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Search and Innovate: A Way Towards Technology Change in Small Countries

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PREFACE

This document argues for greater emphasis on technological search activities in smaller, poorer economies such as those of Central America. This argument is based on simple economic expediencies derived from cost, benefit and timing. Indeed, the need to fall in line with the productivity and supply trends of today's globalized economy is more urgent than ever. Technological advance and search are critical for finding out what technologies exist already and applying them in critical situations at lower costs and in a more timely manner. In addition, there are some basic enabling conditions that go beyond simply improving the business climate. Among these there are better human and machine intermediation between buyers and sellers of technologies and technology/science services.

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Search and Innovate: A Way Towards Technological Change in Small Countries

I. Searching for Ideas to Boost Growth

Technologies available worldwide constitute potential for innovation and growth. Particularly for countries that have fallen behind in their economic and social development, capturing the benefits of technological innovation is a real necessity. The sooner and cheaper they can do it, the better.

One avenue for innovation relies on research and invention, which involve new additions to existing knowledge, and may require a long gestation period for testing for usefulness and cost-effectiveness.[1] Another option is search, which may require less time and fewer upfront costs. It is used to identify what is available and applicable to a given production context, a process that is more global, inclusive, faster, cheaper and accessible than ever before. Search works from the premise that technologies already integrated into one production context may be more readily transferred into another to speed up technological progress. Many technological activities, such as the identification of best practices, the assessment of available technologies for a specific production goal, the evaluation of the utility of international productivity benchmarks, or the pursuit of greater "self discovery"[2], fall under the general practice of search.

Search, as an economic activity, needs to be associated with but remain distinct from research, invention and innovation activities. This paper argues that most enterprises and many of the technological service providers in the smaller, poorer countries of Central America need to undertake more effective search activities. The absence of these initiatives is otherwise significantly slowing down prosperity in the region, even as it gropes to join the global economy. An important prerequisite, however, is to find ways to lower the costs of obtaining pertinent information and knowledge in a timely fashion.

This paper also rides on the Schumpeterian notion that technological change is critical to competitiveness, and that "innovation as creative destruction" is a driver for technological change. Successful innovation leads to competing effectively and, thereby, necessarily destroying less competitive firms or even whole economic sectors. Search being a form to innovate faster is also a way to destroy faster.

Consequently, developing the right mix of policies emerges as urgent for softening the blow to those who may be destroyed. One type of policy is oriented toward what is, by

[1] It is important to keep a distinction between invention and innovation. Invention requires long period of thinking, tinkering and/or research. In this day and age, inventing generally requires sophisticated equipment and highly trained professionals and testing laboratories. In olden days many inventions came come individuals working alone, and many of their ideas came in a flash of inspiration (Archimedes, DaVinci and Edison, for instance). Today, for a flash of inspiration to be original and useful to others you require collaborators, larger investments and easy access to and incorporation of existing knowledge. Inventions can be patented but do not have to be introduced in the market –in fact, many do not. Innovation, on the other hand, is more often than not, an improvement that surpasses the performance of existing products, a variation on a theme, and therefore, it is more likely to be introduced and be successful in the market.

[2] Hausmann and Rodrik.

now, fairly well known as striving for an "appropriate business climate". Less understood are policies related to communities of interest and associated "search engines". Another, possibly more controversial policy option creates a safety net program for those that fall behind or are "destroyed".

The Conceptual Framework

The concept of search that is at the center of this paper is embedded within the notion of innovation and the National Innovation System. Some definitions may be required, starting with "technological innovation".[3] The Oslo Manual,[4] which is mainly concerned with technological product and process (TPP) innovations in firms, offers the following definitions:

- **Technological product innovation:** "A technological product innovation is the implementation/commercialization of a product with an improved performance characteristic such as to deliver objectively new or improved services to the consumer."
- **Technology process innovation:** "A technological process innovation is the implementation/adoption of new or significantly improved production or delivery methods. It may involve changes in equipment, human resources, working methods or a combination of these."[5]
- **Diffusion:** "…diffusion is the way in which TPP innovations spread, through market or non-market channels, from their first worldwide implementation to different countries and regions and to different industries/markets and firms. Without diffusion, a TPP innovation will have no economic impact."[6]

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[3] It is also useful to distinguish an innovation in technology from an innovation in technique. The former develops a rather new technology to solve a unique category of problem. The latter is an innovative adaptation of an existing technology to a new environment with new conditions. Both are technological innovations, however. For further discussion, see Annex 4.

[4] The Oslo Manual is the most important manual regarding innovation, put out by the Organization of Economic Cooperation and Development. It is mainly concerned with TPP innovations in firms.

[5] Organisation for Economic Co-operation and Development (OECD), p. 9.

[6] Ibid.

Box 1: Example of Technology Innovation in Costa Rica

COSTA RICA Materials Technology applied to : Road Paving: Asphalt layers usually have limited life spans, requiring recurring investments in roads and pavements. Additionally, the repeated damage and repair cycles themselves result in costs to the users, including delays, car damage, and so on. The transfer of improved asphalt technology from the United States helped reduce the cost and improved the efficiency of road management in Costa Rica. The National Laboratory of Materials and Structural Models of the Universidad de Costa Rica (LANAMME) knew of experiences in the U.S. in which improved road paving included the application of new materials such as polymers, fiber and new additives that allowed better adherence, thereby increasing savings through lower operations and maintenance costs. LANAMME was able to absorb and "tropicalize" these technologies, adapting them to the local conditions. This helped create a new base for modernizing the paving industry in Costa Rica. The Consejo Nacional de Vialidad and the Ministry of Public Works and Transport have already selected this strategically important adopted technology for three further projects. LANAMME continues working to optimize its performance, experimenting with different mixtures of asphalt concrete, including the use of ground plastic waste originating from banana plantations, which achieves even greater cost reduction.

These definitions require qualification when applied to poorer and smaller nations (see Annex 1). More importantly, they need to be set in the context of a given country, specifically, its environment and capacities for thinking up ideas that have a good chance to result in an innovation.

Fallacies That Affect Technology Policy Design

Often, a linear sequence for arriving at desired innovations is assumed. There are two proven fallacies associated with this assumption. The first is that science can be separated from technology because one leads to the other; in actual fact, they are inextricably intertwined. The second is that innovation itself follows a straight, step-by-step linear path from research and development (R&D) to innovation. Use of the linear model continues because it serves as a justification for investing in basic research, and because of the misguided but widespread "conventional wisdom" that a straightforward sequence starting with basic research leads to technological development and, consequently, economic growth.

Furthermore, many a policymaker still believes that only new science leads to new technology; thus, the two are treated separately. But in fact, technology transfers (instead of science) generally lead to new techniques or technologies in developing countries. Indeed, a technology transfer in effect "invents" the new technique, allowing its adaptation to the new context and resources.[7] It is also easy to recall many technologies that have led to new science. Tanning, dyeing and brewing technologies, going back centuries to the times of Alexander the Great and earlier, are cases in point. The new science that gave rise to chemical products and chemical reactions was developed after these technologies had been in use for at least a couple of millennia. Furthermore, influential students of science and technology like Peter Galison[8] argue that new forms of equipment capable of detecting or measuring certain phenomena have opened the door to new scientific information and paradigms –i.e., technology often leads to science rather than the converse.

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[7] You obviously also need a good engineer well trained in science to devise the new technique, but that is a separate matter, not critical to the argument.
[8] Galison.

The linear model of innovation can be characterized as linking research to economic performance:

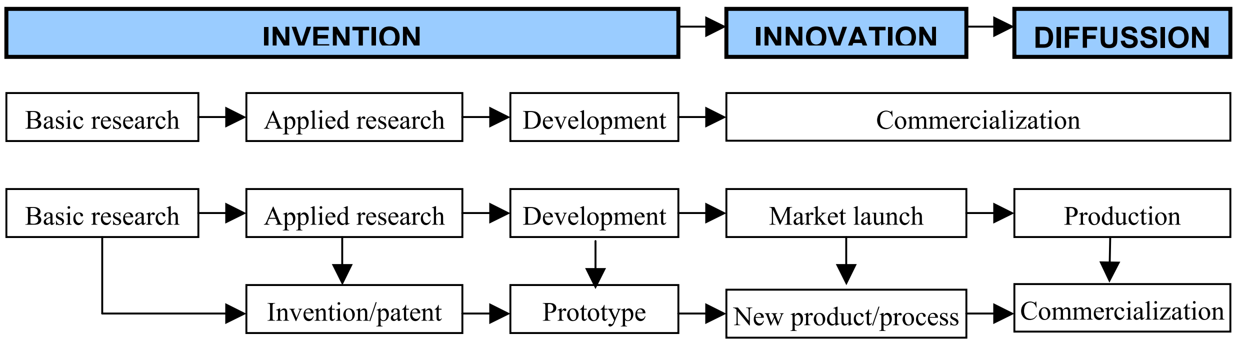

Figure 1.1: A Typical Linear Model of Innovation

This model has been superseded by newer and more analytical frameworks, such as the chain-link model by Kline and Rosenberg, which shows that innovations result from a continuing interaction of research and knowledge within the different stages of the process of innovation. It describes innovation as a rather complex process unique to each endeavor, without clear boundaries between each activity, and integrating different processes at each step. In this model, research and knowledge play a complementary role in providing additional inputs and as a problem-solving tool, while feedback is an important function. Additionally, the model demonstrates that innovation may or may not follow linearly from the origin of an idea or problem to the desired outcome.

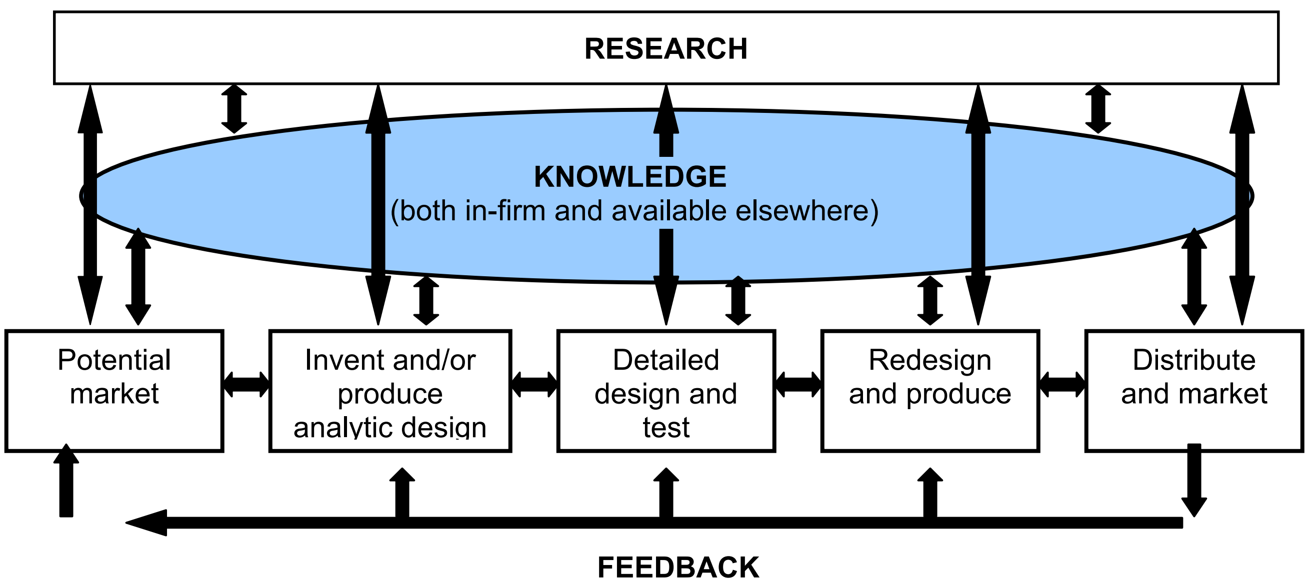

Figure 1.2: Kline and Rosenberg's Chain-Link Model

Clearly, searching for existing knowledge to serve as feedback at any stage of the chain-link model is a cost-effective way of attempting innovation.

National Innovation Systems

The notion of including knowledge and learning as important aspects of business and economic cycles inspired the concept of systems of innovations, specifically the idea of

National Innovation Systems. Lundvall says that the National Innovation System includes: "All parts and aspects of the economic structure and the institutional set-up affecting learning as well as searching and exploring—the production system, the marketing system, and the system of finance present themselves as sub-systems in which learning takes place."[9]

The National Innovation System is a concept that emphasizes the cooperation between a diverse set of public and private institutions that leads to technological development and innovation. Governments, firms, universities and other institutions collaborate on creating and developing new products and services aimed at fostering productivity, competitiveness, and, ultimately, national economic development. This comprehensive approach is highly dependent on successful interaction within networks of institutions. It is influenced by the tone of that networking, and by factors such as the country's macroeconomic and business environment.

Within the framework of the National Innovation System, there are three important factors that foster innovation. The first and most important is the presence of innovative firms that have the necessary scientific and technological capabilities, access to funding and a willingness to take risk. Firms that have the appropriate management and strategic mindset to innovate must, furthermore, build up their human and technological resources and have a vision of future opportunities. Access to funding is critical because R&D projects are long-term undertakings, often requiring constant funding and with unpredictable prospects of success. A willingness to take risk is required to move past this unpredictability.

Firms can only effectively innovate where the second most important factor is present—available supporting institutions. The most important institutional set-up is the educational system, which shapes students and, if efficient, prepares them for the needs of firms. Universities and other higher education institutions, especially technical training schools, should collaborate with firms in an effort to create synergies between their educational curricula and the needs of businesses. Science and technology institutions in particular can offer consultation and collaboration, and provide services such as laboratories, certification and metrology, among others. Innovative firms can also benefit from business associations. These often help locate opportunities such as export markets, lobby, and bring firms together within networks of similar industries, and across regions and value chains.

The third important factor affecting the ability of firms to innovate is a nation's science and technology policies. In a policy environment conducive to innovation, innovative firms will flourish. It is especially helpful when firms receive the support of government through a variety of incentives, such as subsidies to investors, cataloguing disseminating market and technology trends, access to R&D funding, other subsidies and fiscal incentives. Additionally, firms benefit if there are non-restrictive policies that surround the acquisition and transfer of technology and technological services.

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[9] Lundvall (ed.), p. 12.

Box 2: Porter's National Innovation Capacity

A useful way to deal with innovation issues is presented in the concept of "national innovative capacity" by Michael Porter. He understands this as "the ability of a country—as both a political and economic entity—to produce and commercialize a flow of innovative technology over the long term. Innovative capacity depends on an interrelated set of investments, policies, and resource commitments that underpin the production of new-to-the-world technologies."

Porter's framework for organizing the determinants of national innovative capacity consists of grouping elements within two main categories: (i) a common pool of institutions, resource commitments, and policies that support innovation, and (ii) the particular innovation orientation of groups of interconnected industrial clusters.

In other words, a country's capacity for technological innovation depends, on the one hand, on a set of elements contained in a common innovation infrastructure, and, on the other, a set of individual industrial clusters. There are also linkages between these two sets. Together, these contribute to an economy's ability to mobilize resources towards innovation opportunities in specific industrial sectors. The common innovation infrastructure represents the cross-cutting factors that support innovation throughout many, if not all industries.

Even where these three factors are in place, however, they can jointly foster technological success only if they fit within a wider framework of enabling conditions, such as good macroeconomic policies, an open business environment, the rule of law, adequate infrastructure, and healthy national and international markets.

A comparison of the concept of the National Innovation System with that of the community of interest, which is an important element of this paper and is elaborated below, shows that the former is a macroeconomic institutional superstructure dealing with broad policies, all agents and stakeholders, and national institutions such as the financial system, education system, business organizations and associations, and the links among them. A community of interest, on the other hand, is a microeconomic concept dealing with a specific sub-sector.

The small economies of Central America face a number of micro, macro and institutional constraints that prevent the normal mechanisms of complete or close perfect markets[10] from coordinating transactions at an affordable cost. These constraints lead to variations or differences in emphasis in the strategies policymakers can devise to promote technological innovations. While the activities involved in searching, researching, developing, inventing and innovating may constitute complementary elements, per the chain-link model, smaller and poorer economies will likely benefit most from a focus on intense search efforts. For the most part, a successful search for a technology is an end point for some years, needing no further research.

II. The Problem of Making Technology the Handmaiden of Economic Growth

To use knowledge to accelerate economic growth, the first task is to construct a solid and dynamic National Innovation System. It seems to most easily transmit knowledge in the form of technology that can be encoded. However, the adaptation to local conditions that follow when a technology is imported may require significant effort.

[10] Sáenz.

Local conditions may be compatible with the technology of interest, or not. If the environment is not compatible, the National Innovation System should be adjusted to rapidly and cheaply facilitate the technological adaptation—that is, it should have accessible and good technological service providers. Otherwise, the transaction costs associated with the adaptation may be too high to allow the technology to serve as an effective medium for economic growth. Among the critical initial conditions are the institutional variables, discussed above, which would apply to the effectiveness of the search effort as well.[11]

When the essential enabling conditions are in place, the diffusion of technology can play a central role in accelerating economic growth. Yet for that to take place, knowledge accumulation must not exhibit diminishing returns. To prevent that, policies must facilitate technology transfer. Innovators must benefit from the advances in applied science achieved by their counterparts elsewhere, and be able to access this through licenses, collaboration or turnkey projects. In this case, increasing returns are likely to follow in the long term.[12]

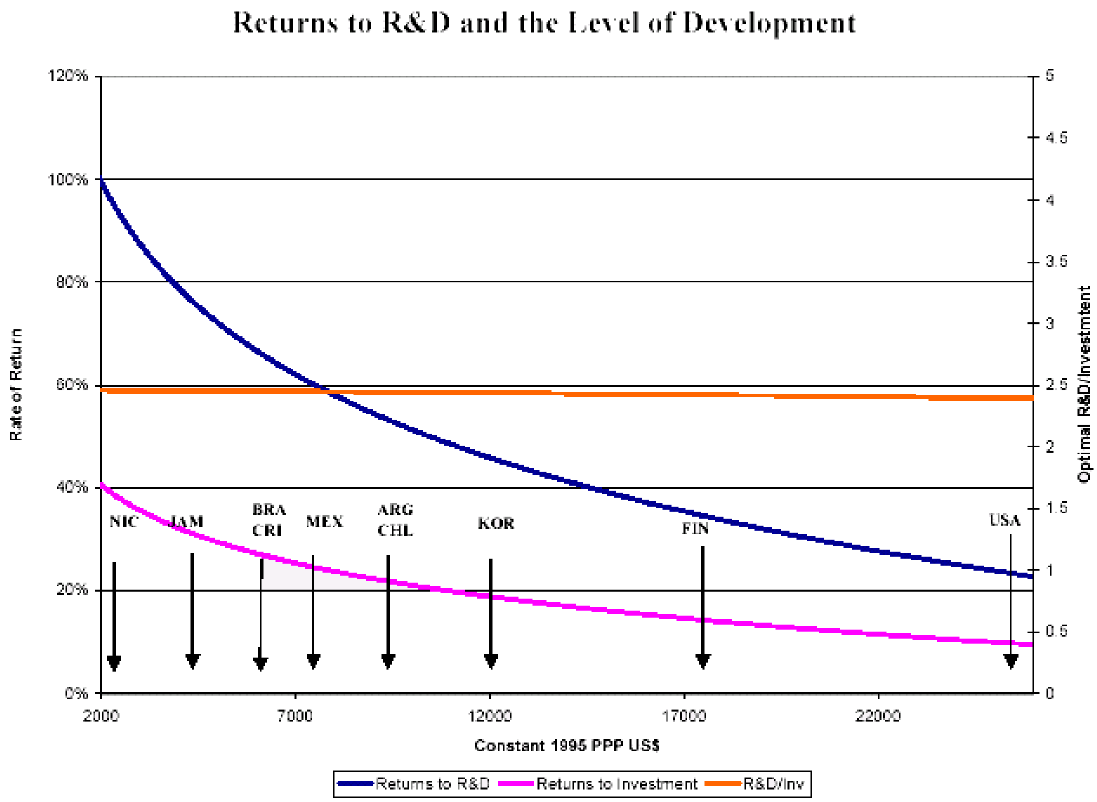
As some economists have noted, technology was simply left out of the loop when the Washington Consensus was formulated. They also specifically singled out the dismal technology knowledge capabilities of Latin America as a major cause for the poor economic performance of the region, despite its considerable economic openness and significant institutional reform.

Jeffrey Sachs of Columbia University's Earth Institute notes that: "Lack of vigorous growth is all the more puzzling because Latin America has plentiful natural resources, reasonably good health conditions and adult literacy rates reaching 90 percent or higher.…" He focuses on two particular problems: One, the social divisions and income inequalities, which de-emphasize large investments in education and health; two, more important in the present context, the basic failure of economic strategy. As Sachs puts it: "Whereas Asian governments, for example, relentlessly act to raise their economies' scientific and technological capacities, national policies to promote science and technology rarely gain such prominence in Latin America. The result is a failure to benefit adequately from the global technological revolutions. Asian developing countries now produce computers, semiconductors, pharmaceuticals and software. By contrast, even Latin America's star performer, Chile, remains largely a resource-based economy, concentrated on copper and agricultural exports. These sectors are technologically sophisticated but form a narrow base for long-term development.... The Latin American countries should increase spending on research and development to around 2% of gross national product (from around 0.5% currently), partly with public support for laboratories and universities and partly with private-sector incentives. They should roll out the red carpet for high-tech multinational firms, just as Asia has done."[13]

[11] Ibid.
[12] Grossman and Helpman, p. 281.
[13] Sachs.

Box 3: Returns to R&D

Daniel Lederman and William F. Maloney confirmed that Latin America underinvests in R&D, especially given that the returns on R&D seem to be higher in developing countries. They point out that differing levels of investment in R&D could be one important reason for the difference in growth performance. The countries that developed rapidly invested heavily in R&D.



Source: Lederman and Maloney

Dani Rodrik and Ricardo Hausmann, in a similar vein, point out that the poor growth response to the Washington Consensus recipes can be blamed largely on a simple fact of growth fundamentals—that it is a false assumption that poor countries can catch up with advanced industrial nations because they have access to state-of-the-art technology, and that property rights enforcement can be readily applied. Moreover, even when the production functions associated with global best practices become common knowledge, much of the technology involved is tacit (that is, it cannot be easily codified into blueprints for easy application). Its transfer to new economic and institutional environments requires adaptations with uncertain degrees of success.

Further, the entrepreneur identifying the new production technique can capture only a small part of the social value that this knowledge generates, because if the regulatory environment is weak, other entrepreneurs can quickly emulate such discoveries. There is no incentive then for entrepreneurs to focus on learning or discovering what they (and the country) are good at producing. In the absence of such incentives, investments in new, non-traditional products, or in improving the quality and market appeal of existing ones, would hardly be significant enough to influence growth. Economic transformation is delayed.[14]

It has also been demonstrated that the extent to which information disseminates across international borders (especially through foreign direct investment) figures prominently in the determination of long-run patterns of trade and in the relationship between trade and growth.[15] By facilitating search about and access to larger markets, trade raises the profitability of inventive or knowledge-based economic activities, and makes investment in R&D more attractive. These activities are bound to increase productivity and, thus, growth. At the same time, there is an important caveat here, especially for the poorer and small economies—the impact of what economist Elhanan Helpman calls the "competition effect". Exposing domestic firms to foreign competition may hurt profits, resulting in fewer resources and/or a lower motivation to invest in R&D.[16] Here, as in so many cases, some strategic and preemptive planning is in order.

The Importance of Communities of Interest Pooling Resources

After looking at the macro and international context, and the effects of transmission of knowledge, it is important to consider the specific community within which search and/or research activities actually take place. This paper starts from the premise that technical advance (invention and technological innovation) proceeds more efficiently and effectively through the work of a community of actors who share complementary interests, where agents with similar technological pursuits are linked within a favorable environment. This facilitates collaboration, synergies and confidence in results.

Whenever communities share complementary interests, they are most likely to have interactions among a range of actors that matter: between component and system producers; upstream and downstream firms; universities and industries; consultants, firms and universities; transnational corporations and local providers of inputs; and government agencies, universities and industries. Such sets of actors are sometimes referred to as clusters, networks or partners, but we would rather refer to them as communities of interest because the potential interactions are not always clear (and may have to be "induced"). Or they are not continuous but sporadic. They may involve multiple groups of partners, or consist of researchers rather than production-related concerns.

To better understand the concept of communities of interest and the need to pursue search, we can look at the case of Motorola.[17] In the 1990s, Motorola faced unusual increases in the pace of innovation from competitors that were gradually destroying its market share. Its management realized that it needed to develop more innovations and introduce them into markets much faster than before. Motorola embarked on a major effort to design and implement a high-level, structured framework with the capability to network the entire enterprise. Not a simple task when you have to track more than 10,000 programs designed to deliver market-leader innovations. Between 1999 and 2001,

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[14] Hausmann and Rodrik.
[15] Grossman and Helpman.
[16] As Helpman notes, competition may also induce tech-based firms to accelerate innovation efforts in order to fend off competition from technological followers. In this case, trade boosts R&D. Helpman, pp. 64-65.
[17] Alignent Software and the Leading Trust: www.alinement.com.

Motorola searched various methods for creating an adequate database that could support the long-range planning activities of as many as 100,000 employees in offices all over the world. By 2001, Motorola had developed software that allowed company-wide planning activities in a centralized database with a standard format. This led to "technology roadmaps" that made certain that the firm as a whole would put in motion, very early on, what was necessary to have in place the right technology, processes, components and experience in order to meet the future needs for products and services.

It may be argued that to follow in the footsteps of Motorola requires levels of investments that are beyond the capacity of the kind of enterprises under discussion here. This is true, but the underlying premises of developing an internal and/or external network are the same. A set of suppliers (local or international), clients that possess basic know-how, and appropriate think tanks, for instance, could be organized into a network to achieve the same results.

IV. Why Should Central America Care About Innovation?

Ask most entrepreneurs, engineers or scientists in Central America whether technological innovation should be promoted, and you will get a positive answer. If you probe a bit further, you are likely to hear qualifications or, indeed, reluctance. One deterring factor may be that technological innovation is complex and requires "too much" research time and costly human resources. International competition may seem too fierce for technological innovation investments to be viable for small firms in poor economies. They are likely to argue that even in the rare cases where investment in research successfully pays off in the development of an innovative product, the idea will be quickly stolen and copied. Thus, the conclusion normally is: leave innovation to the advanced countries where patents and licenses can be enforced and protected.

However, globalization is slowly but steadily bringing change. Central Americans have begun to understand that firms that are not competitive get destroyed, that they need a strategy to forestall such an eventuality, and that the more creative that strategy is, the better its chances for survival. The prior requirement is an appropriate business climate with the right incentives. But this, as difficult as it is to introduce, is not sufficient. What is needed as well is a major feat of engineering or re-engineering, not just on the production floor, but also in the organizational structures of firms themselves. Indeed, product characteristics, prices, marketing plans and production technologies need to be standardized and oriented to specific corporate goals. Corporate goals, in turn, need to be effective in dealing either with the domestic competition, or in visualizing potential opportunities arising in the global markets, if not both.

An organizational culture that understands and values innovations cannot be created in a few months. Therein lies the role of policies that incorporate societal values and the propensities of economic agents. For instance, a strategy based on fostering key communities of interest with the potential to develop comparative advantages may be more useful in coping with global competition than a strategy of indiscriminate mass transfers of technologies or foreign direct investment. Of particular interest would be fostering tight-knit communities with suppliers and service providers with a vested interest in selling goods or services to a set of firms. These enterprises would exchange advice, hopefully leading to new knowledge and to thinking "outside the box". Increasing returns to research, development or even just feasibility studies would be proportionate to the extent that such networks are ongoing rather than one-shot events.

In such a setting, a systematic search activity is a must if an enterprise is to remain abreast of global market trends and changes. In particular, search-related transactions must be targeted to at least four strategic areas: (a) detailed (possibly technical) information on the new products in the global market; (b) information on the major research trends in key industries of interest to a particular firm, and to the economy as a whole; (c) information on organizational arrangements that have been utilized effectively by smaller firms to contribute to an international cluster or network; and (d) understanding how a firm in a small country looks for and identifies a potential provider or buyer at a reasonable cost.

Put differently, since world trade volumes depend on endowments, technologies, preferences and market structures, small countries must be more careful than larger ones about how and where to orient local and foreign direct investments. The argument is that since endowments and preferences are largely exogenously determined, the initiative of small countries lies in making policies to strengthen markets (such as the market for technology services required in key economic sectors) and to promote search for appropriate techniques and technologies. These actions will reduce transactions costs and energize the National Innovation System, leading to more productivity and competitiveness. Indeed, these actions may well facilitate the creation of economic niches that in due time could develop a comparative advantage for certain goods and services.

Existing science and technology and industrial policies are not currently helping the poorer and small countries to get where they need to go quickly. In addition, as long as entrepreneurs think it cannot be done, that it is too difficult, that there are easier and cheaper alternatives to be competitive, innovation will obviously not take place.

One alternative, elaborated below, is that firms need to consider that they do not have to engage in investment or time-intensive R&D to be innovative, and that innovation is not the entitlement of large enterprises alone. Firms do, however, have to be plugged into a community of interest and learn to work in networks, local and international.

This leads us to a question: What do we mean when we say that such and such entrepreneur or production engineer introduced a technological innovation?

Innovation as "Creative Destruction"

Joseph Schumpeter, the economist who possibly did the most to bring the concept of innovation to prominence in his profession, deemed innovation "creative destruction", stating (bold added for emphasis):

> "...Capitalism, then, is by nature a form or method of economic change and not only never is but never can be stationary. And this evolutionary character of the capitalist process is not merely due to the fact that economic life goes on in a social and natural environment which changes... The fundamental impulse that sets and keeps the capitalist engine in motion comes from the new consumers' goods, the new methods of production or transportation, the new markets, the new forms of industrial organization that capitalist enterprise creates.

> "...The history of the productive apparatus of a typical farm, from the beginnings of the rationalization of crop rotation, plowing and fattening to the mechanized thing of today–linking up with elevators and railroads–is a history of revolutions. So is the history of the productive apparatus of the iron and steel industry from the charcoal furnace to our own type of furnace, or the history of the apparatus of power production from the overshot water wheel to the modern power plant, or the history of transportation from the mail coach to the airplane. The opening up of new markets, foreign or domestic, and the organizational development from the craft shop and factory to such concerns as U.S. Steel illustrate the same process of industrial mutation – if I may use that biological term–that incessantly revolutionizes the economic structure *from within*, incessantly destroying the old one, incessantly creating a new one. This process of **Creative Destruction** is the essential fact about capitalism. It is what capitalism consists in and what every capitalist concern has got to live in. . . .[18]"

Today, 60 years after Schumpeter, the upshot is clear. The market can no longer be understood only as a static mechanism to allocate resources. More often than not, it is the locus to discover new needs of consumers that can be satisfied with new methods of production, processes, products and services. As such, far from being static, the market is a conduit for revealing the dynamically changing needs and preferences of consumers to "innovative" entrepreneurs. Led by the profit motive, entrepreneurs compete among themselves to discover products that best fit the evolving needs. And it is the strategic alignment of products, markets and technologies that will provide a competitive advantage.

Furthermore, innovative products, once introduced, directly impact consumer preferences, which are modified by technical changes in new products. Competition takes on an important characteristic unrelated to price, where the constant change of products and production methods is fundamental. This brings us closer to the notion that to the extent that the innovators get it right, supply may be driving many markets, rather than demand.

Ideas, Creative Destruction and Openness to Trade

The implication is that as Central American economies open up their markets to international competition, and as international market integration takes hold, technological proficiency becomes critical. If properly set up, search activities can accelerate prosperity.

Opening up an economy may actually entail a wave of "destruction" if local creativity and search efforts do not find adequate channels to turn potential economic threats (the potential destruction of traditional products) into triggers for innovative activities. This wave of destruction would result from the demise of protected and uncompetitive industries, which now have to compete with better imported products at home, as well as with the demanding and changing preferences of consumers in export markets abroad. Furthermore, if precautions are not taken, a large foreign firm may end up buying the few providers of a good or service and installing, in effect, a monopoly—and reducing local competition. With business not as usual anymore, many local entrepreneurs may perish if they find themselves unable to shape up and adjust.

[18] Schumpeter, 1975 (orig. pub. 1942), pp. 82-85.

When joining the global market, entrepreneurs in poorer nations face the reality that players in industrial nations have known for decades: that one has to revise the commonly accepted belief that simply attending to a steady and predictable consumer demand (a demand driven solely by consumers) and being efficient in production is sufficient to compete. Today, supply is one of the dominant forces driving markets' outcomes. And elements not related to price—such as quality, new characteristics and the availability of innovative new products—shape demand. Therein lies the need to be able to access, absorb or adapt existing and changing technologies in order to be part of a network or international cluster. Otherwise, you must be able to design, develop or invent new products where you can lead.

In this new economy, successful countries are those that pursue creative destruction as a matter of course, and where innovation is bound to be one of the main drivers of wealth. This is because ideas rule, as the influential Paul Romer has pointed out. Ideas actually spark creative destruction, which, at least in advanced industrialized countries, is facilitated by the numerous market mechanisms for new ideas to find their way to the production floor (or, speaking theoretically, for ideas to enter the production function).[19] This production of ideas is a necessary condition for effective global competition, and is probably a function of competitive pressures and the trade regime.

The central point in Romer's paradigm is the externalities that result from the accumulation of knowledge. Ideas and knowledge enter the production function as another input, just like labor. Yet their effect on productivity depends on the firm's stock of knowledge as well as the economy's aggregate stock of knowledge—both of which, in turn, depend on past investments in knowledge by the firm and the economy. As such, firms have a positive stimulus to invest in knowledge, all the more so if the economy's stock of knowledge is large. As they forge ahead investing in knowledge (without consciously being aware of this, as in Adam Smith's invisible hand), they in turn contribute to the aggregate public stock of knowledge. A virtuous circle ensues and leads to sustained growth.[20]

If an economy is too poor or small to be constantly producing ideas, it must at least join some international community of interest that produces successful ideas frequently. Production and acquisition of ideas can be associated with the international mobility of people and investment. Given that the production of ideas is intensive in human capital, the rate of return on that capital may be associated with the openness of the economy, opening the door to the role of trade in the accumulation of knowledge.

[19] Paul Romer emphasizes that economic growth is an endogenous outcome of an economic system, not the result of forces that impinge from outside. As such, the role of R&D and knowledge spillovers that result from investments in R&D endogenously contribute to determining growth. The line that we are pursuing through search places greater emphasis on finding what technology is appropriate and devising an effective technique that deals with local conditions and context. The weight is less on R&D and more on search.

[20] Romer, pp. 3-32.

Box. 4: What Ideas Are Worth Pursuing?

Even if we admit that it is not a society's products, clothes, sugar, computers or widgets that matter, but rather its ideas (as Romer does), we face further obstacles related to the pervasive culture of fear of new ideas, which derives from poor familiarity with the processes associated with turning ideas into products:

"The problem is that only a handful of companies (in the world) understand where today's ideas for tomorrow's blockbuster products come from, much less how to properly develop a vague vision into a perpetual money machine. Like rare orchids, ideas need to be firmly planted, fed, and at times pampered to properly take root. Do otherwise and they will die on the vine... Forget about the image of the lone misunderstood inventor toiling away in obscurity because innovation doesn't just happen. It takes time, effort and hard work. From initial idea to technological advance, every step of the process is fraught with opportunities to ignore, sidetrack, or dilute its inspiration. Look beneath the surface of the companies we admire most, such as Apple, GE, and Sony, and you'll find a dedication to coming up with new concepts and commercializing them into products. Some strive for continual improvement in their processes, while others seek extensions to existing products or invent whole new product categories. In a very real sense, they are no longer mere manufacturers; they're idea factories."[21]

Yet, to a great extent, the economic policies and incentives in Central America point elsewhere. There is a fear of trying out new ideas, of committing to nurturing ideas, or of showing them to supervisors who are likely not to be receptive. And there is still much pressure to continue rent seeking rather than to promote ideas that could contribute to competitiveness. These factors call for more decisive and creative policy-making to break the cultural and attitudinal roadblocks.

V. Search, Research and Googling for Technologies

What Type of Search?

In general usage, search has to do with looking through or examining ideas, resources, sources, markets, catalogs, regulations and so on to find something in particular, something more or less well defined. The interest here, however, is in a particular type of search, namely as it is understood within economic theory. This is a somewhat more involved concept.[22]

Search theory was developed when operators and academics collaborated to apply mathematics to a very tangible task: to find a militarily important object in the quickest, best way possible. The theory has taken a number of routes in its evolution, perhaps most interestingly via operations research, where the interest lies in analyzing the needs and problems of operators (of any kind) in solving pressing operational search problems. Researchers have developed an interesting toolbox of practical techniques for tactically minded decision-makers. The algorithms of search engines such as Google may be considered an evolution of this line of thinking.

Within economics, search acquires a specific connotation. Search theory deals with the analysis of resource allocation, with specified, imperfect technologies for informing agents of their trading opportunities and for bringing together potential traders (these technologies include mechanisms such as a simple auction—or *tatonnement*, a bargaining

[21] Nadel.

[22] Search is not yet defined in science and technology manuals such as the Oslo or Bogotá Manuals, for it is considered part of other activities. As such, it is in need of definition for the purposes of pursuing technological innovation and diffusion. We will approach this concept theoretically at first, and subsequently derive a more operational definition.

process—that are used to achieve a match).[23] The theory deals with the question of how the agents find a potential buyer (or seller) of a good or service, and what is the cost involved for the search. The concept can easily be extended to encompass the situation of interest here, namely, how do economic agents find the best (or a good enough) match to effect a trade, or find the right network partners (suppliers, clients, service providers) interested in forming a community of interest.

Naturally, this way of framing the economic exchange problem does away with the assumptions of instantaneous and cost-less coordination of trade, as in the General Equilibrium theory. (We are neither assuming that the opposing end of general equilibrium prevails, that is, that there is a "random matching" approach to exchange, but rather that there is a directed search).[24]

Box 5: Self-Discovery

Dani Rodrik and Ricardo Hausmann, in *Economic Development as Self-Discovery,* propose a public good solution to deal with the uncertainty that firms and policymakers face regarding what a country is good at producing. Basically, they start by identifying weaknesses in the implicit steps needed to achieve rapid growth through access to foreign technology and governance by good institutions. The main weakness in the developing countries of Latin America involves poor knowledge about what firms from specific sectors may be good at producing in a particular country and environment. Entrepreneurs may have access to foreign technology and protection of property rights—especially intellectual property—and yet err in their choice of industrial sector, and the type, character or size of their investment.

On the other hand, if firms know that in the country where they operate, cut flowers, soccer balls or computer software can be produced at low cost with appropriate technologies, competitiveness is greatly improved. This holds true not just for one but for many entrepreneurs in the sector, who can imitate the leaders. As such, there is great social value to discovering the relative costs of production, which vary by country.

Market failure arises out of the very small part of the value that the first "discoverer" can appropriate, since normally other firms can quickly emulate the discovery without paying for the investments or opportunity costs that the first firm had to incur. In other words, if learning what a country is good at producing requires an investment and the return on that investment cannot be fully appropriated by the investor because others jump in, then there is a serious obstacle to such investments; indeed, the stimulus to invest may be too low.

The question then becomes how to design better policies to deal with market failures—specifically, what can be done to induce investments in nontraditional activities when returns to entrepreneurship in such activities are subject to nonappropriation.

In summary, the loose definition of "search"—namely, that it is related to finding out what is available and applicable to a production context—can now be translated into more technical terms, specifying that in order to allocate its resources efficiently, a firm needs to find out what technologies are available in the market and can be traded (and the costs associated via licenses or turnkey projects, or at zero cost via copying).

[23] The New Palgrave (Encyclopedia of Economics).

[24] We are interested in what is called "directed search". That is, midway between Walrasian general equilibrium and random match we find a family of matching technologies characterized by the assumption that the selling mechanism of each seller matters for both price and probability of trade with buyers. Thus, for example, a set of similar sellers can easily communicate their locations to buyers, but we might also assume that buyers cannot communicate with each other over which seller to visit. (See Kennes.)

Furthermore, the firm is limited by the mechanisms (local or international) in place to inform it (and its potential suppliers-clients) of trading opportunities.

Search and the National Innovation System

With that quick introduction to search theory, let us return to the situation that firms face within the National Innovation System[25] framework. The traders, in this case, are the firms (buyers) that demand technology support for innovation purposes, while the suppliers (sellers) are those firms that sell science and technology services to the former. Among the first are mostly enterprises, but also government institutions and other research- and innovation-related entities.[26] Consequently, the trading opportunities are those associated with articulating or diagnosing obstacles to technological innovation, identifying providers of technological solutions and/or related equipment, facilitating the adaptation and/or transfer of a technology to different contexts and environments, finding the right professionals to carry out a particular component of an innovative project, etc.

The matching technology, or the mechanism by which buyers and sellers of technological solutions find each other, is a primary issue.[27] In most of Central America, this mechanism is rather precarious—typical of any incipient market. Most laboratories, for instance, are in universities that lack a good marketing strategy. There are very few effective *university–enterprise* liaison centers. And mechanisms to set prices are not well-defined and ad hoc in most cases. No marketing means poor information about what kinds of technology-based jobs can be performed—beyond routine ones, which may not be indicative of what labor can be provided for innovative technologies. Even extra-national and extra-regional sellers of services are difficult to identify or contact.

The prevalent matching technology is also risky, for a lot of the terms and conditions of the eventual contract may suffer from asymmetrical information. Warranties are flexible, and guarantee-bonds are expensive. The product or service may lack exposure to local conditions, in which case the durability or reliability may be questionable. Parts and repair services might be abroad. That imposes heavy costs on the production of the non-traditional good in question, which are frequently hidden—purposefully or otherwise—during the negotiations for technology exchange between buyer and seller.

Furthermore, in the majority of cases, search costs can be rather expensive when they can be forecast, and are usually overestimated, because of uncertainty, when they cannot be forecast.

Special mention must be made of the self-discovery model developed by Rodrik and Hausman. It suggests that production should actually be started in earnest to discover the true costs (of technology adaptation, resource inputs, management organization,

[25] The system is not assumed to be so completely networked as to constitute an efficient, economic-signals-emitting grand market.

[26] The form of payment of public institutions does not generally follow competitive market rules, complicating and making search and completing transactions more costly.

[27] It is somewhat awkward to use the expression “matching technology” in connection to “technological solutions”. But this results from our effort to keep up with the jargon of the profession. Search theory uses match technology to refer to the mechanism by which an exchange takes place.

marketing and so on). Only then can the entrepreneur test his or her hypothesis that there are sufficient buyers to make the venture profitable.

While this paper has been inspired by the search theory, it is not rigorous (that is, mathematical) in specifying the imperfect technologies for informing agents that actually exist in a particular country of interest, because that would require an empirical data collection that is beyond the paper's scope. Instead, it makes some basic assumptions that reflect the type of technologies that exist in the technology and science markets for transmitting information and knowledge about trading opportunities. That is, the ideas presented above do not constitute a formal model, but rather a framework for applying search considerations in the analysis of a country's National Innovation System and in setting up policies.

We would like to also observe that the coordination of any trade (technologically related or otherwise) involves two separate steps: information gathering about opportunities and arrangement of individual trades. A simple case is where information gathering is limited to visiting service providers one at a time, and then summing up the costs of gathering information and negotiating a price. This is the case, currently, in most of the Central American countries. The costs, as noted before, can be enormous due to the precarious nature of the market and marketing efforts, and the fact that for most goods and services a community of interest has not developed to any significant degree.

VI. Implications for Central America

The application of a science and technology policy to foster economic growth is complex and risky—complex because of the large gap between the small Central American countries and the developed countries with whom they must now increasingly trade; especially risky because any serious and large investment in a particular direction that fails is bound to have great costs, both economic and social. Thus, it is recommended that Central America should promote the two following policies: communities of interest and a special incentive policy.

Communities of Interest

Central America has already introduced and promoted the idea of production clusters. The communities of interest go beyond a production chain and include all the activities in which science and technology can provide a backbone for industrial development. The goal is to produce a network between knowledge producers and industry. It is here that search could play an important part. It is through search that existing gaps are bridged. The search mechanisms would include technology brokers, computerized databases and search mechanisms.

Technology Brokers

Technology brokers facilitate communication within and among communities of interest, and reduce the transaction costs of identifying the right technology for the right problem. The model is one of a decentralized network, in which the technology brokers are located within institutions that belong to the community of interest. They provide the link to the world of existing technologies and firms, to which they provide diagnostics. With the help of tech search engines and databases, they discover what technologies may be available in the local or world markets that might be useful to the community; they may even be committed to the delivery of technological services.

Googling and Economic Search

Science and technology "googling", that is, using a Google-based technology to facilitate finding a match to a trade, is the logical next step for economies starved of pertinent information and knowledge required for R&D and technological innovations. Indeed, while this paper does not seek to prove this case, it is suggested that in markets with frictions and distortions—and which are competitive in the sense that all agents are price takers—the closest that one can get to a socially optimal allocation is through a major search engine such as Google. If traders on the demand and supply side of technological services can advertise publicly their capacity to provide a service and/or the prices that may be charged for relevant or similar tasks as those likely to be sought by firms who want to innovate, a partial equilibrium in this market can be achieved. Annex 3 presents examples of Web sites that follow the idea of search and allow users to find solutions to specific questions.

Box 6: Why Google?

Google is the most widely used search engine, and due to its user-friendly interface and great accuracy is a great example of possible benefits of creating an science and technology search mechanism. A search engine is a Web site that responds to a search query through the gathering and reporting of information available on the Internet.

Google is so successful precisely because of the accuracy of its results, the size of its database (more than eight billion web pages), its simple format and the ability of its searches to customize. In fact, it has become so popular that "googling" is a term now widely used to refer to searching the Web.

Since the lack of information is one of the biggest obstacles to technological development in small countries, the creation of a network in communities of interest, together with easy search mechanisms and improved access to these technologies, would allow for greater diffusion of knowledge and a reduction in the uncertainty involved in search.

As a firm or a cluster of firms matures, "technology roadmap" software may be required (as in the case of Motorola, described above). Indeed, just as in the Motorola case, numerous firms (suppliers, clients, service providers), institutions and think tanks can be included so that thousands of users can collaborate on supporting, nurturing and testing ideas. Software such as Alignent Software's Vision Strategist, to name one example, can be used to view the community's full range of possible projects and products online along with their roadmaps. In Motorola's case, users participated in online review meetings and received clarifications, feedback and suggestions about their roadmaps. This networking arrangement made for huge savings and presented a greater probability of success with new ideas for innovations.

Incentive Policies

In smaller, underdeveloped economies, the considerations raised by Rodrik and Hausmann are pertinent. They say that there are serious uncertainties about costs associated with producing nontraditional or innovative products. Most entrepreneurs are not willing to invest in discovering these costs because there is no assurance that competitors will not steal the benefits of such investments. In the equivalent search parlance, it would be said that search externalities are not reflected in the returns on investing to explore the production of goods that are not new by world standards, but that are nontraditional by local standards.[28]

Under these circumstances, there is an important role for government intervention to either protect intellectual property or subsidize the investment costs associated with discovering what nontraditional goods a country may be good at producing. As Rodrik and Hausman rightly argue, many innovations do not depend on substantial research that would result in a design or technology that could be patented. Furthermore, there is a strong case to be made for allowing some innovations to be easily copied by competitors, as this scales up the social returns. Consequently, this paper reiterates the need to subsidize the search for nontraditional product possibilities.

While Rodrik and Hausmann propose only incentives for "self-discovery", a form of search, we propose, in addition, that tech search engines, as described above, be developed.

We also recommend that serious attention and analysis be placed on designing a security blanket for those brave enough to pursue the higher risk associated with an aggressive technological innovation approach to growth. The *social emergency funds* that mushroomed in the 1980s to soften the structural adjustments recommended by the Washington Consensus provide a starting point for discussion about safety nets. Another, more expensive scheme is that proposed by Michael Mandel,[29] Chief Economist of *Business Week,* who recommends an income insurance to soothe fear, and make highly educated workers more comfortable with the high risk of being displaced. Entrepreneurs, on the other hand, should be expected to compete and bear the consequences—in the true spirit of what it means to be an entrepreneur.

A Final Caveat: Moving from a "Search-Dominated" Policy to a "Research-Dominated" Policy to Innovation

As stated at the outset of this paper in the description of the chain-link model, the steps from search to research to innovation constitute a circular continuum with feedback loops arising at any point. Search may be enough for a particular firm, but search alone is not enough for an economy to become truly competitive over the long haul. At some threshold point, widening and/or deepening research activity becomes imperative to pursue greater economic gains or maintain market share.

This caveat is important to avoid the misunderstanding that search and only search is all that is needed in small, poor countries over the long term. During transitional phases from slow growth to faster growth, search is bound to return the quickest rewards. This, in turn, will excite investors, both local and international, as they see such indexes as total factor productivity increasing rapidly. But, over the long run, much more than a search-dominated strategy is required.

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[28] Since the products or services exist already in some markets of the global economy, we are not talking at this point about R&D, but about searching for a promising product, and borrowing and adapting the associated technology.

[29] Mandel.

Smaller countries are likely to have or can develop specific and well-defined areas where R&D and innovation efforts should be exerted. Indeed, a country may have the natural resources and human capital to attract the complementary investments to promote successful knowledge creation and accumulation.[30] At the end of the day, however, a small, poor nation must prepare itself for producing ideas, to avoid shrinking its profits due to exposure to foreign competition. The more efficient the use of local human, natural and physical capital, the better the results.[31]

Another way to look at these issues is through Alice Amsden's discussion of "buying" vs. "making" technologies. To "buy" technology, you need to search for it; sometimes, potential innovators even need to search for assistance to help articulate their concerns in technological terms.

Amsden presents a historical record where all developing countries initially buy, rather than make, technology. The successful small- and medium-sized firms of Korea and Taiwan, for instance, started "buying" (at a price of zero) technology by copying ("reverse engineering"). Note, however, that copying requires developing skills both to be able to detect the core technology, and to develop the industrial organization required to produce these new products efficiently. This connection between copying and high-tech technologies and techniques is not present in Central American countries, although it can be promoted over the medium term.

Furthermore, the governments of Korea and Taiwan were effective supporters of technological change since they introduced policies to get the best terms for technology transfers, spent heavily on formal education and slowly increased investments in R&D. While these policies benefited the bigger firms more than the smaller, there were important spillovers.

Amsden says that what has made a difference among developing countries is that some began to "make" technology:

> While all countries continued to buy foreign technology, and continued to invest in production capabilities and possibly project execution skills, leading firms in some countries—the "independents"—also began to develop new technology, a necessary condition for sustainable national enterprise... Korea and Taiwan were the big R&D spenders. The share of R&D in their GNP became comparable by the 1990s to that of North Atlantic countries and Japan... In terms of the high R&D spenders, the efforts of Korea and Taiwan started early and then rapidly gained momentum. *The initial form was quite coercive*. As early as 1973, the Korean government introduced a reserve fund system that "required firms to keep a certain proportion of income for R&D investment" (coverage included firms in manufacturing, construction, mining, computer processing, military supply, and machine engineering). If the amount set aside was spent on R&D (broadly defined) within a given time period, a loss could be deducted from taxable corporate income. If not used, the amount set aside had to be declared as profits and subject to taxation (OECD 1995, p.99). The Taiwan government, fearful of the limited effort of small firms to invest

[30] One way to put this simply is to look at Solow´s production function: Q=Af(K,L), where A is exogenously brought it. In the Romer model, one could say Q=f(A,K,L), where A is endogenous, depending largely on investment decisions on R&D, among others. Now, for a developing country it may still be valid to emphasize the Solow formulation for some or many sectors, while at the same time reflecting a much longer term effect for R&D investments, i.e., a combination of the two models.

[31] Here the need to devise or reengineer institutions to effect the desired incentives is all too clear.

> in R&D, required all firms to spend a stipulated share of their sale revenues on R&D (the exact percentage depending on firm size and industry) or to remit an equivalent sum to finance government R&D (OECD 1990).
>
> Soon, however, both Korea and Taiwan dropped an across-the-board R&D requirement in favor of a *targeted approach*. In 1979 the Korean government designed performance standards such that long-term credit and tax exemptions were made contingent on firms establishing central R&D laboratories, which many large groups began to do like clockwork (Amsden 1989). Simultaneously, it introduced a series of National R&D Projects whereby government agencies collaborated with the most advanced national firms in a given industry to gain technological mastery for purposes of global market expansion.[32]

In conclusion, the chain-link model has applications that should be distinguished from those of the search model. In countries deciding on rapid catching up, say through a more aggressive export promotion program, the need to emphasize a search model that has its own momentum and runs within a sub-loop of the chain-link, is fundamental.

VII. Conclusions

Search theory in economics has had an important impact in widening and deepening markets. The rigorous understanding that has been established may be merged with today's more common usage of technological innovation and "search engines" to arrive at the following related hypotheses:

a. The activities related to search, research, development, invention and innovation constitute complementary elements of a continuum with no discernible boundaries, in practice.

b. At the same time, the smaller and poorer an economy is, the more intense should be the search effort over research or invention. Most of the literature on science, technology and innovation places the emphasis the other way around, because it frequently misses the cost-effectiveness of research vs. search. Both are needed, but the optimal proportions of each are not easily determined.

c. Appropriate search and network mechanisms need to be established to guarantee proper and speedy technological development. Indeed, pertinent and significant amounts of search will better guarantee that an appropriate technique to apply an existing technology is found. In the event that search does not yield technological alternatives sought by firms or communities, there will be a solid justification to proceed to research and/or invention.

d. The preponderance of search over research is justified, but it should not be understood from this conclusion that research is neither important nor unnecessary. On the contrary, at some point in time, it is most likely that to be competitive an economy, no matter how small, will need to do serious research in some niche area(s) where comparative advantage(s) may emerge.

e. A search model requires an adequate and robust engine to carry out the search, and institutional mechanisms to find out what technologies are relevant to a production goal and how to get hold of them (for example, by purchasing them). It also requires rapid skill formation in areas such as identification of the engineering problem (via for instance "reverse engineering", or obtaining the license to pursue a specific technology or technique).

[32] Amsden, pp. 240-245.

f. There is also a need to develop scientific capability to adapt an existing technology to local conditions, environment and culture—including in extreme cases by making or creating innovative instruments, or by urging experimenters to draw together instruments into combinations in pursuit of desirable effects.

In the end, a search model must guarantee the quality of and market effectively a nontraditional good or service. This requires metrology, adequate laboratories and skilled professionals. To coordinate these activities, national ministries or councils of science and technology have to become promoters of these elements. A network of technology brokers may play a supportive role, in conjunction with search engines customized for the communities of interest to bring about new synergies.

Finally, the presence of creative incentives to counter the uncertainty of technology advancement is critical. In addition to the support of current incentives programs such as matching grants, research collaboration programs, seed and risk capital, scholarships and training for workers, there is a need to create a scheme of income insurance to protect highly trained workers from the pitfalls of technology advancement.

Bibliography

Amsden, Alice H., *The Rise of the Rest*, Oxford University Press, 2001.

Eatwell, John, Murray Milgate and Peter Newman, *The New Palgrave: Allocation, Information and Markets*, W.W. Norton and Company, Inc.,1989.

European Commission *EC DG XIII and XVI,* 1996.

Evenson, R.E., and L.E. Westphal, "Technological Change and Technology Strategy." in *Handbook of Development Economics,* 3B, 1995.

Freeman, C., and C. Perez, "Structural Crises of Adjustment, Business Cycles and Investment Behaviour," in Dosi et al. (eds.), pp. 38-61.

Galison, Peter, *Image & Logic: A Material Culture of Microphysics*, University of Chicago Press, 1997.

Grossman and Helpman, *Innovation and Growth in the Global Economy*, MIT Press, 1991.

Hausmann, Ricardo and Dani Rodrik, "Economic Development as Self-Discovery," unpublished.

Helpman, Elhanan, *The Mystery of Economic Growth*, Belknap-Harvard, 2004.

Jaramillo, Hernán, Gustavo Lugones and Mónica Salazar, "Standardization of Indicators of Technical Innovation in Latin American and Caribbean Countries," *Bogotá Manual,* March 2001.

Kennes, John, *Competitive Auctions Theory and Applications*, University of Copenhagen, September 2004.

Kline, S. J., and N. Rosenberg, "An Overview of Innovation," in R. Landau and N. Rosenberg (eds), *The Positive Sum Strategy: Harnessing Technology for Economic Growth,* National Academic Press, 1986, p. 289.

Lederman, Daniel, and William F. Maloney, *R&D and Development*, World Bank, 2003.

Lundvall, B., (ed.), *National Systems of Innovation: Towards a Theory of Innovation and Interactive Learning,* Pinter Publishers, 1992.

Mandel, Michael, *Rational Exuberance: Silencing the Enemies of Growth,* Harper-Collins, 2004.

Nadel, Brian, "Turn your company into an idea factory," *Fortune*, December 2004.

OECD, "Proposed Guidelines for Collecting and Interpreting Technological Innovation Data," *Oslo Manual,* Eurostat, European Commission.

Romer, Paul, "The Origins of Endogenous Growth," *Journal of Economic Perspective*, 8(1),1994.

Sachs, Jeffrey, "Helping the World´s Poorest," www.cid.Harvard.edu/cidinthenews/articles/sf9108.hml.

Sáenz, Pedro, "Knowledge Enhancement in the Small Economies of Central America: Reflections on Building a Strategic Approach," *Economic and Sector Study Series*, Inter-American Development Bank, RE2-02-002, December 2002.

Schumpeter, J. A., *The Theory of Economic Development*, Harvard University Press, 1934.

———, *Business Cycles: A Theoretical, Historical and Statistical Analysis of the Capitalist Process*, McGraw-Hill, 1939.

———, *Capitalism, Socialism and Democracy,* Harper, 1975 (orig. pub. 1942).

Annex 1

The *Oslo Manual*

There are significant debates around the topic of technological innovation. It is one of the aims of this note to make available more than the official definitions to encourage better dialog among stakeholders. That is, to have a common understanding of terms and usage that facilitates communication.

Issued by the OECD, the *Oslo Manual* is the most important manual on innovation. It is mainly concerned with technological product and process innovations in firms, and uses the following definitions:

Technological product innovation: "A technological product innovation is the implementation/commercialization of a product with an improved performance characteristic such as to deliver objectively new or improved services to the consumer."

Technology process innovation: "A technological process innovation is the implementation/adoption of new or significantly improved production or delivery methods. It may involve changes in equipment, human resources, working methods or a combination of these"[33]

Additionally, the manual defines related terms such as technological diffusion:

Diffusion: "…diffusion is the way in which TPP innovations spread, through market or non-market channels, from their first worldwide implementation to different countries and regions and to different industries/market and firms. Without diffusion, a TPP innovation will have no economic impact."[34]

The *Bogotá Manual*

The *Bogotá Manual*, developed by the *Red Iberoamericana de Indicadores de Ciencia y Tecnología* and the Organization of American States, is a reinterpretation of the Oslo Manual to better serve the needs of Latin America. It expands the possible characteristics that an innovation can take. In addition to the Oslo definition of TPP innovation, the *Bogotá Manual* states the need to consider changes in organizational and marketing processes as important factors for changes in production. It includes innovation within the definition, and innovation promoting or facilitating activities.

The *Bogotá Manual* sees some weaknesses in the Oslo definitions, particularly in what it considers ambiguities concerning organizational changes, limited levels of novelty, and a limited focus on "the process of firms accumulating capabilities for creating and using knowledge". These weaknesses discredit diffusive, adaptive and incremental technical

[33] OECD, p. 9.
[34] Ibid.

change as innovation. The *Bogotá Manual* considers it important to identify firms active in the development of innovative capabilities in Latin America.[35]

The European Commission

The European Commission provides a definition that is simple and easily understood. It defines innovation as "the commercially successful exploitation of new technologies, ideas or methods through the introduction of new products or processes, or through the improvement of existing ones. Innovation is a result of an interactive learning process that involves often several actors from inside and outside the companies."

Typologies of Innovation

There are also various types of innovation that are helpful in providing elements to analyze and describe the dynamics of competition in a particular market or National Innovation System, or in providing policy recommendations. The first categorization of innovations is from Schumpeter, who classified innovation by different outcomes.

1. According to the Result of the Innovation

- Product innovation—the creation of a totally new product;
- Process innovation—the creation of new methods of production;
- New raw material—the conquest of a new source of supply of raw material or development of a new one;
- New market—the introduction of new products and new demand (supply driven markets);
- Industrial reorganization—non-firm reorganization (*Oslo Manual,* p. 7).

2. According to the Scope of Change

Freeman and Perez have further typified innovation in relation to the scope of change that results. Innovations can be:

- Incremental: occur more or less continuously in any industry or service activity. They include adjustments, adaptations and customizations of existing technologies;
- Radical: represent the introduction of truly new products and processes, and are discontinuous events that cannot be attributed to the cumulative addition of incremental modifications and improvements to existing products and processes;
- Systemic: a concept that describes greater changes within an economy due to the convergence of radical and incremental innovations that lead to the clusters of firms creating interdependent innovations and leading to the proliferation of radical (new) technologies; and
- Technological revolutions or techno-economic paradigms: changes in technological systems that have a major influence on the behavior of the entire economy.

3. According to the Degree of Novelty

A third way to classify innovation is according to the degree of novelty. Since innovation refers to the introduction of a product or service into a market, the degree of novelty describes at which level this introduction takes place. It may apply the term innovation to a first market introduction in the world, or more broadly to introduction into any smaller

[35] Jaramillo, Lugones and Salazar, p. 47.

market as a result of diffusion. Most literature, including manuals for survey purposes, use a broad definition of novelty, and sets the minimum degree of novelty at the "new to the firm" level. The innovation can be a:

- World innovation or new to the world (new at the world level);
- National innovation (new at the national level);
- Local innovation (new at the local level);
- Industry innovation (new at the industry or sector level); or
- Firm innovation (new to the firm).

Annex 2

Defining Research

It may prove useful to differentiate research from search. For practical purposes, such as defining it for tax purposes, research is not separated from development because a tax credit is an incentive to be productive and not just for the sake of knowledge alone. Thus, the majority of countries that have introduced R&D for tax purposes have based their definitions on the standard accountancy practice and the definition of R&D in the OECD's *Frascati Manual.*

It is tempting for treasury secretariats or ministries to take the simplest linear notion alluded to above: Bright Ideas → Research → Development → Product on the shelf. Yet as already discussed, there are a number of non-linear feedbacks and search activities to resolve unforeseen technological uncertainties that do not end in commercial production. In addition, new processes and intermediate services may also be outputs of R&D.

As such, to stimulate innovation through R&D, there must be recognition that there may emerge "bubbles" of innovative activity at any point and in any direction. This complicates a definition that clearly and unequivocally identifies an activity as R&D.

There is also the issue of creation of new knowledge versus improvement (or redesign and modification of existing products or processes). This confuses many people. Quite frequently innovators absorbing a new technology require substantial redesign of the existing product. They need to undertake R&D to properly redesign or improve or technologically refine the initial product (to make it compatible with the new technology). This type of R&D does not involve creation of new knowledge or of revolutionary new products—as normally understood—but requires tech improvement and it is still considered R&D.

To be specific, let us refer to a definition used by the United Kingdom for tax credit purposes.[36] A firm's eligibility for R&D tax credit rests basically on two factors:

- Definition: Whether the money was spent on R&D; and
- Scope: Whether tax credits are available for the particular type of expenditure (e.g., staff costs).

Following the *Frascati Manual,* research and experimental development is defined as "creative work undertaken on a systematic basis in order to increase the stock of knowledge... and the use of this stock of knowledge to devise new applications." Frascati then subdivides R&D into three categories: basic research, applied research and experimental development.

- **Basic Research:** "…experimental or theoretical work undertaken primarily to acquire new knowledge of the underlying foundations of phenomena and observable facts,without any particular application or use in view."

[36] Defining Innovation: a consultation on the definition of R&D for tax purposes, HM Treasury, July 2003.

- **Applied Research:** "…also original investigations undertaken in order to acquire new knowledge. It is however directed primarily towards a specific practical aim or objective."
- **Experimental Development:** "…systematic work drawing on existing knowledge gained from research and practical experience that is directed at producing new materials, products and devices; to installing new processes, systems and services; or to improving substantially those already produced or installed."

To guide firms into the most innovative activities known to be of greater private and social value and provide clarity as to what is an eligible activity for tax purposes, the U.K. uses the following Frascati criterion: "…the basic criterion for distinguishing R&D from related activities is the presence in R&D of an appreciable element of *novelty and the resolution of scientific and/or technological uncertainty*, i.e. when the solution to a problem is not readily apparent to someone familiar with the basic stock of common knowledge and techniques for the area concerned."

Clearly, there still remains some ambiguity as to what is meant by "appreciable" or "substantial", or the extent of technological uncertainty being resolved. The U.K. is assisted by the concept of the "relevant expert", who can reasonably be expected to understand and judge the issues in a particular case. It also uses the notion of "pre-production development and product development" as part of the R&D categories, differentiating them from "commercial development", which relates to scaling up and marketing (items that are not excluded in the *Bogotá Manual*).

This level of definition of R&D is sufficient to guide most policy-makers and even practitioners. Further reading of the *Frascati Manual, Bogotá Manual* and UNESCO materials will provide more detail for those who need it.

Annex 3

Technology Extension Programs

Government-sponsored programs to promote the diffusion of technology help firms to absorb new technologies by providing them with information that they normally struggle to find, such as new technologies and techniques, best practices, specialized suppliers and so on. The goal is to make firms comfortable with managing technological change, and encourage them to create new technologies by building up their internal capacity. The larger objective is to create networks of research centers and industrial consortia, which expand the technical capacity of a national economy and making it more competitive. This system has been used in many developed countries as part of their R&D policy, including Canada, Japan and the U.S.

Programs can be structured to provide technical and business solutions to industry, improved access to technological and financial resources, and seminars and training for common problems. Initially, a diagnostic analysis is undertaken with each individual firm to appraise its operations, needs and problems. The program can then assist the firm to upgrade technological capacities, and may also help in the search for technical and financial assistance of R&D and adaptation projects. Finally, these programs can also assist in the acquisition of foreign technology, when the firms cannot fund their own R&D or the technology is not available nationally.
United States: www.mep.nist.gov/
Canada: http://irap-pari.nrc-cnrc.gc.ca/
Chile: www.fontec.cl/
Colombia: www.colciencias.gov.co/scienti/

MIT–Mexico International Science and Technology Initiatives

The Massachusetts Institute of Technology (MIT)-Mexico program provides MIT students and faculty with opportunities to develop their skills through internships in companies, laboratories and universities in Mexico. The goal of the program is to provide international experience in topnotch institutions through the world, allowing MIT students and faculty, as well as the corporations, research centers, and government and non-governmental organizations in which they participate to benefit from collaboration, and increase the internationalization of industry, education and research. In addition to Mexico, MIT currently runs the program in China, France, Germany, India, Italy, Japan and Singapore. In Mexico, it has collaborated with the Tec de Monterrey, and is currently in talks with firms such as Cemex, Siemens Mexico, Metalsa and Protego, among others, to expand its program.

GlobalGiving (www.globalgiving.com)

GlobalGiving functions as an online marketplace for specific social and economic development projects, and seeks to connect individual donors to specific projects they can fund directly. The emphasis is on small projects where individual contributions can make a difference. The Web site seeks to allow donors to experience much of the transparency they would with a financial investment, knowing exactly where their money is going and how it is being used. Projects seeking funds are grouped geographically and into themes such as economic development, education, environment, gender and equality, health, human rights, and technology. Donations can be made by credit card, check or stock transfer at any amount up to the project need amount. All donations to projects are tax-deductible through the GlobalGiving Foundation.

Development Gateway (www.developmentgateway.org)

The Development Gateway is an independent, not-for-profit organization. It was conceived by World Bank President James Wolfensohn and initially developed in the bank. It is an interactive site for information on development and poverty reduction, and allows for communities to share experiences on development efforts. The portal supports the objectives of increasing knowledge sharing, improving public sector transparency, enhancing development effectiveness and building local capacity to empower communities. It offers services such as an online directory for information on development projects (AiDA), an electronic procurement market (dgMarket), information on major development topics (Topic Pages) and links to a growing network of country-level initiatives (Country Gateways).

Digital Nations (http://dn.media.mit.edu/)

Digital Nations, by MIT Media Lab, aims to address major social challenges—such as improving education, enhancing health care and supporting community development—through the innovative design and use of new technologies. The consortium's ultimate goal is to empower people in all walks of life to invent new opportunities for themselves and their societies. It focuses especially on populations with the greatest needs—children and seniors, underserved communities and developing nations.

Initiatives include:

- The introduction of new technologies in education;
- The creation of electronic marketplaces to encourage rural communities to participate in regional and global markets through e-commerce;
- The creation of multilingual/multicultural technologies that allow for a greater use of computing;
- Low-cost technological solutions to improve access to communications; and
- Innovative tools to help monitor and plan health care.

Somos Telecentros (www.tele-centros.org)

This is a network for the creation and strengthening of telecentros in Latin America and the Caribbean. Its objective is to create a network of communities, organizations and individuals involved in the creation of telecentros and other experiences using information and communications technologies as tools for sustainable human development. It supports the planning and development of public and private policies to improve the access and use of these technologies.

Annex 4

Technique and Technological Innovation

We are here interested in one form of innovation: technological innovation. For completeness, let us define technology and innovation first, and then we shall dwell on technological innovation.

Technology is defined here in the context of development economics. As such, it "...is most fundamentally, *knowledge about how to do things*."[37] Technique needs to be clearly distinguished from technology because of the special significance these terms have for developing nations. "Techniques are defined as singular ways of doing particular things, and are the result of choices made when applying technology in specific circumstances with respect to economic, physical, and social conditions. In effect, a technique is a solution to a problem of constrained maximization in which technology and circumstances form the constraints."[38] The resulting technique, however, can easily evolve into a distinct technology soon thereafter.

This way of defining technology is critical in assessing the technological needs and efforts of developing countries. For instance, railroad companies had to invest in R&D to come up with new materials for the rail tracks (different types of wood and nails) to withstand the humidity of Panama early in the 20th century. This amounted to a new technique. Furthermore, this definition brings together under one heading such isolated technology-related efforts of development policy-makers as "choice of techniques". These may cover decisions to enhance employment, rapid diffusion of production technology to alleviate structural adjustment shocks on enterprises, epidemic prevention and healthcare technologies, telecommunications for distant rural communities, and many others.

From this perspective, we can no longer presume that an adequate technique for applying a specific technology can simply be bought off the shelves of advanced industrial nations. This, in fact, was never true. In fact, the assimilation, adaptation—and sometimes highly creative and inventive adaptations—of imported technologies was always required. Technological adaptation of a technique involved developing, in effect, a new technique and that was costly both in time and money—with success more closely associated with uncertainty than with measurable risk.

Innovation, on the other hand, having a longer tradition both in developing and developed economies' enterprises, is more straightforwardly defined. The *Oxford Dictionary* defines innovation as the action of introducing a new product into the market; a product newly brought on to the market. The Spanish Royal Academy, by contrast, emphasizes more that the product that is introduced to the market must have been newly created or modified before ("Creación o modificación de un producto y su introducción en un mercado."). But both definitions are basically equivalent.

Thus, putting the two concepts together we obtain a simple definition of technological innovation as a new technology or technique about how to do something that results in a product or service being introduced in a market.

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[37] Evenson and Westphal, p. 2212.
[38] Ibid.

PREFACE

This document argues for greater emphasis on technological search activities in smaller, poorer economies such as those of Central America. This argument is based on simple economic expediencies derived from cost, benefit and timing. Indeed, the need to fall in line with the productivity and supply trends of today's globalized economy is more urgent than ever. Technological advance and search are critical for finding out what technologies exist already and applying them in critical situations at lower costs and in a more timely manner. In addition, there are some basic enabling conditions that go beyond simply improving the business climate. Among these there are better human and machine intermediation between buyers and sellers of technologies and technology/science services.

Pedro Sáenz, Economist of the Regional Operations Department II, Finance and Infrastructure II (RE2/FI2) authored the document with the collaboration of Jorge Uquillas –who worked as a *knowledge intern* of the Bank during the summer and fall of 2004, and served not just as a research assistant but also as an excellent sounding board and critical reader. Andrés Rodríguez (RES), Pablo Angelelli (SDS/MSM) y Roberto Bruno (Massachussets Institute of Technology and Director del Laboratorio de Metrología, Universidad Tecnológica de Panamá) provided very interesting comments and suggestions.

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Regional Operational Department II
Mexico, Central American Isthmus, Haití and Dominican Republic

Washington, D.C., March 2005

Search and Innovate: A Way Towards Technological Change in Small Countries

I. Searching for Ideas to Boost Growth

Technologies available worldwide constitute potential for innovation and growth. Particularly for countries that have fallen behind in their economic and social development, capturing the benefits of technological innovation is a real necessity. The sooner and cheaper they can do it, the better.

One avenue for innovation relies on research and invention, which involve new additions to existing knowledge, and may require a long gestation period for testing for usefulness and cost-effectiveness.[1] Another option is search, which may require less time and fewer upfront costs. It is used to identify what is available and applicable to a given production context, a process that is more global, inclusive, faster, cheaper and accessible than ever before. Search works from the premise that technologies already integrated into one production context may be more readily transferred into another to speed up technological progress. Many technological activities, such as the identification of best practices, the assessment of available technologies for a specific production goal, the evaluation of the utility of international productivity benchmarks, or the pursuit of greater "self discovery"[2], fall under the general practice of search.

Search, as an economic activity, needs to be associated with but remain distinct from research, invention and innovation activities. This paper argues that most enterprises and many of the technological service providers in the smaller, poorer countries of Central America need to undertake more effective search activities. The absence of these initiatives is otherwise significantly slowing down prosperity in the region, even as it gropes to join the global economy. An important prerequisite, however, is to find ways to lower the costs of obtaining pertinent information and knowledge in a timely fashion.

This paper also rides on the Schumpeterian notion that technological change is critical to competitiveness, and that "innovation as creative destruction" is a driver for technological change. Successful innovation leads to competing effectively and, thereby, necessarily destroying less competitive firms or even whole economic sectors. Search being a form to innovate faster is also a way to destroy faster.

Consequently, developing the right mix of policies emerges as urgent for softening the blow to those who may be destroyed. One type of policy is oriented toward what is, by

[1] It is important to keep a distinction between invention and innovation. Invention requires long period of thinking, tinkering and/or research. In this day and age, inventing generally requires sophisticated equipment and highly trained professionals and testing laboratories. In olden days many inventions came come individuals working alone, and many of their ideas came in a flash of inspiration (Archimedes, DaVinci and Edison, for instance). Today, for a flash of inspiration to be original and useful to others you require collaborators, larger investments and easy access to and incorporation of existing knowledge. Inventions can be patented but do not have to be introduced in the market –in fact, many do not. Innovation, on the other hand, is more often than not, an improvement that surpasses the performance of existing products, a variation on a theme, and therefore, it is more likely to be introduced and be successful in the market.

[2] Hausmann and Rodrik.

now, fairly well known as striving for an "appropriate business climate". Less understood are policies related to communities of interest and associated "search engines". Another, possibly more controversial policy option creates a safety net program for those that fall behind or are "destroyed".

The Conceptual Framework

The concept of search that is at the center of this paper is embedded within the notion of innovation and the National Innovation System. Some definitions may be required, starting with "technological innovation".[3] The Oslo Manual,[4] which is mainly concerned with technological product and process (TPP) innovations in firms, offers the following definitions:

- **Technological product innovation:** "A technological product innovation is the implementation/commercialization of a product with an improved performance characteristic such as to deliver objectively new or improved services to the consumer."
- **Technology process innovation:** "A technological process innovation is the implementation/adoption of new or significantly improved production or delivery methods. It may involve changes in equipment, human resources, working methods or a combination of these."[5]
- **Diffusion:** "…diffusion is the way in which TPP innovations spread, through market or non-market channels, from their first worldwide implementation to different countries and regions and to different industries/markets and firms. Without diffusion, a TPP innovation will have no economic impact."[6]

[3] It is also useful to distinguish an innovation in technology from an innovation in technique. The former develops a rather new technology to solve a unique category of problem. The latter is an innovative adaptation of an existing technology to a new environment with new conditions. Both are technological innovations, however. For further discussion, see Annex 4.

[4] The Oslo Manual is the most important manual regarding innovation, put out by the Organization of Economic Cooperation and Development. It is mainly concerned with TPP innovations in firms.

[5] Organisation for Economic Co-operation and Development (OECD), p. 9.

[6] Ibid.

<u>Box 1: Example of Technology Innovation in Costa Rica</u>

COSTA RICA Materials Technology applied to : Road Paving: Asphalt layers usually have limited life spans, requiring recurring investments in roads and pavements. Additionally, the repeated damage and repair cycles themselves result in costs to the users, including delays, car damage, and so on. The transfer of improved asphalt technology from the United States helped reduce the cost and improved the efficiency of road management in Costa Rica. The National Laboratory of Materials and Structural Models of the Universidad de Costa Rica (LANAMME) knew of experiences in the U.S. in which improved road paving included the application of new materials such as polymers, fiber and new additives that allowed better adherence, thereby increasing savings through lower operations and maintenance costs. LANAMME was able to absorb and "tropicalize" these technologies, adapting them to the local conditions. This helped create a new base for modernizing the paving industry in Costa Rica. The Consejo Nacional de Vialidad and the Ministry of Public Works and Transport have already selected this strategically important adopted technology for three further projects. LANAMME continues working to optimize its performance, experimenting with different mixtures of asphalt concrete, including the use of ground plastic waste originating from banana plantations, which achieves even greater cost reduction.

These definitions require qualification when applied to poorer and smaller nations (see Annex 1). More importantly, they need to be set in the context of a given country, specifically, its environment and capacities for thinking up ideas that have a good chance to result in an innovation.

Fallacies That Affect Technology Policy Design

Often, a linear sequence for arriving at desired innovations is assumed. There are two proven fallacies associated with this assumption. The first is that science can be separated from technology because one leads to the other; in actual fact, they are inextricably intertwined. The second is that innovation itself follows a straight, step-by-step linear path from research and development (R&D) to innovation. Use of the linear model continues because it serves as a justification for investing in basic research, and because of the misguided but widespread "conventional wisdom" that a straightforward sequence starting with basic research leads to technological development and, consequently, economic growth.

Furthermore, many a policymaker still believes that only new science leads to new technology; thus, the two are treated separately. But in fact, technology transfers (instead of science) generally lead to new techniques or technologies in developing countries. Indeed, a technology transfer in effect "invents" the new technique, allowing its adaptation to the new context and resources.[7] It is also easy to recall many technologies that have led to new science. Tanning, dyeing and brewing technologies, going back centuries to the times of Alexander the Great and earlier, are cases in point. The new science that gave rise to chemical products and chemical reactions was developed after these technologies had been in use for at least a couple of millennia. Furthermore, influential students of science and technology like Peter Galison[8] argue that new forms of equipment capable of detecting or measuring certain phenomena have opened the door to new scientific information and paradigms –i.e., technology often leads to science rather than the converse.

[7] You obviously also need a good engineer well trained in science to devise the new technique, but that is a separate matter, not critical to the argument.
[8] Galison.

The linear model of innovation can be characterized as linking research to economic performance:

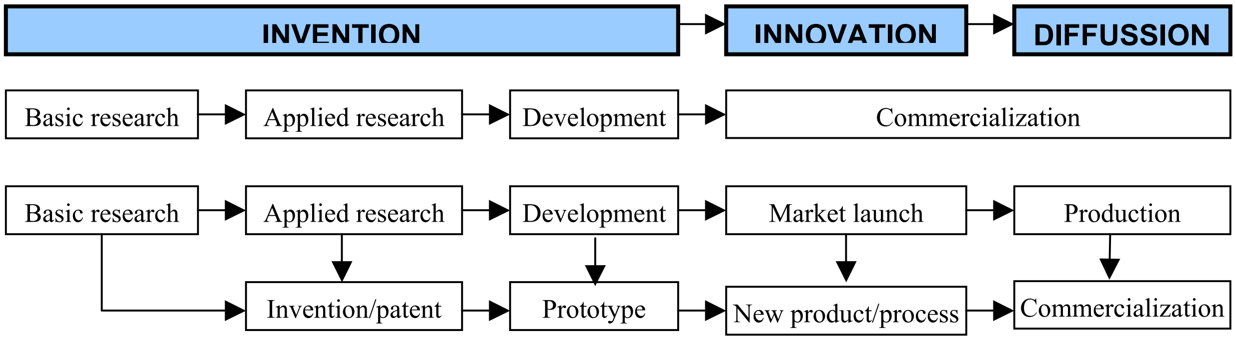

Figure 1.1: A Typical Linear Model of Innovation

This model has been superseded by newer and more analytical frameworks, such as the chain-link model by Kline and Rosenberg, which shows that innovations result from a continuing interaction of research and knowledge within the different stages of the process of innovation. It describes innovation as a rather complex process unique to each endeavor, without clear boundaries between each activity, and integrating different processes at each step. In this model, research and knowledge play a complementary role in providing additional inputs and as a problem-solving tool, while feedback is an important function. Additionally, the model demonstrates that innovation may or may not follow linearly from the origin of an idea or problem to the desired outcome.

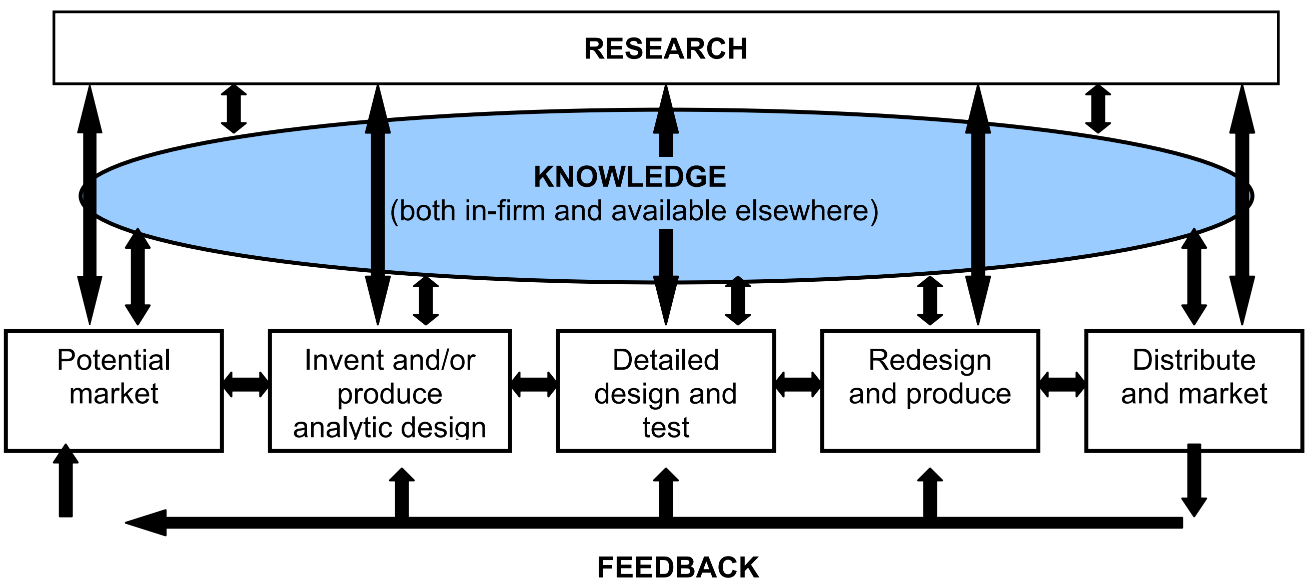

Figure 1.2: Kline and Rosenberg's Chain-Link Model

Clearly, searching for existing knowledge to serve as feedback at any stage of the chain-link model is a cost-effective way of attempting innovation.

National Innovation Systems

The notion of including knowledge and learning as important aspects of business and economic cycles inspired the concept of systems of innovations, specifically the idea of

National Innovation Systems. Lundvall says that the National Innovation System includes: "All parts and aspects of the economic structure and the institutional set-up affecting learning as well as searching and exploring—the production system, the marketing system, and the system of finance present themselves as sub-systems in which learning takes place."[9]

The National Innovation System is a concept that emphasizes the cooperation between a diverse set of public and private institutions that leads to technological development and innovation. Governments, firms, universities and other institutions collaborate on creating and developing new products and services aimed at fostering productivity, competitiveness, and, ultimately, national economic development. This comprehensive approach is highly dependent on successful interaction within networks of institutions. It is influenced by the tone of that networking, and by factors such as the country's macroeconomic and business environment.

Within the framework of the National Innovation System, there are three important factors that foster innovation. The first and most important is the presence of innovative firms that have the necessary scientific and technological capabilities, access to funding and a willingness to take risk. Firms that have the appropriate management and strategic mindset to innovate must, furthermore, build up their human and technological resources and have a vision of future opportunities. Access to funding is critical because R&D projects are long-term undertakings, often requiring constant funding and with unpredictable prospects of success. A willingness to take risk is required to move past this unpredictability.

Firms can only effectively innovate where the second most important factor is present—available supporting institutions. The most important institutional set-up is the educational system, which shapes students and, if efficient, prepares them for the needs of firms. Universities and other higher education institutions, especially technical training schools, should collaborate with firms in an effort to create synergies between their educational curricula and the needs of businesses. Science and technology institutions in particular can offer consultation and collaboration, and provide services such as laboratories, certification and metrology, among others. Innovative firms can also benefit from business associations. These often help locate opportunities such as export markets, lobby, and bring firms together within networks of similar industries, and across regions and value chains.

The third important factor affecting the ability of firms to innovate is a nation's science and technology policies. In a policy environment conducive to innovation, innovative firms will flourish. It is especially helpful when firms receive the support of government through a variety of incentives, such as subsidies to investors, cataloguing disseminating market and technology trends, access to R&D funding, other subsidies and fiscal incentives. Additionally, firms benefit if there are non-restrictive policies that surround the acquisition and transfer of technology and technological services.

[9] Lundvall (ed.), p. 12.

Box 2: Porter's National Innovation Capacity

A useful way to deal with innovation issues is presented in the concept of "national innovative capacity" by Michael Porter. He understands this as "the ability of a country—as both a political and economic entity—to produce and commercialize a flow of innovative technology over the long term. Innovative capacity depends on an interrelated set of investments, policies, and resource commitments that underpin the production of new-to-the-world technologies."

Porter's framework for organizing the determinants of national innovative capacity consists of grouping elements within two main categories: (i) a common pool of institutions, resource commitments, and policies that support innovation, and (ii) the particular innovation orientation of groups of interconnected industrial clusters.

In other words, a country's capacity for technological innovation depends, on the one hand, on a set of elements contained in a common innovation infrastructure, and, on the other, a set of individual industrial clusters. There are also linkages between these two sets. Together, these contribute to an economy's ability to mobilize resources towards innovation opportunities in specific industrial sectors. The common innovation infrastructure represents the cross-cutting factors that support innovation throughout many, if not all industries.

Even where these three factors are in place, however, they can jointly foster technological success only if they fit within a wider framework of enabling conditions, such as good macroeconomic policies, an open business environment, the rule of law, adequate infrastructure, and healthy national and international markets.

A comparison of the concept of the National Innovation System with that of the community of interest, which is an important element of this paper and is elaborated below, shows that the former is a macroeconomic institutional superstructure dealing with broad policies, all agents and stakeholders, and national institutions such as the financial system, education system, business organizations and associations, and the links among them. A community of interest, on the other hand, is a microeconomic concept dealing with a specific sub-sector.

The small economies of Central America face a number of micro, macro and institutional constraints that prevent the normal mechanisms of complete or close perfect markets[10] from coordinating transactions at an affordable cost. These constraints lead to variations or differences in emphasis in the strategies policymakers can devise to promote technological innovations. While the activities involved in searching, researching, developing, inventing and innovating may constitute complementary elements, per the chain-link model, smaller and poorer economies will likely benefit most from a focus on intense search efforts. For the most part, a successful search for a technology is an end point for some years, needing no further research.

II. The Problem of Making Technology the Handmaiden of Economic Growth

To use knowledge to accelerate economic growth, the first task is to construct a solid and dynamic National Innovation System. It seems to most easily transmit knowledge in the form of technology that can be encoded. However, the adaptation to local conditions that follow when a technology is imported may require significant effort.

[10] Sáenz.

Local conditions may be compatible with the technology of interest, or not. If the environment is not compatible, the National Innovation System should be adjusted to rapidly and cheaply facilitate the technological adaptation—that is, it should have accessible and good technological service providers. Otherwise, the transaction costs associated with the adaptation may be too high to allow the technology to serve as an effective medium for economic growth. Among the critical initial conditions are the institutional variables, discussed above, which would apply to the effectiveness of the search effort as well.[11]

When the essential enabling conditions are in place, the diffusion of technology can play a central role in accelerating economic growth. Yet for that to take place, knowledge accumulation must not exhibit diminishing returns. To prevent that, policies must facilitate technology transfer. Innovators must benefit from the advances in applied science achieved by their counterparts elsewhere, and be able to access this through licenses, collaboration or turnkey projects. In this case, increasing returns are likely to follow in the long term.[12]

As some economists have noted, technology was simply left out of the loop when the Washington Consensus was formulated. They also specifically singled out the dismal technology knowledge capabilities of Latin America as a major cause for the poor economic performance of the region, despite its considerable economic openness and significant institutional reform.

Jeffrey Sachs of Columbia University's Earth Institute notes that: "Lack of vigorous growth is all the more puzzling because Latin America has plentiful natural resources, reasonably good health conditions and adult literacy rates reaching 90 percent or higher.…" He focuses on two particular problems: One, the social divisions and income inequalities, which de-emphasize large investments in education and health; two, more important in the present context, the basic failure of economic strategy. As Sachs puts it: "Whereas Asian governments, for example, relentlessly act to raise their economies' scientific and technological capacities, national policies to promote science and technology rarely gain such prominence in Latin America. The result is a failure to benefit adequately from the global technological revolutions. Asian developing countries now produce computers, semiconductors, pharmaceuticals and software. By contrast, even Latin America's star performer, Chile, remains largely a resource-based economy, concentrated on copper and agricultural exports. These sectors are technologically sophisticated but form a narrow base for long-term development.... The Latin American countries should increase spending on research and development to around 2% of gross national product (from around 0.5% currently), partly with public support for laboratories and universities and partly with private-sector incentives. They should roll out the red carpet for high-tech multinational firms, just as Asia has done."[13]

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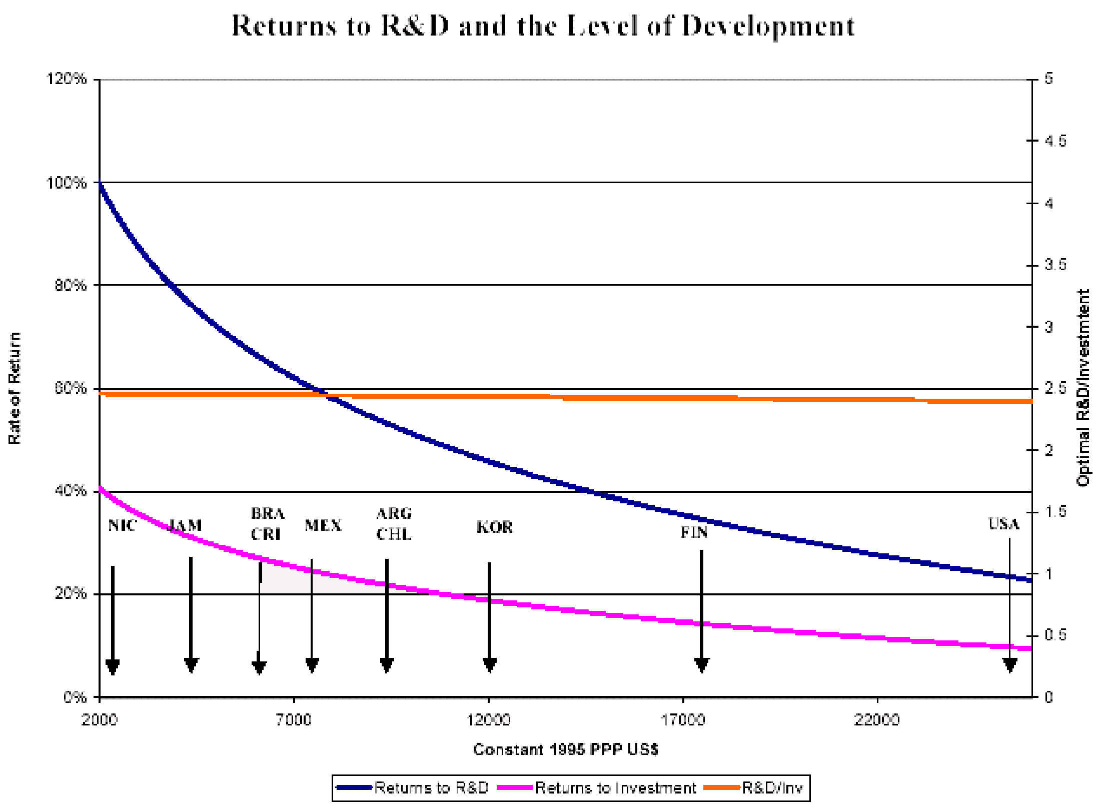
[11] Ibid.
[12] Grossman and Helpman, p. 281.
[13] Sachs.

Box 3: Returns to R&D

Daniel Lederman and William F. Maloney confirmed that Latin America underinvests in R&D, especially given that the returns on R&D seem to be higher in developing countries. They point out that differing levels of investment in R&D could be one important reason for the difference in growth performance. The countries that developed rapidly invested heavily in R&D.



Source: Lederman and Maloney

Dani Rodrik and Ricardo Hausmann, in a similar vein, point out that the poor growth response to the Washington Consensus recipes can be blamed largely on a simple fact of growth fundamentals—that it is a false assumption that poor countries can catch up with advanced industrial nations because they have access to state-of-the-art technology, and that property rights enforcement can be readily applied. Moreover, even when the production functions associated with global best practices become common knowledge, much of the technology involved is tacit (that is, it cannot be easily codified into blueprints for easy application). Its transfer to new economic and institutional environments requires adaptations with uncertain degrees of success.

Further, the entrepreneur identifying the new production technique can capture only a small part of the social value that this knowledge generates, because if the regulatory environment is weak, other entrepreneurs can quickly emulate such discoveries. There is no incentive then for entrepreneurs to focus on learning or discovering what they (and the country) are good at producing. In the absence of such incentives, investments in new, non-traditional products, or in improving the quality and market appeal of existing ones, would hardly be significant enough to influence growth. Economic transformation is delayed.[14]

It has also been demonstrated that the extent to which information disseminates across international borders (especially through foreign direct investment) figures prominently in the determination of long-run patterns of trade and in the relationship between trade and growth.[15] By facilitating search about and access to larger markets, trade raises the profitability of inventive or knowledge-based economic activities, and makes investment in R&D more attractive. These activities are bound to increase productivity and, thus, growth. At the same time, there is an important caveat here, especially for the poorer and small economies—the impact of what economist Elhanan Helpman calls the "competition effect". Exposing domestic firms to foreign competition may hurt profits, resulting in fewer resources and/or a lower motivation to invest in R&D.[16] Here, as in so many cases, some strategic and preemptive planning is in order.

The Importance of Communities of Interest Pooling Resources

After looking at the macro and international context, and the effects of transmission of knowledge, it is important to consider the specific community within which search and/or research activities actually take place. This paper starts from the premise that technical advance (invention and technological innovation) proceeds more efficiently and effectively through the work of a community of actors who share complementary interests, where agents with similar technological pursuits are linked within a favorable environment. This facilitates collaboration, synergies and confidence in results.

Whenever communities share complementary interests, they are most likely to have interactions among a range of actors that matter: between component and system producers; upstream and downstream firms; universities and industries; consultants, firms and universities; transnational corporations and local providers of inputs; and government agencies, universities and industries. Such sets of actors are sometimes referred to as clusters, networks or partners, but we would rather refer to them as communities of interest because the potential interactions are not always clear (and may have to be "induced"). Or they are not continuous but sporadic. They may involve multiple groups of partners, or consist of researchers rather than production-related concerns.

To better understand the concept of communities of interest and the need to pursue search, we can look at the case of Motorola.[17] In the 1990s, Motorola faced unusual increases in the pace of innovation from competitors that were gradually destroying its market share. Its management realized that it needed to develop more innovations and introduce them into markets much faster than before. Motorola embarked on a major effort to design and implement a high-level, structured framework with the capability to network the entire enterprise. Not a simple task when you have to track more than 10,000 programs designed to deliver market-leader innovations. Between 1999 and 2001,

[14] Hausmann and Rodrik.
[15] Grossman and Helpman.
[16] As Helpman notes, competition may also induce tech-based firms to accelerate innovation efforts in order to fend off competition from technological followers. In this case, trade boosts R&D. Helpman, pp. 64-65.
[17] Alignent Software and the Leading Trust: www.alinement.com.

Motorola searched various methods for creating an adequate database that could support the long-range planning activities of as many as 100,000 employees in offices all over the world. By 2001, Motorola had developed software that allowed company-wide planning activities in a centralized database with a standard format. This led to "technology roadmaps" that made certain that the firm as a whole would put in motion, very early on, what was necessary to have in place the right technology, processes, components and experience in order to meet the future needs for products and services.

It may be argued that to follow in the footsteps of Motorola requires levels of investments that are beyond the capacity of the kind of enterprises under discussion here. This is true, but the underlying premises of developing an internal and/or external network are the same. A set of suppliers (local or international), clients that possess basic know-how, and appropriate think tanks, for instance, could be organized into a network to achieve the same results.

IV. Why Should Central America Care About Innovation?

Ask most entrepreneurs, engineers or scientists in Central America whether technological innovation should be promoted, and you will get a positive answer. If you probe a bit further, you are likely to hear qualifications or, indeed, reluctance. One deterring factor may be that technological innovation is complex and requires "too much" research time and costly human resources. International competition may seem too fierce for technological innovation investments to be viable for small firms in poor economies. They are likely to argue that even in the rare cases where investment in research successfully pays off in the development of an innovative product, the idea will be quickly stolen and copied. Thus, the conclusion normally is: leave innovation to the advanced countries where patents and licenses can be enforced and protected.

However, globalization is slowly but steadily bringing change. Central Americans have begun to understand that firms that are not competitive get destroyed, that they need a strategy to forestall such an eventuality, and that the more creative that strategy is, the better its chances for survival. The prior requirement is an appropriate business climate with the right incentives. But this, as difficult as it is to introduce, is not sufficient. What is needed as well is a major feat of engineering or re-engineering, not just on the production floor, but also in the organizational structures of firms themselves. Indeed, product characteristics, prices, marketing plans and production technologies need to be standardized and oriented to specific corporate goals. Corporate goals, in turn, need to be effective in dealing either with the domestic competition, or in visualizing potential opportunities arising in the global markets, if not both.

An organizational culture that understands and values innovations cannot be created in a few months. Therein lies the role of policies that incorporate societal values and the propensities of economic agents. For instance, a strategy based on fostering key communities of interest with the potential to develop comparative advantages may be more useful in coping with global competition than a strategy of indiscriminate mass transfers of technologies or foreign direct investment. Of particular interest would be fostering tight-knit communities with suppliers and service providers with a vested interest in selling goods or services to a set of firms. These enterprises would exchange advice, hopefully leading to new knowledge and to thinking "outside the box". Increasing returns to research, development or even just feasibility studies would be proportionate to the extent that such networks are ongoing rather than one-shot events.

In such a setting, a systematic search activity is a must if an enterprise is to remain abreast of global market trends and changes. In particular, search-related transactions must be targeted to at least four strategic areas: (a) detailed (possibly technical) information on the new products in the global market; (b) information on the major research trends in key industries of interest to a particular firm, and to the economy as a whole; (c) information on organizational arrangements that have been utilized effectively by smaller firms to contribute to an international cluster or network; and (d) understanding how a firm in a small country looks for and identifies a potential provider or buyer at a reasonable cost.

Put differently, since world trade volumes depend on endowments, technologies, preferences and market structures, small countries must be more careful than larger ones about how and where to orient local and foreign direct investments. The argument is that since endowments and preferences are largely exogenously determined, the initiative of small countries lies in making policies to strengthen markets (such as the market for technology services required in key economic sectors) and to promote search for appropriate techniques and technologies. These actions will reduce transactions costs and energize the National Innovation System, leading to more productivity and competitiveness. Indeed, these actions may well facilitate the creation of economic niches that in due time could develop a comparative advantage for certain goods and services.

Existing science and technology and industrial policies are not currently helping the poorer and small countries to get where they need to go quickly. In addition, as long as entrepreneurs think it cannot be done, that it is too difficult, that there are easier and cheaper alternatives to be competitive, innovation will obviously not take place.

One alternative, elaborated below, is that firms need to consider that they do not have to engage in investment or time-intensive R&D to be innovative, and that innovation is not the entitlement of large enterprises alone. Firms do, however, have to be plugged into a community of interest and learn to work in networks, local and international.

This leads us to a question: What do we mean when we say that such and such entrepreneur or production engineer introduced a technological innovation?

Innovation as "Creative Destruction"

Joseph Schumpeter, the economist who possibly did the most to bring the concept of innovation to prominence in his profession, deemed innovation "creative destruction", stating (bold added for emphasis):

> "...Capitalism, then, is by nature a form or method of economic change and not only never is but never can be stationary. And this evolutionary character of the capitalist process is not merely due to the fact that economic life goes on in a social and natural environment which changes... The fundamental impulse that sets and keeps the capitalist engine in motion comes from the new consumers' goods, the new methods of production or transportation, the new markets, the new forms of industrial organization that capitalist enterprise creates.

> "...The history of the productive apparatus of a typical farm, from the beginnings of the rationalization of crop rotation, plowing and fattening to the mechanized thing of today–linking up with elevators and railroads–is a history of revolutions. So is the history of the productive apparatus of the iron and steel industry from the charcoal furnace to our own type of furnace, or the history of the apparatus of power production from the overshot water wheel to the modern power plant, or the history of transportation from the mail coach to the airplane. The opening up of new markets, foreign or domestic, and the organizational development from the craft shop and factory to such concerns as U.S. Steel illustrate the same process of industrial mutation – if I may use that biological term–that incessantly revolutionizes the economic structure *from within*, incessantly destroying the old one, incessantly creating a new one. This process of **Creative Destruction** is the essential fact about capitalism. It is what capitalism consists in and what every capitalist concern has got to live in. . . .[18]"

Today, 60 years after Schumpeter, the upshot is clear. The market can no longer be understood only as a static mechanism to allocate resources. More often than not, it is the locus to discover new needs of consumers that can be satisfied with new methods of production, processes, products and services. As such, far from being static, the market is a conduit for revealing the dynamically changing needs and preferences of consumers to "innovative" entrepreneurs. Led by the profit motive, entrepreneurs compete among themselves to discover products that best fit the evolving needs. And it is the strategic alignment of products, markets and technologies that will provide a competitive advantage.

Furthermore, innovative products, once introduced, directly impact consumer preferences, which are modified by technical changes in new products. Competition takes on an important characteristic unrelated to price, where the constant change of products and production methods is fundamental. This brings us closer to the notion that to the extent that the innovators get it right, supply may be driving many markets, rather than demand.

Ideas, Creative Destruction and Openness to Trade

The implication is that as Central American economies open up their markets to international competition, and as international market integration takes hold, technological proficiency becomes critical. If properly set up, search activities can accelerate prosperity.

Opening up an economy may actually entail a wave of "destruction" if local creativity and search efforts do not find adequate channels to turn potential economic threats (the potential destruction of traditional products) into triggers for innovative activities. This wave of destruction would result from the demise of protected and uncompetitive industries, which now have to compete with better imported products at home, as well as with the demanding and changing preferences of consumers in export markets abroad. Furthermore, if precautions are not taken, a large foreign firm may end up buying the few providers of a good or service and installing, in effect, a monopoly—and reducing local competition. With business not as usual anymore, many local entrepreneurs may perish if they find themselves unable to shape up and adjust.

[18] Schumpeter, 1975 (orig. pub. 1942), pp. 82-85.

When joining the global market, entrepreneurs in poorer nations face the reality that players in industrial nations have known for decades: that one has to revise the commonly accepted belief that simply attending to a steady and predictable consumer demand (a demand driven solely by consumers) and being efficient in production is sufficient to compete. Today, supply is one of the dominant forces driving markets' outcomes. And elements not related to price—such as quality, new characteristics and the availability of innovative new products—shape demand. Therein lies the need to be able to access, absorb or adapt existing and changing technologies in order to be part of a network or international cluster. Otherwise, you must be able to design, develop or invent new products where you can lead.

In this new economy, successful countries are those that pursue creative destruction as a matter of course, and where innovation is bound to be one of the main drivers of wealth. This is because ideas rule, as the influential Paul Romer has pointed out. Ideas actually spark creative destruction, which, at least in advanced industrialized countries, is facilitated by the numerous market mechanisms for new ideas to find their way to the production floor (or, speaking theoretically, for ideas to enter the production function).[19] This production of ideas is a necessary condition for effective global competition, and is probably a function of competitive pressures and the trade regime.

The central point in Romer's paradigm is the externalities that result from the accumulation of knowledge. Ideas and knowledge enter the production function as another input, just like labor. Yet their effect on productivity depends on the firm's stock of knowledge as well as the economy's aggregate stock of knowledge—both of which, in turn, depend on past investments in knowledge by the firm and the economy. As such, firms have a positive stimulus to invest in knowledge, all the more so if the economy's stock of knowledge is large. As they forge ahead investing in knowledge (without consciously being aware of this, as in Adam Smith's invisible hand), they in turn contribute to the aggregate public stock of knowledge. A virtuous circle ensues and leads to sustained growth.[20]

If an economy is too poor or small to be constantly producing ideas, it must at least join some international community of interest that produces successful ideas frequently. Production and acquisition of ideas can be associated with the international mobility of people and investment. Given that the production of ideas is intensive in human capital, the rate of return on that capital may be associated with the openness of the economy, opening the door to the role of trade in the accumulation of knowledge.

[19] Paul Romer emphasizes that economic growth is an endogenous outcome of an economic system, not the result of forces that impinge from outside. As such, the role of R&D and knowledge spillovers that result from investments in R&D endogenously contribute to determining growth. The line that we are pursuing through search places greater emphasis on finding what technology is appropriate and devising an effective technique that deals with local conditions and context. The weight is less on R&D and more on search.

[20] Romer, pp. 3-32.

<u>Box. 4: What Ideas Are Worth Pursuing?</u>

Even if we admit that it is not a society's products, clothes, sugar, computers or widgets that matter, but rather its ideas (as Romer does), we face further obstacles related to the pervasive culture of fear of new ideas, which derives from poor familiarity with the processes associated with turning ideas into products:

"The problem is that only a handful of companies (in the world) understand where today's ideas for tomorrow's blockbuster products come from, much less how to properly develop a vague vision into a perpetual money machine. Like rare orchids, ideas need to be firmly planted, fed, and at times pampered to properly take root. Do otherwise and they will die on the vine... Forget about the image of the lone misunderstood inventor toiling away in obscurity because innovation doesn't just happen. It takes time, effort and hard work. From initial idea to technological advance, every step of the process is fraught with opportunities to ignore, sidetrack, or dilute its inspiration. Look beneath the surface of the companies we admire most, such as Apple, GE, and Sony, and you'll find a dedication to coming up with new concepts and commercializing them into products. Some strive for continual improvement in their processes, while others seek extensions to existing products or invent whole new product categories. In a very real sense, they are no longer mere manufacturers; they're idea factories."[21]

Yet, to a great extent, the economic policies and incentives in Central America point elsewhere. There is a fear of trying out new ideas, of committing to nurturing ideas, or of showing them to supervisors who are likely not to be receptive. And there is still much pressure to continue rent seeking rather than to promote ideas that could contribute to competitiveness. These factors call for more decisive and creative policy-making to break the cultural and attitudinal roadblocks.

V. Search, Research and Googling for Technologies

What Type of Search?

In general usage, search has to do with looking through or examining ideas, resources, sources, markets, catalogs, regulations and so on to find something in particular, something more or less well defined. The interest here, however, is in a particular type of search, namely as it is understood within economic theory. This is a somewhat more involved concept.[22]

Search theory was developed when operators and academics collaborated to apply mathematics to a very tangible task: to find a militarily important object in the quickest, best way possible. The theory has taken a number of routes in its evolution, perhaps most interestingly via operations research, where the interest lies in analyzing the needs and problems of operators (of any kind) in solving pressing operational search problems. Researchers have developed an interesting toolbox of practical techniques for tactically minded decision-makers. The algorithms of search engines such as Google may be considered an evolution of this line of thinking.

Within economics, search acquires a specific connotation. Search theory deals with the analysis of resource allocation, with specified, imperfect technologies for informing agents of their trading opportunities and for bringing together potential traders (these technologies include mechanisms such as a simple auction—or *tatonnement*, a bargaining

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[21] Nadel.

[22] Search is not yet defined in science and technology manuals such as the Oslo or Bogotá Manuals, for it is considered part of other activities. As such, it is in need of definition for the purposes of pursuing technological innovation and diffusion. We will approach this concept theoretically at first, and subsequently derive a more operational definition.

process—that are used to achieve a match).[23] The theory deals with the question of how the agents find a potential buyer (or seller) of a good or service, and what is the cost involved for the search. The concept can easily be extended to encompass the situation of interest here, namely, how do economic agents find the best (or a good enough) match to effect a trade, or find the right network partners (suppliers, clients, service providers) interested in forming a community of interest.

Naturally, this way of framing the economic exchange problem does away with the assumptions of instantaneous and cost-less coordination of trade, as in the General Equilibrium theory. (We are neither assuming that the opposing end of general equilibrium prevails, that is, that there is a "random matching" approach to exchange, but rather that there is a directed search).[24]

Box 5: Self-Discovery

Dani Rodrik and Ricardo Hausmann, in *Economic Development as Self-Discovery,* propose a public good solution to deal with the uncertainty that firms and policymakers face regarding what a country is good at producing. Basically, they start by identifying weaknesses in the implicit steps needed to achieve rapid growth through access to foreign technology and governance by good institutions. The main weakness in the developing countries of Latin America involves poor knowledge about what firms from specific sectors may be good at producing in a particular country and environment. Entrepreneurs may have access to foreign technology and protection of property rights—especially intellectual property—and yet err in their choice of industrial sector, and the type, character or size of their investment.

On the other hand, if firms know that in the country where they operate, cut flowers, soccer balls or computer software can be produced at low cost with appropriate technologies, competitiveness is greatly improved. This holds true not just for one but for many entrepreneurs in the sector, who can imitate the leaders. As such, there is great social value to discovering the relative costs of production, which vary by country.

Market failure arises out of the very small part of the value that the first "discoverer" can appropriate, since normally other firms can quickly emulate the discovery without paying for the investments or opportunity costs that the first firm had to incur. In other words, if learning what a country is good at producing requires an investment and the return on that investment cannot be fully appropriated by the investor because others jump in, then there is a serious obstacle to such investments; indeed, the stimulus to invest may be too low.

The question then becomes how to design better policies to deal with market failures—specifically, what can be done to induce investments in nontraditional activities when returns to entrepreneurship in such activities are subject to nonappropriation.

In summary, the loose definition of "search"—namely, that it is related to finding out what is available and applicable to a production context—can now be translated into more technical terms, specifying that in order to allocate its resources efficiently, a firm needs to find out what technologies are available in the market and can be traded (and the costs associated via licenses or turnkey projects, or at zero cost via copying).

[23] The New Palgrave (Encyclopedia of Economics).

[24] We are interested in what is called "directed search". That is, midway between Walrasian general equilibrium and random match we find a family of matching technologies characterized by the assumption that the selling mechanism of each seller matters for both price and probability of trade with buyers. Thus, for example, a set of similar sellers can easily communicate their locations to buyers, but we might also assume that buyers cannot communicate with each other over which seller to visit. (See Kennes.)

Furthermore, the firm is limited by the mechanisms (local or international) in place to inform it (and its potential suppliers-clients) of trading opportunities.

Search and the National Innovation System

With that quick introduction to search theory, let us return to the situation that firms face within the National Innovation System[25] framework. The traders, in this case, are the firms (buyers) that demand technology support for innovation purposes, while the suppliers (sellers) are those firms that sell science and technology services to the former. Among the first are mostly enterprises, but also government institutions and other research- and innovation-related entities.[26] Consequently, the trading opportunities are those associated with articulating or diagnosing obstacles to technological innovation, identifying providers of technological solutions and/or related equipment, facilitating the adaptation and/or transfer of a technology to different contexts and environments, finding the right professionals to carry out a particular component of an innovative project, etc.

The matching technology, or the mechanism by which buyers and sellers of technological solutions find each other, is a primary issue.[27] In most of Central America, this mechanism is rather precarious—typical of any incipient market. Most laboratories, for instance, are in universities that lack a good marketing strategy. There are very few effective *university–enterprise* liaison centers. And mechanisms to set prices are not well-defined and ad hoc in most cases. No marketing means poor information about what kinds of technology-based jobs can be performed—beyond routine ones, which may not be indicative of what labor can be provided for innovative technologies. Even extra-national and extra-regional sellers of services are difficult to identify or contact.

The prevalent matching technology is also risky, for a lot of the terms and conditions of the eventual contract may suffer from asymmetrical information. Warranties are flexible, and guarantee-bonds are expensive. The product or service may lack exposure to local conditions, in which case the durability or reliability may be questionable. Parts and repair services might be abroad. That imposes heavy costs on the production of the non-traditional good in question, which are frequently hidden—purposefully or otherwise—during the negotiations for technology exchange between buyer and seller.

Furthermore, in the majority of cases, search costs can be rather expensive when they can be forecast, and are usually overestimated, because of uncertainty, when they cannot be forecast.

Special mention must be made of the self-discovery model developed by Rodrik and Hausman. It suggests that production should actually be started in earnest to discover the true costs (of technology adaptation, resource inputs, management organization,

[25] The system is not assumed to be so completely networked as to constitute an efficient, economic-signals-emitting grand market.

[26] The form of payment of public institutions does not generally follow competitive market rules, complicating and making search and completing transactions more costly.

[27] It is somewhat awkward to use the expression "matching technology" in connection to "technological solutions". But this results from our effort to keep up with the jargon of the profession. Search theory uses match technology to refer to the mechanism by which an exchange takes place.

marketing and so on). Only then can the entrepreneur test his or her hypothesis that there are sufficient buyers to make the venture profitable.

While this paper has been inspired by the search theory, it is not rigorous (that is, mathematical) in specifying the imperfect technologies for informing agents that actually exist in a particular country of interest, because that would require an empirical data collection that is beyond the paper's scope. Instead, it makes some basic assumptions that reflect the type of technologies that exist in the technology and science markets for transmitting information and knowledge about trading opportunities. That is, the ideas presented above do not constitute a formal model, but rather a framework for applying search considerations in the analysis of a country's National Innovation System and in setting up policies.

We would like to also observe that the coordination of any trade (technologically related or otherwise) involves two separate steps: information gathering about opportunities and arrangement of individual trades. A simple case is where information gathering is limited to visiting service providers one at a time, and then summing up the costs of gathering information and negotiating a price. This is the case, currently, in most of the Central American countries. The costs, as noted before, can be enormous due to the precarious nature of the market and marketing efforts, and the fact that for most goods and services a community of interest has not developed to any significant degree.

VI. Implications for Central America

The application of a science and technology policy to foster economic growth is complex and risky—complex because of the large gap between the small Central American countries and the developed countries with whom they must now increasingly trade; especially risky because any serious and large investment in a particular direction that fails is bound to have great costs, both economic and social. Thus, it is recommended that Central America should promote the two following policies: communities of interest and a special incentive policy.

Communities of Interest

Central America has already introduced and promoted the idea of production clusters. The communities of interest go beyond a production chain and include all the activities in which science and technology can provide a backbone for industrial development. The goal is to produce a network between knowledge producers and industry. It is here that search could play an important part. It is through search that existing gaps are bridged. The search mechanisms would include technology brokers, computerized databases and search mechanisms.

Technology Brokers

Technology brokers facilitate communication within and among communities of interest, and reduce the transaction costs of identifying the right technology for the right problem. The model is one of a decentralized network, in which the technology brokers are located within institutions that belong to the community of interest. They provide the link to the world of existing technologies and firms, to which they provide diagnostics. With the help of tech search engines and databases, they discover what technologies may be available in the local or world markets that might be useful to the community; they may even be committed to the delivery of technological services.

Googling and Economic Search

Science and technology "googling", that is, using a Google-based technology to facilitate finding a match to a trade, is the logical next step for economies starved of pertinent information and knowledge required for R&D and technological innovations. Indeed, while this paper does not seek to prove this case, it is suggested that in markets with frictions and distortions—and which are competitive in the sense that all agents are price takers—the closest that one can get to a socially optimal allocation is through a major search engine such as Google. If traders on the demand and supply side of technological services can advertise publicly their capacity to provide a service and/or the prices that may be charged for relevant or similar tasks as those likely to be sought by firms who want to innovate, a partial equilibrium in this market can be achieved. Annex 3 presents examples of Web sites that follow the idea of search and allow users to find solutions to specific questions.

Box 6: Why Google?

Google is the most widely used search engine, and due to its user-friendly interface and great accuracy is a great example of possible benefits of creating an science and technology search mechanism. A search engine is a Web site that responds to a search query through the gathering and reporting of information available on the Internet.

Google is so successful precisely because of the accuracy of its results, the size of its database (more than eight billion web pages), its simple format and the ability of its searches to customize. In fact, it has become so popular that "googling" is a term now widely used to refer to searching the Web.

Since the lack of information is one of the biggest obstacles to technological development in small countries, the creation of a network in communities of interest, together with easy search mechanisms and improved access to these technologies, would allow for greater diffusion of knowledge and a reduction in the uncertainty involved in search.

As a firm or a cluster of firms matures, "technology roadmap" software may be required (as in the case of Motorola, described above). Indeed, just as in the Motorola case, numerous firms (suppliers, clients, service providers), institutions and think tanks can be included so that thousands of users can collaborate on supporting, nurturing and testing ideas. Software such as Alignent Software's Vision Strategist, to name one example, can be used to view the community's full range of possible projects and products online along with their roadmaps. In Motorola's case, users participated in online review meetings and received clarifications, feedback and suggestions about their roadmaps. This networking arrangement made for huge savings and presented a greater probability of success with new ideas for innovations.

Incentive Policies

In smaller, underdeveloped economies, the considerations raised by Rodrik and Hausmann are pertinent. They say that there are serious uncertainties about costs associated with producing nontraditional or innovative products. Most entrepreneurs are not willing to invest in discovering these costs because there is no assurance that competitors will not steal the benefits of such investments. In the equivalent search parlance, it would be said that search externalities are not reflected in the returns on investing to explore the production of goods that are not new by world standards, but that are nontraditional by local standards.[28]

Under these circumstances, there is an important role for government intervention to either protect intellectual property or subsidize the investment costs associated with discovering what nontraditional goods a country may be good at producing. As Rodrik and Hausman rightly argue, many innovations do not depend on substantial research that would result in a design or technology that could be patented. Furthermore, there is a strong case to be made for allowing some innovations to be easily copied by competitors, as this scales up the social returns. Consequently, this paper reiterates the need to subsidize the search for nontraditional product possibilities.

While Rodrik and Hausmann propose only incentives for "self-discovery", a form of search, we propose, in addition, that tech search engines, as described above, be developed.

We also recommend that serious attention and analysis be placed on designing a security blanket for those brave enough to pursue the higher risk associated with an aggressive technological innovation approach to growth. The *social emergency funds* that mushroomed in the 1980s to soften the structural adjustments recommended by the Washington Consensus provide a starting point for discussion about safety nets. Another, more expensive scheme is that proposed by Michael Mandel,[29] Chief Economist of *Business Week,* who recommends an income insurance to soothe fear, and make highly educated workers more comfortable with the high risk of being displaced. Entrepreneurs, on the other hand, should be expected to compete and bear the consequences—in the true spirit of what it means to be an entrepreneur.

A Final Caveat: Moving from a "Search-Dominated" Policy to a "Research-Dominated" Policy to Innovation

As stated at the outset of this paper in the description of the chain-link model, the steps from search to research to innovation constitute a circular continuum with feedback loops arising at any point. Search may be enough for a particular firm, but search alone is not enough for an economy to become truly competitive over the long haul. At some threshold point, widening and/or deepening research activity becomes imperative to pursue greater economic gains or maintain market share.

This caveat is important to avoid the misunderstanding that search and only search is all that is needed in small, poor countries over the long term. During transitional phases from slow growth to faster growth, search is bound to return the quickest rewards. This, in turn, will excite investors, both local and international, as they see such indexes as total factor productivity increasing rapidly. But, over the long run, much more than a search-dominated strategy is required.

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[28] Since the products or services exist already in some markets of the global economy, we are not talking at this point about R&D, but about searching for a promising product, and borrowing and adapting the associated technology.
[29] Mandel.

Smaller countries are likely to have or can develop specific and well-defined areas where R&D and innovation efforts should be exerted. Indeed, a country may have the natural resources and human capital to attract the complementary investments to promote successful knowledge creation and accumulation.[30] At the end of the day, however, a small, poor nation must prepare itself for producing ideas, to avoid shrinking its profits due to exposure to foreign competition. The more efficient the use of local human, natural and physical capital, the better the results.[31]

Another way to look at these issues is through Alice Amsden's discussion of "buying" vs. "making" technologies. To "buy" technology, you need to search for it; sometimes, potential innovators even need to search for assistance to help articulate their concerns in technological terms.

Amsden presents a historical record where all developing countries initially buy, rather than make, technology. The successful small- and medium-sized firms of Korea and Taiwan, for instance, started "buying" (at a price of zero) technology by copying ("reverse engineering"). Note, however, that copying requires developing skills both to be able to detect the core technology, and to develop the industrial organization required to produce these new products efficiently. This connection between copying and high-tech technologies and techniques is not present in Central American countries, although it can be promoted over the medium term.

Furthermore, the governments of Korea and Taiwan were effective supporters of technological change since they introduced policies to get the best terms for technology transfers, spent heavily on formal education and slowly increased investments in R&D. While these policies benefited the bigger firms more than the smaller, there were important spillovers.

Amsden says that what has made a difference among developing countries is that some began to "make" technology:

> While all countries continued to buy foreign technology, and continued to invest in production capabilities and possibly project execution skills, leading firms in some countries—the "independents"—also began to develop new technology, a necessary condition for sustainable national enterprise... Korea and Taiwan were the big R&D spenders. The share of R&D in their GNP became comparable by the 1990s to that of North Atlantic countries and Japan... In terms of the high R&D spenders, the efforts of Korea and Taiwan started early and then rapidly gained momentum. *The initial form was quite coercive*. As early as 1973, the Korean government introduced a reserve fund system that "required firms to keep a certain proportion of income for R&D investment" (coverage included firms in manufacturing, construction, mining, computer processing, military supply, and machine engineering). If the amount set aside was spent on R&D (broadly defined) within a given time period, a loss could be deducted from taxable corporate income. If not used, the amount set aside had to be declared as profits and subject to taxation (OECD 1995, p.99). The Taiwan government, fearful of the limited effort of small firms to invest

[30] One way to put this simply is to look at Solow´s production function: Q=Af(K,L), where A is exogenously brought it. In the Romer model, one could say Q=f(A,K,L), where A is endogenous, depending largely on investment decisions on R&D, among others. Now, for a developing country it may still be valid to emphasize the Solow formulation for some or many sectors, while at the same time reflecting a much longer term effect for R&D investments, i.e., a combination of the two models.

[31] Here the need to devise or reengineer institutions to effect the desired incentives is all too clear.

in R&D, required all firms to spend a stipulated share of their sale revenues on R&D (the exact percentage depending on firm size and industry) or to remit an equivalent sum to finance government R&D (OECD 1990).

Soon, however, both Korea and Taiwan dropped an across-the-board R&D requirement in favor of a *targeted approach*. In 1979 the Korean government designed performance standards such that long-term credit and tax exemptions were made contingent on firms establishing central R&D laboratories, which many large groups began to do like clockwork (Amsden 1989). Simultaneously, it introduced a series of National R&D Projects whereby government agencies collaborated with the most advanced national firms in a given industry to gain technological mastery for purposes of global market expansion.[32]

In conclusion, the chain-link model has applications that should be distinguished from those of the search model. In countries deciding on rapid catching up, say through a more aggressive export promotion program, the need to emphasize a search model that has its own momentum and runs within a sub-loop of the chain-link, is fundamental.

VII. Conclusions

Search theory in economics has had an important impact in widening and deepening markets. The rigorous understanding that has been established may be merged with today's more common usage of technological innovation and "search engines" to arrive at the following related hypotheses:

a. The activities related to search, research, development, invention and innovation constitute complementary elements of a continuum with no discernible boundaries, in practice.
b. At the same time, the smaller and poorer an economy is, the more intense should be the search effort over research or invention. Most of the literature on science, technology and innovation places the emphasis the other way around, because it frequently misses the cost-effectiveness of research vs. search. Both are needed, but the optimal proportions of each are not easily determined.
c. Appropriate search and network mechanisms need to be established to guarantee proper and speedy technological development. Indeed, pertinent and significant amounts of search will better guarantee that an appropriate technique to apply an existing technology is found. In the event that search does not yield technological alternatives sought by firms or communities, there will be a solid justification to proceed to research and/or invention.
d. The preponderance of search over research is justified, but it should not be understood from this conclusion that research is neither important nor unnecessary. On the contrary, at some point in time, it is most likely that to be competitive an economy, no matter how small, will need to do serious research in some niche area(s) where comparative advantage(s) may emerge.
e. A search model requires an adequate and robust engine to carry out the search, and institutional mechanisms to find out what technologies are relevant to a production goal and how to get hold of them (for example, by purchasing them). It also requires rapid skill formation in areas such as identification of the engineering problem (via for instance "reverse engineering", or obtaining the license to pursue a specific technology or technique).

[32] Amsden, pp. 240-245.

f. There is also a need to develop scientific capability to adapt an existing technology to local conditions, environment and culture—including in extreme cases by making or creating innovative instruments, or by urging experimenters to draw together instruments into combinations in pursuit of desirable effects.

In the end, a search model must guarantee the quality of and market effectively a nontraditional good or service. This requires metrology, adequate laboratories and skilled professionals. To coordinate these activities, national ministries or councils of science and technology have to become promoters of these elements. A network of technology brokers may play a supportive role, in conjunction with search engines customized for the communities of interest to bring about new synergies.

Finally, the presence of creative incentives to counter the uncertainty of technology advancement is critical. In addition to the support of current incentives programs such as matching grants, research collaboration programs, seed and risk capital, scholarships and training for workers, there is a need to create a scheme of income insurance to protect highly trained workers from the pitfalls of technology advancement.

Bibliography

Amsden, Alice H., *The Rise of the Rest*, Oxford University Press, 2001.

Eatwell, John, Murray Milgate and Peter Newman, *The New Palgrave: Allocation, Information and Markets*, W.W. Norton and Company, Inc.,1989.

European Commission *EC DG XIII and XVI,* 1996.

Evenson, R.E., and L.E. Westphal, "Technological Change and Technology Strategy." in *Handbook of Development Economics,* 3B, 1995.

Freeman, C., and C. Perez, "Structural Crises of Adjustment, Business Cycles and Investment Behaviour," in Dosi et al. (eds.), pp. 38-61.

Galison, Peter, *Image & Logic: A Material Culture of Microphysics*, University of Chicago Press, 1997.

Grossman and Helpman, *Innovation and Growth in the Global Economy*, MIT Press, 1991.

Hausmann, Ricardo and Dani Rodrik, "Economic Development as Self-Discovery," unpublished.

Helpman, Elhanan, *The Mystery of Economic Growth*, Belknap-Harvard, 2004.

Jaramillo, Hernán, Gustavo Lugones and Mónica Salazar, "Standardization of Indicators of Technical Innovation in Latin American and Caribbean Countries," *Bogotá Manual,* March 2001.

Kennes, John, *Competitive Auctions Theory and Applications*, University of Copenhagen, September 2004.

Kline, S. J., and N. Rosenberg, "An Overview of Innovation," in R. Landau and N. Rosenberg (eds), *The Positive Sum Strategy: Harnessing Technology for Economic Growth,* National Academic Press, 1986, p. 289.

Lederman, Daniel, and William F. Maloney, *R&D and Development*, World Bank, 2003.

Lundvall, B., (ed.), *National Systems of Innovation: Towards a Theory of Innovation and Interactive Learning,* Pinter Publishers, 1992.

Mandel, Michael, *Rational Exuberance: Silencing the Enemies of Growth,* Harper-Collins, 2004.

Nadel, Brian, "Turn your company into an idea factory," *Fortune*, December 2004.

OECD, "Proposed Guidelines for Collecting and Interpreting Technological Innovation Data," *Oslo Manual,* Eurostat, European Commission.

Romer, Paul, "The Origins of Endogenous Growth," *Journal of Economic Perspective*, 8(1),1994.

Sachs, Jeffrey, "Helping the World´s Poorest," www.cid.Harvard.edu/cidinthenews/articles/sf9108.hml.

Sáenz, Pedro, "Knowledge Enhancement in the Small Economies of Central America: Reflections on Building a Strategic Approach," *Economic and Sector Study Series*, Inter-American Development Bank, RE2-02-002, December 2002.

Schumpeter, J. A., *The Theory of Economic Development*, Harvard University Press, 1934.

———, *Business Cycles: A Theoretical, Historical and Statistical Analysis of the Capitalist Process*, McGraw-Hill, 1939.

———, *Capitalism, Socialism and Democracy,* Harper, 1975 (orig. pub. 1942).

Annex 1

The *Oslo Manual*

There are significant debates around the topic of technological innovation. It is one of the aims of this note to make available more than the official definitions to encourage better dialog among stakeholders. That is, to have a common understanding of terms and usage that facilitates communication.

Issued by the OECD, the *Oslo Manual* is the most important manual on innovation. It is mainly concerned with technological product and process innovations in firms, and uses the following definitions:

Technological product innovation: "A technological product innovation is the implementation/commercialization of a product with an improved performance characteristic such as to deliver objectively new or improved services to the consumer."

Technology process innovation: "A technological process innovation is the implementation/adoption of new or significantly improved production or delivery methods. It may involve changes in equipment, human resources, working methods or a combination of these"[33]

Additionally, the manual defines related terms such as technological diffusion:

Diffusion: "…diffusion is the way in which TPP innovations spread, through market or non-market channels, from their first worldwide implementation to different countries and regions and to different industries/market and firms. Without diffusion, a TPP innovation will have no economic impact."[34]

The *Bogotá Manual*

The *Bogotá Manual*, developed by the *Red Iberoamericana de Indicadores de Ciencia y Tecnología* and the Organization of American States, is a reinterpretation of the Oslo Manual to better serve the needs of Latin America. It expands the possible characteristics that an innovation can take. In addition to the Oslo definition of TPP innovation, the *Bogotá Manual* states the need to consider changes in organizational and marketing processes as important factors for changes in production. It includes innovation within the definition, and innovation promoting or facilitating activities.

The *Bogotá Manual* sees some weaknesses in the Oslo definitions, particularly in what it considers ambiguities concerning organizational changes, limited levels of novelty, and a limited focus on "the process of firms accumulating capabilities for creating and using knowledge". These weaknesses discredit diffusive, adaptive and incremental technical

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[33] OECD, p. 9.
[34] Ibid.

change as innovation. The *Bogotá Manual* considers it important to identify firms active in the development of innovative capabilities in Latin America.[35]

The European Commission

The European Commission provides a definition that is simple and easily understood. It defines innovation as "the commercially successful exploitation of new technologies, ideas or methods through the introduction of new products or processes, or through the improvement of existing ones. Innovation is a result of an interactive learning process that involves often several actors from inside and outside the companies."

Typologies of Innovation

There are also various types of innovation that are helpful in providing elements to analyze and describe the dynamics of competition in a particular market or National Innovation System, or in providing policy recommendations. The first categorization of innovations is from Schumpeter, who classified innovation by different outcomes.

1. According to the Result of the Innovation

- Product innovation—the creation of a totally new product;
- Process innovation—the creation of new methods of production;
- New raw material—the conquest of a new source of supply of raw material or development of a new one;
- New market—the introduction of new products and new demand (supply driven markets);
- Industrial reorganization—non-firm reorganization (*Oslo Manual,* p. 7).

2. According to the Scope of Change

Freeman and Perez have further typified innovation in relation to the scope of change that results. Innovations can be:

- Incremental: occur more or less continuously in any industry or service activity. They include adjustments, adaptations and customizations of existing technologies;
- Radical: represent the introduction of truly new products and processes, and are discontinuous events that cannot be attributed to the cumulative addition of incremental modifications and improvements to existing products and processes;
- Systemic: a concept that describes greater changes within an economy due to the convergence of radical and incremental innovations that lead to the clusters of firms creating interdependent innovations and leading to the proliferation of radical (new) technologies; and
- Technological revolutions or techno-economic paradigms: changes in technological systems that have a major influence on the behavior of the entire economy.

3. According to the Degree of Novelty

A third way to classify innovation is according to the degree of novelty. Since innovation refers to the introduction of a product or service into a market, the degree of novelty describes at which level this introduction takes place. It may apply the term innovation to a first market introduction in the world, or more broadly to introduction into any smaller

[35] Jaramillo, Lugones and Salazar, p. 47.

market as a result of diffusion. Most literature, including manuals for survey purposes, use a broad definition of novelty, and sets the minimum degree of novelty at the "new to the firm" level. The innovation can be a:

- World innovation or new to the world (new at the world level);
- National innovation (new at the national level);
- Local innovation (new at the local level);
- Industry innovation (new at the industry or sector level); or
- Firm innovation (new to the firm).

Annex 2

Defining Research

It may prove useful to differentiate research from search. For practical purposes, such as defining it for tax purposes, research is not separated from development because a tax credit is an incentive to be productive and not just for the sake of knowledge alone. Thus, the majority of countries that have introduced R&D for tax purposes have based their definitions on the standard accountancy practice and the definition of R&D in the OECD's *Frascati Manual.*

It is tempting for treasury secretariats or ministries to take the simplest linear notion alluded to above: Bright Ideas → Research → Development → Product on the shelf. Yet as already discussed, there are a number of non-linear feedbacks and search activities to resolve unforeseen technological uncertainties that do not end in commercial production. In addition, new processes and intermediate services may also be outputs of R&D.

As such, to stimulate innovation through R&D, there must be recognition that there may emerge "bubbles" of innovative activity at any point and in any direction. This complicates a definition that clearly and unequivocally identifies an activity as R&D.

There is also the issue of creation of new knowledge versus improvement (or redesign and modification of existing products or processes). This confuses many people. Quite frequently innovators absorbing a new technology require substantial redesign of the existing product. They need to undertake R&D to properly redesign or improve or technologically refine the initial product (to make it compatible with the new technology). This type of R&D does not involve creation of new knowledge or of revolutionary new products—as normally understood—but requires tech improvement and it is still considered R&D.

To be specific, let us refer to a definition used by the United Kingdom for tax credit purposes.[36] A firm's eligibility for R&D tax credit rests basically on two factors:

- Definition: Whether the money was spent on R&D; and
- Scope: Whether tax credits are available for the particular type of expenditure (e.g., staff costs).

Following the *Frascati Manual,* research and experimental development is defined as "creative work undertaken on a systematic basis in order to increase the stock of knowledge... and the use of this stock of knowledge to devise new applications." Frascati then subdivides R&D into three categories: basic research, applied research and experimental development.

- **Basic Research:** "…experimental or theoretical work undertaken primarily to acquire new knowledge of the underlying foundations of phenomena and observable facts,without any particular application or use in view."

[36] Defining Innovation: a consultation on the definition of R&D for tax purposes, HM Treasury, July 2003.

- **Applied Research:** "…also original investigations undertaken in order to acquire new knowledge. It is however directed primarily towards a specific practical aim or objective."
- **Experimental Development:** "…systematic work drawing on existing knowledge gained from research and practical experience that is directed at producing new materials, products and devices; to installing new processes, systems and services; or to improving substantially those already produced or installed."

To guide firms into the most innovative activities known to be of greater private and social value and provide clarity as to what is an eligible activity for tax purposes, the U.K. uses the following Frascati criterion: "…the basic criterion for distinguishing R&D from related activities is the presence in R&D of an appreciable element of *novelty and the resolution of scientific and/or technological uncertainty*, i.e. when the solution to a problem is not readily apparent to someone familiar with the basic stock of common knowledge and techniques for the area concerned."

Clearly, there still remains some ambiguity as to what is meant by "appreciable" or "substantial", or the extent of technological uncertainty being resolved. The U.K. is assisted by the concept of the "relevant expert", who can reasonably be expected to understand and judge the issues in a particular case. It also uses the notion of "pre-production development and product development" as part of the R&D categories, differentiating them from "commercial development", which relates to scaling up and marketing (items that are not excluded in the *Bogotá Manual*).

This level of definition of R&D is sufficient to guide most policy-makers and even practitioners. Further reading of the *Frascati Manual, Bogotá Manual* and UNESCO materials will provide more detail for those who need it.

Annex 3

Technology Extension Programs

Government-sponsored programs to promote the diffusion of technology help firms to absorb new technologies by providing them with information that they normally struggle to find, such as new technologies and techniques, best practices, specialized suppliers and so on. The goal is to make firms comfortable with managing technological change, and encourage them to create new technologies by building up their internal capacity. The larger objective is to create networks of research centers and industrial consortia, which expand the technical capacity of a national economy and making it more competitive. This system has been used in many developed countries as part of their R&D policy, including Canada, Japan and the U.S.

Programs can be structured to provide technical and business solutions to industry, improved access to technological and financial resources, and seminars and training for common problems. Initially, a diagnostic analysis is undertaken with each individual firm to appraise its operations, needs and problems. The program can then assist the firm to upgrade technological capacities, and may also help in the search for technical and financial assistance of R&D and adaptation projects. Finally, these programs can also assist in the acquisition of foreign technology, when the firms cannot fund their own R&D or the technology is not available nationally.

United States: www.mep.nist.gov/
Canada: http://irap-pari.nrc-cnrc.gc.ca/
Chile: www.fontec.cl/
Colombia: www.colciencias.gov.co/scienti/

MIT–Mexico International Science and Technology Initiatives

The Massachusetts Institute of Technology (MIT)-Mexico program provides MIT students and faculty with opportunities to develop their skills through internships in companies, laboratories and universities in Mexico. The goal of the program is to provide international experience in topnotch institutions through the world, allowing MIT students and faculty, as well as the corporations, research centers, and government and non-governmental organizations in which they participate to benefit from collaboration, and increase the internationalization of industry, education and research. In addition to Mexico, MIT currently runs the program in China, France, Germany, India, Italy, Japan and Singapore. In Mexico, it has collaborated with the Tec de Monterrey, and is currently in talks with firms such as Cemex, Siemens Mexico, Metalsa and Protego, among others, to expand its program.

GlobalGiving (www.globalgiving.com)

GlobalGiving functions as an online marketplace for specific social and economic development projects, and seeks to connect individual donors to specific projects they can fund directly. The emphasis is on small projects where individual contributions can make a difference. The Web site seeks to allow donors to experience much of the transparency they would with a financial investment, knowing exactly where their money is going and how it is being used. Projects seeking funds are grouped geographically and into themes such as economic development, education, environment, gender and equality, health, human rights, and technology. Donations can be made by credit card, check or stock transfer at any amount up to the project need amount. All donations to projects are tax-deductible through the GlobalGiving Foundation.

Development Gateway (www.developmentgateway.org)

The Development Gateway is an independent, not-for-profit organization. It was conceived by World Bank President James Wolfensohn and initially developed in the bank. It is an interactive site for information on development and poverty reduction, and allows for communities to share experiences on development efforts. The portal supports the objectives of increasing knowledge sharing, improving public sector transparency, enhancing development effectiveness and building local capacity to empower communities. It offers services such as an online directory for information on development projects (AiDA), an electronic procurement market (dgMarket), information on major development topics (Topic Pages) and links to a growing network of country-level initiatives (Country Gateways).

Digital Nations (http://dn.media.mit.edu/)

Digital Nations, by MIT Media Lab, aims to address major social challenges—such as improving education, enhancing health care and supporting community development—through the innovative design and use of new technologies. The consortium's ultimate goal is to empower people in all walks of life to invent new opportunities for themselves and their societies. It focuses especially on populations with the greatest needs—children and seniors, underserved communities and developing nations.

Initiatives include:

- The introduction of new technologies in education;
- The creation of electronic marketplaces to encourage rural communities to participate in regional and global markets through e-commerce;
- The creation of multilingual/multicultural technologies that allow for a greater use of computing;
- Low-cost technological solutions to improve access to communications; and
- Innovative tools to help monitor and plan health care.

Somos Telecentros (www.tele-centros.org)

This is a network for the creation and strengthening of telecentros in Latin America and the Caribbean. Its objective is to create a network of communities, organizations and individuals involved in the creation of telecentros and other experiences using information and communications technologies as tools for sustainable human development. It supports the planning and development of public and private policies to improve the access and use of these technologies.

Annex 4

Technique and Technological Innovation

We are here interested in one form of innovation: technological innovation. For completeness, let us define technology and innovation first, and then we shall dwell on technological innovation.

Technology is defined here in the context of development economics. As such, it "...is most fundamentally, *knowledge about how to do things*."[37] Technique needs to be clearly distinguished from technology because of the special significance these terms have for developing nations. "Techniques are defined as singular ways of doing particular things, and are the result of choices made when applying technology in specific circumstances with respect to economic, physical, and social conditions. In effect, a technique is a solution to a problem of constrained maximization in which technology and circumstances form the constraints."[38] The resulting technique, however, can easily evolve into a distinct technology soon thereafter.

This way of defining technology is critical in assessing the technological needs and efforts of developing countries. For instance, railroad companies had to invest in R&D to come up with new materials for the rail tracks (different types of wood and nails) to withstand the humidity of Panama early in the 20th century. This amounted to a new technique. Furthermore, this definition brings together under one heading such isolated technology-related efforts of development policy-makers as "choice of techniques". These may cover decisions to enhance employment, rapid diffusion of production technology to alleviate structural adjustment shocks on enterprises, epidemic prevention and healthcare technologies, telecommunications for distant rural communities, and many others.

From this perspective, we can no longer presume that an adequate technique for applying a specific technology can simply be bought off the shelves of advanced industrial nations. This, in fact, was never true. In fact, the assimilation, adaptation—and sometimes highly creative and inventive adaptations—of imported technologies was always required. Technological adaptation of a technique involved developing, in effect, a new technique and that was costly both in time and money—with success more closely associated with uncertainty than with measurable risk.

Innovation, on the other hand, having a longer tradition both in developing and developed economies' enterprises, is more straightforwardly defined. The *Oxford Dictionary* defines innovation as the action of introducing a new product into the market; a product newly brought on to the market. The Spanish Royal Academy, by contrast, emphasizes more that the product that is introduced to the market must have been newly created or modified before ("Creación o modificación de un producto y su introducción en un mercado."). But both definitions are basically equivalent.

Thus, putting the two concepts together we obtain a simple definition of technological innovation as a new technology or technique about how to do something that results in a product or service being introduced in a market.

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[37] Evenson and Westphal, p. 2212.

[38] Ibid.