Economics of co-authorship

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Abstract

Starting from the literature on the rising incidence of co-authorship in economics, choices about co-authorship are analyzed with a theoretical model, assuming that authors optimize the returns from publications. Results show that co-authorship behavior depends both on the technology of the production of economic research and on the reward system that a researcher faces. Two pay structures are considered, one that is proportional to the number of authors and one that is not. The researchers' heterogeneity implies a trade-off for the policy maker between the objective of effort maximization and the objective of selection of better researchers. The trade-off is more relevant when low-quality researchers choose to engage in opportunistic behavior to gain from higher-quality collaborations.

Keywords: Co-authorship**;** Academic research; returns from publications.

JEL: A11, J40, D04.

1. Introduction

The frequency of scientific collaboration in economics has been increasing since the early 1950s, resulting in a rising trend in multi-authorship (Hudson, 1996). Some explanations have been proposed and tested in the literature, with varying results. Basically, the growing incidence of co-authorship is ascribed to a technological change in the production function, which fosters increasing opportunities for specialization. The estimates of the effect of co-authorship are referred alternatively to two different measures of output: a quantitative measure (e.g., the number of publications) or a qualitative one (e.g., the impact of each publication). Three limits in the existing analysis of co-authorship can be underlined.

The first limit relies on the focus of the proposed explanations, which are concentrated only on the supply side of the economic research market while the demand side is often ignored. All of the arguments concern the shape of the production function or the evolution of input prices. Different returns to economic research are often considered a consequence of the structural change in research methods. It seems that the market for economic research is taken by assumption as a competitive market.

The second limit concerns the measures that have been used to approximate the output of the research, which may be either qualitative or quantitative measures. The changing measure of the output of the research makes it difficult to compare the assumptions and the results of different studies.

Finally, the lack of a theoretical framework could explain both the first and the second limit discussed above. By simultaneously considering the demand and the supply side of the research market, the conflicting effects of the technological change and the reward system can be evaluated. Empirical findings supporting the hypothesis of an evolution of the production function could be otherwise ascribed to the incentive system for economic research chosen by the research organizer. In the same way, the irrelevance of co-authorship on a quantitative or qualitative measure of research could derive from the pay structure prevailing in the market. A more comprehensive analysis should assess the causal relations that have to be tested and should define an approach to the measurement problem of the research output.

On these bases, a theoretical model of authors' behavior is developed in this paper that, allowing for a quantitative or qualitative approach to the production function, takes into account the effects of different pay structures. The following section reviews the main hypotheses about the rising incidence of co-authorship in economic research, and Section 3 discusses some specific empirical results. The policy implications of the different hypotheses on co-authorship are briefly summarized in Section 4. The model of authors' behavior and its implications are described, respectively, in Section 5 and 6. Finally, Section 7 provides as a case study the analysis of Italian economists' performances. Concluding remarks are found in Section 8.

2. Determinants of co-authorship: a literature review

The literature documents empirical findings suggesting that increasing opportunities for specialization can explain the rising incidence of co-authorship (McDowell and Melvin, 1983). Additional arguments have been tested over time. Barnett, Ault and Kaserman (1988) analyze four different explanations of the rising incidence of co-authorship, finding empirical support for finance researchers for the first three hypotheses.

The *division of labor* hypothesis, tested by McDowell and Melvin, is based on the increasing specialization coming from the growing stock of knowledge in economics. The gain from collaborative work might result from harnessing skill complementarities (Hudson, 1996) or from the fact that "it may be cheaper for and individual to acquire new capacity (human capital) to produce through formal collaboration with someone who already has the requisite human capital than to acquire the needed knowledge de novo, personally" (Laband and Tollison, 2000). From this

perspective, co-authorship fosters higher quality by exploiting complementarities. Nevertheless, empirical analyses of the input relationship between co-authors have shown the existence of a substitutability relation between co-authors (Medoff, 2007). Aside from the benefits of co-authorship, it is necessary to take into account also to the costs associated with scientific collaboration. Hudson (1996) underlines that collaborative work involves compromises and less risky approaches to economic problems. Surely, multi-authored papers involve some costs of coordination and communication, varying with the intensity of specialization of the researchers involved. Combinations of researchers with different specializations favor the division of labor and reduce coordination costs. Researchers with similar skills probably face higher costs of coordination.

The hypothesis of a rising *opportunity cost of time* derives from the tightening of the "Publish or Perish" mechanism. The time before devoted to informal review of colleagues' drafts is now more costly, and, by offering a co-authorship, a researcher can incentive the level of effort required for an accurate review of the paper. Also, from this perspective, collaboration guarantees more adequate quality standards. The *diversification hypothesis* comes from the uncertainty embedded in the editorial review process. Through co-authorship, more papers can be submitted, reducing the variance of the random elements of the review process. In this hypothesis, researchers choosing whether to produce a single authored paper or two bi-authored papers will prefer the second option because it reduces the variance of the random elements of the review process, which may lead to rejection for even good-quality papers. Then, according to the risk diversification hypothesis, a minimum standard of quality is pursued by authors choosing co-authorship.

The fourth hypothesis, which concerns the relationship between *co-authorship and quality*, encompasses all the previous ones. The relation between quality and co-authorship can derive from the increasing need for specialization, the rising opportunity cost of time and risk diversification, as discussed earlier. In addition, it could be also the result of a sort of synergy where multiple contributors can develop results that none would have developed on his or her own. Synergy differs from complementarities because it can exist also between individuals with similar skills (Hudson, 1996). The quality hypothesis has been tested using different measures, such as citation frequency and award winners. Laband (1987), Chung, Cox and Kim (2009) and Johnson (1997) report that the average quality (measured by citation frequency) is higher for co-authored papers. For Laband and Tollison (2000) the evidence that co-authored papers are more likely to be accepted for publication than single-authored papers supports the hypothesis that co-authorship gains occur in the form of higher-quality manuscripts. The Presser's (1980) results for social psychology, showing that collaboration is associated with fewer rejections, are often cited as support for the quality hypothesis. In contrast, Barnett et al. (1988) do not find support for the quality hypothesis, and Hollis (2001) reports differentiated results: by using the journals citation index as a proxy for the quality of the articles, he finds that quality is positively correlated with the number of authors for a given author; on the other hand, total output per period per individual, measured as the sum of published pages weighted by quality indexes and discounted by the number of authors, is lower when more co-authorship occurs. For the author, this evidence supports the conclusion that, though collaboration is privately rational, it is not socially desirable if we care about the sum of quality research produced.

A fifth hypothesis is added in this paper. The *demand-side hypothesis* suggests that co-authorship is enhanced by the academic pressure for publications, to gain high salaries and career advances, which results in "…an oversupply of research tied to personal and bureaucratic imperatives such as promotion and tenure…" (Laband and Tollison, 2003, p.166). If researchers are evaluated on the basis of the number of publications/citations and papers with k authors are not counted as $1/k$ papers, the benefit from co-authorship is straightforward. Researchers choosing whether to work on a single authored paper or on two bi-authored papers, exerting the same effort, will prefer the second option because it doubles the probability of an up move.

Taken as a whole, two explanations remain on the table. According to the quality hypothesis, researchers collaborate to obtain a synergy effect or risk diversification, to exploit skills complementarities or to obtain informal review. The demand side hypothesis stresses that the incentive toward co-authorship is provided from the research organization, which rewards the number of publication or their quality in the same way, regardless of the number of authors. The critical difference between the two types of explanations is in the source of the incentive to co-author. According to the quality hypothesis, co-authorship is fostered by the technological progress embedded in the production function or by more binding conditions in the research market. Conversely, the demand side hypothesis relies solely on the pay structure the principal chooses. From a theoretical point of view, the two hypotheses are not alternatives because they can occur simultaneously.

3. The prolific author, the nearness neutrality and the loneliness of the theoretician

The evidence of Chung et al. (2009) discloses new possible explanations for the relationship between the numbers of authors and the citations frequency. The authors show that papers co-authored with a prolific author are of higher quality (are cited more often), whereas co-authoring with colleagues at the same institution leads to neither higher- nor lower-quality papers. Finally, for purely theoretical papers, the relationship does not hold.

The positive impact of a prolific author suggests a correlation between the quantity of papers and citation frequency, which produces a positive externality for the co-authors as well. Johnson (1997) finds that the number of citations an article receives is positively related to the number of past citations and publications of the author. The author refers this evidence alternatively to the intrinsic quality of the paper or to a bias towards citing famous people.

More papers increase the probability to be cited, but to publish more papers than other authors, more competence in publishing is needed. The prolific author could be a higher-quality author and/or a researcher with more editorial relationship. In any case, the reputation effect of a prolific author has a positive effect on the measures of quality of his co-authors. Whether these measures correspond to the actual quality of the co-authors depends on several conditions. When more publications are synonymous with the higher quality of the leading author, working with a high-quality researcher is, by itself, an indicator of higher effort and/or quality of the co-author. Following the reasoning of the opportunity cost hypothesis, the leading author could play the role of first reviewer or supervisor, ensuring a threshold level of quality of his co-author. The hypothesis of a "mentor-protégé" relationship has been analyzed by Laband and Piette (1995), who did not find empirical support for it[1]. However, the reputation effects of a well-known co-author can be used to reduce the probability of rejection. A low-quality researcher gains a lower risk of rejection, whereas the higher-quality researcher can sustain his prolific reputation if she has a quantity objective. Reciprocal convenience in co-authorship depends on the relative benefits and costs. It could be suitable that the lower-quality researcher takes on a part of the higher quality researcher's costs. To summarize, the prolific author evidence supports two opposite explanations. In the first one, co-authorship signals higher quality for all the co-authors and then is compatible with the quality hypothesis; in the second one, there is only a leading higher-quality author, whereas the others agree to bear part of the costs of the leader to benefit from his "good" signal. This cost/benefit exchange can be defined as the *opportunism effect* that could occur to exploit a citation bias or simply to produce more papers.

The neutral effect on quality of co-authorship inside the same institution has a more complex explanation. It seems arguable that lower costs of coordination and communications occur when collaboration is established between the nearest colleagues, but at the same time, a smaller extent of specialization is available inside the institution than all over the world. The lower cost of

[1] Further investigation on the mentor-protégé relationship is provided by Mixon (1997).

coordination should increase the number of co-authored papers inside the institution, whereas fewer occasions for division of labor should decrease the number of co-authored papers. The two opposite effects can result in a frequency of co-authorship with no statistically significant difference inside and outside the institution.
If the opportunity cost hypothesis holds, a review implicitly paid through the co-authorship is more likely to occur inside an institution, where nearness eases the revision process. The benefit of co-authorship increases the probability of collaboration in the same direction of the lower cost of coordination. The same holds for the risk diversification hypothesis and the synergy hypothesis. More co-authorship and higher quality should be observed within a single institution. Then, the opportunity cost hypothesis is not compatible with the evidence of neutrality, and neither are the synergy effect or the risk diversification hypothesis. Because the evidence of Chung et al. show that co-authoring with colleagues at the same institution leads to neither higher- nor lower-quality papers, the previous arguments show that quality neutrality within an institution is compatible with the quality/specialization explanation.
Finally, Chung et al. report that for purely theoretical papers, the relationship between co-authorship and quality does not hold. Barnett et al. (1988), assuming that a theoretical paper is not favorable to the division of labor, support the specialization hypothesis with the evidence that the number of co-authors is higher for empirical and theoretical/empirical papers than for purely theoretical papers. In the opportunity cost hypothesis, no difference between empirical and theoretical papers should arise. The same would be true for the risk diversification hypothesis and for the synergy hypothesis. The loneliness of the theoretician rejects the idea that collaboration implies synergies and confirms that the higher quality of co-authored papers derives from the specialization if the division of labor is more difficult in theoretical papers.
In conclusion, no evidence supports the positive quality effect of synergies in co-authorship. It seems reasonable that the positive relationship between quality and scientific collaboration arises in fields where growing specialization implies some skills complementarities or when higher-quality authors collaborate to reduce the opportunity cost of revisions. Conversely, the relationship between quality and collaboration breaks down when opportunist behavior occurs between an author of high quality and a lower-quality researcher, if their common objective is to maximize the number of publications they produce.

4. Research policy implications: the quantity/quality approach

Scientific collaboration is often incentivized by promoting research networks and researchers aggregation. When the macro level is concerned, collaboration has additional advantages because it stimulates the circulation of ideas and the transfer of knowledge. From the micro perspective, the only substantial argument for a causal relation between quality and collaboration is the one about specialization and complementarities. Should the individual reward system incentivize or punish the collaborations? The answer partly relies on the objective of an individual reward system. It can be used for the selection of the better researchers or to obtain the maximum results from the researcher. When the maximum result is concerned, it seems reasonable to assume that the main aim of a research institution is to improve research quality rather than quantity. Sauer (1988), estimating the earning functions of 140 academic economists, shows that monetary return to research quality is measurably large[2].
The researcher's output can be interpreted from both a quantitative perspective and a qualitative one, focusing on the number of papers or the citations produced, respectively. From the quantity perspective, Durden and Perri (1995), Landry et al. (1996) find that the number of total publications is positively related to the number of co-authored papers, whereas McDowell and Smith (1992) find no significant result. Nevertheless, the quantitative measure can be improved with quality

[2] See Coupé (2004) for a more detailed overview of research about labour market of academic economists.

refinements concerning the paper diffusion and its relative citations. Until now, the better available measure for the research quality is the h-index, based on the numbers of citations for each publication. The h-index is an acceptable measure of the quality of one paper, if a cited paper has been more useful to other authors than a paper that is uncited. The "dry holes", defined by Laband and Tollison (2003) as publications that subsequently received no citations, have shown a stable incidence in the last decades. Simply compared with the rising incidence in co-authorship, the constant incidence of dry holes shows that more co-authorship does not reduce the fraction of uncited papers. This conclusion should reject the quality hypothesis and the other quality related hypothesis (opportunity cost, specialization and risk diversification).
The uncertainty regarding the better measure of output research suggests the opportunity of a quantitative/qualitative approach to the analysis of researcher's choices concerning co-authorship. If a production function is defined as the relationship between effort and the number of publications/citations, a well-defined incentive scheme will lead to a framework where the efficient use of researchers' effort gives the maximum amount of publications/citations.

5. Choices of co-authorship: a theoretical model

A paper can be produced with the effort of the *ith* researcher or with the combined effort of the *ith* researcher and other *k* co-authors. If individual effort has decreasing returns in the papers production function, the co-authorship has a straightforward advantage: each added author has higher productivity. Nevertheless, co-authorship brings an additional cost in the coordination of reciprocal effort and production.
Consider a production function of publications, with decreasing returns of effort. Because a single authored paper is always possible (and actually produced), the additive function reported in (1.a) seems to adequately fit the framework.

$$P_i = h\sqrt{e_i} + kh\sqrt{\hat{e}} \qquad \text{with } i = 1,...,N \quad \text{and } 0 \le k \le N-1, \tag{1.a}$$

where P is the number of papers produced by the *ith* researcher, e_i is his effort, $\hat{e}$ is the estimated effort of the *k* co-authors and *h* is a skill parameter. Co-authorship has constant returns. To simplify the algebra, assume that the author estimates that each co-author will put the same effort he will reserve for the research, leading to the equation $P_i = (1+k)h\sqrt{e_i}$. Furthermore, this assumption turns the original perfect substitutability between the agent's effort and the others' contribution into imperfect complementarities between individual effort and the total number of authors. This formulation does not exactly represent the skill complementarities of the specialization hypothesis, which would imply a complementary relationship between effort of author *i* and that of author *j*. More generally, this production function shows the scale economies arising from collaboration.
The production function of the researcher can be expressed in terms of the output quality Q_i, where more quality can be obtained by exerting more effort or from the contribution of additional researchers. In what follows, analytical implications will be referred to the quantity production function, but the same conclusions hold when considering $Q_i = (1+k)h\sqrt{e_i}$.
There is a fixed cost of coordination for each co-author (*c*) and a constant disutility of effort (*d*). As a first step, the behavior of the researcher facing a non-proportional pay structure is described. If the reward provider offers a reward Φ, based on the volume of publications/citations, the maximizing researcher will face the problem in (2.a).

$$\max_{e_i,k} \; \Phi(1+k)h\sqrt{e_i} - de_i - ck \qquad \text{s.t. } 0 \le k \le N-1 \tag{2.a}$$

Due to the constant returns to co-authorship, a corner solution arises depending on whether the marginal revenue of coordination is higher or lower than its cost.

$$(e_i^*, k^*) = \begin{cases} e_i^* = \dfrac{\phi^2 h}{4d^2},\ \mathrm{k}^*=0 & \text{if} \quad \phi^2 hN \le 2dc \\ e_i^* = \dfrac{\phi^2 hN}{4d^2},\ \mathrm{k}^*=\mathrm{N}\text{-}1 & \text{if } \phi^2 hN > 2dc \end{cases} \tag{3.a}$$

A researcher will co-author with all of the other *N-1* researchers, when a lower coordination cost or a higher reward is found. Otherwise, when the research organizer offers low rewards, the better choice is to put lower effort into single-authored publications.

If researchers' heterogeneity is introduced, different co-authors' combinations have to be considered. Assume that there are two types of researchers: N_H authors with higher ability $\mathrm{h_H}$ in production of publications, and N_L authors with lower ability h_L. The *ith* low-type author (with $i = 1,...,N_L$) can choose k_{Li} co-authors with the same ability and/or k_{Hi} with higher ability. The same holds for *jth* high ability author (with $j = 1,...,N_H$), where k_{Hj} is the number of his high-type co-authors, and k_{Lj} his low type co-authors. The paper production functions for the two types of researchers are described in (1.b).

$$\begin{aligned} P_i &= (1+k_{Li})h_L\sqrt{e_i} + k_{Hi}h_H\sqrt{e_j} \\ P_j &= (1+k_{Hj})h_H\sqrt{e_j} + k_{Lj}h_L\sqrt{e_i} \end{aligned} \tag{1.b}$$

If the high-quality authors are characterized by more specialized skills, the division of labor is more fruitful than for the lower types. With similar skills, the high-quality authors collaborate to compensate for a high opportunity cost of time. The low-quality authors collaborate for risk diversification if they face a relative lower cost of coordination (as in the collaborations inside the same institution). Consequently, it can be assumed that, when facing the same cost of coordination, the higher-quality author will collaborate, whereas the lower-quality author will not. In the case of homogeneity, the convenience to collaborate emerges when $\phi^2 h^2 N > 2dc$. With heterogeneous skills it can be assumed that the higher-quality author has a productivity h_H that ensures that $\phi^2 h_H^2 > 2dc$, whereas for the low-ability author it is true that $\phi^2 h_L^2 \le 2dc$. If the marginal reward for papers is the same and is equal to Φ, each type of author faces the maximization problem described in (2.b)

$$\begin{aligned} &\max_{e_i,k_{Li},k_{Hi}} \ \phi(1+k_{Li})h_L\sqrt{e_i} + \phi k_{Hi}h_H\sqrt{e_j} - de_i - c(k_{Hi}+k_{Li}) \quad \text{s.t. } 0 \le k_{Li} \le N_L - 1 \\ &\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad 0 \le k_{Hi} \le N_H \\ &\max_{e_j,k_{Lj},k_{Hj}} \ \phi(1+k_{Hj})h_H\sqrt{e_j} + \phi k_{Lj}h_L\sqrt{e_i} - de_j - c(k_{Hj}+k_{Lj}) \quad \text{s.t. } 0 \le k_{Hj} \le N_H - 1; \\ &\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad 0 \le k_{Lj} \le N_L \end{aligned} \tag{2.b}$$

Solutions to the respective maximization problems must be compatible because when an author of a given type wants to collaborate with the other type, the other type should consider the collaboration an optimization choice. Two possible solutions arise. If

$$\phi^2 h_L^2 N_L > 2dc \quad \begin{cases} e_i^* = \dfrac{\phi^2 h_L^2 N_L^2}{4d^2}, & \mathrm{k}_{Li}^*=\mathrm{N}_L\text{-}1, \quad \mathrm{k}_{Hi}^*=\mathrm{N}_H \\ e_j^* = \dfrac{\phi^2 h_H^2 N_H^2}{4d^2}, & \mathrm{k}_{Hj}^*=\mathrm{N}_H\text{-}1, \quad \mathrm{k}_{Lj}^*=\mathrm{N}_L \end{cases} \tag{3.b}$$

$$\text{If } \phi^2 h_L^2 N_L \le 2dc \begin{cases} e_i^* = \dfrac{\phi^2 h_L^2}{4d^2}, & \mathrm{k}_{Li}^*=0, \quad \mathrm{k}_{Hi}^*=\mathrm{N}_H \\ e_j^* = \dfrac{\phi^2 h_H^2 N_H^2}{4d^2}, & \mathrm{k}_{Hj}^*=\mathrm{N}_H\text{-}1, \quad \mathrm{k}_{Lj}^*=0 \end{cases}$$

If the second condition occurs, the low-ability researchers are rationed because they would appreciate the collaboration with high-quality authors. In this situation, only the high-quality authors would collaborate. If the first condition occurs, both types of authors would collaborate with all the available authors (high or low). Notably, according to the first hypothesis, each type of author will put the maximum effort in the production of publications, whereas if the second condition occurs, only the high-quality authors will maximize their effort.

5.1 The opportunistic researcher

Discussion about the different benefits and costs of co-authorship has highlighted that *opportunistic* behavior can justify the emergence of collaboration between authors of different types, as well as when costs and benefits would not allow fruitful collaborations. In analytical terms, this would be the case when the low-ability author, rationed by the optimization choices of high-quality researchers, exploits all the gains deriving from exchange, bearing the coordination costs of the higher-quality author to increase his own total production. The "cost assumption" hypothesis implies that the opportunistic, low-ability researcher bears all the costs associated with coordination and communication in co-authorship, taking on all compromises would need to agree with the high-quality author. The "grin and bear it" situation implies that the higher-quality authors have no coordination cost, whereas the low-quality authors bear a doubled cost, as in (2.c).

$$\begin{aligned} &\max_{e_i,k_{Li},k_{Hi}} \quad \phi(1+k_{Li})h_L\sqrt{e_i}+\phi k_{Hi}h_H\sqrt{e_j}-de_i-c(2k_{Hi}+k_{Li}) \qquad \text{s.t. } 0\le k_{Li}\le N_L-1 \\ &\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad 0\le k_{Hi}\le N_H \\ &\max_{e_j,k_{Lj},k_{Hj}} \quad \phi(1+k_{Hj})h_H\sqrt{e_j}+\phi k_{Lj}h_L\sqrt{e_i}-de_j-ck_{Hj} \qquad \text{s.t. } 0\le k_{Hj}\le N_H-1; \\ &\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad 0\le k_{Lj}\le N_L \end{aligned} \tag{2.c}$$

Solutions to the maximization for different types of authors are shown in (3.c).

$$\text{If } \phi^2 h_L^2 N_L > 2dc \begin{cases} e_i^* = \dfrac{\phi^2 h_L^2 N_L^2}{4d^2}, & \mathrm{k}_{Li}^*=\mathrm{N}_L\text{-}1, \quad \mathrm{k}_{Hi}^*=\mathrm{N}_H \\ e_j^* = \dfrac{\phi^2 h_H^2 N_H^2}{4d^2}, & \mathrm{k}_{Hj}^*=\mathrm{N}_H\text{-}1, \quad \mathrm{k}_{Lj}^*=\mathrm{N}_L \end{cases}$$

(3.c)

$$\text{If } \phi^2 h_L^2 N_L \le 2dc \begin{cases} e_i^* = \dfrac{\phi^2 h_L^2}{4d^2}, & \mathrm{k}_{Li}^*=0, \quad \mathrm{k}_{Hi}^*=\mathrm{N}_H \\ e_j^* = \dfrac{\phi^2 h_H^2 N_H^2}{4d^2}, & \mathrm{k}_{Hj}^*=\mathrm{N}_H\text{-}1, \quad \mathrm{k}_{Lj}^*=\mathrm{N}_L \end{cases}$$

Unlike the previous case, the low-ability researchers are never rationed, and the high-ability authors agree to collaborate with them. Low-ability researchers, taking on the coordination costs of high-ability researchers, are able to remove rationing when collaborating with high-quality authors. As for the collaborations among low-ability authors, they occur only when conditions concerning benefits and costs of co-authorship are favorable.

5.2 How many times do the authors have to be counted?

In the reward system previously considered, the reward provider offers a reward Φ, based on the volume of publications of each researcher, and the reward does not differ between single-authored and multi-authored publications. For multi-authored papers, the same amount of premium is assigned to all co-authors, and the total expenditure is multiplied for the number of co-authors. A cheaper system would be established by a payment proportional to the number of co-authors. Note that the reward is not necessarily represented by an amount of money, so the expenditure argument is not always true. Nevertheless, Sauer (1988), analyzing the returns to co-authorship, estimates a weight for co-authored research in the earning function equal to 0.56, indicating that some form of discounting takes place. In contrast, Moore et al. (2001) find no discounting for co-authorship, whereas McDowell and Smith (1992) show that departments make no difference between co-authored and single-authored papers when deciding promotions rather then salaries.

Assume that the reward is $\phi/(1+k_H+k_L)$ for all the *i* and *j* authors. With the production function in (1.b), the objective functions for the low- and high-quality authors are respectively shown in (2.d).

$$\begin{aligned}
&\max_{e_i,k_{Li},k_{Hi}} \frac{\phi(1+k_{Li})h_L\sqrt{e_i}}{(1+k_{Li}+k_{Hi})}+\frac{\phi k_{Hi}h_H\sqrt{e_j}}{(1+k_{Li}+k_{Hi})}-de_i-c(k_{Hi}+k_{Li}) \quad \text{s.t. } 0\le k_{Li}\le N_L-1 \\
&\qquad\qquad 0\le k_{Hi}\le N_H \\
&\max_{e_j,k_{Lj},k_{Hj}} \frac{\phi(1+k_{Hj})h_H\sqrt{e_j}}{(1+k_{Lj}+k_{Hj})}+\frac{\phi k_{Lj}h_L\sqrt{e_i}}{(1+k_{Lj}+k_{Hj})}-de_j-c(k_{Hj}+k_{Lj}) \quad \text{s.t. } 0\le k_{Hj}\le N_H-1 \\
&\qquad\qquad 0\le k_{Lj}\le N_L
\end{aligned} \tag{2.d}$$

Three different solutions arise, but only one is characterized by choices of collaborations that are mutually compatible. This equilibrium is characterized by no collaboration at all. Indeed, when high-quality authors would collaborate with low-quality authors, the latter are optimizing with no collaboration. High-quality authors are then rationed. Conversely, when low-quality authors would collaborate with the high-quality ones, the better choice for the high-quality authors is zero collaboration and the low-quality authors are rationed. Then,

$$\begin{cases} e_i^*=\dfrac{\phi^2h_L^2}{4d^2}, \quad \mathrm{k}_{Li}^*=0, \quad \mathrm{k}_{Hi}^*=0 \\ e_j^*=\dfrac{\phi^2h_H^2}{4d^2}, \quad \mathrm{k}_{Hj}^*=0, \quad \mathrm{k}_{Lj}^*=0 \end{cases} \tag{3.d}$$

When the reward is proportional to the number of co-authors, co-authorship is never convenient, and each type of author exerts lower effort. However, given that $h_H > h_L$, the high-quality author always produces more publication than the low-quality one. Moreover, it can be shown that with opportunistic behavior the same equilibrium occurs.

6. The optimal reward system

The behavioral model above shows different results from co-authorship, depending on the reward system structure and on the ratio between premiums and costs associated with publications. At the same time, the optimal design of the reward system depends on the objectives pursued by the research organizer providing rewards.

If the aim of the principal is to obtain the maximum amount of effort from each researcher, the proportional reward system is surely not adequate. The maximum amount of effort is obtainable only with a non-proportional reward that is sufficiently high to incentivize all of the possible co-authorships. If $\phi^2h_L^2N_L > 2dc$, all of the authors will exert the maximum effort and will collaborate

with all of the other, *N-1,* authors. This result is insensible to the cost exchange hypothesis. If N_L is sufficiently high, also in the case of low rewards, the principal can obtain the maximum effort, so a research community with many low-type authors will exhibit a great bulk of publications. Conversely, with N_L being relatively low, the reward provider has to put a higher premium to obtain the same result. However, when the objective of the policy maker is to maximize effort, the total papers produced by the low- and high-quality authors will be same, and no selection can be made on the basis of the number of publications.

Consequently, if the reward provider wants to select the best authors for the promotion, the system with non-proportional rewards is not adequate if rewards are relatively high. To observe different amounts of publications between low- and high-quality authors, the principal must choose a reward proportional to the number of co-authors, with the obvious disadvantage of reducing for all researchers the optimal effort. Otherwise, if a non-proportional reward is offered, a relatively low reward has to be set. When the condition $\phi^2 h_L^2 N_L \leq 2dc$ is verified, high-quality authors maximize their effort, co-authoring with other researchers of the same type, both when the coordination costs are on their shoulders and when opportunistic researchers bear the doubled costs of coordination to remove the rationing on co-authorship. Then, the low-ability researchers always choose a level of effort lower than the higher ones and produce fewer publications. The result is that the research organizer maximizes the effort of the high-quality researchers and is able to distinguish between the two types if the selection is based on the amount of publications.

The selection objective can be pursued by fixing a threshold level for publications. Notably, the high-quality researcher will publish more than the low-quality researcher, also when opportunistic behavior occurs, but, in this latter case, more collaborations and more papers are produced with respect to the situation without a cost exchange. Then, the principal should take into account the opportunistic behavior when setting a minimum amount of publications to choose the better researchers. When setting the threshold for publications, the research organizer must select the one suggested by the equilibrium where all of the low-quality researchers try to remove the rationing about collaboration with high-quality researchers. If he decides for the lower threshold corresponding to the rationed authors in (3.b), for the low authors who are willing to support a doubled cost of coordination, it will be easier to win the selection.

Finally, when the reward system is used to give a career move, it is likely that higher rewards are established for those over the standard. Again, rewards that are too high incentivize too much collaboration, making selection no longer possible. When different rewards are fixed for different types of researchers, the highest reward must be sufficiently low, so that the low types choose a lower level of effort in equilibrium.

7. Italian economists and the infinite reform: a case study

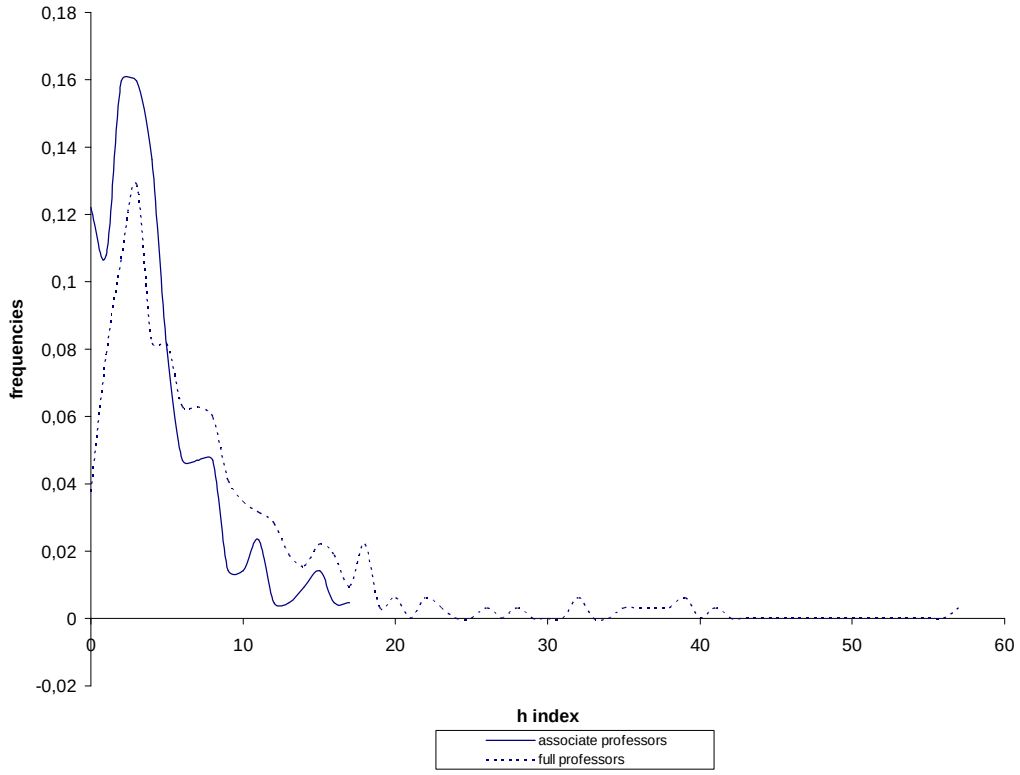
Italian academics are involved in political debates concerning the optimal design of higher education. More specifically, some Italian economists support the policy maker attention on the career mechanism, which is not considered adequate to put the best researchers in the better positions.

From the previous discussion about the researcher reward system, a trade-off between policy maker objectives has emerged. Maximizing the effort of all the employed researchers is a result that could compromise the possibility of selecting between high- and low-quality researchers. Conversely, the perfect discrimination achievable with a reward proportional to the number of authors will reduce the effort among all types of researchers. If the Italian system is unable to ensure the appropriate selection, it would at least maximize the overall effort. Otherwise, it would be correctly classified as being totally inefficient.

In the simplified model above, collaboration is incentivized by a relatively high reward for low types or by a relatively high reward for high types. When collaboration is spread among all authors,

the maximum effort is spent by all types of researchers, all of whom produce the same amount of publications.
Academic careers in Italy have always been determined by peer judgment, characterized by very broad criteria, where no direct publication reward exists beyond promotion, which leads to higher wages. If incentives to publish exist, they rely only in the relatively higher reward for those who have been positively evaluated for higher positions. For this reward combination, the co-authorship model above forecasts the same amount of publications for low-quality and high-quality authors and a pooling between the two types.
To verify the existence of a pooling among Italian economists, two categories of professors are considered: the full professors and those still considered of "lower quality" (associate professors)[3]. Instead of using a simple number of publications, the quality refinement provided by the h-index has been used to classify their research production. Fig.1 shows the distribution of Italian professors of economics per academic position and the h-index score.

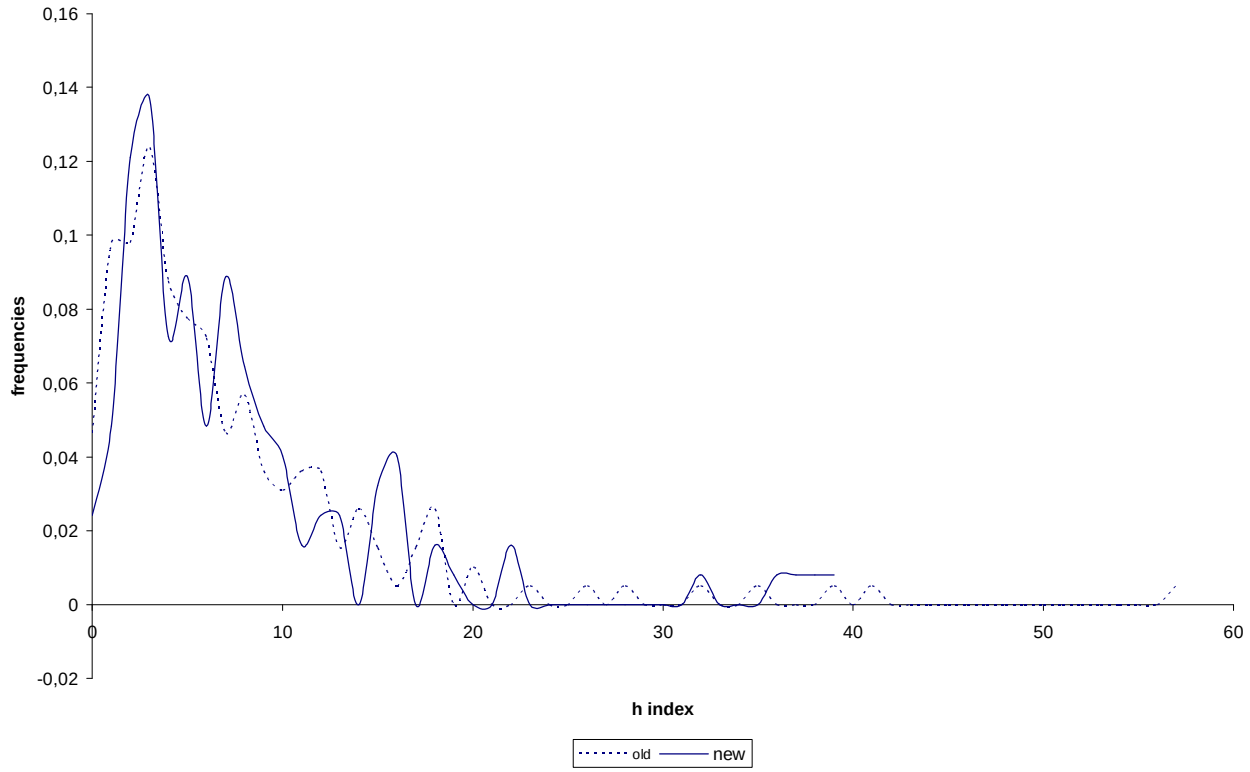
Fig.1 - Italian professors of economics per academic position and h-index score (%) – 2010



Although more associate professors have low scores and more full professors have high scores, a threshold h-value distinguishing full and associate professors does not emerge. It could be argued that the criteria for promotions to full professor have consistently evolved through time so that the current full professors' distribution reflects different thresholds growing over time. To analyze this argument, the population of full professors has been divided into two groups: in the first group (the "old professors", 194 individuals) there are all the economists that were already full professors on 12/31/2001; the group of "new professors" includes those who have won promotions since 2002 (124 individuals). Fig. 2 shows the relative distributions.

[3] Data are from the archive of the Italian Ministry of University and Research (MIUR), updated on September 2010, for professors belonging to the "Economics" area (Economia Politica, SECS-P/01).

Fig.2 - Italian full professors of economics per h-index score, before and after 2001 (%)



The average score of the new professors is slightly higher (+7.4%) than the respective value of the older ones and the same is true for the median value (from 5 to 6), but the "new" professors are distributed along the full range of scores not too much differently from the "old". It seems difficult to affirm that a threshold score higher than zero has been fixed, at least for the last decade.

The absence of a threshold level distinguishing between low and high types corresponds to similar amounts of publications, which is exactly the expected result for a system with a positive reward for high types and no publication rewards for low types, which is found in the Italian research system. As stressed above, this arrangement fosters collaboration between and within types and maximizes the effort of each researcher, giving up the sorting between different types of authors. The meritocratic change that someone invokes should probably improve the individual rewards for some economists, but it would not necessarily yield more productive Italian economic scholarship than before.

Further evidence derives from the analysis of the same individuals with another evaluation system. In the proportional reward system, each publication should be evaluated as *1/k* publication and the same should be true for its quality indicator, which, under the h-index metric, is the number *h* of papers, each of which has been cited by others at least *h* times. A proportional evaluation system should attribute to each researcher the number *h/k* of papers, each of which has been cited by others at least *h/k* times. This adjusted version of the h-index has been calculated for Italian full professors of economics, whose distribution is showed in Fig. 3. A more skewed distribution arises when Italian economists are ranked using proportional evaluation[4]. Italian economists are more homogeneous when co-authorship is taken into account.

[4] The distribution of associate professors, which is not shown, has similar characteristics.

Fig.3 - Italian full professors of economics per h-index score and adjusted h-index score (%) -2010

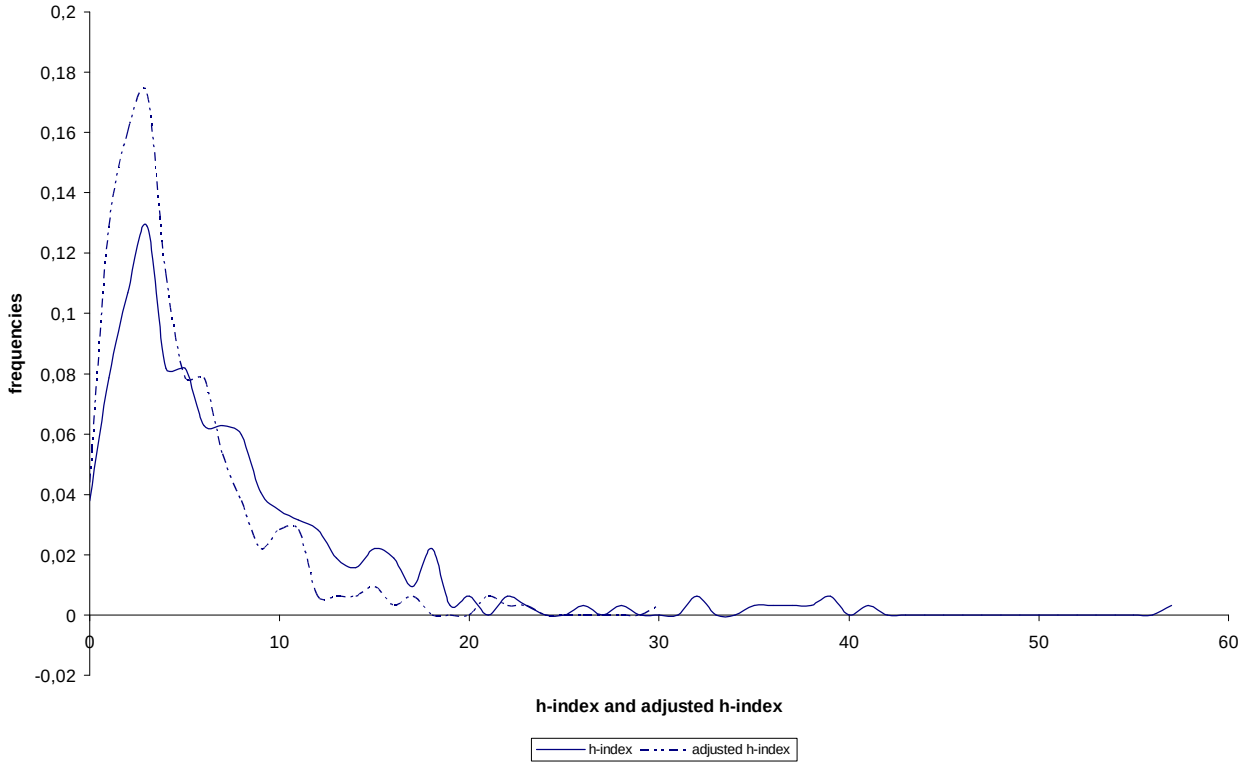
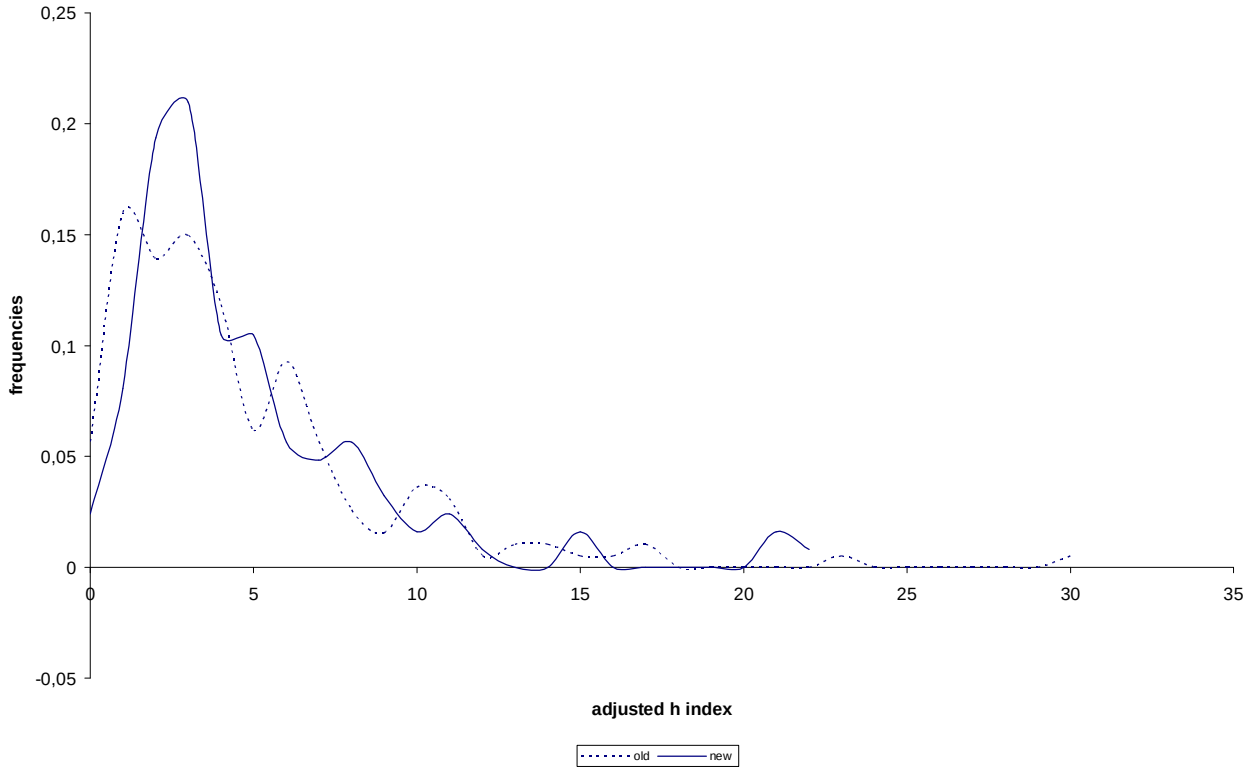


Fig.4 - Italian full professors of economics per adjusted h-index score, before and after 2001 (%)



Moreover, a growing trend in co-authorship emerges from the comparison between "old" and "new" professors. The standard h-index in fig. 2 shows a positive difference between "old" and

"new" professors, both in the average score and its median value. When considering the adjusted indicator, the average score of the new professors is still higher than the respective value of the older ones, but the increase is limited to 2.6%. This trend confirms the results of Marcuzzo and Zacchia (2007), who show a higher number of co-authored papers for Italian economists publishing in core journals. Notably, going from the group of old professors to the group of new professors, the median value of the adjusted h-index decreases (from 5 to 3), whereas the standard h-index shows a higher median value. Although the h-index distribution shows a similar shape between old and new professors, the adjusted h-index shows a more skewed distribution for the new professors than for the oldest ones (fig. 4). A positive trend in co-authorship emerges from the comparisons among Italian full professors of economics, confirming that the current reward system fosters collaboration or simply follows the general trend of specialization.

8. Concluding remarks

The rising incidence in co-authorship in economics raises a question concerning the policy implications for research organization: should the research organizer incentivize or punish the collaborations? The answer depends on what the policy maker wants to obtain. The model developed in this paper shows that the maximum amount of effort is obtainable with a non-proportional reward sufficiently high to incentive all of the possible co-authorships. Conversely, when priority is assigned to the selection of the better researchers, the principal must choose a reward proportional to the number of coauthors, with the obvious disadvantage of reducing for all researchers the optimal effort. Otherwise, if a non-proportional reward is offered, a relatively low reward has to be set.
The trade off between effort maximization and researchers selection has different effects on incentive to coauthor. Researchers choose to coauthor as more as possible if the pay structure does not discount for the number of authors, while the opposite occurs with a proportional reward. These results arise within a quality hypothesis, where the papers production function shows scale economies in co-authorship. The quantity/quality approach shifts the attention from the technology in the production of research to the market demand, where different equilibrium arise whether considering the research market or the researchers market.

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