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Selection environments and innovation regimes: micro-macro innovation dynamics in late development

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ABSTRACT

This paper explores macro-, and meso-economic forces shaping search and explorative behaviour at the firm level. In particular, we focus on top-down selection mechanisms (both direct and indirect) that modify the rate and direction of technological change, as well as the nature of technological learning at the micro-economic level.

Studies on economic development in developing countries focus increasingly on the concepts of technological learning and technology systems. It is well accepted that fundamental causes of differences in long term economic performance expresses technological asymmetries at the firm and sectoral level (Dosi, Pavitt and Soete, 1990; Fagerberg, 1994). Given that technological learning is embedded in production chains, knowledge networks, and institutions, patterns of accumulation of technological capabilities depend in turn on related systems of innovation (Lundvall, 1992; Nelson, 1993). Opportunities for catching-up and narrowing technological asymmetries depend as well on the particular innovation regime, the rules govern search and innovative behaviour that in a particular industry and in a particular time (Nelson and Winter, 1982; Malerba and Orsenigo, 1995).

However, macro-to-micro causality has been largely excluded in these fundamental explanations of economic performance (see Cimoli and Katz, 2002). Macroeconomic environments determining levels and growth rates of key variables can influence directly the rates of technology absorption and local innovation through traditional channels like relative prices of capital, capital turnover rates, market size and growth rates, etc. Next to these quantitative impacts, we argue, macroeconomic settings can also affect the nature of technical change, by influencing market- and firm-level selection mechanisms that govern an economy's capacity of generating variety.

Following Nelson and Winter (1982) model of search and selection, we develop an analytic framework that links explicitly micro-level behaviour and learning, with macroeconomic selection mechanisms. In turn, we show how macro-to-micro causation can bias technological behaviour into certain directions, reinforcing cumulative causation and path-

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dependent features of technological learning. Next, we examine the conditions under which adverse selection environments can generate development traps of slow economic growth, and slow variety generation. In circumstances where active competition and market transference mechanisms operate in a relatively fluid manner across borders, economic resilience is crucial for preventing economic systems to rely purely on static advantages that may result socially and environmentally deleterious in the long term. Finally, we argue how the learning restrictions set by astringent selection environments can and have been overcome under certain innovation regimes.

Introduction: growth, asymmetries and interactions

Empirical evidence on growth dynamics over the XXth century tells a story of variety and divergence. General international trends show absolute divergence in per capita income levels (Pritchett 1997), the clustering of national trajectories around “convergence clubs” (Baumol 1986), and a convergence trend among industrial countries, both absolute as at the industry level (Beelen and Verspagen 1994; Fagerberg and Verspagen 2002). While a group of Asian countries significantly closed the gap with developed countries since the 1970’s (Baumol, Blackman and Wolff 1989), and both China and India have experienced unprecedented growth rates since the 1990’s, the world economic order built around “Europe and its Offspring plus Japan” (Maddison) seems to be rather stable during the last 150 years. Regions in the periphery do not follow similar trends, with some regions experiencing systematic stagnation (Africa) or bursts of catching-up and falling behind (Latin America).

Theories of growth have proposed alternative hypothesis to explain this complex dynamics, that clearly contradict simple predictions of convergence of standard neo-classical economics, a framework that was shared to some extent by “old” development economists.[2] Within the neo-Schumpeterian, evolutionary approach, the economic response that gives rise to growth dynamics (catching-up, staying ahead, or falling behind) follows a fundamentally distinct logic, one in which innovation stands simultaneously as the source of growth and the source of asymmetries. This logic derives directly from the theory’s assumptions about behavior and rationality, technology and knowledge, competition and organization’s dynamics.

Causation under this approach follows a bottom-up direction. Firm-level performance is determined by the firms particular arrangement of technologies or routines (Nelson and

[2] In tune with the Solow model and its Keynesian recasting by Harrod-Domar, theories of economic development in the second half of the XXth century took for granted that “capital deepening” was the central aspect of economic development. Non-convergence or “backwardness” was explained, however, because the assumptions of neo-classical growth did not hold for underdeveloped countries. The main obstacle was low capital availability, but they also faced deteriorating terms of trade due to their international specialisation, a low level of savings. Even if savings could be increased, there would remain a savings gap to be filled with foreign loans or foreign direct investment. With the downturn of import substitution policies, these views lost political support and receded in favour of the idea of natural convergence.

Winter 1982). Given that technological learning at the firm level is embedded in production chains, knowledge networks, and institutions, patterns of accumulation of technological capabilities depend in turn on related systems of innovation (Lundvall 1988; Nelson 1993). Since the nature of technology adoption and diffusion depends on multiple factors, the "natural" migration of industrial activity implied in life-cycle theories (Vernon) fails to hold as, together with traditional market barriers, the critical technological capabilities needed to adopt a technology change as the technology develops and diffuses (Perez and Soete 1988). Opportunities for catching-up and narrowing technological asymmetries depend as well on the particular innovation regime, the rules that govern innovative behavior in a particular industry at a particular time (Nelson and Winter 1982; Malerba and Orsenigo 1995; Malerba, Orsenigo and Peretto 1997). Consequently, the fundamental causes of differences in long term economic performance expresses technological asymmetries at the firm and sectoral level (see for example Dosi, Pavitt and Soete 1990; Fagerberg 1994).

It has been noted that growth models within this approach provide a rich description of microeconomics of innovation, but at the cost of a deficient specification of aggregated dynamics (Mulder, Groot, kes et al. 2001). While macro-to-micro causality has been largely excluded in these fundamental explanations of economic performance (Cimoli and Katz 2001), the connections between the neo-Schumpeterian approach and many heterodox, top-down approaches with well-developed macroeconomic insights have been highlighted many times (see for example Dosi 1988; Dosi, Pavitt and Soete 1990; Cimoli and Dosi 1995; Ocampo 2005). In particular, it is possible to perceive a growing density of overlapping with post-keynesian and structuralist approaches in the Kaldor-Myrdal-Pasinnetti tradition. One such a synthesis (Ocampo 2005) exemplifies how circular causation between firm-, and sectoral-level technological capabilities and macroeconomic external balances become co-determined via the effective-demand effect on technological learning. Dynamics leading to low-growth traps of this kind clearly match with both the cross-sectional diversity and timing in world patterns of per capita income growth.

This paper aims at pointing at one particular micro-macro interaction channel, namely the interplay of the macroeconomic and the meso-economic spheres in determining the range of technological alternatives from which choices can be made. In turn, we show how macro-to-micro causation can bias technological behavior into certain directions, reinforcing cumulative causation and path-dependent features of technological learning.

1. Economic response and innovation

Schumpeter's theory of economic change emphasized the specificity of capitalism as a form of economic organization that constantly destroys and creates its underlying structures, an expression of its built-in logic of perpetual endogenous change (1950 [1942]). Implicit in the process of creative destruction is a notion of active economic rivalry, in which competition takes place between individual capitals driving for self expansion. Technical change and the reorganisation of the firm are seen as the main weapon of competition.[3] This view on competition erodes sensibly the relevance of studying equilibrating processes derived from decisions made under conditions perfect competition; competition-driven growth is always uneven in its pattern and effects (Metcalfe 1998). Static efficiency of allocation processes comes to play a secondary issue in the analysis of economic change; the significant type of decision is not that ruling the allocation of *existing* resources, but the wider problem of strategically creating *new* ones. Moreover, mechanisms leading to short-term efficiency not only looses interest, but may lead to incorrect conclusions; short-term inefficiencies may in some cases be a condition for long term superior performance.[4] This way, economic response to external and internal changes ranges from a *passive adaptation* of existing productive combinations to the *creative response* of experimenting beyond existing practice (Schumpeter 1947).

Evolutionary economics casts Schumpeterian competition into the kernel of structural change processes that underlie endogenous growth. Economic change takes place through a combination of mechanisms of variety generation and selection (Nelson 1995). Agents

[3] For the features of the concept of competition as active rivalry see Semmler (1992) and Metcalfe (1998).
[4] The trade-offs between

struggling for market shares grow or decline according to relative competitiveness, including the capability of "going around competition" (Metcalfe 1988). Agents search and develop techniques and knowledge in order to gain advantages or stay competitive. At a certain stage, some agents may benefit from particular techniques, organization or knowledge, matching demand in a more attractive way, realizing higher competitiveness and growing faster. Asymmetries so created and market power can in turn interact in dynamic ways. Short-run increases in market share may lead to subsequent learning effects and economies of scale and scope. This sort of cumulative causation between learning and growth emphasizes the strong local character of evolutionary improvement (Beelen and Verspagen 1994). The temporary advantages provided by innovation can be eroded by imitation or further innovation from other agents, re-distributing market shares. Innovation stands this way as a mechanism for asymmetry creation, with imitation and diffusion as its equilibrating counterpart.

The features of innovation impose very important conditions for economic development based on imitation as a mechanism for reducing asymmetries. First, innovation produces irreversible and discontinuous effects in social and economic conditions, in the sense that "it creates situations from which there is no bridge to those situations that might have emerged in its absence" (Schumpeter 1947). Second, innovation is uncertain in a radical sense for the outcome of search cannot be planned.[5] Decisions (in search) must be sequential, relatively undetermined so that behavior can react in the future considering new vital information. In this setting, sequential behavior is more likely to success and more likely to proceed efficiently (Rosenberg 1992). Third, learning relies on what firms know how to do and have done in the past. Since these skills must be learnt, innovation processes are the same time the source and the result of firm's capabilities (Nelson and Winter, 1982). Fourth, learning has a strong tendency to be contiguous, in the sense that the probability of assimilation and new findings grows with familiarity. From here derive the principle of guideposts (Sahal 1981), and the idea of paradigms (Dosi 1982); at the same time, it is not easy to translate solutions to environments that differ strongly from that of original

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[5] Uncertainty and conditions for rational choice have been discussed in Simon and March (1957). Interesting is also the proposition that knowledge is *dispersed* (Dew, Velamuri and Venkataraman, 2004), both horizontally (Akerlof 1970 information asymmetry) and in time (Knightian uncertainty).

application. But it can also be of a discontinuous kind, when the trajectory of learning is reorganized under new principles.[6] Fifth, learning is costly, it requires investment (moreover, an investment plan) to acquire and incorporate very different types of resources and services. New knowledge must be "unstuck" through dedicated investment (Hippel 1994). Tacit knowledge must be codified, and both tacit knowledge and codes must be learnt, for which dedicated resources must be allocated in the form of irreversible investments (Dasgupta and David 1994). Sixth, the results of learning tend to be unproductive in the short term and may require off-line practice during its initial phases.

All these features make asymmetry reduction (in the form of imitation of inter-firm diffusion) contingent on local effort, the nature of technology and underlying knowledge bases, and the role of the latter on competition.

2. Catching-up and reduction of asymmetries

Technology is not only a set of designs and a body of practice. It comprises a body of generic understanding about "how things work;" it includes, moreover, a body of knowledge about the key variables affecting performance, and about the nature of major opportunities, binding constraints, and promising approaches to push these back (Nelson 1996). Accepting this definition implies that a realist appraisal of the innovation process must include the and institutional mechanisms for encoding, packaging, and socializing technical knowledge and off-line production of specialized resources needed for technology management, design, and improvement. Innovation (understood as market success) depends on knowledge coming from very different places, actors, and processes. This collection of organizations and processes of knowledge and service exchange, the innovation systems, act as focusing devices as well as problem-solving devices complementing individual firm's technology search and assessment capabilities. From this point of view, innovation systems not only expand firms' technological capabilities but actually transform the structure of costs and benefits of research and development activities.

[6] It must be remembered that the appealing ideas of paradigms and dominant designs are more suitable to some cases than in others, and that their regularity may simply not hold in some cases.

Processes of innovation in developing countries, taking either the shape of adopting technologies radically new to them or even state of the art designs (leapfrogging) has been fostered on the basis that much of a technology's components, in the broad sense described above, can be outsourced from industries and firms from developed countries. Up to a very large extent, international diffusion of process technology to the "periphery" (of the kind of Vernon's life cycle of industrial migration) has consisted in the adoption of certain links of production chains, supported by transferences of technology from international markets or by transfer managed by parent firms in the case of foreign direct investment (Pack and Westphal 1986; Pack and Saggi 2001). This alternative (and only up to a certain extent competing) modes of diffusion demand different types of local economic response and produce different impacts of accumulation of local technological capabilities (Kumar 1998). Differences in the relative importance of each transfer mode, as well as different levels of indivisibility between operative and technological skills (Bell and Pavitt 1997), influence strongly the mode of accumulation of capabilities at industry an national levels.

Thus, the historical patterns of upgrading and imitation in developing countries are based on articulated processes of expansion of local skills and knowledge that accompany and support production expansion capacity. The generation of "knowledge-based assets" (Amsden 2001) in catching-up processes implies the gradual and progressive substitution of old and imported skills for new ones, according to different type of barriers and learning costs. But the relevant "knowledge base" of most developed industrial systems depends on organized bodies of generic understanding, focusing devices and problem-solving skills, distributed among differentiated firm's and organizations (Smith 2002). It is at this level of articulation that external economies and systemic advantages take place. Therefore, real asymmetry reduction must take place at the system level.

Meso-economic structures determine the costs and benefit structure of innovative activities, as well as its range of detection, efficiency, quality, and further economic impact. The components of such innovation systems fulfill several functions: a) provide resolution of the technological landscape and tech opportunities, increasing efficiency of R&D (Nelson and Winter 1982); b) facilitate imitation and transfer by codifying, packaging and unpackaging technologies (David and Dasgupta), and socializing technical knowledge (Nelson 1996); c) act as a “resonance mechanism” for further innovation (Dosi, Pavitt and Soete 1990).

The emphasis on the epistemological, qualitative aspect of the process of asymmetry reduction must not obliterate the economic-value dimension of the underlying interactions. Local linkages among economic activities are an important aspect for qualifying this issue (Ocampo 2005). The economic relevance of learning processes in the end lies not only in efficiency improvement, but more importantly, especially in the case of developing countries, as a means to generate an extra amount of per capita income. Efficiency, especially of the short-term kind, can be attained through a competitive process simply by allowing the most advantaged unit to take over the market; this however says nothing about market size at the end of the process. A learning process can take place in isolation, with an economic unit shifting effectively into an improved practice, but at the cost of reducing direct and indirect value added. By effect of causality channels running from investment to learning, such a process of active response cannot be sustained but at a cost of reducing and concentrating income.

3. Macro-micro selection mechanisms

As explained above, the evolutionary approach focuses on the interplay between mechanisms of variety generation and selection mechanisms. We will highlight here two selection mechanisms relevant for our argument. Downie (1958) advanced one of the first settings in which intra-industry asymmetries were expressed in a range of cost dispersion, a result of imperfect replication and imitation of productive techniques. This range was to reflect the “relative ignorance” of firms about what their competitors do and how they do it. Given that technical knowledge does not diffuse automatically, firms differ in the range of production cost they are able to attain. The “transference mechanism” is the process by which market shares are redistributed from inefficient firms to efficient ones. The market system disciplines competition through this mechanism, exhibiting its “intolerance to cost dispersion” (p. 74). The transference mechanism is then an abstraction of the process that results from the relative success or failures of expansion plans carried on by firms producing substitute products or services.

There are multiple forces that counteract the transference mechanism. Quality, imperfect substitutability, and transport costs are among them. There are also "market imperfections" derived from long term contracts and other institutional barriers to entry. However, among them the most important force is the "innovation mechanism" by which competitors search and develop new technological combinations.[7] The argument for infant industry, which is but a particular case for the argument for "development niches" (Foray and Grübler 1991) can thus be assessed as an institutional setup that expands the "range of tolerance of cost dispersion" in order to allocate resources to learning and support the development of a technique within a demand niche. The market selection mechanisms operates then upon the technology base of the economy but indirectly through the differential survival and growth of firms.

The second relevant selection mechanism operates within the firm boundaries and refers to the behavioral and technological options that are selected and retained by firms from their available options (Nelson 2001). Firms generate their own selection environments (or "search and selection routines") and according to perceived signals from their incumbent markets choose "between competing alternative futures and their corresponding behavioral patterns" (Metcalfe 1994). This pre-market level of selection has received less attention that market selection mechanisms in the discussion of catching-up and accumulation of capabilities. From the concept of routines (Nelson and Winter 1982) we can derive several features of this process of selection. Both these authors and (Malerba and Orsenigo 1995) have introduced the notion of "innovation regime" to refer to the rules that govern choice at this level of choice-making. Economic evolution thus results from this two-tier selection

[7] This type of market dynamics is present in most evolutionary models that are based on the notion of competition as active rivalry and technological heterogeneity at the firm level. In the absence of imitative changes, pure selection raises local competitiveness (fitness) by homogenising the system at the micro-level; that is, innovators seize the whole market. This is a basic result of evolutionary theory is synthesised in the Fisher relation, where "the rate of change of average fitness is proportional to the variance of the population over fitness, which is the selection variable" (Nelson and Winter, 1982, p. 243; see also Iwai, 1984; Metcalfe, 1988).

process. The process in endogenous, for at every step of the process the selection criteria are determined directly from the process' previous state.

However, what we want to highlight is that macroeconomic influences and crucial information can directly affect an economy's innovation capacity precisely at this level of pre-market selection. In the following we argue that there are important macroeconomic conditions acting upon the range of available choices of search and development modes, expressed in different levels and allocations of resources to R&D. In order to clarify this point we turn to a simple model of search and development.

3.1 Technology search, development and outsourcing: the elements of a simple model

Following (Nelson and Winter 1982, chapter 11), assume that firms innovation process is sufficiently described by the following elements:

1. A topography or set of opaque (not completely specified) techniques, with some known technological attributes but with generally unknown economic attributes (can't predict perfectly the second, from the first, only know some "general stochastic relationships").
2. A set of search activities. Here we distinguish between a) A set of activities to find out more about technological and economic attributes; b) A related but distinct set of activities to work out the details and develop a technology to be employed in practice; c) a level of outsourcing of technological products and services. Outcomes of these two types of activities can be imperfectly calculated at different levels of input utilization.
3. A set of search rules. Search activities are in turn guided an directed by a "search strategy" keyed to particular variables and resources (size, imitation, assessment of general and particular projects, the owned complex of competencies, etc.).

As search is uncertain, outcomes are defined stochastically: a) probabilistically, certain techniques will become known, certain techniques will be chosen to be developed, and some needed content of outsourcing will be determined; b) through these actions, firms increase their knowledge about a class or neighborhood of techniques, about their technological and economic attributes. Assume finally: a) product attributes constant for all possible techniques; search is directed only to find the technology with the cheapest cost; b) possible technologies exhibit constant returns to scale and fixed input coefficients; c) the R&D decision maker knows only some technological properties, and that a subclass of them is more promising to deliver unit cost reductions.

The R&D process can then be summarized as follows: 1) sample from a subpopulation of techniques and "study" them; 2) this assessment reveals economic attributes and costs savings of available alternatives, (suppose cost is equal for all techs, and independent of the number of tests); 3) depending on development and outsourcing costs, at least one technology will be developed or outsourced, drawn from a sample determined by the R&D level of effort. In other words, the best choice of the sample will be developed, or outsourced if it reduces current operation cost and offsets development effort.

3.2 Determinants of the level of R&D effort and of R&D productivity

What determines then how much do firms allocate to search, development, and outsourcing? Nelson and Winter propose here to examine demand and supply of R&D, that is the pay-off and costs of search, development and (we add) outsourcing activities. The rationale for choosing these forces is straight forward. On the one hand, following Schmookler (1957), R&D effort is an economic response to demand side factors. The anticipated size of the market for a particular innovation exerts a major attraction to allocate resources. On the other hand, search and development activities also respond to the "ease of invention," or in other words, to the known or estimated effectiveness of those activities. This constitutes the internal R&D productivity expectation and results from the firm's accumulated knowledge and learning skills. It relates to the strength of the science and knowledge base that provides good estimates about what is feasible to explore and try, how can costs be cut down, what forces and materials offer tested efficacy, etc. Summarizing: a) demand or expected market size affects the level of input; b) effectiveness or strength of the knowledge base, affects R&D productivity.

How do demand and supply of search and development activities affect the process? Depending on demand expectations, a firm will allocate a certain "level of effort," an amount of resources to sample among available "grey" techniques (remember that some information about their properties is known). The bigger the sample, the higher the chance to find a better technique (remember search is cost-oriented). The higher the investment the more detailed the specification of economic attributes. Also depending on the "level of effort," the firm will decide how many of the found techniques will be developed and how much of the relevant knowledge and components will be outsourced. In turn, the results of search and development will in turn be determined by the firms capabilities base. The stronger the current knowledge and skill base of search and development activities, the better the outcomes (the lower the costs of development, and the higher the cost saving produced by development). Remember, however, that technology products and services also play a role in the process: the choice of developing a potentially good technology may not be economic at all if there are ready-made versions available through some transfer mechanism.

3.3 Some simple dynamics

The interplay between firm-level, and market level selection mechanisms can be then assessed with these elements. Firms will define a certain level of search and development effort depending on their market expectations, their knowledge and skill resources, and their rules of search. More specifically, selection criteria at this micro level includes therefore both cost-benefit structures and effectiveness of key resources. According to their perceived opportunities they will decide for a level of own effort and outsourcing. the process' outcomes, however, will modify the future structure of cost and benefits by enlarging the knowledge and skill base, reducing uncertainty, and better specifying which areas of the "grey technology" set. Moreover, to the extent that the outcomes of search and development effectively match a market demand, further innovation opportunities will be highlighted, improving expectations and increasing the incentives for allocating resources into future economic experiments. Observe that firms learn both from successes as from mistakes, although economic gains of the latter will be preferred by the selection mechanisms.

As should be evident, the positive feedback between expectations, productivity of key resources, and search and development cost-benefit structures will imprint path-dependent features into this model dynamics. Increasing returns to specific search and development activities will tend to "localize" learning into particular areas of the technological landscape (for this point see Foray 1997). Moreover, the strength of feedback transmission (for example, returns to learning) and accidental early events ("finding" one technology that offers wide higher costs reductions very early in the process) initial choices will bias the firm-level selection process into certain directions.

How does this setting would look like for the case of a "latecomer"? Initially, the latecomer advantage consists in that imitators can skip the cost of carrying on search activities. Imitators can notionally decide their R&D schedule enjoying a reduction in the degree of uncertainty. Many more technological properties will be known, as well as some general economic properties, focusing search activities to a more determined area to the extent and under the assumption that knowledge produced by the search activities of innovators can be transferred. In firms that look around to imitate or transfer existing techniques, the observer would expect to find that search occupies only a fraction of the original search effort and that most of expenditure is devoted to development (in the sense of adaptation to the local environment). However, it is accepted that technology transfer almost always demands some amount of testing and exploration on the technological properties of the relevant system and its neighbourhood in order to "unstick" un-codified, tacit knowledge and to introduce new technical characteristics that are demanded by the new environment or to modify the characteristics of the latter. Additional modifications need be explored in order to realise the unit cost reduction promised by the technology in its original environment. Depending on the technology's complexity, adaptive search can demand a non-negligible amount of effort.

More importantly, in order for adaptation to transcend simple imitation and for it to become *creative*, a deeper understanding of the technology's technological properties would be needed, claiming for additional efforts of searching for modifications. The imitation problem, therefore, seems to comprise a good deal of uncertainty, fundamentally about how deep it is necessary to dig into the technological properties of the available technology set for transfer to be successful and for imitation to deliver firm level advantages. The rules governing the process would determine the deepness of the R&D process and the originality of imitation.

As the reader would have figured out already, an important factor is how the role that search and development rules attribute to outsourcing. The most evident drawback of outsourcing is that, under most circumstances it does not provide exclusive advantages. But more importantly, outsourcing does not increase but marginally local capabilities. As we argued before, a crucial feature of the historical process of development and accumulation of technological capabilities is the progressive enlargement of the local knowledge and skill base. The relevance of this is evident in the model above: this are the only means to increase the productivity of internal search and development activities and transform the cost-benefit structure of innovation. Without any more specifications of the model it is possible to identify one stable equilibrium for search and development rules, namely that firms do not ever develop any technology and limit their innovation activities to search and outsourcing.[8] This situation means no other thing that firms in this state have not managed to develop proper "search and development" routines, and that they simply carry on *investment* routines. In fact, we can by now argue that this is precisely the most current situation at the beginning of the development process of a new industry in a late-development scenario. The transit from an economy dominated by passive response to innovation to one in which creative-

3.4 The macro connections

[8] As can be deduced straightforwardly, this result is robust also for accidental development "tries" if initial returns to learning are very low.

Patel and Pavitt (1988) argued that international differences in technological activities depend to a large extent on the way in which an economic system faces and processes uncertainty, cumulativeness, and irreversibility. Focus on characteristics of the investment allocation processes that bound technological behaviour. At one extreme, a system is myopic to the opportunities of a set of technological activities when it cannot help but evaluate them in an "ordinary" way; ordinary project evaluation would imply the assessment of benefits according to: a) normal rate of return, corresponding to b) an existing and defined market demand, and c) stringent discount rates for risk and time.[9] This type of project valuation biases against cumulative, irreversible and uncertain investment. At the other extreme, in dynamic systems project evaluation "also includes the prospect of creating new market demands, and of accumulating, over time, firm-specific knowledge that opens up further applications and opportunities" (Dosi, Pavitt and Soete, 1990, p. 102).

As we stated above, market demand expectations must be considered the main determinant of the level of search and development effort. Indeed, the level of effort can be interpreted as a proxy of the degree of technological myopia of an economic system. As with any other type of investment, firms search and development routines are not only based on firm and industry level expectations. As with other choices about resource allocation, the level of effort of search and selection activities can be plausibly thought of as including in its calculus aggregated indicators like average market growth rates, average return to capital and profits, discount rates to investment, and responding consequently to choices about alternative uses of capital. But the connection with the signals of economic activity at higher levels of aggregation is more profound.

As Schumpeter (1939) stressed notoriously, the distinct function of entrepreneurship chooses among available behavioral responses by assessing not only the immediate

[9] The argument resembles the notion of technological myopia as advanced by Atkinson and Stiglitz (1969): the case where a firm technical choice is based "solely on current factor prices," without taking "account of the value of the increase in knowledge associated with each technique" (op cit. p. 574).

economic environment, but the *general business situation*.[10] Defining the contours of the general situation rests primarily on habits and experience of interpreting objective data, and by systematic comparison of current affairs with the "normal" situation.[11] The echoes of Keynesian "animal spirits," that is, the subjective, non-optimizing components of economic decision-making, can be appreciated in full display. This domain of choice and behavior is precisely the domain of macroeconomics. As some post-Keynesian macro-economists have argued, one could deal with hypothesis about aggregated behaviour by abstracting that part of the general business situation that operating at the higher level of the system, is shared or subscribed by the whole population of units (Foster 1989). Interdependencies within the macrostructure can produce stagnation or investment booms through the mechanism of effective demand.

The influence of the state of the macro-economy over search and selection activities can be assessed succinctly by looking at general cases. A sustained expansion of the general level of activity can be plausibly expected to increase the frequency and variety of search and development exercises, following an expansion of investment in general. This means not necessarily that investment in R&D augments in every sector and firm. Rather, than more investment projects are being carried by a larger number of firms. The increase in the frequency and variety of R&D activities expanding the range of technological possibilities an economy is able to generate, detect, assess, modify, and absorb. More importantly, learning-by-using in search and development activities would imply that the dedicated inputs and resources allocated to those tasks are at the same time being transformed and improved at faster rates, expanding as well the efficiency with which that economy's specialized systems carry on those tasks. As R&D inputs become more, more efficient and

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[10] Every "businessman knows that his success or failure depends not merely on the degree of efficiency with which he manages his firm and on the fortunes of the particular branch of industry in which he works but also on a set of conditions over which neither he nor the branch as a whole has any control". This "something" is not "simply the sum of total factors acting within each concern or each branch", but "the general background for individual endeavours in the nation or even in the whole industrial world" that determines success or failure "irrespective of their individual merits," something "the elements of which weld into one connected whole capable of being described in terms of comparatively few strong contour lines" (op. cit., p. 3).

[11] For Schumpeter, this semiotics of economic decision-making, clearly opposed to maximising behaviour, is together with innovative behaviour the distinctive feature of capitalism; economic behaviour rested on those crucial habits and experience that rendered at every point in time the ultimate diagnosis on the state of the economy.

more specialized, the underlying cost-benefit structure of R&D changes. This double movement increases the economic return to carry on economic experiments within the economy. A facilitating macroeconomic environment will be one in which “technological myopia” of the system (in the sense of Patel and Pavitt) is reduced.

On the contrary, an increasingly adverse macro-economic environment would imply smaller ranges of technique development, outsourcing, and eventually also of search and exploration. This can be easily confirmed by means of the previous model. Suppose that selection criteria for developing a “grey” technology to be chosen from a detected sample is based on a benefit-cost ratio (b/c). Suppose additionally that in the calculation of such a ratio firms include opportunity costs of alternative investments. To radicalize the example, one can think of the return of a financial asset as the “profit hurdle” for choosing among alternative allocation options ([b/c] – r, where r is the average interest or discount rate). One can then readily deduce the effect of a short-term macroeconomic shock that rises the interest or discount rate. As the hurdle rate increases, riskier and longer-term delivering options will be gradually dropped. The sensitivity of investment in search and development, against macro-economic variables in adverse environments will this way operate to increase the “technological miopy” of the system, out-selecting investment in learning and reducing dedicated efforts. Once investment flows become disrupt and assets are transformed into financial or monetary instruments, spaces for economic experimenting tend to concentrate on rationalization and activity contraction.

3.4 The role of innovation systems

In modern capitalism the entrepreneurs’ skill in both innovation and assessment of the general business situation has been gradually replaced, and increasingly supported, by specialized bodies of technical and scientific knowledge articulate in dedicated services and organizations. How do firms calculate “the value of the increase in knowledge associated with each technique” or technological activity? How do firms assess the productivity of their search and development capabilities? A good deal of relevant information to assess and estimate possible distribution of the results of R&D and future technological opportunities comes from inter-firm interactions and the amount and quality of technological knowledge that a firm is able to “pool” at the moment of searching, assessing, developing, and outsourcing technological options. Innovation systems act as first hand resource bases directed: 1) to improve information and specification of opportunities that help in assigning a value to “knowledge” and “knowledge increase”; 2) to provide access to problem-solving power (or simply, knowledge) and therefore to increase the economic value of learning by reducing innovation, development, and replication costs; 3) provide “technological inputs” that shape technological expectations, reduce search and development costs. In particular, the specificity and efficiency of innovation systems plays a definitive role in the shift between a technology-outsourcing and a technology-developing economy, by augmenting the productivity of local R&D resources.

Innovation systems (considered in its broad version that includes also economic flows), also provide important feedback between changes in the economic structure and allocation mechanisms: “The structure of input-output as well as the untraded technological interdependencies of each economy, can be regarded as a huge feedback machine that amplifies, transforms or smoothes technological and demand impulses generated in any one part of the economy, transmitting them to the rest of the system in ways that are both sector-specific and country- (or region-) specific” (Dosi, Pavitt, and Soete, 1990, p.108). This type of feedback between allocation of resources and meso-economic structure would suggest, in tune with Ocampo (2005), that isolated innovation efforts of the skill-buying type that take place under economic structures without strong backward and forward linkages, can be plausibly expected to produce no “spillover” effects in the technological realm, nor as vehicles of effective demand and investment externalities.

Conclusions

We have argued that macroeconomic environments and innovation systems determine affect the nature of technical change, by influencing market- and firm-level selection mechanisms that govern an economy’s capacity of generating variety. This top-down causation channels are suggested as complements to the broader explanation of economic change and adaptation based on evolutionary principles.

It is worth to note that these effects of adverse macroeconomic environments are being assess at the level of pre-market, firm-selection. These effects are complementary, but of a different nature, to those observed by Katz in the context of macro-adjustment in Latin America after the debt crisis and in consequence of structural adjustment programs (Katz 2001). Katz argued that stabilization programs had operated as “massive selection mechanisms that screens out firms and industries” (p.332). In this case, an increase in technological myopia reduces the Selection mechanisms operating at both market and firm level may have indeed eroded the regions’ ability to respond actively to liberalization, and are surely a major reason of its falling-behind trajectory. As argued by Ocampo (2005), these broad impact on the pool of available skills could have long-lasting effects on the regions’ prospects for recovering a sustainable trend of growth.

We explored how demand and supply of search and development activities can help to explain different dynamics of technological learning. This framework of analysis suggest avenues for exploring policy options and a different interpretation of industrial and technology policies directed to innovation. In particular, it highlights the necessity to articulate meso-economic “science and technology” policies (oriented at reducing asymmetries at the level of innovation systems) with macroeconomic policies (oriented to build facilitating environments and reduce technological myopia). Secondly, this framework also suggests that policies directed to increase the capacity of the economic to generate technological variety and technological resilience may have as a necessary complement policies oriented to temper market selection mechanisms. In circumstances where active competition and market transference mechanisms operate in a relatively fluid manner across borders, economic resilience is crucial for preventing economic systems to rely purely on static advantages that may result socially and environmentally deleterious in the long term.

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