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Innovation Policy for Development: an Overview

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Innovation Policy for Development: an Overview

Abstract

This paper provides a framework for thinking about innovation policies for development; it does so by flashing up the key issues which arise in this context, and by examining in detail the case of innovation policy in Israel. A few premises guide the analysis: First, innovation for development should be construed as a broad notion that includes widely distributed innovations of all stripes, both in products and in processes, generated by rank and file workers as much as by R&D labs. Second, the economic rationale for government support of R&D needs to be adapted to the economic environment of developing countries; the notion of spillovers should be reexamined in view of globalization, and the same goes for the working of "General Purpose Technologies" (GPTs). The Israeli economy offers a fascinating illustration of extraordinary success in innovation, particularly in ICT, yet the benefits from the High Tech sector eluded the rest of the economy, giving rise to a "dual economy" and slow growth for the economy as a whole. Understanding this outcome provides valuable insights for the design of growth-promoting innovation policies. Lastly, the paper discusses the policy corollaries that emerge from the analysis, and in particular the main levers which innovation policies for development should act upon: skills formation, provision of incentives, access to information, and availability of finance.

JEL: O14, O30, O38

Keywords: Innovation, Development, Policy, Spillovers.

Introduction[1]

This paper is meant to provide a framework for thinking systematically about innovation policies for development, without venturing into specific, recipe-like policy recommendations. It does so by flashing up and dissecting the key issues that arise in this context, and by examining in some detail the case of innovation policy in Israel, which sheds light both on the promise and the limitations of such policies. There are a few guiding principles that inform the discussion. First, innovation for economic development has to be construed as a much broader notion than just the creation of new, technologically fancy gadgets; indeed, economic growth stemmed historically from widely distributed innovations of all stripes, both in products and in processes, generated by rank and file workers as much as by R&D labs. The issue then is not just how to elicit say patentable innovations resulting from formal R&D, but how to provide both incentives and basic means for would-be entrepreneurs and small enterprises to engage in productivity enhancing investments.

Second, the economic rationale for government support of R&D, while universal and hence applicable to developing economies as much as to developed ones, needs to be expanded and adapted to the economic environment and idiosyncratic problems of developing countries. In particular, the notion of spillovers should be reexamined in view of globalization, which makes the actual benefits from spillovers depend upon the relative intensity of inwards versus outwards flows. The working of "General Purpose Technologies" is also contingent upon the level of development, and therefore the extent to which GPTs play their role as "engines of growth" depends upon economic policies promoting the adoption of GPTs and the unfolding of innovational complementarities. It is not true that in the realm of innovation there is only one game in town, in the sense of

[1] An upfront disclaimer is in place: I am not a development economist, neither by training nor by practice; rather, my research so far has focused on technological change, innovation, patents, and industrial organization themes, either in the abstract or in the context of developed countries. This is my first venture into development, an area that is increasingly capturing my intellectual interests. Yet, I have had so far little exposure to the relevant literature and acquired but a scanty expertise in it; thus, I am sure that I am overlooking in this paper a great deal of pertinent previous work, as much as established common wisdom in this area. Nevertheless, I hope that this "crossing of research lines" will eventually render fruitful outcomes.

innovating for global markets as part say of the network of multinationals; there is such a thing as local needs and local markets, which are not necessarily well served, and may require enhanced incentives from the government.

The Israeli economy offers a fascinating illustration of extraordinary success in innovation, particularly in Information and Communications Technologies (ICT), which came largely as a result of a concerted, long term strategy of government support for commercial R&D, which levered the potential of a highly skilled labor force. Yet, the benefits from the rapid growth of the High Tech sector eluded the rest of the economy, thus giving rise to a "dual economy" and a mediocre growth rate for the economy as a whole. Understanding this seemingly contradictory outcome may provide valuable insights for the design of growth-promoting innovation policies, which should focus on the trajectory and end destination of the knowledge generated by innovations, as much as in promoting innovation per se.

Lastly, section 6 discusses the broad policy corollaries that emerge from the analysis, and in particular the main levers which innovation policies for development should act upon: skills formation, provision of incentives, access to information, and availability of finance. As said, the paper stops short of sketching actual policies, both because that would be too presumptuous at this still preliminary stage, and because it is a basic tenant of the analysis that heterogeneity is key, and no sensible policy can be designed without paying due attention to the idiosyncratic characteristics of each country.

1. The scope of innovation in the context of development

We commonly associate "innovations" with the development of new products that represent discrete improvements over existing ones in performing known functions (e.g. a CD versus a magnetic tape), or that open up entirely new functional categories (e.g. GPS, cardiac stents). These are labeled "product innovations" and are typically more visible to consumers than "process innovations", which lower the costs of producing given products (e.g. hybrid corn, computerized machine tools). This typology is sufficiently broad to accommodate virtually any type of innovation, yet we are naturally inclined to focus attention on innovations that are both technologically salient, and that have had (or have the potential for) a significant economic impact. In particular, nowadays we tend to associate innovations with improvements in Information and Communications Technologies (ICT), no doubt the leading "General Purpose Technology" of our era. Yet the notion of innovation relevant for policy making in developing countries ought to be much broader, and the same goes for the related notion of spillovers. Indeed, understanding what innovation entails in countries that are technologically laggards, and exploring how a surge of innovation in them may generate wider ripple effects, may well be the key for the design of sound innovation policies in them.

Widely construed, innovation means conceiving, designing and implementing changes in the available set of products and production processes, which have a positive ***expected*** value for the innovator and/or for society. Innovation may thus consist of redesigning the goods produced so as to make them more appealing to buyers or cheaper to manufacture. It may entail altering the production process by rearranging the sequence or timing of tasks, the composition of material inputs, the kind and mixture of skills deployed, the nature of upstream and downstream linkages, etc. Innovation may bring in new, more efficient machinery that triggers a reorganization of work, or new ways of transporting inputs and outputs that in turn require complementary changes in them. All these as well as a myriad of other, small, scattered improvements throughout the whole spectrum of economic activity are part and parcel of what innovation consists of, and as Mokyr (1990) has convincingly argued, when taken together these may be the true unsung hero of economic growth.

There are two important empirical regularities to highlight in this context: The first is that the cumulative effect of widely distributed small improvements has been as significant for secular growth as the impact of discrete, "higher order" innovations (in the sense of entirely new products and production processes). The second is that innovations entail a great deal of *interdependencies*, necessitating and triggering further complementary innovations in order to reap their full benefits (see Rosenberg, 1984, Ch. 3). This is certainly the case for "General Purpose Technologies" (GPTs),[2] but similar interdependencies happen also locally, "in the small", and not just for the dominant technology of an era.

These two features have far reaching implications for thinking about and designing innovation policies. Indeed, it is clear that in developing countries such policies should encompass more than just promoting and supporting formal R&D projects, and certainly more than doing so in technologically advanced ("high tech") sectors. Again, the cumulative impact of "small" and/or "informal" innovations (in the sense of innovations that are not the result of preconceived R&D projects) has been historically as large as that of innovations driven by formal R&D. Furthermore, most of economy activity takes place either in "traditional" sectors or in services, which do not qualify as "high tech." Technological change surely brings about structural transformations which in turn alter the composition and relative weights of the different sectors of the economy, yet in order for sustained growth to take place, most *existing* sectors have to experience innovation. A recurrent theme in this paper is thus that narrowly localized innovations are unlikely to result in economy-wide growth, even if the few sectors that do innovate are "high tech" and highly successful in themselves. We turn now to the economic rationale for government support of innovation on purely analytical grounds, i.e., regardless of whether the economic setting is that of a developed or of a developing country – in later sections we shall focus on the specific issues that arise in developing economies.

2. The economic rationale for government support of innovation

Ever since the path-breaking research of Robert Solow (1957), economists have known that secular growth is due mostly to technological change rather than to factor accumulation, as previously thought. Indeed, a vast array of subsequent empirical

[2] As discussed below, the defining feature of GPT-driven processes is "innovational complementarities", which entails strong interdependencies between the GPT and the application sectors - see Bresnahan and Trajtenberg (1995).

research over half a century has conclusively shown that at least half of the growth in per capita income in virtually every country studied is associated with the growth of *Total Factor Productivity* (TFP) rather than to other, more traditional factors. However, attaching to the famous "residual" (i.e. TFP growth) the label of technological change begs the question of what exactly it contains, and more importantly, what are the *economic* forces that determine its course and pace.

Indeed, one of the frustrating aspects of the early phase of economic thinking about these matters was that the growth of TFP appeared to economists as an impenetrable "black box", and seemed to occur outside the realm of economic forces. A long and very fruitful research agenda pioneered by prominent economists such as Griliches, Jorgenson, Denison, Rosenberg and their associates sought to pierce open this black box in order to provide it with empirical content. With the advent of endogenous growth theory in the late 1980s (Romer, 1986, 1990, Grossman and Helpman, 1991, etc.) the economic profession as a whole came to accept the view that innovation, spillovers and R&D, were indeed the key factors driving ***self-sustained***, long term economic growth and moreover, that these factors were generated from ***within*** the economic system, responding to economic incentives. This is then the conceptual framework that molds our analysis, namely, on the one hand the view of the centrality of innovation and knowledge creation in the growth process, and on the other hand the understanding that these are ***economic*** factors that may thus be shaped and influenced by properly designed economic policies.

One of the corollaries of the developments just sketched was the emergence of a soundly based and carefully articulated economic rationale for public support of R&D and innovation, which is by now widely accepted both among academic economists and practitioners. The basic argument for government support to R&D is that, while innovation is clearly a critical factor for growth (and hence *inter alia* for poverty alleviation), a well functioning market economy cannot generate by itself the optimal levels of investment in innovation.[3] That is so primarily because of two sources of market failures (see Arrow, 1962): (*i*) partial appropriability due to spillovers, and (*ii*) information asymmetries which lead to a serious "funding gap." These failures inhibit private firms from investing enough in innovation and R&D, thus depriving the economy from one of the key levers of sustained growth.[4] We proceed now to discuss these failures in detail.

3.1 Partial Appropriability and Spillovers

A basic feature of knowledge creation is that the returns from investments in it are not fully *appropriable*. Knowledge has significant public good attributes: once created it costs little to reproduce and distribute, and it can be used repeatedly by multiple actors without impairing the amount available to others. This implies that firms making investments in knowledge creation capture only a portion of the benefits so generated, since they do not receive compensation for the "spillovers" that their innovative efforts generate, that is, for the positive externalities of their actions on other firms and agents. Further, new technologies confer benefits to the purchasers of new products (consumers and producers alike) that often exceed any increase in the selling price that can be sustained; these non-appropriable benefits are also commonly referred to as spillovers to consumers. Both type of spillovers, namely the purely technological externalities and the excess benefits to buyers, imply that the social returns from innovations may be far larger than the private returns.

As a result of this gap, innovators operating in a market economy will invest in innovative activities less than the socially optimal amount; the extent of underinvestment depends of course on the extent to which social returns exceed private returns, and that may vary widely across fields, technologies, stages along the innovation cycle, etc.

[3] Investments in innovation are often used interchangeably with "Research and Development" (R&D), yet the former is a more general concept: R&D typically refers to formal investments in dedicated research labs, whereas there are many ways by which innovative activities may take place outside the lab. One has to bear this distinction in mind particularly in the context of developing countries, where formal R&D is much less common.

[4] Clearly though, it is not enough to spell out such economic rationale: in order for it to lead to policy, it must be weighed against the ***costs*** of government intervention, namely the well-known problems associated with "industrial policies", capture, corruption, and the like.

Empirical studies have shown that the social rate of return on R&D expenditures are typically very large, and often exceed private returns by as much as a factor of 3 (see for example Jones and Williams, 1998). Moreover, these studies show that the returns to R&D exceed by a wide margin the returns from other types of investment, in particular from investment in physical capital. This implies that there are wide margins to increase the amount of resources devoted to R&D at the economy-wide level, and that the government should play a role in doing so.

Spillovers may occur in many different ways, one of them being the mobility of R&D personnel. The process of innovation and its commercialization in an enterprise significantly enhances the human capital of its employees. Indeed, employees acquire R&D skills and understanding of technologies and markets which are partly general, i.e. which go beyond the knowledge embodied in any specific innovation that they have developed, and that cannot be fully protected by Intellectual Property Rights (IPRs). Employees that move from one firm to another carry with them this human (or innovation) capital, which may benefit their new employers beyond the increment in wages that the mobile employees may receive. If mobility takes the form of migration, then the origin countries may be unwittingly "subsidizing" the destination countries through these spillovers; thus the mobility of inventors is an important transmission mechanism for spillovers, and hence a channel that should be closely monitored as it may have both positive and negative effects on any given country. Spillovers may also occur through economic transactions, such as trade: countries can increase their productivity by importing goods, particularly capital equipment embedding more advanced technologies (see Coe, Helpman and Hoffmaister, 1997), as well as through foreign direct investment, FDI (e.g. see Blomstrom and Kokko, 1999).

3.2 Information Asymmetries and the "Funding Gap"

A second source of market failure in the creation of knowledge has to do with asymmetric information between inventors and external agents (e.g. funding bodies such as banks). Innovative activities entail by necessity a fundamental information asymmetry, certainly at the early stages when the inventor formulates the idea and seeks funds to develop it. Presumably the inventor has intimate knowledge of the technology and of the details of the planned innovation, of her true abilities to carry it out, and of the efforts she is willing to put into developing the innovation. However, there will always be a significant gap between what the inventor knows and what an external agent can gauge, even if the information on those crucial matters is well documented. In particular, there will be significant information asymmetries in this respect between the inventor and mainstream financial intermediaries like banks and institutional investors, who lack the capacity to verify the information and claims of the entrepreneur. Potential investors will therefore be skeptical of the likely returns on investments in developing new technologies, and therefore entrepreneurs who could offer attractive returns may have no credible way of conveying such potential to risk-averse investors.

The information asymmetry makes it very hard for a creditor or equity investor to predict the returns from a potential investment in new innovative ventures, which implies that such funding is not likely to be forthcoming. Thus in the absence of cash flows or other collateral, a typical start-up company or individual innovative entrepreneur will not have access to traditional sources of finance – this is the so-called "funding gap". At the most basic level then the "funding gap" implies that entrepreneurs face stiff constrains in the funding of innovations, and therefore will not invest (or will invest too little) in innovative projects that may have high social returns.

The information asymmetries are particularly stringent at the very early stages of the innovative process (the so-called "early stage technological development" - ESTD), that is, going from the raw idea to the formulation of a business plan. Not surprisingly, it is at these stages that the funding gap is most acute, and where the market may be particularly prone to failure. Indeed, a study by Auerswald and Branscomb (2002) shows that the three most important sources of funding for ESTD in the US were: internal corporate funds (32 – 47%), the Federal and State Government (23 – 30%), and "angel investors" (24- 28%). Venture capital accounted only for 2 – 8%, and Universities for the remaining 3 – 4%.[5] Equally telling, mainstream intermediaries like banks, private equity and other institutional investors are entirely absent from these early stages.

It is not surprising that internal funds account for the biggest share of ESTD financing, since this is the most straightforward way of overcoming information asymmetries. Established enterprises know the track record of their own inventors/ employees, and typically have a better understanding of the market and the commercial potential of internally proposed innovations than outside agents. Thus enterprises use cash-flows generated by established operations to finance innovation, or source external funds on the basis of their balance sheet strength.

The typical profile of "angel investors" is that of successful entrepreneurs that look for new opportunities to invest private funds (earned from their own previous innovations), and are willing to invest in early-stage projects in technological fields that they understand well ("having been there and done that"). They tend to get deeply involved in the funded ventures, providing managerial guidance, contacts, and acquiring significant overall control.

Early stage financing of innovation thus requires specialized investors with the skills to evaluate and directly manage the risks, or governments with broader public objectives, such as generating and internalizing spillovers that may benefit the economy as a whole. In the absence of internal cash flows and angel investors, even if appropriability is adequate to yield a reasonable profit expectation, it may be impossible to secure the capital necessary to develop a new technology. Quite clearly, the information asymmetries and funding cap problem is typically much more acute in developing countries than in developed economies.

[5] The study was based on a 1998 survey and other data, and the wide range of estimates stems from the alternative use of restrictive or inclusive definitional criteria for the various components. There was a wide variance in these percentages across sectors and geographical areas.

3. Zooming in: innovation in developing economies

4.1 Local versus global spillovers

The spillovers-based argument clearly holds for large economies having a moderate ratio of exports and imports to GDP, the prototypical case being of course the US: being large increases the probability that other ***local*** economic agents will benefit, and trading internationally a relatively small proportion of its GDP lowers the risk of spillovers slipping out. For small open economies this is more complex: on the one hand spillovers may easily spill out of the country, and benefit external firms and consumers rather than the local economy.[6] Thus, increasing local innovation and R&D may not necessarily result in faster growth for the economy as a whole, even if it does propel the R&D intensive sectors, and benefit the global economy. On the other hand, being small and wide open increases the probability of being the ***recipient*** of spillovers that originate elsewhere: indeed, as Coe and Helpman (1995) have shown, these types of economies tend to benefit the most from international spillovers flows (in relative terms of course), mediated by trade. It is much harder to know what happens on net: to be able to capture these international spillovers the country needs to develop "absorptive capacity" (see Cohen and Levinthal, 1989), which entails *inter alia* investing in local R&D. At the same time, and as said, the locally generated spillovers from this same R&D may end up diffusing away from the local economy.

Any policy designed to promote R&D should pay close attention to this issue, namely, it should not aim just at increasing total R&D, but to do so in a way that incentivizes *local* spillovers rather than external leakages, develops absorptive capacity, and ultimately impacts the productivity of a wide range of sectors in the *local* economy. None of it can be taken for granted in small open economies, certainly not in developing countries.

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[6] "Small" here refers not to the size of GDP per se, but to the relative size of the relevant sectors in the economy, that is, those sectors that could potentially benefit from technological spillovers from innovation. Thus, countries such as Brazil or Indonesia would likely be considered "small" in this respect, whereas Finland or Taiwan would be "large".

4.2 General Purpose Technologies

Technological change contributes to growth wherever it happens, but there are certain technological advances that have played a critical role in fostering growth in the economy as a whole over the long haul. Indeed, in any era there are a handful (or even a single) "General Purpose Technologies" (GPT) that drive growth, by spreading over the different sectors of the economy and prompting them to innovate as well.[7] Progress in the adopting sectors feeds back into the GPT sector, providing incentives for further advances in the GPT itself, and thus setting up a positive, self-sustained loop.

Over the past two decades or so, innovation has commonly been associated with the tremendous technological advances that have taken place in what is loosely referred to as "High Tech", and in particular in Information and Communications Technologies (ICT). Indeed, the advent of the personal computer and the Internet, cell phones, the digitization of words, voice and image in a wide array of existing and newly created media, and above all the inexorable march of Moore's Law, have revolutionized the way by which we produce and consume virtually everything. The preeminent General Purpose Technology (GPT) of our era is undoubtedly ICT, and as such it is enabling and fostering economic growth in developed countries, as well as in many transition and developing countries.

Yet, the way a GPT fosters economy-wide growth is not simply and not mainly by innovation taking place just in the GPT itself; rather, economy-wide growth occurs when a wide and ever expanding range of *other* sectors adopt the advancing GPT, and as a consequence improve their own technology. A telling example is the revolution in retailing brought about by WalMart, primarily via the massive adoption of ICT-based methods; in fact, the gains in productivity of the retailing sector by itself made a sizable contribution to the total productivity growth of the US economy during the second half of the 1990s. The GPT sector itself is bound to be small relative to the economy as a whole, and however fast it innovates and grows in itself, it can never pull on its own the whole

[7] See Bresnahan and Trajtenberg, 1995, and Helpman and Trajtenberg, 1998.

economy (e.g. think of the steam-engine producing sector in the 19th century, or the electricity sector in the first decades of the 20th century). In that sense, the often used analogy of the GPT as a "locomotive" pulling the other sectors is wrong and misleading: if the rest of the economy fails to adopt widely the GPT, or fails to make complementary innovations in the adopting sectors, economy-wide growth will just not materialize.

A key issue then in "secondary countries," that is, in countries that are not at the frontier of the GPT, is how to allocate R&D and other innovative inputs so as to lever the growth potential of the prevalent GPT. What is clear is that just trying to jump into the bandwagon of ICT innovation per se is far from enough, and may not necessarily be the most effective strategy. Again, what needs to happen is that ever expanding segments of the economy adopt ICT in ways that increase ***their*** own productivity. These types of complementary actions (i.e. adoption of ICT, local innovations in traditional sectors, etc.) may well be less "flashy", less overtly "innovative", and therefore may not be deemed as worthy of support or encouragement, and yet these ultimately constitute the key to economy-wide growth.

Still, developing a local ICT industry, joining forces with ICT multinationals, and otherwise encouraging the ICT producing sectors may play an important role in the process of development. This is so both because of the concomitant development of local technological skills, managerial expertise, and world-class standards in ICT, and because such strategies require the wide opening of the economy, which brings in itself inflows of capital, expands trade, etc. In both dimensions then the spillovers of a thriving local ICT sector may play a crucial role in prompting the rest of the economy to follow suit. The point is that this latter stage may not happen by itself (or may take too long), and may therefore require government intervention.

Thus, growth-oriented innovation policies have to proceed from a far wider perspective than just promoting the ICT sector per se, and GPTs may well provide the guiding conceptual framework for that purpose. To repeat, the key point is not that ICT in and of itself "causes" growth, but rather that "innovational complementarities" in the adopting sectors ought to materialize for economy-wide growth to take place. The development of the ICT sector itself may be in some cases an effective stepping stone, but by no means the final destination. In fact, the recalcitrant problem may lie in eliciting adoption and innovation, not in ICT-producers but in those that could benefit from its use (see e.g. Jorgenson and Vu, 2005).

4.3 Exports- vs. local markets-oriented innovation

The discussion above of "high tech" versus the rest of the economy already touched upon the issue of export-oriented innovations versus innovations aimed primarily at local markets; the two issues are connected and yet the latter is conceptually distinct and deserves further scrutiny. Widely held perceptions have it that in the era of globalization there is not such a thing as "local needs" or "local markets", particularly not in innovative technologies, but rather that virtually all relevant markets are global, and hence local innovators should aim at serving global demand rather than local niches. There is no denying of course that the ICT sector is preeminently global both in inputs and outputs, and that the extent of global specialization and cost arbitrage is increasing over time, leading to further productivity gains and faster innovation. To repeat, linking up with this vast, enormously complex and extremely dynamic technological web is for many countries a worthy policy goal. However, this does not imply that locally-oriented innovation is not desirable, and even critical for growth.

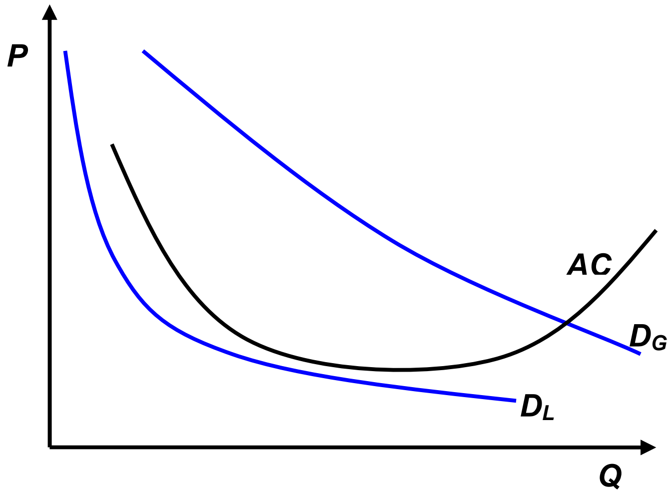
To begin with, globalization does not imply homogenous demands, to be served by uniform products and services. Quite to the contrary, there is increased recognition of the inherent heterogeneity of preferences (and of "needs", even if this notion is ill defined in textbook economics) within specific markets, and of the vast opportunities both to increase consumer surplus and profits by catering to this heterogeneity. In fact, advances in ICT and in the Internet in particular are often heralded as providing the means for such "mass customization", that is, for tailoring products and services to the specific preferences of individuals, without sacrificing scale economies.

What is true for markets *within* (advanced) countries surely holds *across* markets, across countries, across the development divide. That is, the needs to be served in developing countries differ from those of developed countries in a wide array of markets, and in some areas they may be radically different. Therefore, there is not such a thing as just one way of going about R&D and innovation, namely, plugging into the global network of high tech, in order to supply the demand emanating mostly from developed countries. Rather, there are vast areas of economic activity where innovation is needed to serve ***local*** needs, ***local*** demand, whereby "local" may mean a large fraction of the world population.

A few examples illustrate this point: In the area of health care, the incidence of diseases in less developed countries differs significantly from the western world, with the prime example being the prevalence of tropical diseases (e.g. malaria, parasites, yellow fever, etc.). Moreover, given the dearth of access to medical care, often even to elementary medicine, less developed countries require first and foremost innovative ways of delivering simple, cheap, easily administrated preventive medicine. Innovation in sophisticated technologies (e.g. fMRI, stents, "orphan" drugs for rare diseases, etc.) are virtually irrelevant for those countries, and in some cases may end up having the wrong unintended consequences (such as the widespread use of ultrasound in India to select male newborns).

In the context of ICT, and software in particular, what less developed countries typically need is not more features in already highly complex and cluttered software packages, but rather simplicity of operation, "sturdiness", and backward compatibility, so that barely literate workers could use the software in a reliable fashion, and use older versions as well. The same applies to computers and computer-based tools. Likewise, one could think of innovations aimed at improving and reducing the costs of satellite based broadband to deliver Internet services to farmers in isolated villages, and search engines tailored to their prime needs, e.g. having real time information on prices of crops and of agricultural inputs.

It could be argued that if it were profitable to invest in innovation oriented towards local needs, then market forces would lead to it, and therefore there is no reason for concern. The following diagram exemplifies why that may not be the case:



$\boldsymbol{D_G}$ denotes the demand emanating from high income countries (the "global" demand), whereas $\boldsymbol{D_L}$ stands for the local demand; ***AC*** is the average cost curve facing local entrepreneurs, which shape is driven by a fixed cost of innovating, assumed here to be the same both for innovations geared to local and to global markets. Absent intervention the local entrepreneur will surely develop an innovation to serve the global demand, since doing so would result in positive profits, whereas as things stand serving the local market would not even cover the fixed cost. Is it optimal then to leave it at that? Not necessarily: a small R&D subsidy may tip the balance and make it profitable to innovate for the local market, and the local surplus generated may be significantly larger than the subsidy. Recall that the "global" consumer surplus (under the $\boldsymbol{D_G}$ demand curve) is irrelevant from the standpoint of the local economy, only the profits count, whereas if serving the local demand *both consumer and producer surplus* should count equally. In particular, the social gains of serving the local market in terms of consumer surplus may be very large, as is likely to be the case in the area of medical care (e.g. developing a malaria vaccine). Moreover, local spillovers may be in some cases more significant and more widespread if innovating for the local market, if only because of demonstration effects, but that remains of course to be established empirically.

4. Success in innovation, elusive growth: the case of Israel[8]

The development of an innovative and highly successful Information and Communications Technology (ICT) sector in Israel constitutes an interesting case that exemplifies both the potential and the limitations of a "High Tech" strategy as a lever for economic growth. Let us start with a brief recount of the background factors that led to the design of far-sighted innovation policies and to the ensuing emergence of the High Tech sector. After two decades of extraordinarily rapid growth, the Israeli economy had reached an impasse by the early 1970s: the big waves of immigration had subsidized, and the economy had outgrown the centralist mold that worked so well initially. Israel had little natural resources, but plenty of highly skilled manpower, as well as scientific and technological prowess, and hence the question was how to mobilize these assets for economic growth. It is important to point out that at that time the by now commonplace notions of "High Tech", "Knowledge Economy" and the like were not part of the lexicon, and economists were still a long way from appreciating the centrality of innovation and R&D as mechanisms for ***endogenous*** growth. The Israeli government made then a crucial strategic decision: to jump start and breed a "science-based" sector, by providing broad financial support for commercial R&D and making up for market failures.

5.1 Innovation policies in Israel

From the start the hallmark of Government policy in this realm was "neutrality", meaning that the government does not "pick winners", does not decide which sectors, firms or technologies to support, but rather responds to market demand and signals. This

[8] For background on innovation in Israel see Trajtenberg (2001) and (2002).

proved to be a crucial feature that surely played an important role in ensuring the long term success of the strategy. Another defining characteristic of Israel's innovation policy has been its dynamism: new and varied programs have been created in response to changing needs, and existing programs are constantly fine-tuned in light of market developments. The key instrument is the matching grants program, administered by the Office of the Chief Scientist (OCS) at the Ministry of Industry and Trade, which is the main government body in charge of innovation policy. Firms submit proposals for R&D projects, which the OCS reviews according to set criteria that include technological and commercial feasibility and merit as well as risks, and also the extent to which these projects can be expected to generate spillovers.[9] Projects that qualify receive a grant (or rather a conditional loan) of up to 50% of R&D costs; if the project succeeds the recipient pays back the grant in installments defined as a fixed percentage of sales of the product stemming out of the R&D project (about 3% of sales per year).

In the early 1990s a series of novel programs were set up, of which the most important were the "Magnet" industry-academy consortia program, the "incubators" program, and the "Yozma" program jump-starting the venture capital sector. The "Magnet" Program, instituted in 1993, supports the formation of consortia made of industrial firms and academic institutions in order to develop ***generic, pre-competitive*** technologies. These consortia are entitled to multi-year R&D support (usually 3 to 5 years), consisting of grants of 2/3 of the total approved R&D budget, with no repayment requirement. The consortia must be comprised of the widest possible group of industrial members operating in the field, together with Israeli academic institutions doing research in scientific areas relevant to the technological goals of the consortia. Current consortia include nano functional materials, streaming media messaging, and digital printing.

Incubators are meant to provide fledgling entrepreneurs with the basic means required at the very early stages, in order to develop their innovative ideas and set up new businesses, including financial support, physical installations, and advisory services. The

[9] Spillovers became an explicit criterion only recently, following a rewriting of the R&D Law.

program was introduced in the early 1990s, when immigration from the former Soviet Union had reached its peak. Many of these immigrants were scientists and skilled professionals that had plenty of ideas for innovative products, but were lacking in virtually all other dimensions required for commercial success, from knowledge of commercial practices in western economies, to managerial skills and access to capital. The premise is that the technological incubator would significantly enhance the entrepreneur's prospects of raising further capital, finding strategic partners, and thus emerge from the incubator with businesses that can stand on their own. Even though it originally targeted new immigrants, the program is open to all.

From the start, government support to R&D was meant not only to incentivize innovative activities, but also to compensate for the lack of well-developed capital markets. With few exceptions, the high tech sector could not rely on local sources of finance and, given the impediments at the time, for the most part could not raise capital abroad either. Thus, the R&D subsidies provided by the OCS fulfilled also an acute ***financial*** need, but they could hardly make up for the dearth of other financial sources. In addition, Israeli high tech firms were traditionally strong in technology but lacking in managerial expertise and competencies. Recognizing these needs, the government decoded to establish in 1992 the "Yozma" program,[10] which was meant to jump-start the venture capital market in Israel. Yozma established a number of venture capital funds, that were initially funded by the government but that included also local and foreign private investors. The "carrot" offered to the latter was the issuing of options to buy Yozma's shares in these funds in 5 years time at a predetermined price. Yozma managed to attract prominent foreign multinational investors (the likes of Advent of Boston, GAN of France, Daimler-Benz of Germany, the China Venture Management of Taiwan, etc.), which brought along not only their financial resources but most importantly their expertise. Shortly after its establishment, Yozma managed to set up 10 venture capital funds and helped raise close to $200 million.

[10] "Yozma" means "initiative" in Hebrew.

Contrary to other government programs, Yozma had at inception a fixed life expectancy of 7 years. In fact, though, its rapid success allowed it to terminate its activities early on: in 1997 its direct investment portfolio was privatized, and thus its mission came to an end. Since then the venture capital market in Israel has boomed, with over 80 funds in operation, having raised close to $10 billion during the period 1993-2000, with actual VC-backed investments reaching a high of 2.7% of GDP in 2000 (a world record – see Avnimelech and Teubal, 2005). In addition, capital markets have greatly expanded in Israel since the mid 1990s, and international access has improved dramatically; for example, Israel is the foreign country with the largest number of IPOs in Nasdaq (closely contested by Canada). This burst of funding sources imply that government support to R&D can confine itself to its original role of subsidizing innovation in order to bridge the gap between the social and the private rate of return, without having to take on a further financial role.

5.2 Outcomes

These policies, together with other contributing factors (such as the training of young cadres of ICT specialists by the defense sector, the immigration from the former Soviet Union, etc.) managed to unleash the potential embedded in Israel's abundant human capital. The following facts and figures summarize the staggering development of High Tech in Israel since the early 1990s:

- The ICT sector grew during the decade of the 1990s at an average rate of 16% per year, jumping from 5% of GDP in 1990 to 14% in 2000, and contributing a full 1/3 of the growth of GDP.
- ICT exports grew over the 1990s by a factor of ***6***, reaching $15 billion by 2000, and accounting for 1/3 of total exports.
- The Venture Capital sector became the 2nd largest in the world after that of the US.
- Israel stands internationally as number 4 in terms of number of patents per capita granted by the US Patent Office to Israeli inventors, after the US, Japan, and Taiwan.

- Israeli original innovations include major breakthroughs such as ICQ, the disk-on-key, cardiac stents, a camera/pill for gastro imaging, shopping.com, etc.
- The R&D/GDP ratio reached a high of ***4.6%*** in 2004, the world highest; the number of high-tech companies is estimated at 4,000.

For all the staggering success of the ICT sector, the rest of the economy experienced very sluggish growth during the same period and beyond; thus, in recent years (1996-2004) the ICT sector grew at an annual rate of 10.5%, whereas the rest of the economy grew at just 2.3%. Furthermore, and as can be seen in Table 1, in many sectors total factor productivity actually *declined*. The gap between ICT and the rest manifested itself also in increasing socio-economic inequality, and in fact the overall picture that emerges is that of a "dual-economy." This is of course problematic from a normative viewpoint, but moreover, a "dual economy" may affect the growth potential of the economy, by restricting the future pool of skilled labor, and otherwise creating frictions and tensions that are detrimental to growth.

Table 1
Growth of Total Factor Productivity in Israel
Selected sectors, average annual rates, 1996 - 2004

Manufacturing	0.4
Transportation	-0.4
Construction	-2.0
Retailing and business services	-3.3
Average for the business sector	***-0.8***

Source: Bank of Israel Annual Reports

5.3 Accounting for the gap

Why this gap? Why the dual-economy? This is a key question not just for the specific case of Israel but also to understand the limitations of narrowly targeted innovation policies. A whole range of factors surely impinge on the wide disparity between the performance of the High Tech sector and the remaining 85% of the Israeli economy; here though I shall focus just on those that are of particular relevance for the issue at hand. First, despite the overt and formal neutrality of the R&D policies, in fact support was given almost exclusively to ***product*** innovations rather than to ***process*** innovations, which implied also a sectoral (unintended) bias, favoring ICT. Indeed, 79% of Industrial R&D in Israel goes to ICT, whereas the average for OECD countries is just 21%. Process-based sectors such as chemicals and many of the service-based sectors shied away from seeking R&D support,[11] and hence invested little in innovation and remained technologically laggard.

The second pertinent factor is that most industrial R&D was aimed at exports,[12] and hence the ensuing innovations had little if any impact on the rest of the Israeli economy. As already suggested in section 4.3, the innovations developed locally were designed from the outset to serve markets abroad, according to the needs and specifications of users there, and hence they may have increased productivity and/or consumer surplus in the ***importing*** countries (if only marginally) rather than in Israel. Surely some of these innovations served also Israeli users, but that was just incidental and not a prime effect. As to the profits accruing to the exporting innovators, these typically capture just a fraction of the benefits that their innovations bestow on users, particularly in the global, highly competitive markets in which they operate. In other words, spillovers from inventors to users flow mostly out of the country, without benefiting much the rest of the economy. The geographical proximity of a local booming ICT sector seemed to have mattered little for the non-ICT sectors in Israel, both because the innovations generated by the former were not tailored for or aimed at the latter, and moreover, because the two types of sectors did not engage in the type of dynamic interaction associated with "innovational complementarities" (as discussed in the context of GPTs). The presence of a local, innovative ICT sector surely mattered in terms of contributing to the available pool of highly skilled workers (in ICT), that could then be

[11] There was no explicit exclusion of these sectors, but as suggested the equilibrium that emerged was such that it de facto favored electronics, communications, computerized equipment, and the like, and not processes-based sectors.
[12] In fact the R&D Law of 1984 explicitly favored export-oriented R&D projects.

employed in the non-ICT economy. This sort of spillover should not be underestimated, but the fact is that, lacking its own innovative drive, the TFP of non-ICT sectors exhibited a poor record at the same time as ICT flourished.[13]

The third factor is that a tangible fraction of industrial R&D in Israel is done by local labs of multinationals corporations, such as Intel, Motorola, IBM, National Semiconductors, etc.[14] The knowledge generated by these labs goes of course to serve the global needs of the parent companies, and have little relevance for the Israeli economy as such. The Centrino chip which now powers most laptops in the world was developed by Intel's R&D lab in Haifa, Israel; it was widely regarded at the time as a crowning technological achievement, and yet virtually none of the benefits that the chip confers to Intel or to the final users flow back to the local economy.[15] Furthermore, the fact that these labs draw highly skilled workers from a limited labor pool means that their salaries go up, potentially hurting other (local) Israeli High Tech firms.[16] There are countervailing effects as well: the experience gained by the R&D personnel may well transfer to other firms via mobility of workers, and the same goes for managerial expertise. The presence of flagship labs of mainstay multinationals surely enhances the overall reputation of Israel's High Tech sector, it signals its perceived capabilities as well as the confidence of the likes of Intel, and it thus contributes to attract investment (at times by the same multinationals) and to open up global markets. It is very hard to assess the net effect of these factors, but the point to emphasize is that the impact of a given innovation on the local economy depends in large measure on who owns the IP generated, where does it flow to, what sort of lateral connections are there, etc. and not just on the geographical location of the R&D lab.

[13] Much more empirical research is needed though to shed light on this set of issues.
[14] The R&D done by these labs account for about 15% of business-sector R&D, and hence for ~ 0.5% (half a percent) of GDP.
[15] In some cases though the multinational has a large operation in Israel, with "lateral" connections between the different parts of the operation (e.g. R&D and manufacturing) so that local spillovers are much more likely to occur.
[16] The extent of this effect depends of course upon the labor supply elasticity; in the late 1990s for example it proved to be quite inelastic, with overall increases in R&D spending by the business sector causing more of spiraling rise in salaries rather than an increase in the amount of real R&D performed.

Finally, the massive involvement of venture capital funds raises some troubling questions about the final destination and economic impact of local innovations. The modus operandi of VCs is such that they have to exit after 5 – 7 years, which in the case of Israeli-backed startups means, more often than not, selling off to US companies. In some cases local operations continue, in others most if not all of the activity is transferred abroad as well. Thus, and once again, the knowledge assets generated locally by Israeli inventors often end up contributing to the development and profitability of foreign firms, rather than to the growth of the Israeli economy. The later would be the case if those same startups were to keep growing organically in Israel, perhaps acquiring other companies themselves, or sell off/merge with other Israeli companies. The point is that the mode of financing may affect the final destination and hence economic impact of the innovations. Surely VCs are much more than just a way of financing high risk new ventures: they provide expert screening, global connections, managerial expertise, etc. However, in a small open economy these come at a price, i.e. a higher probability that the knowledge generated will be of little direct consequence for the local economy, save spillovers. Note that this is to a large extent dependent upon the size of the economy: the larger and more advanced the local economy, the higher the chances of local exits.

To sum up, R&D in Israel has been heavily concentrated in ICT, and in product rather than process innovations, implying that most of the Israeli economy has not engaged in innovation, even though its High Tech sector is remarkably advanced. Furthermore, the fact that innovations in Israel are aimed for the most part at exports, that a significant fraction of the R&D is performed by multinational labs, and that over 40% of startups are financed by VCs, mean that a great deal of the benefits from those innovations flow to firms and users abroad, rather than to the local economy. Indeed, there is a glaring disconnect between the fact that Israel spends 4.6% of GDP on R&D, which does in fact generate a vast amount of cutting-edge innovations, and the snail-pace growth of the non-High Tech economy. Somehow along the way the potential benefits of this innovation-based strategy are partly dissipated, and fail to reach most of the sectors in the local economy and most of the population. This is then a cautionary tale of the limitations of even the most successful innovation strategy: in a global economy such strategies should address not only the generation of knowledge but also its destination and ultimate economic impact.

5. Spillovers in developing economies

The discussion in section 3 singled out the existence of spillovers as the foremost rationale for government intervention in fostering innovation. However, I referred there just to the commonly held conception of spillovers, that is, technological externalities from one inventor to another, and from inventors to consumers. The intention here is to widen the notion of spillovers and explore it in more detail, emphasizing those aspects that are particularly relevant for developing economies: post-innovation competition within markets, and demonstration effects in the diffusion of innovations.

6.1 Post-innovation competition

Once an entrepreneur breaks the mold of an otherwise static market and introduces an innovation, her rivals will typically be forced to respond in kind, that is, by innovating as well. Thus, post-innovation competition may play a significant role in triggering further innovation, and in that sense should be part and parcel of an expanded view of spillovers.[17] Whether a market is dominated by a tight oligopoly, or characterized by cut-throat price competition, innovation often provides the only viable strategy for new entrants or aspiring small firms striving to grow or to improve profitability. If an entrepreneur does succeed in innovating in an otherwise static market, such action is very likely to trigger a response from her competitors that involves innovation on their side as well. That is, maverick innovators may elicit a competitive response that entails a process of “spiraling innovations” in the market, which benefits go far beyond those that accrue to the originating entrepreneur, and hence fall under the umbrella of spillovers.

[17] Notice that I am not referring here to the well known question of the relationship between the extent of competition in the market and the *ex ante* incentives to innovate – the so-called "Schumpeterian hypothesis" – but to the ex post, competitive response to innovation.

Markets in developing countries tend to be both highly concentrated and technologically stagnant, and for the most part do not exhibit Schumpeterian "gales of creative destruction." Contrary to the requirements of competitive markets in the ***static*** sense (i.e. numerous enough producers and consumers), a ***single*** innovator may trigger a dynamic process by which rivals, however entrenched they might have been to begin with, need to innovate as well in order to survive the fierce competition that ensues. Thus a well defined goal for innovation policy in developing countries is to encourage first-time innovators in static markets, and prevent old time dominant firms from denying them a foothold (often by borderline illegal means).

6.2 Demonstration effects in the diffusion of innovations

"Demonstration effects" in the diffusion of innovations is a catch-all label for the well documented fact that early adopters positively impact the decisions of later adopters, and hence their actions entail a spillover. Indeed, as the extensive literature shows, diffusion processes are typically slow and involve externalities from present to would-be adopters (see e.g. Griliches, 1957, Mansfield, 1968). These may take the form of network externalities,[18] informational effects (e.g. word-of-mouth, learning from the experience of others), as well as other factors such as emulation, conforming to (changing) norms, etc. Adopting a new product or process entails an innovative act by the adopter herself: whether the just adopted innovation consists of mechanized equipment in agriculture or of e-commerce in book retailing, the mere acquisition of the innovative input is but the first step in a sequence that typically involves a range of complementary investments. To repeat, each adopter is to be seen as an innovator herself, and therefore the fact that each unwittingly induces others to adopt as well certainly constitutes a spillover, that may be as important as the more traditional form of purely technological spillovers.

In an extensive cross-country study, Comin and Habijn (2005) found that the diffusion of innovations is significantly slower in countries at earlier stages of

[18] Such as complementary developments that are triggered by the initial adopters (e.g. the emergence of repair services for new computers or cell phones; a wide variety of software for new hardware, etc.), or direct externalities in the sense that the number of adopters (i.e. the size of the network) directly affects the utility of a new adopter, e.g. the number of fax machine users.

development, both in terms of income and of human capital. Thus, it may be justified in those countries to support early adopters of new technologies (particularly those that can potentially enhance productivity in a wide range of sectors), since in so doing widespread adoption is accelerated, and with it the benefits of the innovation are brought forward.

6.3 Emulation and positive-sum norms in historical perspective

There is yet another, more general aspect of "demonstration effects", and that is early innovators providing a new role model for entrepreneurial individuals to emulate, and thus paving the way for a shift from zero-sum to positive-sum type of norms and institutions. As Joel Mokyr (2003) has forcefully argued, up to the 17th century Europe was characterized by and large by rent-seeking behavior, supported by the fragmentation of society into rent-extracting institutions such as guilds, and semi-autonomous regions (hence internal tariffs), etc. In such environment entrepreneurial individuals found it most profitable to devote their inventiveness and creativity to perfecting rent seeking activities, which were of course detrimental for growth. Thus they sought to strengthen barriers to entry (into guilds, local markets, etc.), impede mobility, increase taxation, and the like. The intellectual revolution brought about by the Enlightenment sought to free society from these shackles, and promote instead openness, of ideas as much as of trade. The important point is that once the prevailing norms, substantiated by vivid examples, shifted towards positive-sum type of accepted behaviors, and once institutions changed accordingly, productivity-enhancing innovations became powerful attractors, displacing innovativeness in rent extraction. This was, according to Mokyr, a fundamental precondition for the Industrial Revolution to unfold.

In this sense the Enlightenment has yet to take hold in many developing countries, where rent seeking is still the predominant norm. Why invest in developing uncertain and costly new technologies or in improving production processes, if ingenuity can bring higher returns by further exploiting the system? The traits that typically define an entrepreneur can become very handy for engaging in rent extraction as well (often bordering on corruption), and surely will be deployed there rather than in innovation, if simple cost-benefit considerations so indicate. Changing such basic, deeply rooted patterns is extremely difficult, but not impossible. Demonstration effects can help a great deal: what is needed is the emergence of a local Thomas Edison, a local Steven Jobs, i.e. highly successful innovators that may serve as models to emulate. Skilled, young, aspiring would-be innovators need to convince themselves that coming up with better products and production processes may be as promising a route to upward mobility and to economic success as tricking the system.

There are of course innumerable obstacles to overcome on the way to legit innovation, since those that have a stake in the prevailing regime of tight control over markets would do their outmost to keep it that way. On the other hand, the more zealously players cling to the zero-sum, rent extraction mold, the wider the disparity between it and more efficient technologies, products, and market configurations, and hence the more attractive the legit innovation alternative becomes. Indeed, one of the benefits of openness (in the flow of ideas and knowledge) is that the tensions between obviously inefficient and efficient economic patterns cannot be hidden. Thus, policies that help inventors, market pioneers and early adopters succeed, in spite of the efforts to the contrary of stakeholders, may have wide ripple effects and benefits, far beyond those stemming from the original innovation itself. In particular, the government should aim at dismantling the web of regulations that often afflict markets in developing countries, and that constitute "barriers to innovation", very much as the traditional "barriers to entry" impede competition in the static sense.

6. Policy instruments

The discussion so far offers as corollaries a few principles that should guide the design of innovation policies in developing countries:[19]

- Innovation should be ***widely distributed*** over the whole spectrum of economic activity, that is, across sectors (not just "high tech"), and type of innovations (not just formal R&D projects).

[19] This is of course not an all-inclusive list, but rather it includes those principles that I regard as particularly important for policy making.

- Policies should be ***bottom up*** and not top down: the point is to provide the enabling conditions and to strengthen the incentives, but growth-enhancing innovation should spring from ever widening cohorts of aspiring, would-be entrepreneurs / inventors.

- Policies should alter the balance between innovations aim at ***rent creation*** versus ingenuity in ***rent extraction***; it is often more feasible to do so by enhancing the former than by penalizing the latter.

There are many ways by which those principles may be implemented; here I wish to focus on the following four areas, which may provide key levers for policy: ***skills, incentives, access to information, and availability of finance***.

7.1 Skills

The wide availability of skills is of course a basic precondition for any innovation-based growth strategy to succeed: basic skills are necessary for innovative ideas to arise in the first place, advanced skills are required for would-be innovators to be able to search for and absorb the necessary information, and yet more sophisticated skills are typically called for in order for inventors to be able to tackle the technological and business-related problems that stand along the way. Skills in this context thus refer to a wide spectrum of capabilities, to be acquired both through formal education, and through learning by doing. They range from basic literacy to advanced science and technology (S&T), and include also managerial abilities, business acumen and computer skills. Many of these should arise endogenously, that is, once innovation gets going the demand for skills increases, presumably prompting more individuals to acquire them, and there is more room for learning by doing. What is important for policy in this respect is a two-pronged strategy, consisting of the supply of the traditional public good-type of education and skill formation on the one hand, and ensuring the responsiveness of vocational and advanced skills supply on the other hand.

The first and foremost policy goal in this respect is of course the provision of universal access to literacy and basic math, and also the rudiments of English and of computer literacy. The later two are essential as a gateway to ICTs and to global markets, which sooner or later need to be accessed for innovation to succeed. Furthermore, this baseline education should be periodically revised and upgraded in response to a changing environment, particularly if innovation becomes widespread. That is, success in triggering innovation requires continuous, concomitant changes in the institutions supplying human capital, otherwise these will soon turn into bottlenecks holding down further innovation. The initial conditions of many developing countries are far removed from the baseline alluded to here, and therefore they should seek creative ways of short-circuiting the process of providing for it. One generic approach is to rely increasingly on ICT to impart basic skills, through e.g. distant learning, internet-mediated short courses, etc. There is plenty pf room for innovation also in this sense, and indeed in some countries such as India (which suffers from high rates of illiteracy), this may be a highly promising route.

The second aspect of the strategy is to make sure that endogeneity kicks in, i.e., that the institutions and markets responsible for the supply of skills respond indeed to changes in demand. In particular, vocational schools, training programs, colleges and universities should be made highly responsive to shifts in the demand for skills. This is by no means to be taken for granted, and in fact in many cases the educational system is isolated from the (changing) demands of the economy, and prides itself in being so. While some of it should indeed operate according to its own norms (such as basic scientific research), most of the system should not only adapt and respond to demand shifts (e.g. train more computer programmers, less mechanics), but even anticipate and stay ahead of the changes. Rosenberg and Nelson (1994) have extensively documented the very important role that Universities played in fostering innovation in the US since the early 20th century, as opposed to their European counterparts – a disparity that continues, if slightly diminished, to this day. The key is the high responsiveness of US Universities to the technological and scientific needs of industry, a classic example being the fact that shortly after the invention of the transistor in 1948, MIT and Stanford were offering courses in solid state physics, taught not by resident professors but by outside adjunct faculty coming from industry, whereas in Europe it took years for such courses to be introduced.

7.2 Incentives

Behind any innovation, be it the most trivial or the most sophisticated, there is of course an innovator that discerns the problem to be solved, envisions the innovative solution, and carries it through its initial stages. These activities are costly, often very much so, and hence entrepreneurial individuals would engage in them only in so far as they foresee that the expected rewards from the innovation would be significantly larger than those upfront costs.[20] Thus, incentives in this context refer to the extent to which potential inventors can anticipate sufficiently high rewards. A traditional aspect of this issue is the availability of suitable mechanisms of appropriability, such as effective patents and other means of protecting intellectual property. This is surely a highly relevant issue for developing countries, not for the reasons typically alluded to by developed countries (i.e. that ***their*** IP is not properly protected) but rather because weak local IP regimes may discourage ***local*** inventors. I am not going to dwell on IP since that would take us far a field, but rather focus on other aspects of incentives.

In particular, the question is whether potential inventors can expect to be properly rewarded, given the nature of institutions in which they operate. As said before, innovation in developed countries has been historically very widely distributed, which means that innovators came from all sorts of occupations, ranks and sectors. For that to happen would-be innovators within enterprises, whatever their rank, should either have a stake in the success of the company and/or foresee internal upward mobility. Furthermore, labor markets should be very fluid, in the sense of offering opportunities of mobility ***across*** firms, sectors, and geographical area. Likewise, as previously argued, "barriers to innovation" within markets should be low, both in the sense of officially

[20] The reason to expect what Schumpeter called "extraordinary" rewards is simply to compensate for the high risk that usually accompanies innovations.

sanctioned regulations and tacit collusion. Lastly, the alternative course of tinkering with rent extraction mechanisms should be made less attractive.

Incentives for innovation in less developed countries thus mean first and foremost promoting policies of ***inclusion*** and ***openness***. If workers in the production line of traditional manufacturing as much as in software design do not have a stake in the results of their efforts, or if avenues of internal or external mobility are foreclosed for them, they can hardly be expected to unleash their creativity to enhance productivity. Policies to improve incentives in this sense are difficult to articulate, let alone implement: first, such policies are likely to run into stiff opposition from those that benefit from the inertia and stagnation of the system, and second, by definition these policies should provide incentives not for what is currently done (which is observable), but for what ***could*** be done, which is typically ill defined and unobservable (such as potential mobility), and hence much more difficult to mold and codify.

R&D labs in large, well established enterprises are well aware of these issues, and typically handle them well, as reflected in the incentives provided for in the contracts with their scientists and technicians. However, that is only part of the story, and in developing countries a rather small part of it: R&D labs can be expected to spring up only within a small number of enterprises within yet fewer sectors, whereas innovation as envisioned here should be much more generalized and pervasive, touching virtually every corner of economic activity. It is possible that labor markets, organizational structures, promotion practices, and related institutional molds will eventually react endogenously to an upsurge of innovations, making adaptive changes. However, initial conditions matter, endogeneity in this sense cannot be taken for granted, and hence it is the role of the government to give the initial push to such changes.

7.3 Access to information

Access to knowledge stocks and to up-to-date information flows is a necessary condition for there to be innovation, primarily access to information about technology, and about markets for inputs and outputs. Consider for example a potential innovation that entails enhancing the functionality of a product, such as increasing the ruggedness of a bicycle for countries devoid of paved streets. Would-be innovators need to understand the wider technological context (e.g. the physical properties of various materials, including their durability), the relationship between design and manufacturing requirements and materials used (e.g. cannot use very heavy metals even if more durable, and likewise for materials that are not sufficiently malleable), and other such issues. They need also know what is "best practice" in those dimensions, both in bicycle design and manufacturing and in other, unrelated products whereby similar issues may arise (e.g. golf clubs or car seats). In fact, innovation often comes from "recombination of ideas" as Weitzman (1998) has convincingly argued, and hence knowledge of a wide variety of both immediately related as well as of "distant" issues is extremely important.

Intimate knowledge of the market for the (improved) product is required as well for the innovation to have reasonable chances of commercial (and not just technological) success. This entails gathering information on the market for existing close substitutes, and for forming estimates of market size for the new/improved product. The innovator needs also to gather information on prices and availability of inputs, typically covering a wide range of alternatives that may affect profitability, and to assess future competition, both local and international, that may arise as a consequence of the innovation.

Access to such wide range of information is thus key for inventors to be able to formulate and work out their innovations, and yet it may elude big segments of the population of potential inventors. There is a great deal that can be done policy wise to increase access, including encouraging knowledge intermediaries, promoting competition and openness in various kinds of media, developing channels for continuing education at various levels, making sure that data on markets are widely publicized, etc. Providing for Internet access to the population at large is perhaps one of the most effective means of securing widespread access to relevant information. However, that goes beyond deploying a fiber optics network, having access to PCs and to ISPs: users need to be taught rudimentary computer skills, as well as search techniques. Moreover, and as said before, basic working knowledge of English may be sine qua non.

7.4 Availability of finance

As already discussed, one of the economic features of knowledge creation is that it entails information asymmetries that lead to a funding gap. In developing countries this problem is gravely compounded by the fact that capital markets are typically not well developed, and in particular by the dearth of funding for small enterprises and individual entrepreneurs. The inherent risks associated with innovative projects, the absence of collaterals for such projects (as opposed say to investment in physical capital, equipment or structures), and the lack of expertise to screen them make it extremely hard for inventors to secure the necessary financial resources. Providing with such funding is then a preeminent role for the Government to play in the context of virtually any plausible innovation policy. The question is how to structure financial support so as provide strong incentives to inventors, while at the same time avoid the ills of corruption on the one hand, and of moral hazard (of inventors) on the other hand. These difficulties notwithstanding, this is an area where there exists a great deal of accumulated cross-country experience, which can be tapped in order to design sensible policies and support programs.[21]

[21] I shall not expand on this extensive topic here - see Goldberg, Jaffe and Trajtenberg, forthcoming (2005).

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The main emphasis in the professional activity of the Samuel Neaman Institute is in the interface between science, technology, economy and society. Therefore the natural location for the Institute is at the Technion, which is the leading technological university in Israel, covering all the areas of science and engineering. This multi-disciplinary research activity is more important today than ever before, since science and technology are the driving forces for growth and economic prosperity, and they have a significant influence on the quality of life and a variety of social aspects.

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The initiative for establishing this Institute in Israel was undertaken by Mr. Samuel Neaman. He nurtured the concept to fruition with an agreement signed in 1975 between himself, the Noon Foundation, the American Society for Technion, and Technion. It was ratified in 1978 by the Senate of the Technion. Mr. Neaman, a prominent U.S. businessman noted for his insightful managerial concepts and innovative thinking, as well as for his success in bringing struggling enterprises to positions of fiscal and marketing strength, devoted his time to the activities of the Institute, until he passed away in 2002.

Organization

The Director of the Samuel Neaman Institute, appointed jointly by the President of the Technion and by the Chairman of the Institute Board, is responsible for formulating and coordinating policies, recommending projects and appointing staff. The current Director is Professor Nadav Liron. The Institute Board of directors is chaired by Prof. Zehev Tadmor. The Board is responsible for general supervision of the Institute, including overall policy, approval of research programs and overseeing financial affairs. An Advisory Council made up of members of the Technion Senate and distinguished public representatives, reviews research proposals and consults on program development.

Manuel Trajtenberg is a Professor of Economics at Tel Aviv University, Research Associate of the NBER and of the CEPR, and has been just asked by Israel's Prime Minister to set up the ***"National Council for the Economy and Society"*** at the Prime Minister Office, and serve as first Head of the Council. He obtained his Ph.D. at Harvard University, and held visiting positions at Harvard and Stanford Universities. His main research interests are in the economics of innovation, patents, industrial organization, R&D policy, and development. He is also the Head of the *Science, Technology and the Economy* (STE) Program at the Neaman Institute for Advanced Studies, Technion, and director of a program on the *Economics of Higher Education*. He has been a member of the Directorate for the Support of Generic Technologies at the Ministry of Industry and Trade, Israel, and serves as advisor to policy makers in this area. Prof. Trajtenberg serves also as a consultant for the World Bank on *R&D and Innovation Policies for Development*.

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