Proposta Caminati

Proposta di contributi monografici da inserire in una *sezione monotematica* di numero speciale di rivista:

Knowledge production, technological evolution and economic organization

Introduzione:

Recently, a growing number of contributions to the literature on knowledge growth in the technology domain has deemed it useful to think of R&D as a search activity on complex search spaces. The complexity dilemma arises in this as in other domains, as a result of the potentially large and growing number of interactions between (knowledge) components, which make the landscape of technological performance typically rugged (Kauffman and Macready, 1995). Depending on the context at hand, knowledge interactions may be interpreted as the outcome of complementarities in nature and technology, or as reflecting the inter-face conditions that are necessary in order that knowledge spillovers are effective. In either case, the outcome of such interactions is twofold: (i) the local search procedures that guide discoveries firmly rooted in a given knowledge base are not suitable for radical discovery, because such procedures will soon get stuck on possibly poor local optima; (ii) since the performance landscape is not purely random, the very performance peaks in the landscape are separated by large troughs. For both reasons, attempts at radical discovery aiming at the very high performance peaks of the landscape, can not avoid highly uncertain long-distance jumps into the unknown. Indeed, the situation facing R&D investment is that innovators aiming at radical discoveries have a low chance to succeed; but if success arrives, the reword may be very high. This is mirrored by an empirical distribution of R&D returns which is close to being fat-tail (Scherer, Harhoff, Kukies, 2000). The contributions in this issue seek to analyse some implications of the premises above on R&D organization and economic structure more generally.

A first point to be made is that problem complexity, in this framework, is itself endogenous, because it is affected not only by the very accumulation of knowledge, but also by the organization of R&D in the different layers of the R&D structure: micro (e.g. intra-firm), meso (e.g. inter-firm) and macro (e.g. inter-sector).

The attempt at gaining a better understanding of the ways in which technological evolution may benefit from appropriate ways of R&D organization has found fertile ground in the set of ideas on the relation between evolution and near-decomposability laid down long ago in the seminal paper of H. Simon (1962). Two of the following contributions (A. Vercelli - M. Caminati; M. Caminati – A. Stabile) discuss how a slight extension of Simon's ideas (Watson 2006) provides wider scope for their application to the technology domain, thus supporting previous more informal arguments and historical examples on technological evolution with a more rigorous formalization. Interestingly, the way to attack problem decomposition and the identification of effective, boundedly-rational R&D strategies affects R&D organization at the micro, meso and macro layers just defined. In particular, one would expect to find evidence of the complexity dilemma not only in the internal organization of R&D in the innovating firm, as discussed in the contribution by D. Giammanco, but also in its relation with other innovating firms in the same sector and in the pattern of knowledge flows between technology fields.

The fact that R&D activity aiming at radical discoveries typically operates in that intermediate range of maximum complexity located between 'regularity' and 'pure randomness' (Crutchfield, 2001), has also profound implications on the incentive structure which is needed to sustain R&D investment. In particular, the appropriate incentive structure

will be sensitive to the type of knowledge produced, basic or applied, knowledge 'that' or knowledge 'how' (Mokyr, 2002). Topics in the organization of basic research between private and publicly funded R&D, and in the organization of R&D between the invention and the innovation stage, as well as their impact upon productivity growth and welfare, are discussed in the contributions by G. Cozzi and S. Galli and by L. Spinesi.

Knowledge accumulation is not invariably the outcome of purposeful R&D investment, but may also result from more general forms of learning, including the serendipitous forms of learning by doing the take place as the by products of production and consumption activities. The learning processes, both on the side of firms and of consumers, have been considered at the origin of the structural dynamics considered by Pasinetti (1981). However, so far no explanation has been provided to changes of technical coefficients in production and consumption as they have been given exogenously. The paper of D'Agata is an attempt to develop a model of structural change in which technology and consumption are explained endogenously within a bounded rationality framework.

The prevailing organizational forms of knowledge accumulation in the different layers of the economy understood as a complex, evolving system, are bound to affect the macro (inter-sector) pattern of technological evolution, and, ultimately, of productivity growth. If the above premises are correct, more direct or indirect empirical correlates to this emerging macro-pattern should be found in economic data on R&D and on the structure of material output and employment. The paper by M. Caminati and A. Stabile investigates the hierarchic structure of knowledge flows between technology fields as emerging from patent data; the paper by G. P. Mariutti investigates the empirical evidence on the relation between the composition of economic output-production and the composition of human knowledge production.

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Contents:

- Alessandro Vercelli Mauro Caminati: "**Complexity, modularity and technological evolution**" (sostituisce 52).

Il paper si propone di analizzare e mettere a confronto diverse nozioni e misure di complessità e modularità recentemente proposte dalla letteratura al fine di studiarne la rilevanza dal punto di vista della crescita della conoscenza tecnologica, con particolare riferimento all'emergere di innovazioni radicali.
Verrà sottolineato in particolare come lo studio dell'evoluzione endogena di sistemi, sociali, tecnologici o biologici, talora rappresentabili mediante strutture di rete, abbia messo in evidenza alcune questioni che attraversano gli specifici domini di indagine.

1. Quali sono le diverse definizioni del concetto di modularità emerse nella letteratura sull'evoluzione dei sistemi biologici, tecnologici o artificiali e quali le implicazioni di tali diverse definizioni?
2. In che senso la modularità favorisce la capacità di evoluzione in un ambiente complesso?
3. Fino a che punto i vincoli posti dalla organizzazione pre-esistente e dalle circostanze storiche influenzano l'evoluzione futura? In altri termini, quali gerarchie organizzative sono in grado di favorire l'emergere di novità radicali, pur in un ambiente complesso e fortemente interrelato?

Si cercherà di affrontare le tali questioni, anche alla luce dei risultati degli altri lavori sul tema della crescita della conoscenza, contemporaneamente sviluppati dall'unità di Siena.

- GianPaolo Mariutti: "**Something new under the sun – The structural evolution of learning and wealth since the First industrial revolution**" (50.1)

The aim of this paper is threefold. First, it tries to collect in systematic form some empirical evidence on the composition of a) economic production (sectoral composition of output) and b) human knowledge production in particular as it appers the skill composition of the labour force and in the the educational system. (in particular in the composition of university departments and students by academic field); Second, it tries to show from this evidence that in the long-run structural change is an important dimension of both system a) and b), and that the two systems do not change one independently from the other, but rather that they co-evolve. Third, the paper tries to outline some regularities (stylized facts) of this new dimension in a multisectoral model of economic growth with non-proportional dynamics. In so doing, it singles outs two structural components in the process of economic growth: the intrasectoral component which acts within each sector and allows the raise of productivity through time; and the intersectoral component which acts –through the movement of the labour force – across sectors. It is the interplay of these two components that produces, in an economic system, the overall rate of growth.
Too much writing on economic growth takes place in a historical and empirical vacuum, or creates factual artifacts in which events convenient to the author's interpretation are plucked selectively from the record, or, conversely, ready-to-use statistical databases are plugged into ready-to-use software applications to squeeze from them some unquestioned synthetic indexes. This is to a larger extent true also for writings on economics A more comprehensive knowledge of the empirical evolution of the economic and educational system is preliminary to the urge to make correct theoretical generalisations. This paper tries to make some steps in this direction.(E1)

Antonio D'Agata: **"An adaptive model of structural change"**

This paper presents a multisectoral model of structural dynamics. Learning of consumers and of producers are explicitly formalised, although in a very stylised way, and generate structural dynamics of the economy. Hence, unlike existing models of structural dynamics (see e.g. Pasinetti (1981, 1993), Notarangelo (1999)), our work endogenises the technological and consumption dynamics. We provide a concept of (secular) equilibrium and study the dynamic properties of the economy. It is pointed out also that our model can easily and consistently incorporate a variety of firms, this allowing the study of the dynamics of the economy from an evolutionary point if view (see e.g. Metcalfe (1995), (1998)). From this point of view, therefore, our model could be considered as providing a bridge between the literature on structural change and that one on evolutionary dynamics.

- Mauro Caminati e Arsenio Stabile: "**The Pattern of Knowledge Flows between Technology Fields: Modularity, Near-Decomposability and Compositional evolution**" (40, titolo modificato)

Which knowledge inputs are relevant to R&D in a specific technology field is largely determined by the organization (hierarchy) of knowledge concerning, on the one hand, the relations within the physical and natural world (knowledge 'what'), on the other, the specification of useful practices (knowledge 'how') in the technology domain. Although such a knowledge hierarchy is partly shaped also by institutional factors, which may differ across different environments, it certainly has determinants which are common to these environments, and which are intimately related to the selection between alternative ways of organizing complexity.
In this paper we recover from the NBER patent citation data, for the period 1975-1999, the directed network of knowledge links between technology fields, and the corresponding weighted network, which is so defined that every link in the former has an intensity measure in the latter. We call connection matrix the matrix representation of the weighted network. Technology fields are here defined at the patent-class representation level. A companion paper used a more aggregate definition of a technology field and was primarily directed at showing the potential uses of the connection matrix for the sake of modelling the distribution of innovation across these fields. The main focus of the present paper is on the detailed analysis of network structure, which is carried out through a variety of measures that are appropriate to characterize directed weighted networks (vertex degree and strength distribution, centrality, small-worldliness, clustering…), with a particular emphasis on modularity. Structural change and emergent phenomena are investigated by comparing the parameters referring to different windows within the period 1975-1999.

- Guido Cozzi and Silvia Galli: "**Half-Ideas and Growth with Homogeneous Labor**"

ABSTRACT

We try to extend the standard multisector neo-Schumpeterian growth theory to a more realistic direction by introducing the concept of product innovation resulting from a two-stages uncertain research activity. R&D activity splits itself into two subsequent stages (i.e. two "half-ideas"): inventing and innovating. If the result of the first stage is patentable the private research firms behave like optimizing agents and they decide to engage an inventive or innovative race at both stages. We compare their general equilibrium innovative performance with the case of unpatented half-ideas freely disseminated by public research institutions such as the universities. We prove that, with homogeneous labor as the primary factor of production, despite the inefficiencies of the publicly run universities, their privatization coupled with the patentability of research tools does not guarantee an improved innovative perfmonance. Keywords: R&D and Growth, Vertical Innovation, Sequential Innovation, Research Tools, Public R&D. JEL CLassification: O31, O34, O41.

- Luca Spinesi: "**Basic Research and Product Development: the role of Public and Private research effort**" (14.2).

Standard neo-schumpeterian growth theory considers research and development as the fundamental engine for economic growth. Usually, this strand of literature considers that private agents/firms undertake R&D investment spurred by monopolistic rents they can appropriate. The usual way in which the government enters in R&D activity is by granting intellectual property rights protection to innovators, and by directly or indirectly subsiding R&D. I consider the case in which the government plays an active role in conducting research, that is the government is engaged in basic research program. I study the interplay between private and public R&D, moreover I investigate the complementary or substitution relationship between private and public R&D. Finally I study how the presence of both public basic research and private R&D affects the economic performance of a country.

- Maria Daniela Giammanco: "**Conoscenza organizzativa e processi di innovazione e diffusione delle tecnologia**" (21).

L'obiettivo dello studio è quello di approfondire l'analisi degli strumenti della conoscenza che rendono possibili i processi di innovazione e diffusione delle tecnologie in ambito evolutivo con particolare attenzione alle problematiche relative alle competenze e all'apprendimento organizzativo.
A tale scopo intendo effettuare una ricognizione dei temi legati alla conoscenza all'interno del filone teorico evolutivo, partendo dai precursori e dagli *alleati* degli evoluzionisti, tra i quali Polanyi che introduce il concetto di conoscenza inespressa; Alchian,1950, che enfatizza il ruolo dell'incertezza, dal punto di vista ex-post, quando alcune azioni si rivelano appropriate ed altre errate; Simon (1959, 1979) per il quale la razionalità dell'uomo è limitata, le decisioni quotidiane sono troppo complesse per essere comprese a pieno e quindi le imprese non possono massimizzare e considerare dato il set di tutte le

alternative possibili. L'azione è guidata da scelte decisionali semplici. Il comportamento delle imprese è soddisfacente, non massimizzante.
Il lavoro seminale di Nelson e Winter (1982) in cui l'apprendimento tecnologico, rappresentato in termini di variazioni nello spazio di alcuni coefficienti tecnologici, è innestato in una teoria di apprendimento organizzativo basato in gran parte sull'affermazione, riproduzione e cambiamento di routine organizzative, ha stimolato in ambito evolutivo un ricco dibattito, ancora in corso, sulla rilevanza della capacità di apprendimento organizzativo nel processo di innovazione. La letteratura ha dedicato crescente attenzione a tematiche quali: - il ruolo attivo dei soggetti nella costruzione e nella validazione della conoscenza, l'emergere di un comportamento soddisfacente piuttosto che massimizzante a causa della complessità procedurale legata alle decisioni che gli agenti devono prendere (Tamborini, 1991; Egidi, 1991; Dosi et al 1999); - l'importanza dell'apprendimento organizzativo in cui le competenze individuali sono rilevanti nella misura in cui vengono impiegate in un particolare contesto organizzativo, con la conseguenza che all'interno dell'impresa le competenze economiche/tecniche ed organizzative non possono essere considerate separatamente (Teece et al 1994; Coriat e Dosi 1998); - l'impresa come una *organizzazione che apprende* all'interno della quale l'insieme delle opportunità che essa stessa può cogliere non sono note a priori, e la capacità di processare l'informazione e le regole decisionali non sono date ma coevolvono attraverso un procedimento di apprendimento adattivo (Dosi e Marengo, 1994); -la presenza di alcuni assets dell'impresa non facilmente *commerciabili,* lo sviluppo di capacità e competenze specifiche, difficili da replicare, al fine di avere la meglio sui meccanismi selettivi del mercato (Dosi 1997; Levinthal 1997; Levinthal e Warglien 1999; Teece et al 2000;); -il ruolo cruciale delle imprese nello sviluppare un *sistema di innovazione* creando connessioni tra diversi attori, articolando e mettendo insieme i diversi livelli di conoscenza necessari per l'innovazione (Metcalfe, 2002);-l'importanza non solo dei successi ma anche degli errori sull'apprendimento a livello sistemico (Dosi e Lovallo 1997).
L'analisi di tale dibattito intende essere il fulcro del lavoro da me proposto, che prevede sia di *sistematizzare* le posizioni dei partecipanti che di tracciare lo *sviluppo* della teoria stessa.
Ad esempio, per quanto concerne l'evoluzione della teoria, il concetto di comportamento soddisfacente, proposto da Simon, è ampliato da Dickson (2003) facendo ricorso a una teoria della selezione artificiale, ovvero della selezione sulla selezione. Per Dickson, all'interno dell'organizzazione, i processi di impiego delle risorse, di controllo e operativi sono subordinati agli effetti di processi di apprendimento di ordine superiore. Questi ultimi a loro volta sono determinati dalla capacità, di *process thinking* dell'impresa che dipende dal comportamento dei manager. Per il management, la selezione ex-ante di capacità che migliorino il processo di apprendimento è un modo di evitare la selezione ex-post del mercato sul suo *process thinking* . Tale teoria spiegherebbe il perché dell'osservazione di un comportamento soddisfacente relativo a particolari processi organizzativi: un'impresa con capacità di apprendimento e *process thinking* superiori concentrerà gli sforzi di *process thinking* solo sui processi particolarmente problematici. Tale spiegazione si contrappone a quella suggerita da Cyert e March (1963) e Winter (2000) secondo i quali il comportamento soddisfacente è a volte osservato a causa della mancanza di processi di ricompensa, apprendimento e controllo di ordine superiore.