Government Policy for Innovation in Latin America

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Abstract

A review of various innovation indicators for the Latin American and Carribbean countries suggests that these countries are underperforming in a number of dimensions when compared to others with similar levels of GDP per capita, especially in the area of business R&D and the contribution of universities and public research institutions to business innovation. The paper presents the arguments for government intervention in this area and reviews the available policy instruments such as tax credits and subsidies, drawing to some extent on the successful experience of the East Asian Tigers. However, the paper concludes that the current global environment may not be as hospitable as the one in which those countries developed due to the requirements of the TRIPS agreement with respect to patent policy.

Keywords: innovation, development, Latin America, R&D policy, patent policy

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1. Introduction

Considerable evidence exists for the proposition that one of the chief determinants of economic growth and catch-up is innovation, especially during the recent past. The intensification of this relationship is one aspect of the well-documented rise of the knowledge economy. Among other studies, see Fagerberg and Verspagen (2003), who examine the factors affecting GDP per capita growth during the past four decades for a wide range of countries at different levels of development. These authors conclude that although such growth has always been related to the development level (including a technology level indicator) in low income economies, during the 1990s the science and technology output of the economy, as measured by patents and publications, has become a more important predictor of growth in low income economies. Hence there is considerable interest on the part of many governments in the choice of policies that might encourage innovation within their economy. For a prominent example, one has only to look at the announced "Lisbon strategy" of the European Union. [3] Among other goals, this strategic initiative has been interpreted to call for increases

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[3] In 2002, the Commission named one of three priority areas as

> "Increasing investment in knowledge to ensure future competitiveness and jobs. The European Union must step up the effort in the areas of research, innovation, education and training, and increase its impact by pursuing a more integrated approach and place these policies under a common banner: a European area of knowledge…" (European Commission 2002).

And in 2004, the goal had scarcely changed:

> "Improving investments in knowledge and networks, by implementing the 'Growth Initiative', all the while giving greater priority to the level and quality of investments in research, education and training;" (European Commission 2004).

in R&D investment in European countries to a level of three per cent of GDP. In Europe as a whole as well as in some individual European countries, this initiative has led to a number of specific policy initiatives intended to encourage both private and public R&D spending (Czarnitzki *et al* 2004; Czarnitzki and Hussinger 2004).

Similarly, the World Bank, along with the more developed Latin American countries such as Argentina, Brazil, and Chile, have begun to look at the innovative performance of Latin America and to wonder how it could be improved by means of government policies (De Ferranti *et al* 2003; Lederman and Maloney 2004: Porter, Furman, and Stern 2000). The evidence presented later in this paper, which is drawn from a number of sources, quantifies and documents the relative underperformance of these countries along several dimensions using a range of innovation measures: business R&D, capital goods investment, patent and scientific output, productivity, and the quality of public research institutions. With the facts in hand, the paper goes on to address the possible policy responses available that might improve innovation performance and ultimately lead to increased productivity and economic growth.

At this point it is useful to define exactly what we mean by innovation, since the word has taken on a number of different meanings when applied to different settings. A good discussion of the issue can be found in Fagerberg (2004), who follows the usual distinction between invention ("the first occurrence of an idea for a new product or process,"), innovation ("the first attempt to carry it out into practice"), and diffusion (the result of "copying it and introducing it in a different context," sometimes called technology transfer). Often the product or process in question is actually a change in the organization of production or the way of doing something rather than a strictly "technological" invention. For the purpose of this paper, which is concerned with policy options for enhancing innovative performance in Latin America, I use the broader concept of innovation, which includes invention, innovation in the narrow sense, and diffusion, that is, the introduction of new products, processes and ways of doing things into Latin America. Because the problem here is to some extent one of catch-up, it is important to include diffusion and technology transfer activities in the definition, in addition to "new to the world" innovative activities (Fagerberg and Godinho 2004).

As a general rule, the exploration of government policies towards innovation needs to answer a sequence of questions: 1) Is there a problem of innovative underperformance for this particular country? 2) What are the reasons for this underperformance? 3) Can and should government policy attempt to address these reasons? 4) Which are the policies that might solve the problems encountered or at least mitigate some of the factors that discourage innovation? In undertaking this analytic task, the policymaker also needs to keep two factors in mind that will limit the immediate effectiveness of any policy: first, innovation typically occurs in an environment determined by a set of institutions, sometimes referred to in the literature as the "national innovation system" (Nelson 1993). Second, changing the system in ways that will encourage the building of a knowledge infrastructure is a long term undertaking. Given the inertia built into most systems of innovation, both factors combine to mean that the best policies are ones that can be sustained over a period of time.

Yet the fact that institutions take time to develop and that changes to them are slow to impact the economy has second consequence that we will return to later in this paper: measuring the impact of such institutions and policies is difficult precisely *because* they change so slowly. A common method is the comparison of a wide range of countries with different policies and institutions, but the concern exists that there are left out factors whose effects may be related to the included variables that describe the innovation settings (and therefore that the impact of the those variables may be overestimated). However, when average country effects are removed, leaving only changes over time in the institutions and policies to identify their effects, we are not likely to have enough information to make our conclusions precise, because of the slowness with which such things as the operation of the intellectual property system or the quality of research institutions change.

This measurement problem is compounded by the fact that there are feedback effects from a country's innovation success to institutional change, both because successful innovators often become an effective force in the body politic and because some of the needed institutions are rather costly public goods that must be provided by the government and therefore require resources to pay for them. An example of the first feedback phenomenon is the fact that the development and expansion of intellectual property systems often takes place after the initial wave of innovation in a country or technology area.[4] An example of the second could be high quality public research institutions, which are in some ways a luxury good for developing countries that have insufficient provision of education at the primary and secondary level. Thus the challenge for innovation policy research has been to find

[4] A number of examples, both contemporary and historical, demonstrate that patenting tends to come about as a result of the creation of a new technological industry, rather than the other way around. See Murmann (2004) on the absence of product patents in the German chemical dye industry during its early development. A contemporary example is US software patenting, which came about rather late in the development of the software industry.

true "instruments" that will let us evaluate the effects of policy changes while controlling for unobserved differences across countries.[5]

In this paper, I review the research on measuring innovative performance and its determinants at the aggregate country level, and then discuss what has been learned about the reasons for Latin America's relatively dismal performance in both economic growth and innovation. Keeping the specifics of the research findings in mind, I then discuss the possible government policy responses that might be available to mitigate some of the shortfalls in various areas of these economies with respect to innovative infrastructure and performance.[6] My review of policy options will focus on those that are specific to R&D and innovation. Nevertheless, because technology-intensive industries reside within and are linked to the entire economy, it will be necessary to at least mention other policy preconditions for successful development in this area. Perhaps the most of important of these, but also one of the most difficult to achieve, is macroeconomic stability. Investment in R&D and innovation are by their nature long term and require continuous rather than intermittent financial support on the part of firms and governments. This fact makes them particularly vulnerable to periods of rapid inflation and instability in the economy, and this fact may discourage firms from undertaking them in the first place. The relevance of this point for the Latin American setting is perhaps obvious.

Section 2 of this paper outlines the case for market failure in innovation and the production and adoption of new technologies. This is followed by a brief review of the evidence on Latin American innovation performance and its shortcomings. The next two sections of the paper summarize the policy instruments that are available to encourage the individual actors in the economy to engage in increased innovative activity and include a discussion of the administrative burdens that they may impose; special attention is paid to the chief policy advocated by those who would prefer to keep active government policy to a minimum, the strengthening of the patent system and intellectual property rights more broadly, a policy that has both costs and benefits to developing countries.

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[5] See Lederman and Maloney (2003) for one such attempt, using past levels of productivity performance and R&D to instrument for current changes.

[6] Throughout this paper I have ignored the effects of the macro-economy per se and the disruptions arising from cyclical effects. This is not to say that they will not be important, especially in Latin American countries in the recent past. It is simply beyond the scope of this investigation and there is room for more research on the relationship of the cycle to long term growth in this setting. See Fishlow (1990) and references therein, as well as the conclusions of Baldwin (2002), which emphasize the role of prudent monetary and fiscal policies along with a stable and non-discriminatory exchange rate system in enhancing growth.

2. Innovation and market failure

To a mainstream economist, arguing for government policy towards a particular market area requires evidence that the market itself will fail to make an appropriate allocation of resources in that area. In the setting considered here that implies that the market should be seen to fail in what Arrow (1962) called "the allocation of resources for invention." In this seminal article, Arrow identified three reasons for market failure in the markets for invention, innovation, and information: 1) indivisibility, which implies that ideas and their implementation are fixed costs, with possibly negative consequences for competition and market structure; 2) inappropriability, or the fact that the production of knowledge tends to generate positive externalities; and 3) uncertainty, coupled with incomplete markets for risk. The last reason is of course a familiar problem for all types of investment, although it does apply with particular force for innovation investment. The arguments of this 1962 paper were grounded very much in the newly developed theory of general equilibrium, in whose development Arrow was a major participant; even if we might view this theory today as too abstract to be a very useful description of a real economy, it remains the foundation of the arguments for *laissez faire* government policy towards the economy. It is therefore important to understand how Arrow's three market failure arguments play out in the case of innovation, in order to assess whether there is a role for government intervention in this area.

The first failure of the assumptions necessary for the welfare theorems, indivisibility, essentially implies increasing returns to innovation investment within the firm, at least over a broad range of output. The chief implication of this fact is that the size of the market matters in encouraging such investments. Firms in a relatively small country or in a country with low average income will therefore inevitably find that they face lower incentives for R&D investment from their domestic markets than their counterparts in large wealthy countries. Alternatively, such firms will benefit from a focus on the world market and exporting, at least in some sectors. To a great extent, this is the policy pursued by the smaller Asian tigers such as Taiwan and Singapore. For example, Hou and Gee (1993) describe how Taiwanese policy evolved from import substitution to export promotion during the early 1960s as it became apparent that the size of the local market could not support industrial growth.

The second failure, inappropriability, is probably the most important argument behind the need for government policy in the innovation area. The argument is familiar: invention and innovation are essentially the creation of the knowledge of how to do something new, and once created, such knowledge is free for others to use. Because this aspect of innovation creates positive externalities, the social return to investment in knowledge will be greater than the private return, and underinvestment (from the perspective of society) will therefore ensue. Most scholars of the economics of technical change subscribe to this view of knowledge production to some extent, although not to the extent that the extreme "pure public good" story would suggest. There is considerable evidence that imitation of innovation costs something, perhaps as much as half the original innovation (see Mansfield *et al* 1982, *inter alia*). Imitation requires the ability to identify and understand the technology in question, an ability sometimes referred to as absorptive capacity. As Cohen and Levinthal (??) argue in an influential paper, creating such a capacity usually requires investment in learning and R&D. Nevertheless, in support of Arrow's insights, we have abundant evidence that the social returns to R&D are often considerably higher than the private returns in a wide range of settings (Griliches 1992; Bernstein and Nadiri 1989; Mansfield 1977).

One consequence of partial (rather than full) appropriability of the returns to innovation will be the observation of an apparently high required rate of return for such investments, leading to difficulties in financing. In addition, by now there is a fairly large literature, both theoretical and empirical, making the point that the cost of financing R&D can also be high because of asymmetric information between the entrepreneur/inventor and potential financiers as well as moral hazard on the part of the entrepreneur.[7] An inventor usually has better information about the likelihood of success and the nature of the contemplated innovation project than potential investors. Therefore, the marketplace for financing the development of innovative ideas looks like the "lemons" market modeled by Akerlof (1970). The lemons' premium for R&D will be higher than that for ordinary investment because investors have more difficulty distinguishing good projects from bad when the projects are long-term R&D investments than when they are more short-term or low-risk projects (Leland and Pyle, 1977). When the level of R&D expenditure is a highly observable signal, as it is under current U.S. and U.K. rules, we might expect that the lemons' problem is somewhat mitigated, but certainly not eliminated.[8]

[7] See Hall (2002) for a survey of this evidence.

[8] Since 1974, publicly traded firms in the United States have been required to report their total R&D expenditures in their annual reports and 10-K filings with the SEC, under FASB rule No. 2, issued October 1974. In 1989, a new accounting standard, SSAP 13, obligated similar disclosures in the UK. Most other countries do not have such a requirement, although they may evolve in that direction due to international harmonization of accounting standards, at least for publicly traded firms. In any case, only the total amount of such spending, and not its character, is observed.

In the most extreme version of the lemons model, the market for R&D projects may disappear entirely if the asymmetric information problem is too great. Informal evidence suggests that some potential innovators believe this to be the case in fact. Reducing information asymmetry via fuller disclosure is of limited effectiveness in this arena, due to the ease of imitation of inventive ideas. Firms are reluctant to reveal their innovative ideas to the marketplace and the fact that there could be a substantial cost to revealing information to their competitors reduces the quality of the signal they can make about a potential project (Bhattacharya and Ritter, 1983; Anton and Yao, 1998). Thus the implication of asymmetric information coupled with the costliness of mitigating the problem is that firms and inventors will face a higher cost of external than internal capital for R&D due to the lemons' premium. Later in the paper we present some survey evidence addressed to this point.

A survey of the quantitative evidence by Hall (2002) reached the following conclusions from the evidence on financing constraints for R&D investment: In general, small and startup firms in R&D-intensive industries face a higher cost of capital than their larger competitors and than firms in other industries. In addition to the compelling theoretical arguments and empirical evidence, the mere existence of the Venture Capital industry and the fact that it is concentrated precisely where this type of startup is most active suggests that this is so. On the other hand, the evidence for a financing gap for large and established R&D firms was harder to establish, at least for firms in developed economies. It is certainly the case that these firms prefer to use internally generated funds for financing investment, but less clear that there is an important role for policy, beyond the favorable tax treatment that currently exists in many countries.

In addition, the Venture Capital solution to the problem of financing innovation is not a panacea: First, such investors tend to focus on only a few sectors at one time, and to prefer making investments with a minimum size that is too large for startups in some fields. Second, good performance of this market requires a thick market in small and new firm stocks (such as NASDAQ or EASDAQ) in order to provide an exit strategy for early stage investors, so it is unlikely to provide a financing solution for firms in smaller developing countries.[9] For these reasons experiments with public venture capital funds have been increasing around the world, although even here the need to provide a transition mechanism to public equity markets is apparent (Sweden, Lombardia, Catalonia, Piemonte, etc…..)

[9] One exception to this rule is Israel, whose firms are very active on NASDAQ. For a fuller account of the development of the VC industry in Israel, and the preconditions for success, see Avnimelech and Teubal (2004, 2005).

As was first argued by Nelson (1959), the gap between private and social returns can vary considerably depending on which particular innovation project we are considering. Once we look more closely at the wide heterogeneity of potential investments in new and improved technologies, a number of considerations emerge that should affect the direction of policy in this area. For example, projects should probably be more favored when the benefits are diffuse across society, implying that the transactions costs of mobilizing groups to pay for the research are high (the traditional public goods argument) and also when the externalities are large and the firms in the relevant sector small (e.g., agriculture in many countries and also some electronic components industries). In addition, there may be social reasons to undertake some investments even though the size and risk of the effort required are not commensurate with the size of the market, as in the case of orphan drugs, or even vaccines targeted to diseases in very poor countries (the malaria vaccine example).[10]

A more controversial but frequently used class of arguments for technology-oriented industrial policy is the argument that some technologies and industries (semiconductors, flat panel displays, manufacturing itself, agriculture, etc.) are of national strategic importance, either because they are important for national security and defense, or because they are closely linked to the development of other industries. The argument here is that investment in these technologies is particularly important for the economy as a whole because it builds skills and generates positive externalities for other sectors. Although this view is pervasive in some of the policy literature, it is difficult to find hard evidence that the benefits of such policies for the economy outweigh their costs in wasted investments and rentseeking activity. In countries with weaker government institutions and greater corruption in public life, such costs are even more likely to outweigh the benefits.

The final area where there is likely to be private underinvestment in innovation is the area of education and human capital. Individual investment in advanced education and training is a risky undertaking because of the need to specialize in a particular scientific area that may not turn out to be in demand in the future. Imperfect (human) capital markets mean that individuals are not always willing or able to borrow enough to finance their training. For this reason most governments subsidize university

[10] The opposite situation can apply for pharmaceuticals targeted at chronic diseases that exist worldwide (such as anti-depressants and anti-ulcer drugs). In this case the existence of patent protection implies that the incentives to introduce a slightly better version of such a drug and take the market away from your competitor actually can leave to overinvestment in R&D relative to the social optimum.

education and graduate training in some way or another, either by guaranteeing free education to all who meet a certain standard or via a mix of scholarships and loans for qualified individuals.

An additional consideration for policy towards R&D is the size and worldwide integration of the economy in question. Large developed economies that are fairly closed like Japan and the United States will tend to keep most of the benefits from their R&D inside the country, and will also benefit from others' R&D investments due to their size and absorptive capacity. Small open economies such as the Netherlands or those in Scandinavia may find that much of their R&D spills outside the country rather than inside, because of their integration into the world economy and the relatively small size of their home markets. This problem is probably more severe for economies doing research on the frontier than for countries whose efforts are devoted to catch-up and increasing the local technological capacity. That is, if the focus is on encouraging diffusion and imitation of the best practices in production, and on tailoring innovations to particular environments, spillover of the efforts outside the country are less likely to be a problem. The challenge in this case is to obtain "spill-ins."

Once we accept the partial public good nature of R&D and innovation investments, then policy design becomes a matter of weighing the cost and effectiveness of the usual instruments of tax, subsidy, and various methods of "internalizing the externality," including intellectual property. Most developed countries use a mix of these polices, recognizing that direct government funding and even performance is necessary for such things as basic research that have potentially large spillovers and where there is very low private incentive. On the other hand, for a wide range of industrial innovations where governments lack the ability and knowledge needed to choose projects and where the gap between social and private returns may be somewhat lower, encouraging the investment behavior of the private sector is the alternative preferred. This takes two distinct forms plus a third which is a hybrid of the two: public finance with private project choice (tax credits for some types of innovation investment) and private finance with private project choice but with some grant of market power (the IP system, especially patents). However, as I will argue later in the paper, the use of patents to encourage innovation is a double-edged sword for developing countries, in that it may foreclose one productive avenue for learning and "catching up" to the technological frontier, namely reverse engineering and imitation of the technological leaders.

The third (hybrid) form of government intervention is widely used and has been quite successful in some areas. For example, this is the main type of direct subsidy used at the European Union level. It relies on firms to suggest projects and to help pay for them, but a governmental agency is charged with choosing projects and monitoring their performance, in return for cost-sharing of the project with the firm. A range of cost-sharing figures can be used, but 50 per cent is a typical level. The advantage of this mechanism is that it combines the ability of firms to identify useful projects in their area with the (presumed) ability of government to identify those with higher social returns, and imposes some kind of market test by requiring firms to put up some of their own money. As in the case of full government subsidy, the question of "additionality" of the government funds still arises; later in the paper I present some quantitative evidence from a number of countries on the presence or absence of crowding out in this context.

Before presenting more detailed information on potential policy choices, in the next section of the paper I first review the facts about Latin American underperformance in innovation in order to identify the areas that might be appropriate for policy targeting.

3. Innovative input and performance in Latin America

A number of investigations into the determinants of economic growth and innovative performance at the country level have recently been undertaken. These studies vary in a number of dimensions: the choice of innovation measure, unit of observation, method of analysis, whether there is a control for unobserved or left out country effects, and so forth. Some are based on readily quantified and publicly available data such as R&D and patent statistics, while others use data from the innovation surveys that have been conducted recently, first in Europe and now to some extent in Latin America. I will not attempt a complete survey here, but will review a few of these studies to indicate the range of approaches, and also to highlight the conclusions as they relate to Latin America.

Furman, Porter, and Stern (2002) and Mohnen, Mairesse, and Dagenais (2002) have developed the use of a concept called "national innovative capacity" or "innovativeness" to describe the set of factors that influence a country's ability to undertake innovative activity. In the case of Furman *et al*, the innovation measure used is the number of U.S. patents granted to inventors in a country. This measure is regressed on various input measures such as country-level R&D intensity and education levels, and the resulting predicted value is used as a measure of national innovative capacity. The idea is to use the observed relationship between input measures (which can plausibly be assumed to be malleable with policy) and the desired output to develop a single index that will describe the innovation performance of a country as a function of the choice or policy variables.

Using this approach on a set of 17 OECD countries between 1973 and 1995, Furman *et al* (2002) find that a large part of the difference in patenting across countries is explained by R&D manpower and spending, with an elasticity of about one. However, they also find that policy choices matter, with important positive effects from the extent of IP protection and share of spending devoted to higher education. Also positive but somewhat less important are openness to international trade, the share of research performed by the academic sector, and the share of research funded by the private sector. In Porter *et al* (2000), the same authors apply the results from this regression to make an out-of-sample prediction of the innovative capacity of a set of the seven largest and/or most developed Latin American economies. Note that this exercise required constructing predicted values for patenting in 1998 in a part of the data space where little data was observed for their original regression, so that if the relationship was not linear, there may be some bias in the result.[11]

In spite of this caveat and those of Lall (2001), it is worthwhile comparing the predictions of Porter *et al* with the actual results for these countries. We show this comparison in Table 1. The results show significant shortfalls for Argentina, Colombia, and Costa Rica, whereas Brazil and Chile perform almost as predicted. Mexico and especially Venezuela patent considerably more than predicted by their R&D and income levels and the strength of their innovation institutions. In the case of Venezuela, 40 per cent of the patents during the 1976-1998 period are attributable to one firm, Intevep SA, which is the national petroleum research institute. In the case of Mexico, the patents are more dispersed, with the largest share (10 per cent) going to the national steel champion, Hylsa S.A.

The first paper to explicitly break innovative performance down into two different components, predicted innovation given the level of inputs and the residual or unpredictable part is the paper by Mohnen, Mairesse, and Dagenais (2002). This distinction is of interest, since the former depends to some extent on factors we measure and therefore might think subject to policy change, whereas the latter summarizes our ignorance about the determinants or alternatively, the bias inherent in the measure we are using. In the example just given, it is possible that patenting propensities vary across countries at times in ways that do not reflect the full innovative performance of the economy. Given our paucity of performance measures, this does not imply we should not use patents as indicators, but it does suggest augmenting them with other measures.

[11] See Lall (2001) for a number of other critiques of this methodology, which underlies the World Economic Forum's competitiveness index.

In the case of Mohnen *et al* (2002), the measures are based on the firm-level report on the share of sales during the past three years that were sales of products new to the market. From this, they construct two measures, one of which is the value of innovative sales predicted by firm size, group membership, R&D intensity, and a number of other factors such as industry, and the second is the residual from this regression. They call the first innovation performance and the second innovativeness. That is, they distinguish between what might be expected given the industry composition and R&D intensity of a firm (or firms in a country) and the unexpected component which may be due to other institutional factors not accounted for.

They apply their analysis to data from the Community Innovation Survey for seven European countries: Belgium, Denmark, Germany, Ireland, Italy, the Netherlands and Norway, finding that the average innovative performance of firms in these rather similar countries varies even after controlling for firm size and industry, its membership in a group or holding company, its R&D intensity, whether it does collaborative R&D, and the closeness of its technology to basic research. In fact, a relatively small amount of the variation in innovative sales is explained by these factors, leaving a fair amount to be explained by differences across the countries or unexplained altogether. Although this exercise has not yet been performed for Latin American countries, it may be an investigation worth pursuing because many of these countries have now conducted innovation surveys.[12]

De Ferranti *et al* (2003) review a number of measures of skills and technological attainment for Latin American countries and benchmark them against the East Asian Tigers (Hong Kong, Singapore, Korea, and Malaysia) and a set of Natural-Resource-Abundant countries (Australia, Canada, Finland, New Zealand, Norway, and Sweden). With respect to education, they conclude that the average educational attainment in many Latin American countries is low, and that education is distributed less equitably than in the other groups of countries. In many countries, there appears to be too much tertiary education relative to secondary education, and both students and adults in Latin America perform poorly on international tests, especially in math, and when compared to other countries at same income level. However, consistent with the relative overweighting of tertiary education, it does not appear that most Latin American countries have a low stock or flow of scientists and engineers given their income level.

[12] E.g., See Benavente (2004) for results from the innovation survey in Chile and Sanguinetti (2004) for Argentina.

With respect to the import of new technology, an important avenue for technology transfer to developing countries, Latin American countries receive fewer imports, including far fewer imports of capital goods, than East Asian countries, and they spend relatively little on the licensing of foreign technologies. There is also a great deal of variation in FDI penetration within Latin America. During the late 1980s, as the lower cost personal computer became more widely available, East Asia opened up an important lead in computer penetration and this lead did not shrink during the 1990s. In 1995, more than 10 per cent of the population had access to PCs in Singapore and Korea, while in Latin American the number was less than five per cent.[13]

Correspondingly, the domestic production of new technology in Latin America is relatively low, measured as input (R&D) or as output (patents granted in the U.S.). Latin American countries have a lower domestic R&D capital stock than Korea or Singapore (but not Hong Kong or Malaysia), or than the Natural Resource–Abundant Countries. The number of patents granted to residents of most Latin American countries is also low by comparison to the other two groups of countries, even when compared to the overall level of R&D (but not when compared to business R&D, see below).

Tables 2 and 3, drawn partly from Lall (2001, 2003) and augmented by the author using patent data from the USPTO (Hall, Jaffe, and Trajtenberg 2002) and the latest Penn World Tables (Heston, Summers, and Aten 2002), shows some of these measures for 1995, for the four largest Latin American economies, and for four East Asian countries that have experienced rapid growth recently. Note that all but one of the comparison countries (Malaysia) have higher GDP per capita in 1995, so they may not be directly comparable: they are being measured after they have achieved a degree of success in development. For this reason, I also show some data for three countries that have levels of GDP per capita which are similar to those in Latin America: South Africa, Hungary, and Poland.

With respect to education (Table 2), the main differences between the two groups of countries are relatively low secondary school enrollment, especially in Brazil, and a somewhat higher share of tertiary education in the core mathematical and engineering sciences in Korea and Taiwan. The FDI share is notably higher in Singapore, but in general the Latin American countries exhibit levels that are similar to East Asia, although possibly of a different composition, with less going to manufacturing activities that might facilitate technology transfer.

[13] http://www.uis.unesco.org

The differences between these two sets of economies are most dramatic in the R&D and patents areas (Table 3). With the exception of Malaysia, which looks like the Latin American countries, the R&D to GDP ratios are about four times as high in East Asia, and this difference is entirely explained by the fact that enterprise R&D is much higher in these countries. The difference in the patenting rates is even greater, with patenting per R&D rates about ten times those in Latin America. This may be partly due to industrial mix: the East Asian countries are heavily in the electronics, computing, and communications sector, where worldwide patenting has increased enormously during the past 15-20 years, but the difference remains quite striking. And even Malaysia has significantly higher high technology exports, capital goods imports, and foreign technology licensing payments than the Latin American countries. So there are signs here of underperformance in industrial R&D even when compared to countries with similar GDP levels. Although the population-weighted average R&D intensity of the four Latin American countries is almost as high as that for South Africa, Hungary, and Poland, the business share of R&D is less than half that of these countries, so that business R&D intensity averages 0.13 per cent versus 1.3 per cent in the East Asian countries and 0.32 per cent in the other countries.

Table 4 updates the R&D numbers to the most recent numbers available for Latin America, which are mostly from 2000-2003.[14] This table underscores two things. First, the business R&D performance of Latin America is still very low, although Brazil, Mexico, and Costa Rica (not shown in Table 3) show some improvement (See also National Science Foundation 2000). Because Brazil and Mexico account for about 85 per cent of the R&D in Latin America, the increase in business R&D in those countries means that the overall business R&D share rose from 0.13 per cent in 1995 to 0.21 per cent in 2000/2003. The second obvious implication of this table is that performance differs dramatically within Latin America. The table shows the countries in order of descending R&D to GDP ratio and the first seven countries on the list have ratios that are comparable to those of other mid-level developing countries such as Malaysia, Hungary, and South Africa. However, the bottom half of the table includes a number of countries, mostly small, that do very little R&D and almost none of the R&D they do is performed by private businesses. Policies that might be directed at the first group of countries may not be appropriate for the second group, where there is so little experience with the technology development process. However, implicit in the discussion of science and technology policy in this area

[14] These numbers come from the website of Red Iberoamericana de Indicadores de Ciencia y Tecnologia (RICYT), which is an organization of Latin American countries that is developing and improving science and technology indicators for this area, using the guidance provided by the OECD and the Frascati manual.

is a view that the positive effects of encouraging R&D and innovation in the larger and more developed Latin American countries will spill over eventually to the other countries in the region.

Recently the World Bank has developed a series of Knowledge Economy Indicators (World Bank 2005) that can be used to assess a country's performance in a number of areas. From the over 80 indicators developed, they propose three indicators of the level of "Knowledge" development, for Innovation, Education, and Information Infrastructure. These three indicators are in turn based on indicators like those shown in Tables 2 and 3:

- **Innovation:** R&D researchers per capita; US patents per capita; Scientific and technical journal articles per capita

- **Education:** Adult literacy rate, secondary and tertiary enrollment rates

- **Information Infrastructure:** Telephones per capita; Computers per capita; Internet users per capita

Table 5 shows the summary indicators derived from these raw indicators for the most recent year available and for the same countries considered in Tables 2 and 3. Clearly Latin America as a whole substantially underperforms all the comparison countries. Focusing on Argentina, Brazil, and Chile, we see that they are outperformed in most dimensions by Singapore, Korea, Taiwan, Hungary, and Poland, but not by Malaysia and South Africa. The best performance in Latin America is Argentina in education and Chile in information infrastructure.

In a series of Innovation Briefs based on these kinds of indicators, the World Bank (2003) identified the innovation performance weaknesses of seven of the more developed Latin American countries (Argentina, Brazil, Chile, Colombia, Costa Rica, El Salvador, and Mexico), relative to a worldwide benchmark based on countries at similar levels of GDP per capita. In all seven of these countries, the rate of return to R&D investment is quite high and the level of R&D investment correspondingly low. With the possible exception of Chile and Costa Rica, the quality of their public R&D institutions and university-industry cooperation is identified as poor. They also tend to underperform their peers in patenting, although some of them (Brazil, Costa Rica, El Salvador) do license foreign technology at levels comparable to countries of similar size and income levels. Summing up, it appears that there is a need both for policies that encourage R&D in private firms, and also for attention to be paid to the problem of encouraging public R&D institutions and universities to increase their relations with industry.

A more thorough analysis of R&D in Latin America and its contribution to productivity growth is given by Lederman and Maloney (2003). These authors find that the apparent returns to R&D for countries in Latin America (at least those in the top half of Table 4) are quite high.[15] This finding also suggests underinvestment in R&D in those countries, so they turn to examining the determinants of R&D. They conclude that the reason poorer countries invest less in R&D in spite of the fact that the returns are apparently high can be ascribed to 1) difficulties in financing innovation; 2) weaker intellectual property rights; 3) lower quality research institutions; and 4) lower government support. This list of problems clearly directs our attention to a set of policies that might be designed to ameliorate them.

However, although it is tempting to call for a stronger IP regime and attempts to improve the quality of research at public institutions, the suspicion persists that these institutions are a sign of high GDP per capita rather than a cause of it. The GMM system regression shows that levels of IP and public research quality variables that can be predicted by past growth rates in R&D and GDP per capita do indeed influence current R&D positively, even holding the development level constant. Is this enough to convince us that simply changing these institutions in an economy with low R&D and GDP growth rates will produce the desired effect? The interpretive difficulty is that the instruments in this kind of panel regression are past values of the ultimate outcome variables so that it is very difficult to disentangle the economic growth-R&D increase-IP increase-R&D increase-growth cycle in order to clearly determine causality. The results are nevertheless suggestive and we can be sure that strengthening IP systems and R&D/GDP growth tend to move together.

A similar effort has been undertaken by Fagerberg and Verspagen (2003) in the work previously cited. They focus on the changes in the determinants of growth convergence during the 1990s as compared to earlier eras and use factor analysis to find that the most important determinants for low income country growth in the very recent past (as opposed to earlier periods) are educational efforts, R&D (measured as scientific publications), and innovative activity (measured as US patenting), rather than

[15]However, Benavente (2005) reports that the gross rate of return to R&D in Chilean manufacturing firms is about 30 per cent, which is comparable to that in the United States during the 1980s and early 1990s (Griliches 1994; Hall 1993).

openness or the level of Foreign Direct Investment. Unfortunately, they did not include the cost of capital or other financial factors in the set of predictor variables. Neither were they able to include R&D spending in this exercise, presumably because of lack of data. Nevertheless, their results otherwise seem consistent with those reported below for Latin America.

Benavente (2004) reports the results of two innovation surveys conducted among Chilean manufacturing firms in 1998 and 2001. More than half (about seventy per cent) of these firms reported that they faced obstacles to innovation; of these obstacles, the most important were the high cost of innovation, the lack of access to qualified personnel, and resistance to change within the firm. For comparison, when a similar question is asked of large innovating UK firms, slightly fewer (about 55 per cent) report financial obstacles, whereas only about 20 per cent of non-innovating firms (large or small) report such obstacles. Lack of qualified personnel displays a similar pattern, being a constraint of some importance for large innovating firms 54 per cent of the time and for small innovating firms 35 per cent of the time. Eurostat (2001) reports results for European manufacturing firms that innovate but delay, abolish or fail to start projects. Such firms rank financial factors first when abolishing or failing to start projects, but the most important reason for project delay is the lack of qualified personnel.[16] Thus if we compare Chile to these developed economies, we see that the most important reasons for underinvestment are roughly the same, but that many more Chilean firms seem to face these obstacles. And note that Chile is one of the best performing Latin American countries on the basis of the various performance measures.

Before leaving this review of Latin American performance with respect to innovation, it is important to discuss another policy area that is relevant for innovation-related growth: industry regulation, especially regulation of entry. One of the stronger stylized facts that has emerged from the study of innovation among private firms is that radical or drastic innovations are more likely to come from new than from established firms and industries, because the latter find it difficult to reorganize production when faced with disruptive innovations, and are reluctant to destroy existing channels of operation and competencies in order to create new ones (Acs and Audretsch 1990; Henderson 1993). The implication of this finding for the encouragement of innovative activity in the economy is that regulation which raises the cost of entry into an industry and/or the cost of exit from an industry will

[16] Unfortunately, given the way these different surveys (CIS2, CIS3, and the Chilean survey) are constructed, the samples answering the innovation obstacles questions are different for each one so they cannot really be compared numerically.

tend to discourage the very entrepreneurs that are most responsible for producing innovation in the private sector.

Some evidence is beginning to be accumulated on this question: Alesina *et al* (2004) find that the strength of regulation in the form of entry barriers, public ownership, and price controls in the non-manufacturing sector of 21 OECD countries discouraged investment in those sectors. Fisman and Sarria-Allende (2004) use measures of the cost of entry developed by Djankov *et al* (2002) to compare the structure of industries with naturally low and high entry barriers in countries with low and high entry regulation. They conclude that industries with naturally low entry barriers, but in countries with high costs of entry, are composed of a few large firms, and that in such countries, the response to growth opportunities is expansion by existing firms rather than new startups. There is some reason to think that this may imply less innovative activity in these industries than would be the case if entry barriers were lower. The last column of Table 3 shows the estimates of Djankov *et al* for the countries and it is clear that entry cost is considerably higher for the Latin American countries than for other countries with similar GDP per capita.

Cole *et al* (2004) look directly at this question as it applies to Latin America. First, they document that the failure of convergence for Latin American countries is primarily due to low Total Factor Productivity rather than to slower growth of inputs (labor, capital, and human capital). Then they argue that Latin America has now and has had for some time significantly higher barriers to competition than in Europe and other successful countries and that these barriers have served to limit TFP growth considerably. Such barriers include tariffs and quotas as well as entry barriers, inefficient financial systems, and large subsidized state-owned enterprises. They present a number of case studies in support of this argument, such as the removal of zero import quotas in the Brazilian computer industry and the privatization of various state-owned enterprises. To the extent that low TFP growth is a sign of less innovative activity the implication is that barriers to competition may be partly responsible for lack of innovation.

The results in this section of the paper can be summarized as follows: as a whole, Latin American countries have relatively poor productivity growth and low innovation output relative to their innovation inputs. This is not due to lack of education, although the fact that tertiary education is somewhat stronger than secondary education may contribute to these outcomes, because it implies that there may be a dearth of semi-skilled workers capable of adapting to new technologies. It does seem to have been due in the past to relatively high barriers for foreign direct investment, which limited technology transfer, although some of these barriers have now been lowered in countries like Brazil and Chile. There is also a problem of low business enterprise R&D even in the presence of relatively high rates of return, which is a clear indicator of the type of problem identified by Arrow 1962, and of weak university-industry relationships. Reasons for the failure of business enterprise innovativeness may be financing difficulties as well as the entry barriers and costs facing potential new innovative firms.

This summary and the survey in this section have focused on the more advanced of the Latin American countries because of a belief that if the region's innovative performance is to be improved, it is best to begin with policies targeted at these countries, since they have more of the infrastructure necessary to make them work, as well as a larger market size. The hope is that any progress one can make in these countries is likely to spill over to neighboring countries and also that the process of implementation will increase our understanding of what might work or not work in the Latin American context.

4. Government policies for R&D and innovation

Overall, the menu of government policies that would encourage invention and innovation are much the same in all countries: education systems that develop and reward independent thinking, intellectual property systems that reward creativity without too much discouragement for follow-on inventions, and public policies that subsidize some forms of innovation, especially those with high social payoffs. Of course, it is helpful if these policies are embedded in a culture that does not unduly penalize failure and that is receptive to new ideas. Achieving successful performance in all of these institutions is a tall order, of course.

Turning from the general to the specific, it is apparent that to some extent the choice of policy will be determined by the level of development in the country in question. Many countries will benefit more from policies such as public research and extension services to both perform R&D and quality testing, and to disseminate technical information and standards than from direct government funding of R&D in private firms. The initial focus should perhaps be on developing absorptive capacity so that licensing, foreign direct investment, and even strategic R&D alliances with foreign firms can be effective at increasing the innovative capacity of the host country. At some point it becomes necessary to ensure that the private sector has the incentives and means to finance innovative activity itself, which implies greater reliance on the use of internal funds (profits), venture capital and other private equity, and the intellectual property system. I discuss some of the potential policies for targeting each of these activities in this section of the paper.

4.1 *The East Asian experience*

It is tempting to look at the successful East Asian tigers for hints of how to manage policy for technological development. Ferranti *et al* (2003) give a detailed comparison of these economies with Latin American countries, showing that Hong Kong, Singapore, Korea, and Malaysia have surged ahead during the past 20-30 years. Lall (1996) argues that the polices pursued by these countries have actually been quite varied, with Korea and Taiwan pursuing an inward, domestic oriented industrial policy with export subsidies, credit targeting, FDI restrictions, and little IP protection at first, emphasizing skill-building and R&D, while Singapore and Malaysia have focused on a government-directed and influenced FDI approach, where foreign multinationals are encouraged to transfer technology and skills as the price for being allowed to invest in the country. As is well known, Hong Kong pursued a more *laissez faire* approach to development, and today lags the others in technological performance, with the exception of Malaysia. Even comparing Korea and Taiwan there are important differences related to a very different firm size distribution, the Korean *chaebol* versus the focus on extension services for SMEs in Taiwan.

In addition, although it is natural to examine the policies pursued by the successful East Asian countries, an important caveat needs to be mentioned: the policy environment in terms of world trade agreements and TRIPS has changed considerably since those economies began their successful run. First, the most aggressive forms of industrial policy and subsidy are probably no longer acceptable to the WTO (Nelson 2003). Second, most of these countries benefited from a rather loose IP regime until quite recently. For example, Hou and Gee (1993) report that Taiwanese government policy shifted its attention to strengthening IP rights during the mid-1980s; prior to that time, patenting had essentially been a non-issue for Taiwanese firms. In Korea, patents with a short life of 12 years were introduced in 1961, but excluded foodstuffs, chemicals and pharmaceuticals (a common exclusion in developing countries or during the early phases of a patent system). Not until the mid-1980s was a system more like that in the United States introduced via legislation (Barton 2003).

Figure 1 shows the number of patents per capita applied for in the United States by a number of East Asian countries in the U.S. over the 1963-1998 period. Taiwanese patenting takes off beginning in 1984, that in South Korea in about 1990, and in Singapore in 1992, whereas Malaysian patenting is still negligible. Clearly a weak or nonexistent domestic patenting system influenced the take-up of patents by firms in these countries in the United States, but there is some question about whether this actually slowed development. In terms of real GDP per capita, the Taiwanese economy grew an average of 12 per cent per year between 1960 and 1980 and 10 per cent per year between 1980 and 1998 (Heston, Summers, and Aten 2002). For Korea during the same two periods, the numbers are 10 per cent and 9 per cent. There is ample qualitative evidence that the earlier rapid growth in both countries was due partly to extensive reverse engineering and innovation imitation activities that would have been impeded by the enforcement of domestic patents held by multinational firms.

In addition to changes in the world economic policy environment during the past several decades, a number of other factors make the lessons from the Newly Industrialized Countries in East Asia for development policies somewhat misleading with respect to Latin America. Noland and Pack (2002) review the contributions of targeted industrial policy to development in Japan, Korea, and Taiwan after World War II and the Chinese Communist Revolution and ascribe relatively little of the TFP growth in these economies to industrial policy *per se*, although they do identify the monitoring of export performance by firms that went along with this type of policy as helpful in ensuring technical progress. Macroeconomic policies and relatively low inflation were viewed by these authors as important influences, although they argue that the government-directed credit policies necessary when targeting particular sectors led to a relatively backward financial sector and that this ultimately played a role in the financial crisis of 1997. Finally, they point to the relative lack of corruption and relatively high status/high pay of the civil service in these countries as important in ensuring that the government's role targeting firms and industries for development did not degenerate into simple satisfaction of rent-seekers' desires. This kind of benign environment may not be present in all Latin American countries.

4.2 *Policy choice*

Developing the innovative capacity of a country usually involves a number of measures and actors. But the first requirement is to define the goal more precisely: should we target private R&D spending, the diffusion of best practice technology, or the research capacity of public institutions? As we have seen, all these factors are likely to contribution to economic growth via innovation and all are relatively weak in Latin America, but they require different measures. In the long run, the most important thing is probably the educational infrastructure: it is impossible to create high quality research institutions or a supply of skilled labor without good secondary and tertiary schooling.

However, this kind of infrastructure takes time to develop and may operate too slowly to generate a quick start. In particular, the choice of talented youngsters to enter science and engineering fields is strongly influenced by their perception of the returns in those fields, which implies that it may be important to send signals that such human capital investment will be rewarded in the future in addition to subsidizing its acquisition in the present. One way to do this is to ensure that access to employment in any government-funded university or public research institution is truly open and merit-based. To ensure continued good performance once scientists and educators enter the system, it may be necessary also to provide that security of employment in such activities takes some time to achieve, rather than being guaranteed at the outset of one's career, as it is presently in many countries, such as those in continental Europe.

Turning to innovative investment itself, in addition to the larger set of policies that lead to a stable macro-economic environment and those that minimize the regulatory burden, especially on small and new firms, the menu of policies that might encourage private firms to undertake innovative activities includes direct subsidy or government-industry partnerships, lowering the cost of R&D capital via tax credits, and improving access to science and technology either via public research institutions or via various extension services that help transfer technology to private firms. And although trying to pick "winners" among industries and sectors is probably not the best way to proceed, it is perhaps helpful to at least think about the current revealed comparative advantage of a country and avoid policies that are negative for it.

Another set of policy instruments designed to correct market failure in innovation and R&D are those that come under the heading of "internalizing the externality." These instruments include the encouragement of joint R&D ventures between firms in the same industry and the use of intellectual property rights of various kinds to ensure that the innovator has exclusive use of his innovation. However, because of the nature of R&D output, correcting market failure by allowing firms to capture the external benefits (spillovers) via collusion or temporary monopoly carries with it a well-known cost in terms of market power, so use of these instruments is not without cost.

In the following, I follow the development sequence discussed earlier by first looking at targeted R&D subsidies and other public research instruments. I then look briefly at the development of private sector incentives and consider the use of R&D tax credits, an instrument that has been widely used in developed economies. Finally I turn to a discussion of intellectual property policy in developing countries.

4.3 *Public research institutions*

Martin and Scott (2000) consider the design of policy to alleviate innovation market failures as they vary across different sectors that face different sources of underinvestment. One of the most relevant of their innovating categories for Latin America would seem to be the "application of inputs developed in supplying industries," for which typical sectors are agriculture and light industry, but might also include mining. The market failures here are due to small firm size and the large external benefits from such innovation, and they suggest the development of low-tech bridging institutions such as extension services to facilitate technology transfer. In their Innovation Briefs, the World Bank identifies the following sectors as having technological comparative advantage in the seven Latin American countries they considered: agriculture and food, metals and metal products, specialized industrial machinery, chemicals, textiles, rubber and plastics, and in some cases ordnance and ship building. Most of these, with the possible exception of chemicals, ordinance and ship-building, are mid-technology industries with relatively small firm sizes and therefore suitable for government extension services that might provide technology, best practice information, and quality enhancing services.

In this context it is interesting to note the early 20th century U.S. experience. As Mowery and Rosenberg (1989) report, one of the strengths of the American university system is its diversity: although most are familiar with the role of the elite public and private research universities, fewer know that a number of engineering experiment stations were established during the 1900-1940 period, mostly at land grant colleges and universities. These institutions were often linked to the needs of local industry, such as the Mines experiment station at the University of Minnesota and research on rubber at the University of Akron near Cleveland, Ohio, the traditional center of the tire industry. Thus there was a long tradition of university-industry links in the United States even before the recent increase in such activity, in addition to the well-known links between agriculture and the university.

Given the relatively poor quality of public research institutions and university-industry links in Latin America, it is perhaps useful to consider ways that these might be strengthened. Taiwan has had considerable success with using public research institutes such as the Industrial Technology Research Institute (ITRI), founded in 1973, and the Electronics Research Services Organization (ERSO), founded in 1974 to foster the development of technology-oriented SMEs (Mowery 2005). For example, ITRI has performed and currently performs research on a number of targeted technology areas such as new materials and PC components. When a technology shows promise, a spin-off firm is formed, usually about 50 per cent funded by private investors and often with the involvement of the engineers who developed the technology. These features have several benefits: risk is shared, the engineers both participate in the returns if successful and are guaranteed at least some employment if it fails, and they have the incentive to transfer the necessary tacit knowledge to the new firm. An important feature of this mechanism is that ITRI or the government does not attempt to capture the full profits from the new technologies that they develop. In this sense it looks like the United States university spin-off/venture capital relationship that has been so successful in California. The division of returns appears to be consistent with the models of Anton and Yao (2002), who show that the bargain made when an idea or invention is sold for development usually results in the buyer expropriating some or most of the value, due to the necessity that the seller disclose some of the information about the invention in order to signal its value.

A large number of government-funded targeted R&D program already exist in OECD countries, ranging from Europe (Belgium Germany, Finland, France, Norway) through Canada and the US to Asia (South Korea, Taiwan, and Japan). David *et al* (2000) surveyed the literature on the ability of such programs to induce additional R&D performance by private firms and concluded that although the evidence was mixed, more studies found complementarity between government and private R&D than found substitution (crowding out), especially when the studies using non-US data were considered. However, as Klette *et al* (2000) point out, many of these studies had inadequate controls for the fact that firms selected to receive government R&D funding are usually not a random sample of all firms, but may already be better performers. Table 6 reports on a series of studies of R&D "additionality" that have been performed using data from developed countries since the surveys by David *et al* and Klette *et al*. Most of these studies use some kind of matching algorithm (based on the propensity to receive a subsidy, or on the sample selection model due to Heckman) to compare the R&D performance of similar firms that did or did not receive a subsidy. In almost all cases, substantial additional R&D was performed; because many of the studies are not able to control for the amount of R&D subsidy, it is difficult to estimate the actual amount of additionality with precision. The table also reports the performance effect of the R&D in terms of patent outcomes where this was measured. Generally, more patents were obtained and the programs that encouraged collaboration among firms were particularly productive.

There is already some limited experience with targeted R&D programs in Latin America, not all of it encouraging. Sanguinetti (2005) shows that Argentina's FONTAR program (soft credits for R&D, tax subsidies for participation) appears to have been successful in inducing more R&D among firms that participated, but the results for innovation expenditures as a whole are more ambiguous. Depending on the particular matching algorithm used, they can go up or down on average in response to the subsidies, but the precision of the measurement is very poor, so it is difficult to draw strong conclusions.

4.4 *Foreign direct investment, exporting, and technology transfer*

A set of policies frequently advocated for development in general are those that encourage technology transfer across international boundaries via openness to the rest of the world. These policies or transfer channels include trade, especially in capital goods and technologically-intensive inputs, technology licenses that include the know-how and training necessary to make effective use of the new technology, and foreign direct investment. Non-market methods of acquiring such information include reverse engineering, local spinoffs by the employees of foreign firms, the temporary residence of students, scientists, and technical personnel in developed economies, and the study of technical publications and patents.

A large literature exists that attempts to measure the effectiveness of openness and trade with the rest of the world on countries' innovative capacity and productivity growth, but unfortunately without reaching strong conclusions about its effectiveness. In an influential 1999 paper, Rodriguez and Rodrik argued that much of the earlier work on this subject was methodologically flawed and that the evidence that lower tarrifs and non-tarrif barriers led to growth was weak. They argue for closer examination of individual firm behavior rather than cross-country studies. However, Baldwin (2002) produces a more nuanced view, and reports that low trade barriers do have a positive effect when combined with sound macroeconomic policies. From what evidence there is, a cautious conclusion would be that trade barriers probably do not help to increase innovative behavior by domestic firms and may even hinder such behavior. Unless carefully designed, they will certainly discourage the transfer of certain kinds of new technology and capital goods, which may be a disadvantage for countries in catch-up mode.

A study by Alvarez (2001) on Chilean firms using the new Innovation Survey data demonstrates that exporting and technological innovation go hand-in-hand, without one clearly causing the other, whereas the level of Foreign Direct Investment and licensed technology has little impact on the domestic firm's own innovation. Evidence from Ciarli and Giuliani (2005) on the effects of encouraging FDI in Costa Rica is similar: successful industrialization has taken place, dominated by

Intel and its suppliers, but there has been little spillover of technology to the local economy. Skilled trained workers tend to remain within the foreign subsidiaries and only about 20% of these subsidiaries actually undertake R&D in Costa Rica, mostly for customization to local requirements.

Robertson and Alvarez (2001) have findings for Chile similar to those of Alvarez and also find somewhat stronger effects on innovation for Mexican firms that are exposed to foreign technology. This paper also finds interesting differences depending on the level of development of the country to which these countries export: exporting to developing countries tends to be done by firms with R&D laboratories and by firms that innovate in product design, whereas exporting to developed countries is associated with organizational innovation and new product and tool innovation. However, Vallejo-Carlos (2005) found a reduction of local R&D investment by foreign multinationals in Mexico following NAFTA and the removal of local content requirements.

The above evidence and that from Chile and Costa Rica suggests that simply encouraging FDI in a country is unlikely to lead to significant migration of technological assets, unless it is accompanied by some measures that encourage technology transfer along with the FDI. In this regard, the FDI policies of the East Asian tigers discussed by Lall (1996, 2000) are instructive. Although Korea, Taiwan, and Singapore pursued quite different policies with respect to the level of FDI they encouraged, all these countries tended to target particular technologies and to insist on the transfer of technology to domestic firms as a condition of entry.

4.5 *Financing private R&D*

Many countries and regions are now exploring the use of government-guaranteed Venture Capital funds to try to solve the early stage financing problem and encourage innovation by new private firms, although as of a recent survey, only the United States, Israel, and the East Asian countries have a significant amount in start-ups rather than buyouts and restructuring deals (Mani and Bartzokas 2004). As referred to earlier, recent work by Avnimelech and Teubal (2004, 2005) emphasizes the importance of staging the development of private sector financing of R&D including venture capital in three phases, during which the system evolves from one that emphasizes government funding of business sector R&D with support for startups to one that relies primarily on venture capital and private equity. These authors hold out Israel's strategy of transition from a government-funded model in 1985 to one based primarily on private funding in 2000, especially the Yozma program, as an example of how to achieve successful development in this area. They highlight the following features of the program as important:

- It was a fund of funds and direct investments in start-ups that favored VC limited partnerships, with a focus on early phase investments in Israeli high tech companies. Ten privately owned Israeli VC Funds were created, each managed by a local management company and including reputable foreign financial institutions.

- The target level of capital for the whole program was 250M$ (with a government share of 40%), providing a 'critical mass' for the emergence of a VC industry. Strong incentives were provided, namely a five-year option to buy the government's share at cost; thus other investors were insured on the downside and benefited on the upside.[17]

- The program was begun in 1993 and privatization was completed in 1998. Yozma became a catalytic program, triggering a strong process of collective learning and attracting professional VC agents.

In addition to venture capital and private equity, other countries have pursued different strategies: as mentioned earlier, Korea has relied largely on financing by large firms (*chaebols*) and Taiwan has relied on the use of spin-offs from ITRI and ERSO (Mowery 2005).

4.6 *R&D tax credits*

In countries with well-developed corporate tax systems, tax credits designed to encourage R&D are commonly used policies that have been shown to be effective in increasing R&D spending by industrial firms (Hall and Van Reenen 2000). The argument in favor of this kind of policy is that it is designed to lower the cost to the firm of doing R&D without specifying the sector or type of R&D that

[17] Note that this is substantially larger than such programs as Finlombardia (for the Lombardy region of Italy, 37 million euros) and Fonsinnocat (for the Catalonian region of Spain, 20 million euros), even though the size of the Israeli economy is probably not ten times the size of these regions.

should be done, thus leaving these difficult decisions to the private sector, which often is better at choosing where to invest its funds than governments. However, there are some drawbacks, some of which may render this policy unsuitable for developing countries with immature tax systems.

The first problem is design and cost. The usual R&D tax credit is incremental and specifies that firms should receive a credit on their corporate tax equal to some statutory percentage (ranging from about 10 per cent to 50 or 100 per cent in some cases) of the amount of R&D they perform above some base level. The advantage of using a base is that the credit is not given on inframarginal R&D that would have been performed in any case, which saves considerable government revenue, especially since R&D often behaves as though adjustment costs are high (it is fairly smooth over time within firm). However, defining the base for each firm has proved problematic: in the United States and some other countries, the base was initially determined from the firm's own R&D in the previous two or three years, but this has the consequence that the effective credit becomes much lower than the statutory rate due to the consequence of increasing R&D spending for the base in subsequent years. The current U.S. credit base is computed from firm R&D intensity in the years 1984-1988 and firm revenue in the current year, and this has produced numbers that are less and less relevant to the position of each individual firm as time passes.[18] Some countries, including the U.S. (in some cases) offer an alternative credit in addition or instead of the incremental tax credit. This alternative involves a fairly small credit rate applied to all the firm's R&D, which may forego greater tax revenue and certainly has a much lower incentive effect.

A second problem is auditing and the definition of R&D. Experience in the United States suggests that tax auditors in general tend to find this one of the most difficult areas with which they have to deal, primarily because they do not have science and engineering experience in general and have little understanding of the R&D process (Stoffregen 1995; US GAO 1989). On the firms' side, there is of course a temptation to define as many expenses as R&D as is reasonable or feasible, especially if the credit rate is high. This type of behavior may be even more problematic in a developing country with an immature tax system, especially if tax avoidance is a widely practiced art.

[18] At the time of writing, revision of the R&D tax credit to change the base among other things is under consideration by the U. S. Congress.

The third possible disadvantage of an R&D tax credit system is that the incremental projects chosen will be those that rank highest in terms of private returns, whereas from a policy perspective the ranking should be in terms of social returns. Project choice is unlikely to be the same under the two rankings and this is the reason that most governments combine an R&D tax credit system with public spending in areas that are perceived to have especially large gaps between private and social returns (basic science, health research, environmental research, and pre-commercial research of all kinds).

Hall and Van Reenen (2000) review the econometric evidence on the effectiveness of these kinds of fiscal incentives for R&D and conclude that a dollar in tax credit for R&D stimulates a dollar of additional R&D. If the tax credit is truly incremental, then this marginal effect translates into an increase in private R&D spending that is roughly equal to the cost in terms of lost tax revenue. Therefore, except for enforcement and record keeping costs in the case of tax and administrative costs in the case of public R&D subsidies, the benefit-cost ratio is roughly comparable to direct subsidies, although the R&D elicited may be different in the two cases.

4.7 *Intellectual property policy*

Granting strong intellectual property rights to inventors and innovators is often advocated as a policy that will encourage and increase innovative activity in an economy. For example, this belief lies behind some of the policy initiatives during the past twenty years in the United States, the European Union, and at WIPO. However, there are reasons to think that such policies need to be implemented cautiously and with a full understanding of their implications for invention costs in developing economies such as those of Latin America. Throughout history, stronger IP systems have tended to be the *result* of technological development and the creation of firms capable of taking advantage of these systems, at least as much as they have been the cause of development (Barton *et al* 2002).

Scotchmer (2001) develops these ideas more precisely in the context of a game-theoretic model. She shows that treating foreign inventors the same as domestic inventors (national treatment) tends to increase the strength of IP beyond the optimal level, and that international harmonization exacerbates this effect, while at the same time mitigating the underinvestment due to inter-country externalities in R&D. Lall (2003) explores the preconditions that will make a country a net beneficiary of strengthened IP protection. He divides countries into four groups, the top two of which are likely to benefit from stronger IPRs. The larger and more developed Latin American countries are in the second group, while countries like Peru, Ecuador, Colombia, and Bolivia are in the third. He argues that stronger IPRs may have little impact on the location of transnational corporation activity in the short run, but may encourage its location in the long run and clearly views attracting such investment (such as IBM assembly plants in Mexico) as valuable for technological development. He also emphasizes the fact that the importance of IP protection varies greatly across industry and therefore the effects of stronger IP on any particular country will depend strongly on its particular industrial strengths.

A number of other economists have explored the interaction between IP protection and development. One area where there may be a direct connection is the willingness of firms from developed countries to transfer their technology to developing countries. Maskus (2004) summarizes the evidence on the relationship between patents and technology transfer as follows: 1) patents do serve as a conduit for learning and their citations reflect knowledge flows across borders; 2) stronger patent rights are likely to increase payments from developing to developed countries for technology rights; 3) international trade flows and FDI respond positively to strengthened patent rights in middle income and large developing countries, but not in poor countries; 4) as in developed countries, strengthening of patent rights tends to shift transfer towards intangibles (technology information). That is, patents enable the development of markets for technology. Nevertheless, other factors besides patents such as the investment climate, efficient governance, market size and growth, and infrastructure are also important in determining technology transfer (Maskus 2004).

The finding that FDI responds positively to strengthened patent rights is somewhat controversial, and the evidence is mixed. Most researchers cite Mansfield (1993), which is based on the author's survey of executives in multinational corporations. However, new evidence from Branstetter *et al* 2005 suggests an increase in the transfer of intangibles to affiliates after IPR reform in 16 countries, including Argentina, Brazil, Chile, Mexico, and Venezuela, as well as increases in R&D by affiliates of U.S. firms in these countries. So if FDI is demonstrated to be important in encouraging innovation in domestic firms via competitive and spillover effects or if the transfer of intangibles and technical information is desired, patents may be important for encouraging this. As Lall (2003) suggests, these things may be important once a country reaches a certain level of "absorptive capacity."

5. Conclusions

The paper has documented the innovation underperformance in Latin America according to a number of indicators: the knowledge economy indicators constructed by the World Bank, high-technology exports per capity, and various measures of innovative output based on patents. Although the most developed Latin American countries (Argentina, Brazil, Chile, Costa Rica, and Mexico) do not perform badly relative to their GDP per capita peers on some of these indicators (notably tertiary education and innovation more broadly) there are considerable shortfalls in other areas such as US patenting and business R&D performance.

Based on my review of the literature and indicators, the chief areas to which policy attention should be directed are therefore underinvestment in business R&D, low quality public sector research institutions and their weak links to industry, and generally low government support for R&D. The literature has identified the reasons for underinvestment (and a correspondingly high rate of return to private R&D) as the following: 1) difficulties in obtaining finance; 2) weak intellectual property protection, and 3) possibly barriers to new firm entry. There is some controversy over the second factor, since many of the successful development stories during the past 30 years took place without strong IP rights and were facilitated by imitation strategies, at least in their initial stages.

The remedies for underinvestment in R&D are to raise its return or lower its cost and the two chief sets of policies are tax credits and government subsidies. In a setting like Latin America, tax credits may be problematical. First, they tend to be expensive unless they are incremental and an incremental credit is very tricky to design. Second, they require that there be a sufficient corporate tax bill to be useful and that tax-skilled enforcement is available if they are not simply to be a giveaway to firms. For this reason, they have not been a widely used instrument in developing economies.

The public subsidy or R&D cost-sharing alternative looks more attractive, although it is also accompanied by a requirement for high quality civil service administration, some of which might be provided on a multi-country basis in order to reduce its cost. The government R&D subsidy approach has experienced some success in several countries, notably Finland and Israel, at least to the extent that R&D spending increases and new firms are created or grow. It has the advantage of substantially lowering the cost of R&D to the firm, but leaving the upside risk to the entrepreneur, which tends to provide strong incentives. At the early stage of development, it is probably preferable not to target the subsidies in a particular direction, although evidence on this question is mixed. Most of the studies that have looked at firm behavior when these types of matching subsidies are available have concluded that they do not crowd out the firm's R&D completely (David and Hall 2000).

The remedies for weak institutions and weak industry links are somewhat harder to design and implement, since they will require the employment of a number of trained and skilled personnel, and it is not clear where these are to be obtained other than redirecting academic researchers or spending more resources on training and education. Some lessons from history are the 19th century US university-allied extensive services for manufacturing as well as agriculture, which were largely government-funded and played a role in technology transfer to firms. Besides diffusing technology, such institutions can play a role in educating entrepreneurs in best practices and the setting of standards. A slightly different model for the performance at, and transfer of research from publicly funded institutions was provided by Taiwan and seems to work well in an economy that is dominated by small and medium-sized firms. As in the cost-sharing subsidies above, it is important that the entrepreneur who leaves the institute to commercialize the technology faces an appropriate return-risk tradeoff, or he will be reluctant to undertake the difficult task of commercialization.

In designing policies for innovation in developing countries, it may be helpful to examine some programs that are viewed by experts in the field as failures, in order to see which design features are to be avoided. One area where there appear to be more successes than failures is in the numerous attempts to “kick-start“ a Venture Capital industry. Problems arise when there is insufficient private demand for capital (the Chilean case described in Avnimelech and Teubal 2005 and perhaps the EASDAQ example) or with excessive government intervention, goals that are primarily financial rather than developmental, and with downside insurance instead of an upside payoff (Israel’s Inbal program, also described in Avnimelech and Teubal 2005).

A second set of policies that may be successful for industrializing but not for developing innovative capacity are policies that encourage FDI via low taxes and import/export duties but with no policies to encourage technology transfer activities. The lessons from Latin American countries like Chile, Mexico, and Costa Rica and the contrasting performance of Taiwan, Korea, and Singapore suggest that if FDI is to produce technology transfers, a *laissez faire* approach (such as that used by Hong Kong also) may not work.

The final policy area where some doubts about recommended policies emerge is the role of intellectual property protection in encouraging innovative activities in developing countries. The chief modern example of rapid industrialization and development is the experience of the Newly Industrialized Countries in Asia such as Singapore, Korea, Taiwan , etc. It is clear that the early phase of their successful technological development was based to some extent on imitation, and that patents were largely not used and in fact, unimportant in the domestic economy. Only in the past twenty years have firms in these countries begun patenting aggressively, partly due to changes in the use of patents in the

ICT sector and partly because they are engaging in more frontier-type research. Many, although by no means all infant industries have had a similar experience of lack of patenting during their earlier phases, for example, the development of steam-driven pumping engines in Cornwall, England (Nuvolari 2001), the science-based chemical industry, especially the manufacture of synthetic dyes in Germany and the UK in the late 19th century (Murmann 2004), and the early phases of the semiconductor and software industries (Hall and Ziedonis 2001). An important question for current policy design is whether TRIPS has foreclosed this avenue of technology development and technology transfer, and whether anything can be done to modify the way in which the agreement applies in developing economies.

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Table 1

Predicted and Actual Patenting Performance
Selected Latin American Countries, 1998

Country	NIC Index (predicted patents per capita)*	1998 Patents per capita**	Average 1976-1998 Patents per capita**
Argentina	2.50	1.19	0.72
Brazil	1.12	0.95	0.26
Chile	1.08	1.08	0.35
Costa Rica	0.64	0.27	0.67
Mexico	0.37	0.60	0.54
Colombia	0.29	0.10	0.13
Venezuela	0.16	1.16	0.88

*The NIC index is the predicted patents per capita from a regression of U.S. patents granted 3 years later on R&D, sci. and eng., GDP, etc. for a sample of OECD economies 1973-95.
**U.S. patents granted to inventors resident in the country per million population.
Source: Porter, Furman, and Stern 2000 (column 1); authors' calculations (columns 2 and 3).

Table 2

Latin America vs East Asian Tiger Economies in 1995
Comparing Education Indicators

	Gross enrollment rate				
Country	**Primary education**	**Secondary education**	**Tertiary education**	**Tertiary/ secondary**	**Pop share in core tech tertiary ed***
Argentina	111	67	36	0.54	0.49%
Brazil	114	46	11	0.24	0.19%
Chile	99	68	27	0.40	0.67%
Mexico	112	58	14	0.24	0.45%
Singapore**	107	68	19	0.28	0.56%
Korea	95	99	55	0.56	1.55%
Taiwan	100	88	38	0.43	1.09%
Malaysia	93	61	10	0.16	0.14%
South Africa*	114	90	15	0.17	
Hungary*	103	95	33	0.35	
Poland***	99	101	46	0.46	

Sources: UNCTAD World Investment Report; World Development Report 1996, 1997; UNESCO Statistical Yearbook 1995, as summarized by Lall (2000).

* 1998/1999
** The tertiary education numbers for Singapore exclude polytechnics.
***1999/2000

Table 3

Latin America vs East Asian Tiger Economies

Comparing Industrial Development and Technology Indicators

Country	1995 GDP per capita ($1996)*	1993-1997 FDI share of GDI	1995-1998 Capital goods investment per capita	1995 Total R&D to GDP ratio*	Business R&D share of total R&D*	1998 Tech licenses per capita (1998$)	US patents granted 1996-2000 per M population	US patents granted 1996-2000 per $M R&D	High tech exports per capita ($1998)	Cost of entry as a share of GDP/capita
Argentina	$10,266	10.3%	$191.6	0.30%	16.7%	$11.7	1.18	0.049	$17.81	0.2323
Brazil	$6,765	5.1%	$76.3	0.84%	20.0%	$6.5	0.49	0.009	$19.25	0.6735
Chile	$8,488	20.3%	$323.2	0.80%	20.0%	$3.8	0.73	0.019	$7.08	0.1161
Mexico	$7,175	11.0%	$178.1	0.40%	22.5%	$5.2	0.64	0.048	$326.12	0.5742
Latin America (pop-wtd average)	**$7,378**	**8.2%**	**$132.3**	**0.64%**	**20.4%**	**$6.6**	**0.63**	**0.026**	**$111.73**	**0.5656**
Singapore	$22,642	26.5%	$8,803.5	1.10%	62.7%	$559.2	37.66	0.128	$19,699.59	0.1239
Korea, Rep. of	$13,552	1.0%	$534.7	2.70%	84.1%	$51.0	59.96	0.229	$775.72	0.1563
Taiwan	$14,785	2.8%	$992.3	1.80%	55.6%	$65.0	145.36	0.734	$1,767.43	0.0072
Malaysia	$8,705	14.1%	$716.8	0.40%	42.5%	$107.8	1.20	0.077	$1,547.77	0.1723
East Asia (pop-wtd average)	**$13,091**	**5.4%**	**$1,005.9**	**1.90%**	**67.1%**	**$87.0**	**65.73**	**0.309**	**$1,922.07**	**0.1237**
South Africa	$7,222	6.3%	$168.9	0.70%	54.4%	$4.0	2.81	0.057	$22.31	0.3666
Hungary	$8,639	23.6%	$313.7	0.65%	38.9%	$21.2	3.77	0.062	$471.21	0.8101
Poland	$7,282	13.3%	$191.4	0.71%	38.9%	$5.0	0.38	0.007	$58.59	0.2795
Other (pop-wtd average)	**$7,413**	**11.4%**	**$195.6**	**0.70%**	**45.8%**	**$6.4**	**1.85**	**0.036**	**$90.45**	**0.3800**

Sources: UNCTAD World Investment Report; World Development Report 1996, 1997; UNESCO Statistical Yearbook 1995, as summarized by Lall (2000, 2003). Patent data from Hall et al (2002); Population and GDP data from Heston et al (2002). Entry cost data from Djankov et al 2002.

*Numbers for Hungary and Poland are for 1996.

Table 4
Recent R&D Performance in Latin America

Country or region	Most recent year of data	R&D (millions PPP)	R&D/GDP	Business R&D/GDP
United States	2002	$276,434	2.64%	1.70%
Canada	2002	$17,869	1.88%	0.85%
Spain	2002	$9,882	1.03%	0.51%
Portugal	2001	$1,488	0.84%	0.26%
Latin America	**2002**	**$19,694**	**0.57%**	**0.21%**
Brazil	2000	$13,564	1.04%	0.40%
Chile	2001	$767	0.57%	0.14%
Argentina	2003	$1,789	0.41%	0.09%
Panama	2001	$75	0.40%	0.04%
Costa Rica	2000	$129	0.39%	
Mexico	2001	$3,321	0.39%	0.12%
Venezuela*	2002	$463	0.38%	0.08%
Bolivia	2002	$61	0.26%	0.04%
Uruguay	2002	$58	0.22%	0.10%
Peru	2003	$140	0.11%	
Colombia	2002	$275	0.10%	0.05%
Trinidad & Tobago	2001	$13	0.10%	
Paraguay	2002	$21	0.10%	0.00%
Ecuador	1998	$36	0.09%	0.00%
El Salvador	1998	$21	0.09%	
Jamaica	2002	$8	0.08%	
Nicaragua	2002	$6	0.07%	
Honduras	2000	$8	0.06%	

*S&T expenditures rather than R&D expenditures.

Source: www.ricyt.org, Tables 3 ,4, and 9

Table 5
Knowledge Indicators for Most Recent Year

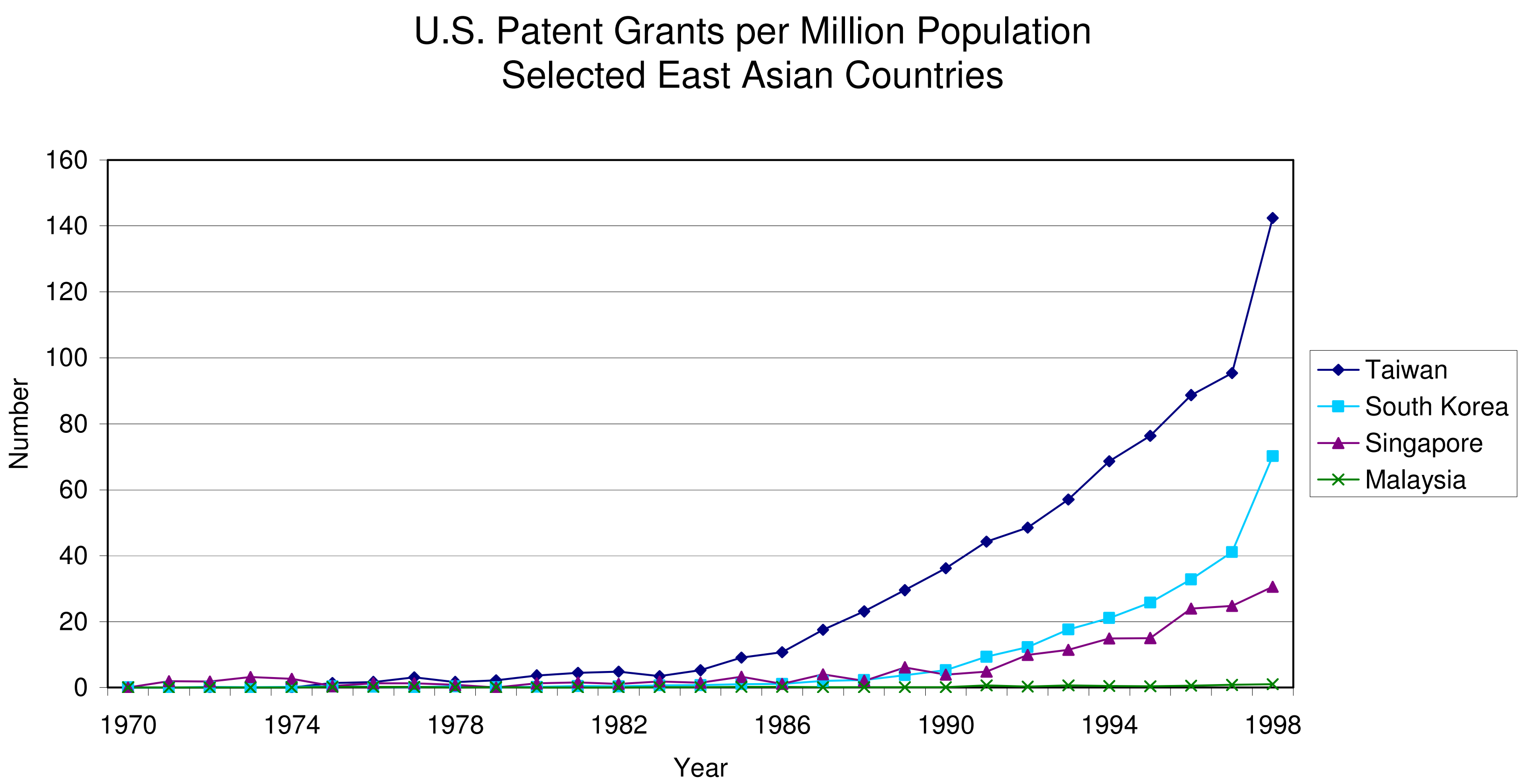
Country	Innovation	Education	Information infrastructure	Aggregate Indicator
Argentina	6.15	7.49	5.53	6.09
Brazil	5.02	5.75	5.50	5.42
Chile	5.51	6.13	6.59	6.08
Mexico	4.67	4.43	5.51	4.87
Latin America	**3.30**	**4.50**	**4.73**	**4.18**
Singapore	7.82	5.50	9.01	7.82
Korea	8.32	7.86	9.00	8.32
Taiwan	8.30	6.98	8.93	8.30
Malaysia	5.46	4.48	7.02	5.46
South Africa	5.00	4.47	5.26	5.00
Hungary	7.00	7.33	6.66	7.00
Poland	6.98	8.22	6.59	6.98

Source: Worldbank, at http://info.worldbank.org/etools/kam2005

Table 6
Effects of Public R&D Subsidies in OECD Economies

Authors	Country	Dates	Sample size	Share with grants	Agency	Restrictions or targeting	Particpation determinants	Selection controls	Crowding out findings	Performance Findings
Aerts & Czarnitzki 2004	Belgium (Flanders)	1998-2000	776	23%	Flemish, Belgian govts; EU		larger, more patenting, larger export share, domestic	Modified propensity score matching	R&D about 150% higher if funding received	Patenting only slightly higher (2-10%?)
Czarnitzki, Ebersberger & Fier 2004	Finland	1998-2000	1520	48%; 64% coop	TEKES	Matched grants; prefer collaborations (incl. univ. collaborations)	larger, more R&D intensive, more patenting, larger export share	Modified propensity score matching		almost no effect unless there is also collaboration, which increases patenting about 15%
Duguet 2004	France	1985-1997	~1500	30%	French Ministries of Defense, Industry, and Research and Education		larger, more R&D intensive, more debt intensive	kernel propensity score	finds no substitution of public for private; difficult to evaluate magnitudes	
Czarnitzki & Fier 2002	Germany	1992-2000	4033	39% collab.; 10% funded collab.	Federal Ministry of Education and Research, Defense, etc.	favored collaborative R&D funding	more R&D intensive, slightly older and larger, more patents	kernel matching		30% more patenting if collab., 50% if funded collab.
Czarnitzki & Hussinger 2004	Germany	1992-2000	3779	16%	Federal government	East German companies	larger, more patenting, larger export share, older	Modified propensity score matching	R&D about 30% higher	patent applications about 20% higher (slightly less than R&D increase)
Hussinger 2003	Germany	1992-2000	3746	19%	Federal Ministry of Education and Research	East German companies	more R&D & patent intensive, larger export share, larger domestic	variety of matching methods; Heckman	R&D about 20-40% higher if funding received, depending on selection control	
Czarnitzki & Fier 2002	Germany	1996-1998	1008	21%	National public R&D programs	only know participation; SMEs; target East Germany; service sector	Larger, more R&D intensive, less urban, younger	kernel matching	R&D about 100% higher if funding received	
Almus & Czarnitzki 2003	Germany (East)	1994-1998	925	66%	all public R&D		larger, more R&D intensive, domestic, younger	Modified propensity score matching	R&D about 100% higher if funding received	
Czarnitzki, Ebersberger & Fier 2004	Germany (West)	1998-2000	1464	21%; 29% coop	Projekttraeger?	Matched grants; prefer collaborations (incl. univ. collaborations)	larger, more R&D intensive, more patenting, larger export share	Modified propensity score matching		either collaboration or public funding increases patenting about 10%, both about 27%
Lach 2002	Israel	1990-1995	1098	60%	Office of Chief Scientist	matching, startups, preferred areas	larger, more R&D-intensive	Diffs in diffs	average R&D about 23% higher in long run (but small firm effect large and large firm effect zero)	
Busom 2000	Spain	1988	154	45%	Centro para el Desarrollo Tecnologico e Industrial	some Natl; some European funds; only know participation	smaller, older, domestic, more patents	Heckman	increase of 20% in firm's own spending n average; but for 30% of firms, complete crowding out	
Wallsten 2000	US	1990-1992	707	73%	Small Business Administration	Small Business Innovation Research from Defense or NASA	larger, patent slightly more	3SLS with SBIR budget available	complete crowding out (based on small sample)	no effect on employment

Figure 1


U.S. Patent Grants per Million Population
Selected East Asian Countries
Number
160
140
120
100
80
60
40
20
0
1970
1974
1978
1982
1986
1990
1994
1998
Year
Taiwan
South Korea
Singapore
Malaysia