Factors that determine the impact of innovation policies in a sectoral innovation system in Colombia: A methodological approach from Applied Evolutionary Economics and Complex Systems

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Outline

• The Motivation
• The Questions
• The Methodological Approach
  – The conceptual basis
  – The basics of the model
• Next steps
NIS and Productivity in Colombia

• In 1990 the National System of Science and Technology was formally created.
• In the mid 90’s the idea of a National Innovation System was introduced as concept for articulating the elements of the System.
• Nowadays, there are evidences of low growth levels in terms of productivity and productive diversification.
• This suggest that the impact of the Colombian National Innovation System on economic competitiveness is still not significant.
• System’s capacities are still in their early stages.
There is a need for revising Technical Change Policies

- Colombia undertook during the early 1990s a market-opening processes
- At that time, priority was given to transversal (or functional) policies on:
  - macro-economic and legal stability;
  - physical infrastructure;
  - the financial system;
  - ensuring free competition
- But functional policies, although necessary, were not sufficient to allow for improving firms’ competitiveness
- Horizontal and sectoral (vertical) policies are also required. The experience in East Asian countries confirms this (Lall and Teubal, 1998).
The Importance of Micro-level Policies

• There is a need of an adequate and realistic understanding of firms’ learning processes.
  – Firms have imperfect knowledge of the relevant options in front of them,
  – Tend to be myopic in searching for relevant information, suggestions, and solutions
  – They are entities with a “particular personality”: they are idiosyncratic

• Then, vertical/sectoral policies must ensure the efficient access by firms and sectors to the specific factors that condition their capacities and performance.

• In sum, the public policy agenda for the promotion of innovation in firms should include a combination of functional, horizontal and vertical policies. (Lall and Teubal, 1998)
Market and Non-market Relationships: The need for coordination

• The market is not, in all cases, the most efficient way in which technological activity is organized and in which good practices and knowledge are distributed.

• Non-market mechanisms play a crucial complementary role since:
  – Strategies involve not only economic but non-economic objectives (cooperation).
  – They allow for catalyzing market forces, by promoting “endogenization” of those activities necessary for diffusion of new organizational and management routines among firms.

• And it requires a high degree of coordination with bureaucratic, professional and political components.

• Then, firms' learning requires policy interventions, as there are failures in coordination.
The Questions

• Which are the most important factors that, at micro-economical level, determine the impact of policies to promote innovation in a specific sector in Colombia

• What criteria, strategies and measures must be implemented as part of a public policy agenda, for effectively promoting a better performance by firms on the selected sector.
Content

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The Systemic Nature of Innovation

• I focus, based on Teubal (2002), on three sub-systems of the innovation systems at a meso and micro levels:
  – the business sector (BS);
  – the supporting structure (SS): Government, financial and research institutions
  – the interactions and links: the connections

• The transformation of a system is cumulative and comprises the co-evolution of its elements in a circular causality process

• Changes in the system can take place through:
  – Learning processes within the elements of the system
  – Changes in its architecture, such as:
    • the incorporation of new elements, be the firms or institutions in the SS
    • the appearance of new connections.
The Importance of Connections within the Economic System (Potts, 2000)

- Concepts such as uncertainty, bounded rationality and incomplete information, from heterodox economics can be unified around the concept of “geometry of the economic space”.
- As opposed to the orthodox assumption, it is not one of an integrated space, but rather one of a complex system.
- Connections are incomplete and determine the structure and dynamics of the economic system.
- Institutions and actors change as much as connections change, provided that these generate new behaviors, routines and social structures. And vice versa.
- Knowledge creation and diffusion, information and coordination are closely associated to the geometry of the connections in the economic system.
The Complexity of Innovation Systems: In the search of new Analytical Representations

- Complexity: systems with multiple elements adapting and reacting to the patterns these elements create (Arthur, 2004)
- Complex systems arise naturally in the economy and can not be understood through reductionism of standard economics (Colander, 2004)
- Economic theory has not been especially successful at finding structural laws (ibid)
- Computer technology offers a means to gain for far more insight into complex systems of dynamic equations:
  - Does not provide analytic solutions but provide numerical ones by using “brute force”
  - Allows for the construction of Analytical Tools which can be connected with empirical research (Colander, 2004)
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The model by Grebel, Pyka and Hanusch (2004):

- An evolutionary approach to entrepreneurial behaviour that uses a computational simulation model
- Draw on an actor-centered perspective.
- Does not assume optimal behaviour, nor an equilibrium concept
- Its core elements:
  - The heterogeneity of actors and behaviours
  - Their bounded rational behaviour to make myopic decision (which may eventually lead to suboptimal outcomes)
  - The feedback effects from the micro- to the macro level and vice versa
  - The historicity of events
Objective

To model a specific sector for understanding its structure, patterns of change and historical evolution

- How firms compete, cooperate and co-evolve with other actors
- What factors determine its evolution: their capacities, strategies and interactions
- Which institutions govern the interaction between the agents: norms, routines, habits
A simplified view of an Economic System: Agents and Connections

Agents
- In this case, for example: firms, consumers, banks, etc..
- They have attributes, associated with their capacities
- Attributes determine:
  - How agents make decisions
  - How external factors influence agents decisions
  - The agents’ performance
- Attributes change in time

Connections
- Connections are incomplete among agents in a system
- Changes in connections may affect:
  - agents attributes and vice versa
  - As well as the architecture of the system
- Exist in the form of, v. gr.:
  - Contracts
  - Technology
  - Flows of information
  - Competition
  - Cooperation
The Elements of the Model

- Firms
- Government Institutions
- Research Institutions
- Financial Institutions

Diagram showing connections between the elements.
### Firms

- Are heterogeneous and differ in their attributes
- Face uncertainty
- Make decisions on the basis of environmental factors such as economic and sectoral indicators, public policies and incentives (Feedback effects)
- Make alliances with other firms and actors (non-market relations)
- Compete (market relations)
- Firms attributes can be associated to
  - Organizational capacities
  - Human Capital
  - Innovation capacities
  - Interaction capacities
  - Financial Capital

\[ f_i^t = \{ c_{1i}^t, ..., c_{ki}^t \} \] describes the firm \( i \) as having \( k \) attributes or characteristics in time \( t \).

For example:

- \( c_{1i}^t \) = organizational capacities
- \( c_{2i}^t \) = human capital
- \( c_{3i}^t \) = financial capital

Where \( c_{1i}^t, c_{2i}^t, c_{3i}^t \) are randomly created for the \( n \) firms of the system and uniformly created for the interval

\[ F^t = \{ f_i^t \}_{i \in \{1,..,n\}} \]
Government Institutions

- Comprise such government institutions devoted to promote directly firms’ innovation capacities
- For the model:
  - Establish relation with firms and operators
  - Eventually with banks
- Their attributes could be associated to:
  - Public policies quality and scope
  - Financial resources to allocate
  - Coordination and networking capacities
  - Capacities for providing relevant public goods

\[ g_i^t = \{c_{gi1}^t, ..., c_{giL}^t\} \] describes the government institution \( i \) as having \( L \) attributes or characteristics in time \( t \).

For example:
- \( c_{g1}^t = \) Public policies quality and scope
- \( c_{g2}^t = \) Human capital
- \( c_{g3}^t = \) Coordination capacities

Where \( c_{g1}^t, c_{g2}^t, c_{g3}^t \) are randomly created for the \( m \) government institutions of the system and uniformly created for the interval

\[ G^t = \{ g_i^t \}_{i \in \{1,..,m\}} \]
Research Institutions

- In the case of Colombia are:
  - Research Centers
  - Technological Development Centers
  - Universities
  - Providers of Scientific and Technological Services

- The attributes can be associated with:
  - Human capital
  - Experience
  - Scientific and technological capacities
  - Interaction capacities

\[ r^t_i = \{ cr^t_{i1}, ..., cr^t_{pi} \} \] describes the research institution \( i \) as having \( p \) attributes or characteristics in time \( t \).

For example:
- \( cr^t_1 = \) Human capital qualifications
- \( cr^t_2 = \) Experience of its members
- \( cr^t_3 = \) Scientific and Technological Capacities

Where \( cr^t_1, cr^t_2, cr^t_3 \) are randomly created for the \( v \) research institutions of the system and uniformly created for the interval

\[ R^t = \{ r^t_i \}_{i \in \{1, ..., v\}} \]
Financial Institutions

• Provide financial capital
• May be not only banks but capital markets

• Its attributes for the sake of the model:
  – Availability of capital
  – Quality of its financial products
  – Supporting clients capacities

\[ b_i^t = \{ cb_{i1}^t, \ldots, cb_{q_i}^t \} \] describes the operator \( i \) as having \( q \) attributes or characteristics in time \( t \).

For example:
\( cb_1^t = \) Financial capital for innovation initiatives
\( cb_2^t = \) Quality of its financial products
\( cb_3^t = \) Supporting clients’ capacities

Where \( cb_1^t, cb_2^t, cb_3^t \) are randomly created for the \( s \) financial institutions of the system and uniformly created for the interval

\[ B^t = \{ b_i^t \}_{i \in \{1, \ldots, s\}} \]
The Basic Structure of the Model

Set of Firms
- Firms' attributes

Set of Gov. Inst.
- Gov. Inst.' attributes

Set of Resea. Ins.
- Resea. Ins.' attributes

Set of Financial Instit.
- Fin. Inst. attributes

Matching Process

Potential Connections for Alliances

Cooperating Threshold

Some alliances are made

Firms with allies

Firms without allies

Competition

Firms Performance in the Market

Failure

Success and learning

Learning
The case for Firms-Research Inst. Alliances

- Set of Firms
  - Firms' attributes
- Learning
- Firm Learning
- No
- Firm-Firm Matching
- Cooperating Threshold
- No
- Firm-Firm alliances are made
- Firms with allies
- No
- Firm's Competitiveness Threshold
- No
- Failure
- Firms Performance in the Market
- Yes
- Competition
- Success
- Set of Rese. Ins.
  - Res. Ins' attributes
- Learning
  - No
- Firms-Res. Inst Matching
  - Cooperating Threshold
  - No
  - Some alliances made
  - Firms without allies
The Matching Process

- For each iteration:
  - The population of agents, not yet connected, is permuted and a number of agents are randomly brought together.
  - The chances of making alliances are evaluated on the basis of specific attributes of each agent.
  - That is, for each match, a function $\beta$, based on the information and analysis of the sector and the policy incentives, operates the attributes of the agents that have been brought together and calculates a value for the potential of creating an alliance.

- For example, the potential of an alliance between two firms would be:

$$pa_{q}^{t} = \beta(f_{i}^{t} , f_{j}^{t}) \forall i \neq j$$

Where:

$q \in \{1, \ldots, m\}$ denotes the specific potential alliance between firms.

$f_{i} = \{cf_{i1}, \ldots, cf_{ik}\}$ describes the firm $i$, that has $k$ attributes or characteristics.

And the set of potential alliances between firms at time $t$ is:

$$PA^{t} = \{pa_{q}^{t}\}_{q \in \{1, \ldots, m\}}$$

$m$ is the number of potential alliances between firms.
The Cooperation Threshold

- For modelling reasons a Cooperation Threshold $\varphi$ is introduced, a ‘meso-macroeconomic signal’ which, as a hypothesis, depends on:
  - $c_t =$ Level of competence on the sector at time $t$
  - $e_t =$ Economic indicators at time $t$
  - $i_t =$ Public policy incentives to create alliances at time $t$
- Continuing with the previous example of two firms

$$\varphi^t = \varphi(c^t, e^t, i^t)$$

The set of newly created alliances in period $t$ is
$$A_{new}^t = \left\{ p\alpha_q^t : p\alpha_q^t > \varphi^t \right\} \text{ where } p\alpha_q^t \in PA^t$$
Next Steps

• To decide which sector to model (availability of information). Probably de Agro-industry sector
• To determine and validate each agent’s attributes and the probabilistic functions to be used in allocating attributes among the various agents’ populations
• To formulate the functions for:
  – The matching process
  – The thresholds
• To model, based on stochastic tools, the competition process
Thanks