projects that are likely to favor the introduction of radical innovations are sorted out. The downward shift of the demand of knowledge is the cause of a selective undersupply: the undersupply of high quality large scale research projects.

These effects may be mitigated by the possibility that the limited appropriability of knowledge affects not only the derived demand of knowledge but has -positive- effects on the supply of knowledge as well. External knowledge, in fact, spills and enters the knowledge generation function as an input. The cost of knowledge –now regarded as an output- is lower because of the effects of spillovers on the knowledge production function (Adams, 2006) [6].

Figure 3 helps analyzing the joint effects of knowledge appropriability on both the demand and the supply of knowledge.

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[6] In the recombinant knowledge production function, external knowledge is an indispensable input strictly complementary to internal R&D activities and other inputs. According to the knowledge appropriability levels the costs of external knowledge fall below the benchmark levels that would take place were all inputs standard goods. The effects of spillovers on the cost of external knowledge depend on the actual conditions of absorption and use of knowledge as an input on the production of new knowledge. The lower are the levels of knowledge costs as an input and the lower is the cost of knowledge as an output (Griliches, 1979, 1984, 1986, 1992; Cohen and Levinthal, 1989; Weitzman, 1996).

INSERT FIGURE 3 ABOUT HERE

FIGURE 3. THE SHIFTS OF THE ACTUAL DEMAND AND SUPPLY OF ARROVIAN KNOWLEDGE WITH RESPECT TO THE BENCHMARK DEMAND AND SUPPLY OF A STANDARD GOOD

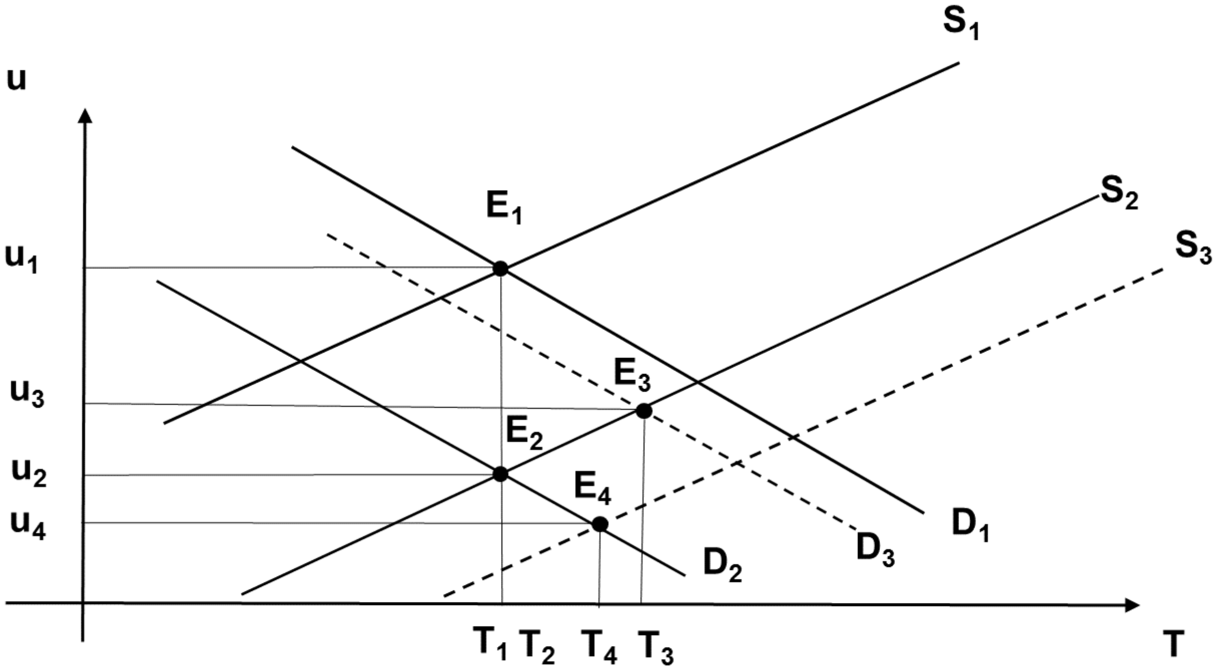

Figure 3, with the price of knowledge (u) on the vertical axis and the quantity of knowledge (T) on the horizontal axis,, presents the shift of the derived demand from the benchmark D_1 to D_2 -as determined by the consequences of knowledge limited appropriability on the output and the downstream price of the goods produced using knowledge as an input and consequently on the derived demand - and the shift of the supply curve from the benchmark S_1 to S_2 -as determined by the positive effects of knowledge spillover and externalities on knowledge marginal costs[7].

Let us consider, for the sake of armchair theorizing, the interesting case that takes place when the shifts of S_2 and D_2 are symmetric. The new equilibrium is found in E_2 where the quantity of knowledge as a standard

[7] The dotted curves D_3 and S_3 exhibit the effects of policy interventions on the demand and supply of knowledge respectively. See the following section 4.

good and as an Arrovian one, is exactly the same ($T_1 = T_2$) while its price u is much lower ($u_1 > u_2$).

The analysis of the sheer quantities reveals that, when the positive effects of knowledge spillovers on the supply of knowledge are taken into account, together with the negative ones on its derived demand, there is not the expected undersupply of knowledge. The positive effects of spillover on the supply side compensate for the negative effects on the demand side. This is an important result. Next to the effects on the quantity, however, there are also effects on the price of knowledge.

The joint analysis of the supply and the derived demand of knowledge -characterized by its Arrovian properties- enable to grasp the problem of the depreciation of knowledge.

The derived demand of knowledge, in fact, can be regarded as an ordered structure of investments projects: those with higher levels of marginal productivity are placed in the upper part of the curve. As Figure 3 shows, the depreciation of knowledge that stems from the downward shift of the derived demand curve has negative effects in terms of adverse selection with the exclusion of the high quality and high yield projects. High quality research projects cannot be any longer afforded because of the reduction of the price of goods produced using knowledge as an input.

The identification of the causes and consequences of the depreciation of knowledge is important. The depreciation that stems from the downward shift of the supply curve, instead, yields the typical positive effects of an increased consumer surplus. The latter compensates for the shift of the demand but only with respect to low quality projects[8].

[8] The simultaneous solution of the CDM system of equations enriched by the knowledge derived demand equation that underlies this essay enables to take into account the feedback of the decrease of the price of knowledge as an input and the consequent 'additional' downward shift of the derived demand of knowledge.

When the effects of the public interventions with the provision of public subsidies and scientific knowledge generated by the public research system are taken into account, we see that the dotted line S_3 shifts further to the right of S_2. The quantity of knowledge increases, the price of knowledge declines further, farther away from the benchmark situation that would take place if knowledge were a standard good, and the consumer surplus increases. The adverse selection however is not reduced. Only interventions on the demand side (the dotted line D_3) are able to increase the price of knowledge and avoid the negative effects of the adverse selection of high quality research projects.

The Arrovian remedy, fully concentrated on the supply side, favors the increase of the supply of low quality projects but does not take into account the negative effects of the shift of the derived demand on the price of knowledge in terms of adverse selection. The discovery of the depreciation of knowledge seems to be an important contribution to the economics of knowledge as well as the identification of its causes whether determined by the shift of the supply or the demand curves. The effects of the depreciation of knowledge depend upon the cause: they are positive if the stem from the shift of the supply curve and negative if they depend on the shift of the derived demand.

4. IMPLICATIONS FOR KNOWLEDGE POLICY

The analysis carried out through this paper yields two results: i) the positive effects of limited knowledge appropriability may be compensated by its positive effects on the supply of knowledge; ii) the depreciation of knowledge stemming from the downward shift of the derived demand is cause of major concern in terms of selective undersupply.

The identification of the fall of the prices of knowledge because of its Arrovian properties and of its twin effects, positive if they stem from the shift of the supply of knowledge and negative if they stem from the shift of the supply of knowledge, seems an important result not only from the viewpoint of the economics of knowledge but also for its implications for knowledge policies. The positive effects stemming from the downward shift of the supply of knowledge call for an active policy that helps to increase further the downward shift of the supply of knowledge. The negative consequences of knowledge depreciation in terms of excess-selection of research projects may be quite important. High quality projects that are likely to engage large undertakings with high yields but also large size risk to be sorted out (Arrow and Lind, 1970). The case of selective undersupply –as opposed to a generic undersupply- should be taken into account. Targeted public policies aimed at contrasting the selective undersupply are necessary. Substantial efforts are necessary to complement and integrate the support to the generation of knowledge by means of the public provision of knowledge (David, Hall and Toole, 2000) and subsidies to private R&D activities[9], with interventions able to shift the position of the actual derived demand for knowledge D_3 closer and closer to the benchmark position D_1 i.e. the benchmark position of the derived demand for knowledge if it were a standard economic good and even beyond.

Public policies aimed at supporting the supply of knowledge in the system via the direct production of new knowledge by the public research infrastructure and the provision of public subsidies to firms that undertake R&D activities are most likely to reinforce the mechanisms that lead to the downward shift of the supply of knowledge with all its positive effects. As such they must be implemented. It should be clear, however, that supply policies can not limit the negative effects of the depreciation of knowledge. Supply policies can help increasing small scale low productivity projects that are more likely to favor the introduction of incremental innovation. Supply policies cannot prevent the adverse selection engendered by the downward shift of the derived demand.

[9] See the sistematic reviews of the literature by Hall and Van Reenen (2000) and the recent one by Ientile and Mairesse (2009).

Public policy should focus the negative effects on the system of the depreciation of knowledge that stems from the downward shift of the derived demand of knowledge. The downward shift of the demand of knowledge with the consequent depreciation of knowledge leads in fact to the excess and adverse selection of knowledge generating projects reducing the opportunity to take advantage of types of knowledge that can yield a large marginal output. Specifically the downward shift of the demand of knowledge risks to exclude of large scale and high quality research projects that are more likely to make the introduction of radical innovations possible. The occurrence of undersupply does not apply to the full range of research projects, but specifically only the to high-yield ones. It does not take place, in fact, because of the effects of the economic properties of knowledge on its supply, but because of the downward shift of the derived demand for knowledge. As such the depreciation of knowledge stemming from the downward shift of the demand engenders an adverse selection that must be contrasted by an effective and dedicated knowledge policy. The case for selective-undersupply as opposed to the Arrovian generic undersupply applies. As Arocena and Sutz (2010) note, the risk of under-demand and consequent excess-selection and selective undersupply of knowledge is especially strong in developing countries.

The shift of the demand curve can be contrasted by targeted public policies that take into account the specific market failure determined by the selective undersupply. This amounts to reconsider the foundations of the demand pull hypothesis. The large literature on the demand pull makes it possible to identify three distinct components: i) the sheer size effect: the larger is the demand of a good and the larger are the incentives and the efforts of firms to invest in R&D activities in order to generate new knowledge. This effect would take place even if knowledge could be fully appropriated; ii) the user-producer interactions: larger demand from competent users should be able to support the efforts of upstream producers. This in turn requires that procurement is qualified and competent (Antonelli and Gehringer, 2015); iii) the price effect: a demand that is able to pay fair prices i.e. prices that are close to the benchmark cost of the new products including R&D expenses can support effectively R&D expenses as firms can cope with lower risks of -poor- appropriability.

The support to the demand for high quality and large scale research projects can be implemented by means of both direct and indirect public interventions. Direct interventions consist in the demand of knowledge intensive products by public administrations. A wide range of public activities is active as direct customers of goods produced by the private sector, from weapons to health-related products. Direct interventions can affect not only the size of the demand and the quality of user-producer interactions, but also and primarily the price for knowledge intensive products and hence contribute directly to shifting D_3 closer and closer to the benchmark D_1.

The analysis of public procurement has highlighted the positive effects of the prices paid by specialized and competent public customers on the derived demand for R&D projects that focus high-quality and large scale projects. The rightward shift of the demand for knowledge can take place when a reliable public demand for knowledge intensive goods is implemented (Edquist, Vonortas, Zabala-Iturriagagoitia, Edler, 2015). Dedicated procurement in weapons typically seems able to provide suppliers with a reliable price that includes the full appropriation of the resources invested in the use of knowledge as an input of their technology production function. The closer is the price of goods in downstream markets to the benchmark and the larger the levels of the derived demand for knowledge hence the closer is D_3 to D_1. It seems important to try and apply this positive experience to other types of goods (Eliasson, 2010; Mowery, 2012).

The appreciation of the price effect has important implications for the selection procedures of public procurement. Beauty contests seem more appropriate than rebate auctions. The implementation of beauty contests, however, implies competent customers.

Indirect interventions consist in interventions aimed at stirring the demand of knowledge by means of the support to the demand of downstream customers of knowledge-intensive products. Their implementation can take place by means of subsidies to dedicated knowledge intensive products as well as by means of strategic standards able to direct the demand towards innovative products. The effects on the size of the derived demand and the intensity of user-producer interactions are likely to be strong, but the effects on the price of the knowledge are weaker.

Public subsidies can support the purchase of knowledge embodied in intangible knowledge intensive services by downstream firms. Indirect interventions to increase the demand of knowledge might include specific subsidies to the purchase of patents, the payments of royalties and the outsourcing of research activities to the public research system (Guerzoni and Raiteri, 2015).

INSERT TABLE 1 ABOUT HERE

TABLE 1. DEMAND SIDE PUBLIC INTERVENTIONS

	SIZE EFFECT	KNOWLEDGE USER-PRODUCER INTERACTIONS	PRICE EFFECT
DIRECT	ADVANCED PUBLIC PROCUREMENT	COMPETENT PUBLIC PROCUREMENT	PUBLIC PROCUREMENT WITH 'FAIR' PRICES
INDIRECT	SUBSIDIES TO THE DEMAND	SUBSIDIES TO THE PURCHASE	SUBSIDIES TO THE PURCHASE

	OF KNOWLEDGE INTENSIVE GOODS STRATEGIC STANDARDS	OF KNOWLEDGE INTENSIVE BUSINESS SERVICES SUBSIDIES TO THE PURCHASE OF PATENTS AND RESEARCH CONTRACTS	OF KNOWLEDGE INTENSIVE BUSINESS SERVICES SUBSIDIES TO THE PURCHASE OF PATENTS AND RESEARCH CONTRACTS

As Table 1 shows, the support to the demand of knowledge as an input into the technology production function by downstream firms has a wide range of possible interventions ranging from direct public procurement to indirect subsidies to the purchase of knowledge embodied in services and of disembodied knowledge. The distinction between size, knowledge interaction and price effect is useful to focus an effective demand side knowledge policy. Its implementation is successful as far as it is able to engender the shift of D_3 closer and closer to the benchmark D_1 pushing both the quantity and the price for knowledge towards to benchmark levels so as to mitigate knowledge 'under-demand'.

The analysis of the consequences of the actual position of the derived demand curve of knowledge with its specific and actual properties, as compared to the derived demand of a standard good, confirms not only that it exerts major effects on the actual working of the markets for knowledge, but also and primarily that it is a necessary component of the array of interventions that may make possible the remedy to the Arrovian market failure.

5. CONCLUSIONS

The analysis of the economic properties of knowledge and the identification of its limits and idiosyncratic characters has been most successful. For quite a long time, the attention of the literature has focused the consequences of the economic properties of knowledge on the supply of knowledge intensive products. The advances of the economics of knowledge and specifically the identification of the augmented production function and the knowledge generation function and their systemic combination into the CDM approach provide a fertile framework. It enables, in fact, to single out and investigate the effects of the economic properties of knowledge not only on the supply of knowledge intensive products, but also on the demand and supply of knowledge. In this context in fact, the appreciation of the role of knowledge as an intermediary input and an output yields important insights. The demand of knowledge is very much influenced by the outcomes of competition in the downstream markets where the goods that have been produced using knowledge as an input, are sold.

The derived demand for knowledge is affected, as much as its supply, by its limited appropriability, asymmetric information, non rivalry in use, radical uncertainty in its generation and exploitation. Agents are not only reluctant to generate knowledge. They are also reluctant to purchase and use it as an input in the production of all the other goods. As a consequence the derived demand for knowledge lies far on the left of the benchmark derived demand of knowledge were it a standard good and its price risks to be lower than it would happen for standard goods. For the same token limited appropriability, however, exerts positive effects on the production of knowledge. The analysis of the effects of the leftward shift of the derived demand for knowledge combined with the appreciation of the effects on the supply of knowledge, questions the economic rationale of public policies centered on supply. Supply-side policy interventions can enhance the increase of the supply of knowledge and favor the decline of the price of knowledge below the benchmark levels, but cannot contrast the excess-selection of large scale and high quality research projects.

The remedy to the selective undersupply of knowledge can work only if public policies focus both the supply and the demand for knowledge. Selective public procurement, both direct and indirect, able to provide a reliable demand for radical innovations characterized by high levels of knowledge intensity and high quality and large scale research projects can compensate the leftward shift of the derived demand and complement the effects of supply policies on the position of the knowledge supply schedule.

These results seem important from many viewpoints. From an analytical viewpoint the analysis of the derived demand for knowledge provides a novel approach to the analysis of the economic properties of knowledge as an intermediary economic good and highlights the risks that the price of knowledge -both the shadow prices within corporation and the monetary prices in the markets for knowledge- falls well below the benchmark levels. The negative consequences in terms of excess selection of high quality and large scale projects and selective undersupply of knowledge –as opposed to the generic undersupply of the Arrovian approach- should be taken into account. From an empirical viewpoint it provides a field of investigation that can enrich and implement the CDM approach. From an economic policy perspective, it highlights the need to articulate and implement an integrated approach able to frame a set of public interventions that combine the support to both the supply of knowledge and its derived demand.

6. REFERENCES

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