Institutions and Incentives for R&D: Implications for L.A.C. Economies

Walter G. Park,
Associate Professor,
Department of Economics,
American University,
Washington, D.C. 20016

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Abstract: This study evaluates the role of intellectual property rights, fiscal incentives, and public funding in supporting research and development (R&D) activities, with particular attention to R&D activities in the Latin America and the Caribbean (LAC) region. The study bases its evaluations on case studies of individual countries and on cross-country empirical analyses.

The study initially compares R&D activities in LAC to other regions (for example, U.S., Europe, East Asia) and finds the level of R&D activity in LAC to be comparatively low. The study then proceeds to examine how different R&D policies might impact on R&D activities in LAC. Strong conclusions are hard to draw given the limitations with the theory and empirical evidence, but the evaluations seem to suggest the following. First, a strengthening of intellectual property rights, particularly patent rights, will likely impact significantly on R&D and total factor productivity in LAC. Secondly, the success of fiscal incentives for R&D is not as clear for the LAC region, unless inefficiencies in the system of public finance can be dealt with. Thirdly, public R&D funding has the potential to stimulate private R&D, but currently the size of the public research sector in LAC may be "too large" from an efficiency point of view. A greater balance is needed between public and private R&D. Thus, an R&D matching grant program which raises public and private R&D spending in tandem (and coordinates them) will likely be a good starting point.

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1. Introduction

Research and development (R&D) activities are much touted as an important source of economic development, economic growth, and social welfare, but exactly how important they are is the subject of much debate; for instance, what are the social rates of return to R&D or the marginal productivities of R&D capital? Given national resource constraints, how much should society invest in R&D versus say human capital development, physical capital formation, or judicial reform? In other words, is R&D such an important factor to economic progress that society's scarce resources should be further allocated to this activity at the expense of other socially desired activities? Another subject that generates much debate is the issue of what influences R&D activities. Is it market structure, market size, resources, institutions, or government policy?

The relevance of these debates for developing countries is that promoting R&D is seen as an important means by which to help catapult their technological development. The development of local R&D capabilities should better enable domestic inventors to generate new technologies for local needs and better enable the local economy to utilize advanced technologies from abroad. This shift – if one can call it that – towards R&D is relatively recent. Until now, there has been much emphasis on promoting human capital (in development projects and other efforts), through improving schools, enrollments and completion rates, and better financing of education. Both education and R&D have complementary aspects. But there are some differences: education is generally broader (affecting the population as a whole) whereas R&D tends to be sector-specific (namely, but not exclusively, the manufacturing sector). In addition, the economic impacts of educational investments may take longer to be felt than those of R&D investments; R&D investments on the other hand may have higher failure rates than educational investments. Also, at any moment in time, policy authorities face resource constraints, so that even if R&D investments and educational investments are complementary, a choice or tradeoff between them may nonetheless be entailed.

This study focuses on the role of certain institutions and incentives that drive R&D, namely intellectual property rights and fiscal policies (such as R&D tax incentives, subsidies, and grants), with emphasis on the Latin America and Caribbean (LAC) region. The study also examines the kinds of benefits that R&D investments and R&D policies can have, for example on total factor productivity, domestic innovation, and foreign technology inflows. The analysis also controls for human capital factors (such as the number of scientists and engineers in the workforce and the level of tertiary education in the population). Human capital and R&D capital are more than complementary inputs into economic development; the study finds that those human capital factors are an important determinant of R&D and source of total factor productivity. Even when intellectual property rights, fiscal incentives, and public R&D funding are controlled for (which are often the policy instruments advocated for R&D), those human capital variables remain a positive influence on R&D, and in some cases reduce the statistical significance of property rights and incentives. Thus, an implication of this study is that human capital and R&D investment considerations not be detached when it comes to promoting the level of scientific and technological activities within LAC.

It should be noted at the outset that the policies that are often advocated to stimulate R&D – such as strong intellectual property rights, fiscal incentives, and public R&D funding – are controversial particularly in the context of LAC. First, previous empirical studies are few. Secondly, from a theoretical perspective, the positive and welfare effects depend on various settings and assumptions, and there are often no clear cut answers to guide policy. These two points will be apparent during the course of this study. However, another controversy relates to the appropriateness of some of the R&D stimulating policies in the context of LAC. Currently in LAC, the R&D activities are fairly low in comparison to the rest of the world, lagging behind the OECD, Far East Asia, and Israel. As a share of world R&D, Latin America accounts for 1.5% of it, while the OECD accounts for 74%.[1] Although recently, LAC economies (such as Brazil, Mexico, and Costa Rica) have made great strides in R&D and innovative activities – and much greater activity seems to be in the offing. The point, though, is that with a small R&D sector, does it make sense to strengthen intellectual property laws (and shift economic rent to foreign multinationals who own most of the technologies)? To provide tax credits and subsidies to large manufacturing firms whose R&D is of a small scale (compared to that of the U.S., Europe, or Japan)? Such questions ignore the feedback between R&D activities and policies. R&D sectors may be small – and the scale (or quality) of R&D projects low – precisely because the incentives to do R&D were weak or because the institutions failed to protect property rights. These discourage not only inflows of foreign technology but also local (potential) innovation. This is a theme to which we return.

This study is outlined as follows: section 2 provides a discussion of R&D behavior and trends. In particular, it presents a simple model of R&D behavior to help conceptualize how different policies. This section also compares measures of R&D activities of countries during the recent past, highlighting how LAC fares vis-à-vis the rest of the world. Section 3 discusses the different R&D policies and institutions behind R&D. In particular, it covers (a) intellectual property rights, (b) fiscal incentives, and (c) government funding (such as grants and subsidies). For each of these policy areas (a) - (c), we provide some background definitions and concepts, a discussion of how these policies can be measured empirically, and a literature review of past studies. Section 4 provides an empirical analysis of the determinants and effects of R&D. Section 5 considers the implications of the study for the LAC region, highlighting the R&D policy challenges ahead. Finally, section 6 concludes with some thoughts for future research.

2. R&D Behavior and Trends

2.1 Basic Model

Until recently, most analyses of R&D behavior were *ad hoc*, in the sense that they were not founded upon microeconomic principles but upon some reasonable ideas about what influences R&D. For the most part, these intuitive influences made sense. Rigorous models have tended to yield behavioral equations which have accorded well with some of the ad hoc approaches, but with added insights and nuances as to how the influences work, in which direction, and to what degree. Nonetheless, to help organize one's thoughts about how policy and other factors influence R&D, it is useful to develop a conceptual model.

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[1] See Correa (2000).

In doing so, it is useful, as David et. al. (2000) point out, to think about the supply and demand for R&D. Firms rationally compare the expected benefits and costs of conducting R&D projects. Each project is associated with some expected rate of return. Demand side influences affect the marginal rate of return to R&D, while supply side factors affect the marginal cost of R&D. In private equilibrium, that level of R&D is conducted where the marginal rate of return equals the marginal cost of R&D, which need not be the socially desired level of R&D. Park (2001) develops a dynamic, optimizing model of R&D suppliers and users. The following is a sketch of the demand and supply approach to R&D.

On the demand side, firms maximize the present discounted value of the stream of profits:

$$(1)\ V = \int_{t=0}^{\infty} e^{-\rho t}\left(F(R_p, R_g, \ldots) - (1-\tau)pR_p\right)dt$$

subject to:

$$(2)\ \dot{R}_p = I_p - \delta R_p$$

where V denotes the value of firms, F the production function, R_p the stock of private R&D capital, R_g the stock of government R&D capital, p the price of R&D capital, the real interest rate, the depreciation rate, the R&D investment tax credit rate, and I_p gross R&D investment. Implicitly in (1), it is assumed that the price of final output is unity. Instantaneous profits are the difference between revenues and tax credit-adjusted cost of R&D. In steady-state, the necessary condition for value-maximization is:

$$(3)\ p = \frac{F_{R_p}}{(1-\tau)(\rho+\delta)}$$

where F_{Rp} is the marginal product of R&D capital. In other words, the price of R&D capital equals the discounted value of the marginal product of capital (adjusted for the tax credit). The relationship in (3) is the standard "user cost equated to the marginal product of capital" expression found in the investment literature.[2]

On the supply side, it is assumed that firms compete to sell R&D capital services to the

[2] In this optimizing model, firms are assumed to face no borrowing constraints. Otherwise, current output or profits would influence R&D decisions. This possibility is more important to deal with at the firm level; this paper models R&D at the national level. The firms' ability to borrow depends on its assets (e.g. tangible physical capital, which is one of the determinants of R&D that we include).

demand side of the market.[3] The critical feature is that knowledge spillovers exist among them. When a firm conducts R&D, it not only generates knowledge for itself but also for others, including its rivals and future follow-on researchers. Thus the cost of performing R&D is lower the greater the spillovers. To capture the essential implication of this – namely that firms underinvest in R&D relative to the socially desired outcome – let us assume that there are only two firms (that behave as price-takers). Let gross R&D expenditures (in (2)) be the sum of the individual firm investments:

(4) $I_p = i_1 + i_2$,

where i's denote R&D flows. The profits of each firm are:

(5) $\quad _1 = p\, i_1 - c_1\, (i_1, i_2, ...)$

(6) $\quad _2 = p\, i_2 - c_2\, (i_2, i_1, ...)$

where p is the same price of R&D capital denoted in equation (1). Note that in the cost functions, $\partial c_1/\partial i_1 > 0$ and $\partial c_2/\partial i_2 > 0$, but that $\partial c_1/\partial i_2 < 0$ and $\partial c_2/\partial i_1 < 0$, indicating the beneficial effect of spillovers.[4] In the cost functions, all other relevant factors are denoted by ... .[5]

A social planner would choose the level of firm 1's R&D output to maximize $\ = \ _1 + \ _2$, yielding the first-order condition:

(7) $p = \partial c_1/\partial i_1 + \partial c_2/\partial i_1$

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[3] It would not be difficult to extend the model to the case where the supply of R&D comes from within a firm (i.e. internally) through a research department.

[4] In Park (2001), to be more precise, the cost of research is assumed to be negatively related to the "stocks" of spillovers, not the flows. The purpose here is to get at the essential elements without cluttering up the notation and model.

[5] One might wonder why we model the costs of research as being variable, when it is often assumed that research costs are fixed or sunk, F. Once a breakthrough is made, the marginal costs of production (and reproduction) of the knowledge or of its products (e.g. medicines, chemical compounds, software programs, ...) is relatively small. Thus, firms would have trouble recouping their F if others can also market the products. This is behind the standard rationale for intellectual property protection – namely to allow the innovator to charge sufficiently above marginal costs for some time (by giving it temporary monopoly power) until such time that F can be recouped. The role of intellectual property rights is further discussed below, but the point here is that there need not be a conflict between the idea that research costs tend to be sunk costs and the cost functions in (5) and (6) which appear to be variable. We could assume that firms have a choice as to how much of that sunk costs it wishes to spend on a research project. In other words, a priori F is endogenous, depending say on market conditions in the user market. But once a research project is undertaken, and completed, that F is fixed, a bygone. Thus, (5) and (6) describe the technology for conducting some research project.

But the private firm 1 chooses to produce that level at which:

(8) $p = \partial c_1/\partial i_1$

Since $\partial c_2/\partial i_1 < 0$, firm 1 underinvests in R&D, as does firm 2. Neither is able to appropriate the full benefits of its R&D.[6] In fact, if:

$\partial c_1/\partial i_1 + \partial c_2/\partial i_1 < p < \partial c_1/\partial i_1$

firm 1 will conduct zero R&D, since privately the marginal costs exceed marginal gain, yet from society's point of view, the marginal gain exceeds social marginal costs.

The source of the market failure is that the spillovers are unpriced in the marketplace. There are various public policies that could address the market failure. One is to subsidize private research. The optimal subsidy rate would be $s = \partial c_2/\partial i_1$. A second policy is to provide cash grants, such that the net cost of conducting research is $c_1' = (1 - \ \ )c_1$, where   is the grant rate. If   = ½, a matching grant program is in effect where firm 1 pays for half of the cost of its research project. Yet another policy is to stimulate user firms to invest in R&D by raising the tax credit rate, .

Another factor that critically affects the decisions to conduct research is the effect of imitation or infringement by other firms. To the extent that there exists imitation and infringement, R&D firms sell less. Their market share is smaller and returns are lower. With more competitors, the price of R&D tends to be lower. Hence, we could model p = p(IPR) such that the first derivative is positive (i.e. dp/dIPR > 0) where IPR denotes the level of intellectual property rights. But a cost of providing IPRs is that they may reduce the extent of knowledge diffusion since some agents have proprietary rights to new technologies. Knowledge spillovers and diffusion may be restricted if the enjoyment of spillover knowledge depends on being able to use and produce with the new technology, but the law prohibits it. If that is the case, we model the spillovers, $\partial c_2/\partial i_1$, as a negative function of IPRs.

Before concluding, there are two caveats. The first is that in a more general model, there should really be no presumption that the social returns to R&D always exceed the private returns. One often models it this way because of feedback from empirical evidence, but theoretically it is also possible for the private sector to do too much R&D. There are at least two incentives firms have to do too much R&D. One is the phenomenon of patent races. If some idea is public – that is, many firms can work on an idea (as opposed to private ideas where many researchers can independently work on their own projects) – there is an incentive to be first, since the patent system or research grant competition tends to have a "winner-take-all" feature. Firms will then carry out duplicative investments and spend additional resources to try to win (for example, develop prototypes, lobby or rent seek) which from society's point of view are wasteful. A second potential cause of excessive

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[6] This illustration omits other ways in which the firm cannot capture all the benefits of its R&D, such as the gains to consumers from higher qualities per price of goods and services.

R&D is what is known as the "profit destruction effect."[7] New inventions displace old. Thus while society benefits from increased consumer surplus and knowledge spillovers to future innovators, existing producers suffer a loss in producer surplus. Since researchers and innovators do not take into account the producer surplus losses to others, their private incentives to do R&D and innovate can exceed social incentives.

A second caveat is that it is not always the case that R&D policies (that address gaps between marginal social returns and marginal private returns) will produce optimal outcomes. In general, to produce optimal outcomes, R&D policies will need to vary by research agents, since the socially optimal level of R&D is likely to vary by firms, industries, countries, technology fields, and types of R&D (basic versus applied). However, public authorities tend not to have knowledge about what the optimal level is for each agent. If they had that knowledge, they could design a subsidy or other policy for each individual agent. Instead, governments typically provide a subsidy rate that imperfectly, if at all, varies by firm or industry. Consequently, any fixed subsidy will be inefficient. It may be too much for some agents, too little for others. Likewise, policy authorities tend to grant the same level of intellectual property protection for different kinds of technologies, even though some technologies require greater costs to develop or are easier to imitate. Thus, a given IPR regime may be too strong for some, too weak for others.

2.2 R&D Trends

Table 1 presents a summary of recent historical trends in R&D and human capital indicators. A 58-country sample has been collected, and is divided into four regions. Region 1 consists of the OECD countries (excluding Korea and Japan). Region 2 consists of LAC economies. Region 3 consists of the East Asian economies (including Korea and Japan). Region 4 consists of selected Middle-East, African, and Southeast Asian economies (for example, India and Pakistan). In what follows, when we refer to the world as a whole, we are referring to the sample as a whole (i.e. all 58 countries). For practical purposes this is the universe of R&D conducting nations.

The bottom of Table 1 provides sample statistics for all regions pooled. The mean rate of R&D investment (as a percentage of GDP) is 0.98% for all 58 countries. Countries in region 1 exceed this mean (with the exception of Greece, Spain, Portugal, and Ireland). The most intensive R&D nation is Switzerland followed by the U.S. Swiss R&D as a percentage of GDP is 2.9%. Swiss private R&D spending per worker is also the highest (at $653 in real 1990 U.S. dollars), followed by the U.S. In absolute terms, U.S. private R&D spending is the highest in the world, but the Swiss labor force is much smaller. The U.S., however, has the world's highest public R&D spending per worker (at $482.2 in real 1990 U.S. dollars). This is followed by France, Germany, and Switzerland. Greece spends the least on private and public R&D per worker in this group, followed by Portugal. The overall world mean private R&D spending per worker is $146.9 in real 1990 U.S. dollars and the overall world mean public R&D spending per worker is $91.7 real 1990 U.S. dollars. The countries in region 1 on average spend $283.6 of private R&D per worker and $169.8 of public

[7] See Grossman and Helpman (1991).

R&D per worker (again in real 1990 U.S. dollars).

As to the share of R&D between public and private sectors, in region 1 on average the government funds 46% of R&D. The highest share is in New Zealand (at 65.5%), followed by Australia. The lowest share is in Switzerland (at 25.3%). Again, in absolute terms, the U.S. government spends the most (or funds the most) R&D, but in relative terms, its share has been below the mean in recent years (compared to other countries in this region and in the world at large). For the world as a whole, the mean share of public R&D is 59.1%.

Turning to the LAC Region, we observe R&D rates as a percentage of GDP to be below 1%. The average is 0.28%, which is the lowest of the four regions. Comparatively speaking, the most R&D intensive Latin American economies are Brazil (at 0.56%), followed by Chile (at 0.48%), then by Argentina and Venezuela. Brazil accounts for about half the R&D in this region. In terms of government funding share, the LAC region on average has governments funding 76.7% of R&D. This is the highest mean share among the four regions. In some economies, the government has in some periods funded all of R&D (e.g. Panama and Venezuela). The smallest share of public R&D funding is in El Salvador (at 52.2%). On average, in this region, $6.3 of private R&D is spent per worker, and $25.1 of public R&D per worker. These are the lowest average rates of spending among all four regions.

Thus in recent history, R&D activities in LAC have not been comparatively intense. Possibly due to reliance on technological imports, there might have been less emphasis on domestic R&D; or the causality could be the reverse. Due to a shortage of domestic R&D, these economies depended more on foreign technology. The situation is now changing. According to a recent report of the National Science Foundation (NSF), R&D spending increased markedly in Brazil, Mexico, and Costa Rica during 1990-1996 (although some declines were experienced in Argentina, Chile, and Venezuela).[8] Brazil and Mexico have nearly doubled their R&D spending over this period, while Costa Rica has more than doubled its R&D expenditures.

Still, the dominant source of funding and main performer of R&D is the government, although this too is changing, particularly in Venezuela and Brazil, where privatization has led to greater industrial R&D initiatives. One conceptual issue, however, is that the industrial sectors include publicly-owned firms so that the public's share of R&D funding may be somewhat understated. Universities also are important sources of R&D funding in the LAC area (and are channels for further public funding of R&D).

It is also still the case that the LAC region lags behind the rates of R&D in other parts of the world, despite the R&D spending increases in Brazil, Mexico, and Costa Rica. As shown in Table 1, the Asian economies on average devoted 0.85% of GDP to R&D, while region 4 countries devoted on average 0.56%. LAC, as mentioned above, contributed 0.28% of its GDP to R&D. This too should change since countries like Brazil have begun to adopt new policies, such as introducing an

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[8] See National Science Foundation (2000), March.

R&D tax credit and strengthening its patent laws. Another noteworthy trend discussed in the NSF Report is the increased involvement of international organizations (such as the Inter-American Development Bank (IDB) and World Bank) and the U.S. in funding R&D activities in LAC. The World Bank and IDB have approved nearly $600 million of loans for scientific and technological activities in Argentina, Brazil, and Mexico (with the governments and private industries of these countries putting up an additional $700 million). U.S. firms are actively performing R&D in Argentina, Brazil, Chile, Costa Rica, Mexico, and Venezuela through affiliates of U.S. multinationals, and the U.S. government is involved in cooperative R&D with various partners in Latin America. Thus the R&D scene in LAC is changing.

But in terms of past R&D activities, if one excludes Korea and Japan from region 3 and Israel and South Africa from Region 4, the R&D to GDP ratios in LAC are fairly comparable to those in regions 3 and 4. Of course, one information that R&D data (whether expressed in ratios of GDP or labor) cannot reveal is the quality of R&D. It may be that on a per dollar basis, LAC research is of comparatively higher quality, in terms of yielding new high-value innovations. Looking at total patent applications are also problematic because patent counts do not indicate the overall quality of the underlying inventions.

Table 1 also provides statistics on human capital indicators. The two indicators that are focused upon are the number of scientists and engineers per 10,000 workers and the school enrollment rate in tertiary education as a gross percentage of the relevant population age-group.[9] Loosely speaking, as the conceptual model discussed, the scientists and engineers variable could represent the quantity of human capital in the R&D sector whereas the education enrollment rate could proxy the quality of human capital. It is useful to focus on tertiary education rather than primary or secondary since R&D activities typically require highly trained individuals with advanced educational attainments.

For countries as a whole, on average there are 24.31 scientists and engineers for every 10,000 workers. In region 1, the mean is 41.33. The country with the highest is the U.S., followed by the Netherlands. For the world as a whole, Israel has the highest, with 120.99 scientists and engineers per 10,000 workers. Israel has an active scientific research community backed by a number of government sponsored programs, as will be discussed in the next section. In LAC, the average is 8.36 scientists and engineers per 10,000 workers. Within this region, the highest is in Uruguay, followed by Costa Rica. It is interesting that Uruguay has the highest density of scientific human capital but low rates of R&D to GDP. A likely possibility is that the scientists and engineers are employed in manufacturing, rather than in research. In comparison to LAC, Japan and Korea have 83.04 and 33.2 scientists and engineers per 10,000 workers respectively.

In terms of tertiary education enrollment rates, the world mean is 23.1% of the relevant

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[9] Note that in "net" enrollment rates (as opposed to gross enrollment rates), the numerator includes only those who are in that appropriate age bracket. For example, a 55 year-old who is enrolled in tertiary education would be counted in the gross rate but not in the net rate.

school age population. The mean for region 1 is 38.3%, for LAC 17%, for region 3 (East Asia) 17.8%, and for region 4 12.2%. The rates are low for less developed economies such as Malawi and Zambia. The highest in the sample is Canada (at 77.3%), followed by the U.S. In Japan and Korea, the rates are 29.3% and 34.8% respectively. Within LAC, the highest percentage is in Argentina (at 28.8%). Thus, for LAC and East Asia the tertiary enrollment rates are comparable. In these regions, there are alternatives to universities for higher education, such as technical training institutes or employment-based training centers, which may explain the lower percentages compared to those countries in region 1. Like the R&D data, the enrollment data does not the actual quality of the tertiary education (the level of knowledge taught, and so forth). But the data will tell us something about the implications of having tertiary education versus not having it.

Having discussed briefly the trends in R&D and human capital inputs into R&D, we turn now to discussing some of the policy instruments bearing on R&D activities.

3. R&D Policies

We describe the role of three policy areas: (a) intellectual property rights, (b) fiscal incentives, and (c) public funding of research and development. The coverage is selective, rather than exhaustive. For each type of policy, we define what they are in principle and in practice, explain how to construct empirical measures of these policies (which are used in the empirical analyses), and survey previous research on them concerning their relationship to R&D. The literature survey for each policy area is provided last in each section since ongoing research work is likely to be easier to follow or appreciate if some explanations of key definitions, concepts, and background institutional details are provided first.

3.1 Intellectual Property Rights

(A). Conceptual Issues

There are several different kinds of intellectual property rights, such as patent rights, copyrights, trademark rights, geographic indications, industrial designs, and so forth). In this study, we limit our attention to the big three: patents, copyrights, and trademarks. Patents protect ideas, while copyrights protect expressions.[10] Usually, but not always, patentable ideas are scientific and technological ideas, whereas copyrightable expressions tend to be, but not limited to, artistic creations. Some inventions have a bit of both (ideas and expressions), namely computer programs. Trademark rights protect symbols, marks, and names.

The logic of intellectual property rights protection is discussed extensively in the literature.[11]

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[10] For example, *Romeo and Juliet* and *West Side Story* are about the same 'idea' but are different expressions of that idea. Patent protection would protect that idea, copyright the expression.

[11] See, for example, Maskus (2000).

It is therefore best here to clarify a few points, particularly regarding patent protection, which the empirical section finds better explains R&D activities than copyrights and trademark rights (largely because R&D activities tend to be more of a scientific and technological nature than artistic and trade reputation building activities).

First, in the absence of a patent system, markets for ideas would be 'missing' due to the public good nature of knowledge. A patent system therefore creates a market which would otherwise not exist. The market in question, however, will not be perfectly competitive, given that the patent owner has exclusive rights to the invention. There is no free entry and exit of other suppliers to drive prices down to marginal costs. Without positive economic profits, however, inventors might not otherwise be able to *recoup* their up-front fixed research and development (R&D) costs, given how relatively cheaply the output can be reproduced by imitators. Hence the classic tradeoff between technology creation and diffusion: patent systems must provide on the one hand adequate incentives for technology creation and on the other hand opportunities for competitive, efficient diffusion. Thus dynamic efficiency (i.e. a positive long run rate of innovation) is achieved at the expense of static inefficiency (i.e. non-competitive pricing and supply).

Unfortunately, this characterization of the patent system often creates some misconceptions. The first is that patents create monopolies, in the traditional sense of a single firm in an industry. Rather, the patent gives the holder the *right to exclude* others from using the new idea commercially; it does not allow the holder to exclude other firms from the industry in which it serves. A more appropriate paradigm would be that of a monopolistic competitive industry, as Romer (1990) models innovation, where there are many agents in an industry, each producing a differentiated innovation. Indeed, it is relatively infrequent for an agent to have patent rights over an entire (self-contained) product - for example, a cell phone, television, motor vehicle, and so forth. Most inventors own patent rights to pieces that make up a product (or process of production) - for example, technological components. Exceptions exist of course; for example, pharmaceutical firms do often own patents to an entire product (e.g. Prozac, Claritin, etc.). In such industries, there is likely to be free entry and exit in the sense that these differentiated inventions compete with one another (say solve similar problems in different ways). They may also compete against old goods. Consumers, for example, may not upgrade to the new technology if the price gap does not justify the quality difference.

A second misconception is that the tradeoff is between technology creation and knowledge diffusion; rather it is between the former and the diffusion (or supply) of output embodying the new knowledge. Patents do not restrict the diffusion of knowledge per se; rather, they help diffuse it. The reason is that, in exchange for patent protection, inventors must publicly disclose their new knowledge. For this reason, it is inaccurate to suggest that patents restrict access to knowledge (they restrict the *use*.) On the contrary, patent databases exist all over the world for researchers and practitioners to access. The databases are filled with detailed technical information (including drawings) about previous patents, and the information is supplied both publicly by patent offices and privately by firms that specialize in database services. Because of the internet, access to patent information is much easier and cheaper than it used to be.

A third misconception is that patent protection may impede future scientific research because, even though technical information is fully disclosed, the fact is that only a few (patent owners) have the right to use it. This view comes from a failure to distinguish between *basic* R&D and *applied* R&D. Of course granting protection very broadly to basic scientific knowledge can impact negatively on future research. After all, basic research is the foundation for applied research as well as for future basic research. Applied research can also generate future knowledge externalities, but to a lesser extent than basic research. However, in actuality, basic scientific discoveries, theoretical concepts, and mathematical principles are not patentable anyway. It is the commercially or *industrially applicable* ideas developed out of that research or knowledge that are patentable.

A fourth problem is that certain observers fail to recognize endogenous relationships. For example, some argue that because an inventor recouped her up-front R&D costs in her own domestic market, there is no need to provide her with exclusive protection in foreign markets. Thus, the output should be competitively supplied in foreign markets, especially in the less developed countries. First, inventors may seek global markets precisely because their kinds of inventions require a larger world market to help recoup their costs. Secondly, knowing that they can serve a larger world market influences the scale of inventors' research projects. If it is only possible to recoup R&D costs from the (smaller) domestic markets, inventors may choose smaller than potential investments in R&D.

(B). IPR Indexes

We now turn to the question of how the level of intellectual property protection might be measured.

I. Overview

The rating of IPR systems here is not about measuring the quality of IPR regimes, but rather the "strength" of IPR regimes. It is not, for instance, attempting to determine the "optimal" level of protection. The optimal level need not be the one associated with maximal strength. Quality and strength may go together, but they are distinct. Issues of quality would deal with the equity of rights (between different intellectual property owners, and between them and non-owners), the effect on welfare and economic efficiency. The indexes here measure how protective systems are of the rights of intellectual property owners. The empirical section then determines whether productivity and R&D are influenced by the "strength" of those IPR rights.

Another important remark is that the indexes largely measure statutory levels of protection (i.e of laws on the books) rather than actual practice. However, the correlation between statutory protection and actual enforcement, while not perfect, tends to be high. Countries that have strong laws on the books tend to be the ones that also actually carry out the laws. Moreover, independent of enforcement, statutes can play a role; that is, statutory protection might produce a *signaling* effect about the policy authorities' willingness and capacity to defend IPRs.

A guiding principle in choosing legal features is not to be exhaustive but selective: that is, to choose those legal features that yield maximum variability across countries.[12] Furthermore, the information has to be widely available across countries.[13]

For each of the three basic IPR instruments (patents, copyrights, and trademarks), the index consists of five sub-categories: Coverage, Duration, Restrictions, Membership in International Treaties, and Enforcement. Coverage refers to the subject material (type of invention, expression, or symbol) that can be protected; duration refers to the length of protection; restrictions refer to the less than exclusive use of those rights; membership in international treaties indicates the adoption into national law of certain international agreements; and enforcement refers to the mechanisms countries provide for enforcing rights. The following sub-section provides further details about each of the measures of IPR protection. The variable name used in the empirical analysis is given in parentheses.

II. More Detailed Description of the Indexes

i) Patent Rights (PAT): The measure of patent rights is taken from Ginarte and Park (1997) and Park, Vijaya, and Wagh (1999).[14] The index of patent rights ranges from zero (weakest) to five (strongest). The value of the index is obtained by aggregating the five sub-indexes: extent of coverage, membership in international treaties, duration of protection, and absence of restrictions on rights (such as compulsory licensing). The numerical value of each of these sub-indexes ranges from zero to one and indicates the fraction of legal features in that sub-index available in the particular country. For example, a value of ⅓ for membership in international treaties indicates that a country is a signatory to one-third of the international treaties listed under that sub-index (namely the *Paris Convention*, *Plant and Varieties (UPOV)*, and the *Patent Cooperation Treaty*). A value of ½ for duration implies that a country grants protection for half the international standard time (of 20 years from the date of application or 17 years from the date of grant). The value for coverage indicates the fraction of invention classes the country allows as patentable subject matter. The value for the 'restrictions' category indicates the fraction of patenting restrictions which are *not* exercised in the country. Patenting restrictions refer to conditions attached to patent rights; for example, a working requirement (which is the requirement to *exploit* the patent right, say to manufacture a good) or compulsory licensing (which is the requirement to allow third parties to get a license to exploit the technology). Some authorities reserve the right to revoke patent rights for the failure to meet these conditions.

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[12] For example, incorporating 'derivative works' adds no variability because all countries in the sample provide protection for them in their copyright laws.

[13] For instance, only few countries specify the levels of punishment or penalties for IPR violations (e.g. length of sentences, amount of fines, etc.). Most countries indicate that infringement can be punishable as a civil or criminal offense, but are not explicit enough to allow for comparisons of punishment levels across countries.

[14] Information on national patent laws are largely from Baxter (2000).

Working requirements, from the point of view of the inventor, are restrictive because the patentee might either be financially unable to work the invention or find the market to be such that working is not profitable at the time. In the case of holding a foreign patent, the patentee might prefer to manufacture in her home country and then market her products abroad. On the other hand, some patent regimes operate on the premise that the purpose of a patent is not to profit inventors but to bring economic value to the community. For this reason, in some countries, if a patent is not worked within a certain time, the patentee is required to give a license to a third party willing and able to work the patent (in exchange for a "reasonable" royalty).[15]

<u>(ii) Copyrights (COPY):</u> This index varies also from 0 to 5, and is based on Park (2001). Each of its five categories is also scored out of one. The score is again the fraction of features that are available. The coverage category includes those works that are among the primary victims of piracy, such as literary, dramatic, artistic, musical, cinematographic works, and so forth. The duration of protection is based on an international standard of 50 years. Note that countries may provide different lengths of protection for different types of copyrightable works. The duration score for each of these types of works is the ratio of its statutory duration to 50 years. If more than 50 years of protection is provided, the maximum score of 1 is given. The country's overall duration score is the average of the duration scores of the different types of copyrightable works.

The category on restrictions includes rights to resale (i.e. *droit-de-suite*) which permit the copyright owner to share in a percentage of all subsequent sales of her work, thus enabling her to benefit from any appreciation in the value of her works. It also covers extended collective licensing schemes. Collective Licensing Societies are organizations of authors and performers. Their extended licensing schemes are deemed to weaken copyrights since they impose conditions on the individual rights holder (see Campbell and Cotter (1997)); moreover, the licensing schemes may typically permit more liberal reproduction of works by photocopy or by broadcasting. The copyright restrictions category also incorporates compulsory licensing. Major international copyright treaties include the Berne Convention, Rome Treaty, Universal Copyright Convention (UCC), and Phonogram Convention.

<u>(iii) Trademark (TMARK):</u> The trademark index also varies from 0 to 5, and is based on Park (2001). It is the sum of scores from five categories (again coverage, duration, restrictions, membership in international treaties, and enforcement). Each category is scored out of one (indicating the fraction of available provisions). The coverage category lists three types of marks: service marks, certification marks, and collective marks. *Service marks* are words, names, symbols, or devices that identify services. *Certification marks* are words, names, symbols, or devices that certify the origin (e.g. region) of particular types of goods, such as Champagne. These marks help identify the type of product. *Collective marks* identify trade associations or membership in some cooperative or other organization. The association (or its independent members) may be responsible for some product(s). The collective mark should tie the product(s) to the reputation of the collective.

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[15] Currently there is a case before the World Trade Organization (WTO) involving Brazil. The complaints concern Brazil's use of compulsory licensing for AIDs-treatment drugs.

For the duration of trademark protection, the international norm is 10 years. Again, the duration score is ratio of the statutory length of protection to 10 years; if the statutory length exceeds 10 years, the maximum score of 1 was given. The restrictions category examines whether countries require proof of use at the time of trademark rights renewal (e.g. demonstrate commercial use); whether there are linking requirements (e.g. linking foreign trademarks to a locally-owned firm); whether there are licensing restrictions (on royalties, technology transfer agreements); and whether there are conditions for the protection of well-known marks (e.g. that they be used in the local economy). The international treaties category includes three major treaties: the *Madrid Agreement* which governs the international registration of marks; the *Nice Agreement* which governs the international classification of goods and services for the purposes of registering trademarks; and the *Paris Convention* which also has provisions on Trademark rights.

(vi) Enforcement Provisions: It is worth elaborating a bit on this fifth component in each of the indexes. In this category, the selected conditions are the availability of: *preliminary injunctions*, *contributory infringement pleadings*, and *burden-of-proof reversals*. A country that provides all three receives a value of 1 for its enforcement score (in each of the indexes, PAT, COPY, and TMARK). While litigation, arbitration, and settlement comprise different enforcement 'routes' should infringement occur, patent holders may have recourse to a number of statutory provisions which can aid in enforcement. Preliminary injunctions, for example, are pre-trial actions that require the accused infringer to cease the production or use of the patented product or process during the course of the trial. Preliminary injunctions are a means of protecting the patentee from infringement until a final decision is made in a trial. Contributory infringement refers to actions that do not in themselves infringe a patent right but cause or otherwise result in infringement by others. Thus, contributory infringement permits third-parties also to be liable if they contribute negligently to the infringement. Burden of proof reversals put the onus on the accused to prove innocence. Given the difficulty IPR owners may have of proving that others are infringing on their ideas, expressions, or symbols, the shift in burden can be a powerful enforcement mechanism.

III. Sample Statistics

The last three columns of Table 1 show the sample averages of these IPR indexes for each country (and by regional group). Generally region 1 countries have the strongest IPR regimes. The U.S. has the strongest system of patent rights, while France has the strongest copyright and trademark regimes. The weakest patent regime within this group is Portugal, and the weakest copyright and trademark regime is Ireland. The next strongest IPR regimes are found in region 3, East Asia. Japan has the strongest IPR regime overall, followed by Korea. Singapore and Korea used to have much weaker patent systems until the mid-1980s. The relatively weakest IPR regimes in this group are Thailand and the Philippines.

The weakest patent regimes are overall region 2, the LAC economies. The lowest rated country in this region is Nicaragua, which is also the weakest overall among the 58 countries listed in Table 1. In the LAC region, Haiti is recorded as having the strongest; this is because of their adoption of laws based on that of the U.K. Since few countries patent in Haiti, the laws have not been fully tested (in terms of enforcement and litigation activity). Since R&D data are lacking for Haiti, it is not included in the empirical analysis. Of those LAC countries that are included in the empirical analysis, Chile has the strongest patent system, followed by Argentina. The strongest copyright regime in this group is Colombia and the strongest trademark regime is Uruguay. Venezuela has the weakest copyright and trademark laws in this group. Overall, this group is comparable to region 4 in terms of the strength of their IPR laws; for example, India's IPR regime is comparable in strength to that of Peru and Venezuela. In region 4, Israel has the strongest IPR regime.

Table 2 shows the simple correlations between these indexes, R&D, and human capital. First, the IPR variables are positively correlated with one another, with correlation coefficients in the range of 0.72 - 0.863 for all countries. By group, the correlation coefficients are lower, and lowest for region 2 (the LAC economies). This suggest that in some LAC countries, patent rights might be strong while copyrights and trademark rights are weak, and vice versa. Overall, the IPR indexes are positively correlated with the measures of human capital and with R&D to GDP and R&D to labor supply. The causality could go either way: either IPRs influence investments in R&D and human capital or IPRs are strongest where countries have high levels of R&D and human capital, so that policy authorities have something of interest to protect.

But the interesting finding in this table is the negative correlation between the share of government in R&D and the other variables. This suggests a possible tradeoff. Governments either resort to market mechanisms to solve the market failure problem with R&D (such as granting intellectual property protection) or finance the R&D itself. In other words, IPRs and government funding appear to substitute for each other. The substitutions seem to correlate with the development of markets. For instance, in regions where markets are less-developed, the public sector funds a relatively large share of national R&D and weakly provide IPRs (since there is little inventive and creative output that the private sector produces); but in regions where markets are well-developed, the share of public sector financing is relatively low and IPRs relatively strong.

Next, the negative correlation between the share of government funding and R&D variables might be due to the fact that the higher share of government funding reflects a relatively larger (overall) government size, and the consequent taxation of resources to finance the public sector. This might then have diverted resources and savings that would otherwise have gone towards the accumulation of both private and public sector knowledge capital (and human capital).

IV. Alternative Index of IPRs

One simple way of testing whether the IPR scores are reasonable is to compare them to another study. One such study is Sherwood (1997) which rates the IPR regimes of 18 countries. In addition to patent rights, copyrights, and trademark rights, the Sherwood study examines other aspects of IPRs, such as trade secrets, life forms, patent administration, and so forth. Each country is rated out of 100; various points are deducted for poor provision of these different kinds of IPRs. The maximum score would therefore be 100 (if no points are deducted, or if the provision of IPRs is very strong). The minimum score is zero.

The top of Table 3 reproduces the scores for those countries in the Sherwood study that overlap with our sample. The table indicates how many points were deducted for patent rights, copyrights, and trademark rights. The far right column indicates the overall score. (We omit the points deducted for other kinds of IPR: trade secrets, life forms, etc.) The regional group to which a country belongs is also indicated. As the table shows, most of the countries in the Sherwood sample are LAC economies. This enables us to compare our IPR index values to an independent source. Overall, Australia scores highest, followed by Korea. Of the LAC countries, the Sherwood study rates Mexico the highest, and Guatemala the weakest. For patents in particular, most points are deducted for Costa Rica, followed by Nicaragua and Paraguay. The least points are deducted for Mexico and El Salvador. For copyrights, the most points are deducted for Guatemala, Nicaragua, and Paraguay. The least points are deducted for Costa Rica, followed by Chile. For trademark rights, the most points are deducted for Panama and the least points for Argentina and Mexico.

The bottom of Table 3 examines the correlation between the Sherwood ratings and our IPR indexes. Our patent, copyright, and trademark indexes are positively correlated with the overall Sherwood ratings. Individually, our patent rights index is positively correlated with the Sherwood patents score (that is, those countries that were given high values on our index tended to have fewer points deducted on the Sherwood scale). Likewise, our trademark index and Sherwood's trademark ratings are also positively correlated. The correlation between our copyright index and Sherwood's copyright rating is, however, near zero. This indicates that for some countries, there was agreement between the two methods of rating countries (i.e. we both rated countries strongly or weakly); but for others, there was disagreement (one study would rate a country high, the other low, and vice versa). Overall the agreements and disagreements nearly cancel out. The comparison on the whole suggests that the two studies have similar ratings of IPRs in these countries.

(C). Economic Effects of IPRs (Literature Survey)

The link between IPRs, innovation, and productivity has stirred some controversy. The theoretical literature is divided over the welfare and efficiency effects of stronger intellectual property (IP) regimes, and the empirical literature is few and far between. For example, in theoretical work on patents, Takalo and Kanniainen (2000) find that a strengthening of patent rights can delay the introduction of a new technology to the market (i.e. raises the value of the innovator to wait); Bessen and Maskin (2000) develop a model of sequential and complementary innovation in which patent protection reduces innovation and social welfare. On the other hand, Diwan and Rodrik (1991) argue and show that stronger global patent rights may encourage foreign research and development to focus on technology areas that matter more to the local (developing) economy.

Other theoretical work on patents and R&D focus on the kinds of laws that best stimulate R&D – for example, a narrow but long-lived patent versus a short-lived but broad patent. Here, broad or narrow refers to how widely protection may be given. If patents are narrow, rivals can more easily invent around a patent. But if they are broad, rivals need to develop more radical inventions in order to avoid infringing a patent. Economists have debated whether technological change is better served by a broad or narrow scope (see Merges and Nelson (1994)). On the one hand, a broad scope gives more market power to an inventor and might be a strong inducement to invent; on the other hand, it makes it more difficult for competitors to develop new inventions. One branch of the literature thus asks what combination of *patent scope* (i.e. broad versus narrow) and *patent length* (i.e. duration of protection) minimizes the social deadweight loss of patents subject to a given level of R&D incentives. For example, Gilbert and Shapiro (1990) using a homogenous product model find the more efficient policy is to have a narrow patent with a long life. Klemperer (1990) using a product differentiated model shows that if substituting varieties is costly (e.g. say that it is difficult to switch among drugs for a particular cure), a broad patent with a short life is more efficient. The shorter life is good for consumer welfare (e.g. drug consumers) but broad enough to give incentives to develop the innovation. Scotchmer and Green (1990) model cumulative innovation (i.e. where there is a sequence of innovations over time which improve upon the original innovation). In this case, the patent scope must be narrow enough to enable future generations of the innovation to be developed, yet broad enough to give the original innovator the incentive to develop the first breakthrough.

Theoretical studies on copyrights and trademarks are provided in Landes and Posner (1987 and 1989). Trademark protection is argued to encourage economic efficiency by reducing the search costs of consumers (by allowing them to recognize quality products by symbols or name). Furthermore, firms or intellectual property owners in turn invest in promotional expenditures to attract consumers and expenditures to maintain the quality of their products or services. Without being able to link their investments and products to their trademark, they would have less incentive to invest in those quality-promoting investments. There are occasions, however, where trademark protection can be too broad (e.g. a name or symbol becomes generic) and would increase the cost of business for rival firms such that economic efficiency is harmed in the aggregate. Copyrights over original and derivative works also stimulate creativity by increasing the odds of appropriating the benefits of the creations. Copyrights can also complement other rights, such as patent rights, where the ideas are not protectable but the expression is; for example, pure computer and mathematical algorithms. There may also be situations where stronger copyrights may be adverse to economic efficiency - namely where the rights reduce the incentive of rivals to create, or the owner's incentive to produce future new creations. Each creator is part of an intertemporal chain of creators. Thus stronger protection on expressions affect subsequent generations of creators (who themselves would like to build on previous works).

In terms of empirical work, a survey by Levin et. al. (1987) of U.S. firms finds that patent protection is not the most important means firms have to appropriate the returns to their R&D (as compared to lead time and reputation). Moreover, firms patent for reasons other than to protect their innovations (for example, to acquire strategic bargaining chips for cross-licensing negotiations). These findings suggest that patent rights are not very important to stimulating innovation. On the other hand, case studies conducted in developing countries indicate that IPRs are considered very important to innovation (see Sherwood (1990)). This suggests that the marginal value of patent rights (or IPRs) is higher in developing markets (where legal and other institutions are not as well developed and where, as a result, firms have few other alternative means of appropriation, if any). Another interesting case study is by Korenko (1999) which finds that, for the Italian pharmaceutical industry, a strengthening of local intellectual property rights helped expand domestic R&D and market share (rather than result in a situation where foreign firms crowded out domestic).

3.2 Fiscal Incentives

(A) Conceptual Issues

"To *expense* or to *amortize*?" is a question of importance in accounting. Expenditures on a good or an asset can yield benefits over varying lengths of time (measured in accounting periods). Consumption versus investment is an example of where differences in the time horizon of benefits come into play. The returns to consumption are typically dissipated in a short period of time (say within a year) whereas the returns to investment accrue over several periods. In the latter case, the purchase of a fixed asset (or its cost) is typically "amortized" over time (usually for tax purposes). This spreads the burden of the cost of the asset over time, at least over its useful economic life. A more technical way to describe this accounting (balance sheet) procedure is that the cost of the long-lived asset is "capitalized." The periodic amortization – known also as depreciation – is recorded to write off the cost of this asset over its useful economic life. The amount of depreciation recorded per period depends on (a) the asset's estimated useful life (which characterizes its asset class, for example 3-year, 5-year, 15-year, etc.), (b) salvage (or terminal) value, and (c) the depreciation method. The method of depreciation can be *straight-line* (which assumes equal benefits from the asset in each period of its life), *accelerated* (which assumes that more benefits are derived from the asset during the earlier parts of its life), or *double-declining* (which assumes twice the rate of the straight-line method of depreciation).

Unlike investments in tangible capital, countries treat R&D expenditures the same way "consumption" expenditures are treated. Instead of being amortized, these costs are fully expensed in the period in which they are incurred. In other words, the depreciation rate is 100% and the costs are written off that period (and importantly, deducted from taxable income in that period). In general, firms may prefer accelerated depreciation since greater up-front depreciation expenses permit lower taxable income earlier on in the asset's life, but greater taxes later on. Due to the time value of money, firms would prefer to pay taxes later rather than sooner. A 100% depreciation rate then is the ultimate acceleration. Thus firms that expense their R&D fully get to avoid tax burdens on "assets" which are still (economically-speaking) active, yet have been written off the books. A disadvantage is that, to the extent that the R&D leads to an innovation which benefits firms over several future periods, expensing everything in the current period leads to an undervaluation of the firms' assets. The reason policy authorities give for treating R&D expenditure as an item to be expensed is that the future benefits cannot be clearly identified and measured, and that the causal relationship, if any, between expenditure and benefits is not clear.

As long as, on the whole, the undervaluation of the R&D assets is of a relatively low order of magnitude, the opportunity to fully expense R&D should act as an inducement to do R&D since the spending is written off yet the revenue generating capability of the R&D spending is not gone. In most OECD countries, it is the *current* expenditures on R&D – for example, salaries to staff (scientists, engineers, technicians, and administrators) – that are fully expensed. These current expenditures may include, in some systems such as the U.S., costs incidental to the development of an invention; for example, the costs of obtaining a patent (filing fees, attorney fees). However, excluded from current R&D expenditures are the costs of testing and inspection, advertising, and marketing. In the case of *capital* R&D expenditures (for example, on equipment and buildings), the costs are typically amortized like ordinary physical capital investment (although some jurisdictions, such as Canada and the U.K., do allow for accelerated depreciation of capital assets, other than buildings).

In addition to this incentive (from the 100% depreciation rate of current R&D spending), another tax break for firms is the *R&D tax credit* which enables firms to acquire deductions from income taxes. The precise amount of deduction or R&D tax credit is based on a percentage of R&D expenditures. For example, let R denote current R&D expenditures, b some base amount, and the credit rate (e.g. 10, 25, ...). The R&D tax credit is then equal to:

% of (R - b)

Under a *volume-based* system, b = 0, indicating that the credit applies to the entire R&D expenditures incurred during the period. Under an *incremental-based* system, b equals some past value of R&D expenditures (say some historical average or moving average); for example, $b = R_{-1}$ indicates that the tax credit applies to the excess of current R&D expenditures over last period's.

Thus /100)(R - b) is the amount by which taxes payable is reduced. Of course, firms must have sufficient taxable income to benefit from this credit. In the event that the total credit exceeds taxable income, there may in some jurisdictions be provisions for carrying forward (or carrying backwards) the excess (unused) credit. In other words, the credit can be applied to future taxes or to back taxes (and enable the firm to obtain tax refunds). The kind of firms that would benefit from *carryforward provisions* would be start-ups or firms that suffer temporary losses.

The pioneers of R&D tax credits are Japan and Canada. In the early 1980s, a few other OECD countries followed suit and incorporated them into their R&D policies. Table 4 presents a brief comparison of the R&D fiscal incentives across countries. The first column indicates the depreciation method for current R&D (which consists mostly of salaries to scientists and engineers). As shown, most countries allow current R&D expenditures to be fully expensed. The second column indicates the depreciation method for capital R&D expenditures. In most cases, these are treated as ordinary investment, allowing for accelerated depreciation or straight line depreciation (with a three year asset life). The middle column indicates whether countries permit tax breaks to be carried forward (if firms have no tax liability in their current period). The fourth column indicates whether or not R&D tax credits are provided (and at what rate). As shown, only ten countries provide this policy. The fifth column, where relevant, indicates how the R&D tax credit applies: whether to the volume of R&D or the incremental change in R&D.

(B). Index of Fiscal Incentives

One novel way to amalgamate these features into an index of fiscal generosity towards R&D is the B-index developed by McFetridge and Warda (1981). Specifically, let B denote the present value of before-tax income needed to break even on a $1 expenditure of R&D. In other words, B is the critical minimum benefit-cost ratio. It tells us what benefit, B, is needed to cover the cost of an initial outlay of R&D of $1. Usually one would think of B = $1 as the break-even point. However, if R&D tax support is generous, a firm might be able to break even with a lower B, say B < $1. Thus, for firms with B > $1, R&D projects would be profitable and would be undertaken. For firms with B < $1, the R&D projects would not be profitable and would not be undertaken without fiscal support.

To be a bit more detailed, the break even takes place where:

(1 - t) B = after-tax cost (ATC) of a $1 of R&D expenditure

where t denotes the corporate income tax rate, -1 < t < 1. Or,

$$(9)\quad B = \frac{ATC}{1-t}$$

Now, the after-tax cost to the firm of investing in R&D after incorporating all the available R&D tax incentives is:

(10) ATC = [(1 -) (1 - t)] + (1 -) (1 - zt)

where z is the present value of depreciation allowances, the R&D tax credit, and the proportion of R&D expenditures that are expensed (and (1 -) the proportion that are amortized). If t > 0, the firm faces a tax; else, if t < 0, the firm faces a subsidy. The greater t is, the higher B needs to be in order for the firm to break even on an R&D investment. For t > 0, the greater t is, the greater B exceeds one. Conversely, for t < 0, the lower t is, the greater B will fall below one. Hence B rises or falls with t, and thus is a measure of the generosity of the tax system. The higher the B is, the less generous the tax system; the lower B is, the more generous the system.

The B-index method makes a number of simplifying assumptions. It assumes equal interest rates across countries (that is, the cost of finance is the same for all countries). It also assumes away international differences in the definition of R&D for tax purposes. Other taxes that may indirectly affect the motivation to do R&D are ignored (for example, commodity taxes, property taxes, capital gains taxes). This omission would be rather serious in jurisdictions without corporate income taxation but which rely on a host of other types of taxes. Any tax relief for R&D in these regions would not be picked up by this B-index. Also, another drawback to the B-index is that countries with fairly high corporate tax rates will be recognized for providing generous R&D tax support. The reason is that a country with a high corporate tax rate and a large number of tax incentives will score higher because those tax incentives will take effect in reducing the after tax cost of R&D; however, a country with low corporate taxes to begin with (which already is an inducement in itself to stimulate firms to invest) will have little need to introduce tax incentives, and thus will not score well on the B-index. Finally, another simplifying assumption is that the firms are large corporations, rather than small businesses. The methodology assumes that firms have sufficient taxable income and thus does not incorporate explicitly any carryforward or carryback provisions.

Table 5 presents data on B-index values, with lower values indicating more generous R&D tax support systems. The data are from Warda (1996). As shown, most of the countries that provide fiscal incentives for R&D investment are region 1 countries. The data are not available at the same five year intervals as for the IPR and R&D data (i.e. 1980, 1985, 1990, and 1995). In 1980, the most generous country from this perspective was Singapore (with a score of 0.41), followed by Canada (with a score of 0.84). Germany had the least generous regime. By 1995, the most generous R&D tax support system (among the data available) is Spain, followed by Canada. The U.S., France, Netherlands, Korea, Australia, and Austria are also countries with relatively generous systems. The least generous system is New Zealand.

Overall, the mean value of the B-index for all the countries listed (over 1980, 1990, and 1995) is 0.953. The B-index is somewhat positively correlated with the measures of IPR and share of government R&D funding. Again, this might suggest a kind of policy tradeoff or substitution; that is, where IPRs are strong (or where public R&D funding is high), countries rely less on fiscal incentives, and vice versa (such as Canada, where fiscal incentives are generous yet its patent protection levels are relatively low compared to other OECD nations). The B-index is also somewhat positively correlated with the rates of R&D (as a percentage of GDP or labor supply). This suggests that the more intensive R&D countries have less generous R&D tax incentives. This could either mean that R&D tax incentives exert a negative influence on R&D investment or that fiscal incentives are less needed where R&D investment rates are high (and where R&D is profitable to conduct, particularly in regimes where $B > 1$). Other factors need to be properly controlled for.

(C). Economic Effects of R&D Fiscal Incentives (Literature Survey)

This subsection discusses the theoretical debates and empirical evidence on fiscal incentives in general (and R&D tax credits in particular).

The theoretical analyses are also divided as to the advantages and disadvantages of fiscal incentives. In comparison to government R&D subsidies or grants, tax incentives are said to involve less government interference in the marketplace, give private decision makers autonomy, and preclude government bureaucrats from having to choose which technologies they should promote.[16] It is also argued that, administratively, there is less bureaucracy (red tape) involved and that fiscal incentives tend to be more open-ended (in contrast to grants and subsidies which last for a specified

[16] See Leyden and Link (1992) for a survey of these arguments.

period). However, each of these purported advantages faces some criticisms. With R&D grants, it is technically possible to give the grants recipient (i.e. the private firm) much discretion. Similarly with tax incentives, authorities could always establish criteria in a way that the tax breaks go to the desired sector or research project. The structure of tax incentives could also be as complex as the underlying tax regime, and may require a commensurate bureaucracy within a firm to interpret the rules (e.g. tax law and tax accounting divisions). Thus an onerous bureaucracy is shifted from the public sector on to the private. As for tax incentive programs being longer-lived, this depends on the fiscal budgetary situation. In some studies, firms have been found not to respond strongly to the tax incentive precisely because were uncertain as to whether an R&D tax credit was permanent or temporary.

The theoretical debate also spills over into issues concerning the design and implementation of fiscal incentives. First, consider the appropriability problem vis-à-vis R&D investments. Due to the externalities associated with R&D, there is a gap between the social and private incentives to engage in R&D. But are the tax incentives – for example, the R&D tax credit rate – sufficient to close that gap? The present value of the tax credits may not be sufficient (or may be more than sufficient) to cover the up-front costs of R&D. Suppose for example the R&D cost of developing a new drug is $75 million. Are the tax credits or reductions in taxes payable per period sufficient over time to recoup that amount? Suppose, without patent protection, imitation is widespread and the market for the drug is competitive. With reduced profits and taxable income, the tax credit is likely to be ineffective.

But more generally, the tax credit rate could be too high or too low for certain individual firms (as far as recouping costs is concerned). The rate may apply to all firms regardless of size or sectoral classification. But this is the same problem with patent protection: the same duration of protection applies whether for small or large innovations. Another general point is that the R&D tax policy should be viewed as part of a broad overall innovation policy (which includes R&D grants and intellectual property policies). In the drug example above, the tax credit would be effective in conjunction with patent protection. In the case where basic research is involved, externalities may be especially large and the gap between social and private incentives to do R&D very wide. To the extent that R&D tax incentives permit private firms more leeway to choose their own projects, a particular research area (e.g. DNA-based therapeutic drugs) which the government might want to stimulate may not be pursued by the private firm unless it happens to find the project profitable for itself. Hence in this case, the government may prefer a direct, target-oriented R&D subsidy specifically for that research area, or to complement the tax incentive with a direct subsidy. Moreover, for some countries with tight budgets, a choice might have to be made between subsidies and tax incentives. Thus, countries with generous subsidies and grants may have less generous R&D tax incentives, and vice versa. This appears to show up in Table 5 (the correlation between the B-index and the percentage share of government funding of R&D is positive, indicating that countries with a high share of public funded R&D tend to be less generous with fiscal incentives). The point is that focusing only on the treatment of R&D tax incentives gives a limited view of the overall innovation policy stimuli of countries.

Other design and implementation issues are whether the tax credit and other incentives should be available to research that will lead to commercial success or to basic, generic research. Along this line of thought, should applied R&D be given fewer incentives or less generous tax breaks? The reason is that, as applied R&D is likely to generate fewer spillovers, firms can better appropriate their returns, if not with patent protection then with lead time advantages, reputation, and marketing skills.

A major design issue is whether a volume-based system is preferred or an incremental one. The issues are as follows. Some argue that tax incentives generate windfall gains to the firms that would have undertaken the R&D project even without the tax break. Here, one needs to distinguish between *inframarginal* R&D (what would have been done anyway) and *extramarginal* R&D (what would not have done without the tax incentive). Thus, some may favor an incremental-based R&D tax credit system precisely to support extramarginal R&D, whereas the advocates of a volume-based system argue that giving credits only for incremental R&D penalizes those firms who have high, but constant, R&D expenditures. On the other hand, to the extent that total R&D spending generates spillovers, the credit should apply to the total outlay, not just the incremental part. If a firm spends $110 on R&D this year and $100 last year, the entire $110 of R&D activity generates knowledge spillovers, not just the extra $10 done this year. Moreover, under an incremental system, a second firm that does $1 million dollars of R&D in one year, and $10 more the next year obtains the same tax credit as the first firm, though surely the overall effort levels are different. Finally, an incremental system can also give rise to "negative" effective marginal tax credits. This can happen if a large increase in R&D in one year raises the base (or the standard) for the next year such that the firm is denied a tax credit in the following years. If subsequent R&D falls below the base, credits may have to be paid back.

Another criticism with tax incentives is that they are biased against new (start-up) firms which typically may have little or no tax liability early on. The carryforward provisions may help to some extent but, due to the time value of money, tax credits received later are not the same as cash received in the present. Moreover, the new start-up firm may not be around in the future without the benefit of a tax advantage early on (and thus the enjoyment of the carryforward provision is moot).

Re-labeling of expenditures as R&D so as to take advantage of tax breaks is also an issue. Several surveys conducted by Mansfield and Switzer (1985) have found this. This relates to the issue of how to define R&D. Should marketing expenditures be included? One could make the case that marketing also generates learning by doing and creates knowledge capital. Should outsourced R&D count as well as in-house R&D? If so, how do we prevent double-crediting where two firms both obtain tax credits for the same (joint) project? A clear definition of R&D expenditures helps arbitrary labeling but at the same time, there may be incentives to classify expenditures under the expanded definition; for example, firms may claim that a purchase of a good is for marketing purposes, and so forth. Clearly, the re-labeling phenomenon affects empirical estimates of the how strongly fiscal incentives stimulate (true) R&D.

It would also be useful to speak to the issue of the cost-benefit methods underlying the evaluation of fiscal incentive programs. One such evaluation method is to compare the tax revenue forgone to the R&D generated or stimulated. If the latter exceeds the former, the fiscal policy is deemed a success. This is peculiar (as Hall (1993) points out) in that the R&D that is generated may not be the socially optimal amount. Thus a more appropriate measure of evaluation should be the extent to which the gap between private and social returns to R&D has been narrowed. Moreover, it is not always the case that society underinvests in R&D, or that social incentives exceed private incentives. Section 2 described some circumstances under which the private sector might have excessive incentives to do R&D.

Turning now to the empirical evidence on the effects of R&D tax credits, the evidence is mixed, but there is a pattern.[17] Earlier research (conducted during the 1980s) tends to find a weak effect on R&D. Cordes (1989) finds that, in the U.S., the R&D tax credit generated 35 - 93 cents of R&D for every $1 of tax revenue forgone. Likewise, the Mansfield (1985) surveys also show that the R&D stimulated by the tax incentives fell short of the forgone revenues. The surveys of companies were conducted separately in the U.S., Canada, and Sweden. The Mansfield surveys also find substantial relabeling of activities as R&D. Roughly 13-14% of the growth in reported R&D may have been due to this.[18]

Baily and Lawrence (1992) and Eisner et. al (1984) also find weak quantitative effects of R&D tax credits. In particular, these studies find low R&D price elasticities (in the range of -0.2 to -0.3). This poses a problem because such low sensitivities to the price (or cost) of conducting R&D imply that manipulating the cost of R&D through tax incentives will impact marginally on R&D activity. Moreover, that the demand for R&D is *price-inelastic* should suggest something – that research and development might be an integral part of corporate strategy for some firms. Hence the results suggest that R&D tax credits may be more important to firms for which R&D is not a *necessity*.

Some other explanations for the weak quantitative effects of R&D tax credits (other than that the demand for R&D might be inelastic) are (i) that R&D spending for many firms did not exceed the "base" so that they could not take advantage of the tax credit, (ii) that firms did not have sufficient tax liability or that carryforwards were ineffective due to the time value of money. Indeed, Mansfield (1986) finds that only about 60% of potential R&D tax credits could be used (the rest being carried forward). Moreover, (iii) as firms increase their R&D, under an incremental system, there is a built-in effect which prevents the after-tax price of R&D from being reduced by the full amount of the R&D tax credit. Suppose, for illustration, that the base is an average of the previous three years:

$b = (R_{t-1} + R_{t-2} + R_{t-3})/3$

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[17] For a comprehensive survey, see Hall and van Reenan (2001).

[18] This is inferred from the finding that only a small proportion of the estimated residuals of the model could be accounted for by the R&D tax credit.

Let r be the discount rate. Then the tax reduction equals:

$$(11)\ \Delta = \tau\left(1 - \frac{1}{3(1+r)} - \frac{1}{3(1+r)^2} - \frac{1}{3(1+r)^3}\right)$$

where is the R&D tax credit rate. Thus if = 25% and r = 15%, the effective reduction in taxes per $1 of R&D is 6 cents.

Now, later research (conducted during the 1990s) tends to find more favorable evidence of the impact of R&D tax credits. Hall (1993), for example, finds R&D price elasticities between unity and 1.5 using a sample of 1,000 U.S. manufacturing firms. Moreover, in crude cost-benefit terms, the tax cost of the R&D tax credit program is about $1 billion but the induced R&D is twice that. Hall attributes the difference in results between newer and older studies on the fact that the earlier elasticity estimates were based on a time period when firms were uncertain as to whether the R&D tax credits were permanent or temporary. Given the costs of adjusting R&D capital, firms appeared to choose to wait. However, the impact of the R&D tax credit did appear to be sensitive to the tax position of individual firms (for example, to the degree to which they had sufficient tax liabilities). Thus, the "average" estimates belie the number of firms that did not obtain much or any benefit from the tax credit program.

Shah (1995) using cost function approaches also finds favorable evidence for Canada and for Pakistan. Shah models the cost minimization behavior of firms and works with the derived demand for R&D capital. Overall, he finds that for every $1 of tax revenue forgone, $1.80 worth of R&D investment was generated in Canada; the benefit-cost ratio for Pakistan was 1.49. These estimates are obtained indirectly. First, he estimates the elasticity of R&D capital with respect to the user cost of R&D; secondly, he estimates the elasticity of the user cost of R&D to the price of R&D capital; and finally, he estimates how the price of R&D capital varies with the R&D tax credit.

The studies mentioned thus far have been for individual countries. A panel data analysis is presented in Bloom, Griffith, and van Reenan (2001). A panel of nine OECD countries are analyzed over the period 1979-1997.[19] One advantage of cross-country data (over single country studies) is that tax credit rates vary across countries (and thus additional variation can be picked up). Firms within a country face the same tax credit rate (unless there are special provisions for small firms) so that the variation comes largely from the different tax positions of firms and from different bases. The disadvantage is that firm heterogeneity is not picked up in aggregate data.

A key innovation in this study is the comprehensive calculation of the after-tax price of R&D. As in the B-index methodology, the authors incorporate depreciation allowances and tax credits, but also incorporate any tax discrimination between retained earnings and distributions. The authors also

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[19] As Table 4 points out, few regions have adopted R&D tax credits, hence the small number of countries in the sample.

look at three different asset classes: current expenditures, plant and machinery, and buildings. The user cost formulae used is:

$$(12) \quad {}_{ijt} = [(1 - (A^{d}_{ijt} + A^{tc}_{ijt}))/(1 - {}_{it})] * [r_{it} + {}_{j}]$$

where subscripts i, t, and j refer to country, time, and asset type respectively. T denotes the corporation tax rate, r the interest rate, depreciation, A^d the present value of depreciation allowances per $1 of R&D investment, and A^f the present value of tax credits per $1 of R&D investment. The correlation between and the B-index is in the range of 0.79 - 0.88 (depending on the country).

The authors use this user cost variable in their regression model:

$$(13) \quad r_{it} = \quad + \quad y_{it} + \quad r_{it-1} - \quad {}_{it} + \quad {}_{it}$$

where r denotes R&D expenditures (flow) and y output. The long run elasticity of R&D with respect to the after-tax cost of R&D is equal to (/(1-)). The authors find the short run response of R&D to be 1% (near unit-elastic) but the long run response to be about 10%. Thus R&D expenditures here strongly respond to R&D tax credits.

A couple of limitations with this study are that it has a number of important omitted variables, such as intellectual property rights, public R&D grants and subsidies, human and physical capital. Secondly, there may be a sample selection bias. Half the OECD countries provide R&D tax support, and half do not. Yet the latter half are quite research-intensive economies (like Switzerland). What explains their R&D behavior if they do not provide R&D tax credit support? If the sample were extended to include countries that do not provide R&D tax support, would the user cost variable be as statistically significant?

3.3. Public R&D, Matching Grants, and Ownership Rights

(A) Conceptual Issues

The next potential determinant of private R&D expenditures is public funding of R&D. A central issue is the extent to which public R&D stimulates (or crowds out) private R&D. Public funding can be whole (whereby the government sponsors an entire project) or partial (as in matching grants programs, to be discussed further below). Publicly sponsored R&D and its effect have been extensively studied (see David and Hall (2000) for a survey). Thus our attention below shall be on matching grants.

Another common term for matching grants is cost sharing. Recipients put up a certain percentage of research costs, thus signalling a pre-commitment to do a certain research project. This helps to remove some of the moral hazard problems with funding research where effort levels cannot be monitored. The solution here is the classic one of getting the researcher or the recipient to bear some of the risks of the project. The purpose of these grant programs varies, but typically they help to fund generic, enabling technologies – technologies that are of a broad use to the public and are in the early stages (say, the stages before venture capitalists are approached). It is often said that the comparative advantage of these programs is to fund gaps; for example, something that is relatively too basic for the private sector yet relatively too applied for universities and national laboratories.

(B). Measures of Public R&D Subsidies and Grants

For empirical analysis, since we are working with aggregate data, we will use total government R&D funding to analyze the effects of grants and subsidies. Clearly, the total amount of funding does not do justice to the intricate details of public sponsorship of research or of the nuances in their effects. But this is where microeconomic studies are better able to pick up these details and effects. On the other hand, micro level studies sometimes provide conflicting evidence since they each focus on different sectors or different regions. The advantage of a macroeconomic study is that it helps to capture the net effects.

(C). Economic Effects of Public R&D Funding (Literature Survey)

I. Experience of Matching Programs

As grant programs vary in nature, it is useful to describe some case studies. Four types of programs shall be reviewed: (a) the Advanced Technology Program (ATP); (b) the Small Business Innovation Research (SBIR) program; (c) Challenge Grants; (d) Israeli Office of Chief Scientist (OCS) programs. These programs – evaluations of them – are based on U.S. and Israeli data. Since few other countries have provided such programs, we focus on the experiences of the U.S. and Israel, and see to what extent lessons can be drawn for the LAC region.

(i) Advanced Technology Program (ATP): This program comes under the jurisdiction of the U.S. Department of Commerce. It was established in 1990 as part of the U.S. Omnibus Trade and Competitiveness Act of 1988, and is administered by the National Institute of Standards and Technology (NIST). It awards cost sharing grants to industry on a competitive basis. High-risk enabling technologies are targeted, namely those that have the greatest potential for yielding follow-on innovations, and the potential to assist firms to apply generic research results in their commercialization efforts. Table 6 provides a brief historical summary of the activities under the ATP. Nearly 5,000 proposals have been received from industry and12.3% of them were awarded matching grants. 68.2% of them were to single applicants and the rest to joint ventures. About half of all the awards went to small business applicants or cooperative ventures (though 3/4 of all proposals came from small businesses). More than half the applications or proposals involved university participation; the universities themselves being awarded about 10% of the ATP funds.

Overall, industry had committed $1.8 billion and the ATP matched that amount. The leading technological area is information technology, but this lead is not significant over the other areas highlighted. The States that received the most funds happen also to be the ones where top research universities reside; for example, California, Massachusetts, and Texas.

Several studies have been conducted to evaluate the success of the ATP (in terms of stimulating private R&D, helping firms overcome technical barriers, producing prototypes, and conducting experimental production). However, these studies were almost all commissioned by the NIST, the very institution which overlooks the program. Of course, the NIST has likely carried out these evaluations to improve internal efficiency and would benefit from unbiased critical assessments. However, there is a moral hazard problem when the commissioned studies asked the recipients of the awards to rate the success of the projects for which they received funding. Few would likely want to report failure at innovating or generating knowledge spillovers (and thereby risk rejection of future funding or cancellation of their project). Offsetting these incentives to self-report success are some *objective* criteria that the investigators themselves had set up to evaluate the programs and thereby provide a database of some hard facts.

One such study is by Feldman and Kelley (2001). The authors report a "halo effect" of receiving ATP funds. That is, an ATP award signals or helps certify firm quality and helps that firm attract further funding from private and public sources. Indeed, the authors find that winners of ATP awards were more successful in securing additional support than the non-winners. Moreover, winners were able to complete their R&D projects, while most non-winners were not. 60% of non-winners did not proceed with the projects in their proposals, 30% went ahead on a smaller scale than planned, 4% on a larger scale, and 5% on the same scale. For the authors, this is evidence that the ATP program did not crowd out private R&D spending or fund something that the private sector would have done anyway (since many of the non-winners could not proceed with their project at the same scale or better than they had proposed). In retrospect, this may be evidence of other factors. The first is the selection bias – that those who were awarded were perhaps more capable of carrying out the research (a factor which attracted the attention of the judges of the awards). Secondly, and perhaps more importantly, financing does matter to R&D. The non-winners faced *financial constraints*. Because they could not be awarded, a number of socially valuable projects had to be forgone. Thus a selective, competitive grant award system may not be as welfare improving as a uniform across-the-board subsidy (although the latter would also fund projects that are not quite worthy). Israel's matching grants program was more like the latter, where anyone with minimum criteria received an award. There was no rivalry for the awards. More on this is discussed below. Nonetheless, the ATP contest might have produced a "rich get richer, poor get poorer" effect whereby the winners obtained more funding and the non-winners obtained less. Net potential R&D could fall if the increase in R&D conducted by winners is less than the decrease (or forgone) R&D of the non-winners.

Another ATP evaluation study is by Laidlaw (1997) which finds that 90% of winners say that the R&D support helped accelerate their R&D cycle (causing them to proceed to the next step, say innovation or commercialization sooner). 13% reported that they were ahead of schedule by less than one year, 53% by 1 to 3 years, 7% by more than 3 years, and 2% unsure. Independently, Silber (1996) surveys 125 companies involved in 60 ATP-funded projects. 62% report that they anticipate a commercial product. 122 of them indicate that funding was crucial to their innovative efforts.

These results do conform with studies of the impact of public R&D in general on stimulating company R&D. However, a number of reservations should be addressed. As mentioned above, there are problems associated with evaluating programs by the awardees and contractors of ATP. A second concern is that joint ventures and research alliances make anti-trust authorities potentially wary. A third concerns the fact that, like patent races, competition for awards also feature a winner-take-all outcome. The competition may encourage firms to rent-seek or to spend excessively to win (e.g. to conduct experiments, develop blueprints, publish preliminary results, etc.). There may also be duplication of research spending by rivals prior to an award being granted. A fourth problem (which is to be addressed below) is that of endogeneity. It may not be the case that government R&D support causes private R&D, but the reverse. Those that engage in intensive R&D activities are more likely to be chosen by the government for research support. A fifth concern is that in the end, governments have to select. The government, in other words, has to decide which technologies or projects it deems worthy. The NIST indeed is actively involved with the projects, with specialists making on-site visits and acting as a resource throughout the projects' phases.

A sixth, and last, issue concerns one of the original aims of the ATP. The Omnibus Trade Act of 1988 was a response to flagging U.S. competitiveness during the early 1980s. Thus a concern here is whether the ATP has been an instrument of strategic trade and industrial promotion. Is the ATP protectionist? Is it a good lesson for developing countries that seek to catch up? Three examples will illustrate. One of the ATP supported projects helped the Flat Panel Display Industry in the U.S. These flat panels are found in the screens of laptops and television sets. Japan dominates the world market, having a 95% share (with the U.S. share at 2.5%). The ATP provided substantial support to a consortia of U.S. firms (Photonics Imaging, Planar Systems, and so forth) while the U.S. government put in place tariffs on foreign screens. Likewise, the ATP supported a joint venture for Optical Recording (a method for storing data on CD Roms, laser video disks). Japan's world market share is 80%, the U.S. 10%. Again, a consortia of U.S. firms such as Eastman Kodak, IBM, Applied Magnetics, and so forth, received matching grants. Thirdly, a joint venture among AT&T, Texas Instruments, Digital Equipment, and United Technology received ATP funds to improve the technology for Printed Wiring Boards (which provide interconnections between individual electronic devices used in automobiles, computers, communications, and so forth). The U.S. share of the world market was 42% in 1984, and 27% in 1991, at which time the joint venture received its funding.[20]

<u>(ii)</u> <u>Challenge</u> <u>Grants</u>: These are grants supervised by the National Institute for Allergy and Infectious Diseases (NIAID) in conjunction with the National Institutes for Health (NIH). Matching grants were provided to private firms in the biotechnology, pharmaceutical, and medical devices industries. The novelty of this program was that grants were "performance-based," meaning that continuation of support depended on the success of stages in the development of a final product. Traditionally, continued support rested on scientific progress. Here, the requirement is similar to that of what venture capitalists might require of the entrepreneurs they are underwriting, namely whether or not the research is yielding specific working innovations. Whether it is a good thing for public R&D programs to be guided by commercial prospects is the subject of the next case study.

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[20] See Link (1996) for more details.

(iii) Small Business Innovation Research Program (SBIR): Wallsten (2000) investigates whether SBIR grants stimulated private R&D. The SBIR is a program which requires federal agencies, such as the Department of Commerce, Defense, Energy, Education, and so forth, to set aside part of their budgets for extramural R&D (i.e. R&D conducted by outside contractors). Small business contractors and/or their organizations submit applications to a federal agency directly. Annually, the SBIR provides $1 billion of R&D grants to small firms.

The Wallsten study makes two related contributions: first, it finds that SBIR government grants crowd-out privately financed R&D dollar for dollar. Secondly, it points out a potential endogeneity problem. In order for public subsidies or grants to stimulate private R&D effort, the subsidies or grants must stimulate firms to undertake projects that they would otherwise not find profitable (but which is socially valuable). But lately, as in the case of Challenge grants, public subsidies and grants have been made available for research that has the potential to lead to commercial success. Thus a criteria for choosing which firms to support financially is the commercial promise of their research proposals. But then these are precisely the research projects that would likely be privately profitable to undertake; that is, they are inframarginal R&D projects. To the extent that the government funds inframarginal R&D, there is little additional stimulus to overall R&D. Moreover, the simultaneity problem is whether government subsidies and grants stimulate private R&D or whether private firms that engage in the right amount of R&D receive the subsidies and grants. In other words, "receiving awards may be endogenous to a firm's R&D activities" (Wallsten (2000), p. 83).

The policy implication of this is that to promote innovation, government grants should not be awarded to the best programs, but to the best of those proposals that are not likely to receive financial support from alternative sources. Thus an efficiency criterion would be to choose marginal R&D projects that would generate net social benefits and which would otherwise produce net losses to the R&D firm. A political economy reason (and one which may be relevant to the LAC region) as to why bureaucrats would support commercially attractive projects is the potential embarrassment of funding projects that fail. The marginal projects are most likely to have higher risks of failure. However, voters or the local public may not appreciate the principles behind optimal public R&D evaluation. There is a kind of veil at work, where voters may not see that public funds spent on a commercially successful R&D project might have been *rent* to private firms.

(iv) Israeli Office of Chief Scientist (OCS) Programs: The situation is somewhat different for Israel whose public R&D grant programs targeted commercially promising R&D projects. In Israel, the evidence appears to indicate that public support helped to "crowd-in" private R&D and to be associated with increased patenting activities by Israeli firms and exports of high-tech products. Trajtenberg (1999) attributes this to certain differences between the U.S. economy and Israel's – namely that capital markets in Israel were underdeveloped and that a venture capital market was virtually non-existent. Another aspect of the success may be that the government followed a principle of "neutrality" in deciding which firms to award matching grants. This principle allocated resources based upon market signals rather than bureaucratic directives. The Office of Chief Scientist (OCS), which oversaw the programs, set up eligibility criteria for R&D projects – criteria that reflected their technological and commercial feasibility – and then provided support to all projects that met them. There had been no attempt to rank projects or select projects according to technological field. The government provided up to 50% of the total costs of R&D. Start-up companies could qualify for up two-thirds of the costs of R&D. Support ceased once the firms passed the pre-competitive stage and had developed "pilot plants."

Eventually the principle of neutrality had to be abandoned once Israel faced fiscal constraints and increased budgetary deficits. This led to more discrimination of projects by field of technology or by type of firm. This may be a lesson for LAC as to how awardees might be selected in the face of fiscal constraints.

II. IPRs and Government Funded R&D

To conclude this section, we turn to the issue of intellectual property rights and government funded R&D. This is a natural extension to the above discussion of matching grants and R&D subsidies. Any participation between industry and government in promoting research will bring up the heated question of property rights. Who has the right to use the results of the research? Since it was funded with taxpayers' money, should the research results be put into public domain? Or should the researchers who contributed their value-added have the exclusive rights to use the research results as well as the right to licence their inventions. Thus, any discussion of public R&D funding will not be complete without some discussion of the ownership of intellectual property rights arising out of publicly supported R&D.

Many inventions are government funded. In most countries, the government funds nearly half the nation's R&D (recall Table 1). Typically, the ownership rights to government funded R&D are spelled out in contracts between government agencies and the performers of research, and thus are not explicitly mentioned in the national patent laws, except in the case of Canada, France, Germany, Japan, UK, and the U.S. The pattern is very similar to employee-employer arrangements, which often are specified in national patent laws. The general idea is that if an employee works for hire and develops an invention, the exploitation of which falls under the business of the employer, the rights to a patent rest with the employer; else, the rights go to the employee, with the employer having the right to obtain a license. In the case of government funded research, inventions made by a contractor or public servant in the course of public service belong to the public entity; else, the contractor or public servant retains title and allows the public entity to obtain a license, usually non-exclusive, irrevocable, and royalty free.

A few remarks about the treatment of government funded research in different countries. In the U.S., the *Bayh-Dole* Act of 1980 allows industry contractors of the government, national laboratories, and academic institutions to retain title automatically to the inventions that come out of their research work even if it is funded by the government. In addition, the Act gives them the right to issue exclusive licenses for the use the results of their research work. Prior to 1980, these institutions were able to patent, but only on a case by case basis. An Institutional Patent Agreement (IPA) might be drawn up between a government agency and its contractor. The Bayh-Dole Act replaced the system of IPAs with a uniform policy. The main reason for formalizing this policy was that when the research output remained in the public domain, few got commercialized. This was viewed as being adverse to U.S. competitiveness and productivity. Consequently, for example, universities, which are traditionally open institutions for exchanging ideas, were encouraged to be more "commercially-oriented" about their output or to team up with private industry. In turn, the policy of the government was to receive from university or industry a royalty-free license for governmental purposes.

In Japan, it used to be the case that the government held all patent rights to projects funded by the Ministry of Trade and Industry (MITI); the Japanese or foreign company participants were required to pay license fees in order to use the very technology they helped create. This changed in 1994, motivated also by the desire to (a) increase international competitiveness, (b) attract foreign companies, and (c) promote Japanese-international research collaboration. The arrangement now is for the government to retain at least 50% of the ownership rights and the private companies (including foreign) at most 50% of the rights. In the U.K., the government retains title to inventions arising out of contract research, but companies can retain title if the government provided only subsidies. Whichever party does not retain title has the right to license the technologies for free. In the 1980s, the U.K. also encouraged universities to manage their own intellectual properties (and grant licenses to industrial companies), and to pursue funds beyond government grants and subsidies in order to help commercialize their output.

Studies on the economic effects of the patenting of government funded R&D have been few, focusing largely on the U.S. experience with the *Bayh-Dole* Act. We shall summarize a few of these studies. First some background facts. National laboratories and academic institutions do quite a bit of generic, basic research. While university research accounts for less than 15% of national R&D in the U.S., universities account for nearly 60% of national basic research. A large share of university research is funded by the government (approximately 60-70%). The majority of public funding of research goes, however, to the national laboratories.[21]

As was suggested above, the motivation for the Act was to increase technology transfers from the research sectors of the economy to the productive sectors. It was believed that intellectual property rights would help accelerate the commercial exploitation of the discoveries of labs and universities because of the *additional investments* needed to turn university and laboratory R&D into commercially viable products for the marketplace. No private manufacturing firm, for example, might undertake that challenge unless it gets to have the exclusive right to manufacture something out of the new discoveries. One view is aptly summarized as follows: "what is available for exploitation by everyone is undertaken by no one."[22]

[21] See National Science Foundation *Science and Engineering Indicators* 2001.

[22] Speech from a National Patent Planning Commission hearing, circa 1945, quoted in Jaffe and Lerner (2001).

Critics (see Mowery et. al.(1998)) charge that if the knowledge is put into public domain, competition will ensure that worthy ideas are exploited for commercial purposes. That is, firms will compete to be first to come up with a commercially applicable idea and then market it (and possibly try to seek patent protection for their value-added contribution). This is one issue where we need to reiterate the importance of distinguishing between basic R&D and applied R&D. Basic R&D or basic knowledge is not patentable. Applied is, by definition. Thus to the extent that a university or a lab researcher is allowed to seek patent rights, that researcher is only entitled to patent that portion of the knowledge that is of an applied nature (or industrially applicable). The Mowery et. al. argument is that the lab or academic researcher should place his/her applied R&D into public domain. But the lab or academic researcher would then be throwing away a chance at commercially profiting from it himself or herself. Another party (say a manufacturing firm) would come along (and compete) to be the first to manufacture and market the idea. This transfers the potential gains from the researcher to the manufacturer. What motive would the researcher have for putting his/her work into public domain? Also, what motive would the manufacturer have to exploiting something in public domain? If it is indeed first, it may profit from a lead-time advantage. However, as competition from the second, third, and nth firm arrives, economic profits will be dissipated. This is entirely a possible equilibrium market outcome unless the first manufacturer does need to make additional investments to turn the applied R&D that is in public domain into something that is commercially feasible. That is, a few more inventive steps might be needed before it is market ready. The manufacturer may be able to obtain temporary intellectual property rights for his/her value-added work, but it depends on how novel the value-added work is. Recall that the applied R&D knowledge that the manufacturer exploits is in the public domain, and knowledge that so resides in public domain is not patentable (since it is not novel). Thus if the value added work is costly but not novel enough to warrant protection, the first manufacturer (or any other manufacturer) might not exploit the opportunity, and thus we have the same problem as before, where applied knowledge exists but is not exploited commercially.

The Mowery et. al. (1998) argument makes sense if the research that the universities or laboratories put into public domain is of a basic nature. But in this case, it is not patentable. Firms may freely build upon such knowledge and only obtain intellectual property rights over industrially applicable inventions that build upon and utilize the basic knowledge. In this case, universities and laboratories do not need intellectual property rights (and should not if the research is of a basic nature) and competition will take care of ensuring that worthy knowledge gets into the marketplace. But relying on competition without resolving legal ownership issues leaves the applied R&D of universities and laboratories in limbo, which is the problem that the Bayh-Dole Act had tried to redress.

Nonetheless, theoretically and empirically the debate is not settled as to whether it is prudent to let these research organizations retain title to publicly funded research. Some common arguments against are:

1. Matter of Principle. Since taxpayers' money funded the research, the public as a whole deserves to have free use (whether the knowledge is applied or basic).

2. Shifts in Research. Labs and universities might move away from basic research, which is their comparative advantage, into applied research, and become more profit-oriented rather than community-service oriented. One defense is that perhaps there is too much basic research and not enough applied, practical work.

3. Differences between Academic Culture and Corporate Culture. In the pre-Bayh-Dole era, scientists would freely exchange data and samples. These days, it is common for scientists to charge each other for them. This raises the cost of research and may impact negatively, if it has not already.

4. Mistakes Happen. We have been discussing the importance of distinguishing between applied R&D and basic R&D, permitting the patenting of the former but not the latter. In reality, there is sometimes a fine line between them, so that it is conceivable that authorities have mistakenly or controversially granted intellectual property rights over what was thought to be applied discoveries but were basic. An example comes from biotechnology, where firms have patented expressed sequence tags (EST), which are enzymes, but more importantly they are what scientists consider to be "research tools," much like some statistical formulae are for economists. Intellectual property protection for research tools works to increase the cost of R&D and restrict the diffusion of research results, and impactly adversely on follow-on research. The system does allow for challenges of invalid patents, but the system can be slow to correct past mistakes.

These points just raised are theoretical and speculative. We turn now to some empirical studies on the effects of Bayh-Dole. The empirical evidence is very limited and mixed. Two studies which concentrate on the effects of the Act on *universities* find that the Act played a weak role in stimulating patenting and in improving the quality of patented inventions. A study which concentrates on *national laboratories* finds that the Act stimulated patenting activity and the quality of patents.

First, on university research, Mowery et. al. (1998) argue that the Bayh-Dole Act did not stimulate university patenting and licensing because the trend had already begun before the Act was implemented. There are also other factors which stimulated universities to patent more; for example, increased public R&D funding of university research, an increase in the number of technology transfer offices (TTOs) across universities which helped faculty search for industrial partners, and a landmark patent case (known as the *Diamond* vs. *Chakrabarty* case) which opened the door to biotechnological patenting, an area in which university science departments are strong. Thus the authors argue (p. 2) that "even without the Bayh-Dole Act, the evidence . . . suggests that U.S. universities would have increased their patenting and licensing activities."

Still, universities patented before 1980 precisely because the option to patent did exist (via IPAs). But after 1980, there was a very steep rise in university patenting. Thus laws do have an effect on whether universities patent. Moreover, the Mowery et. al. study does not compare which system is better for technology transfer: putting university research results into public domain or allowing university research results to be owned by the university. Such an exercise is left for future investigation.

The Henderson et. al. (1998) study examines whether the Bayh-Dole Act might have affected the *quality* of university inventive activity. In the literature, patent citations are used to help measure how worthy or valuable the underlying inventions are. In each and every patent application, inventors must cite the relevant past inventions on which they build and upon which they are an improvement. The purpose of citing is not so much to communicate with researchers but to communicate with potential rivals (and their lawyers) so as to avoid infringement. The patent application describes how technologically novel its invention is relative to others in existence. Nonetheless, for researchers the information on citations is invaluable. One can examine not only backward citations (the inventions cited in the patent application) but also forward citations (the citations by others of one's patented invention). An invention's value is often associated with the number of citations it receives (in the absence of any explicit market value of the invention).

The Henderson et. al. (1998) study finds that until 1980, university patents were highly cited (relative to a random sample of all patents), but that after the mid-1980s, there was a decline in the rate of citations for all universities. To the extent that this reflects a decline in the quality of university invention, the data suggest that the contribution of universities to commercial technological development was not high (in recent periods). One possibility is that the Bayh-Dole Act shifted universities away from what it does best (basic research) to what it does not do best (applied R&D). However, another possibility is that due to the lag between R&D and patenting, the Act could have stimulated high quality R&D during the 1980s but that the patent applications based on that R&D effort did not appear until after 1988 (which is the end of their sample period). Moreover, if Mowery et. al. are correct in asserting that the Bayh-Dole Act had little effect on subsequent university patenting, then it might be fair to say that the Act also had little to do with the patenting activity of low quality university inventions.

Finally, the Jaffe and Lerner (2001) study examines the behavior and quality of patenting by U.S. Department of Energy laboratories (for example, Lawrence Livermore, Sandia, Los Alamos). In contrast to universities, national labs are found to have been more successful commercially, as measured again by the patent citation rates. Until 1980, national labs lagged universities in terms of patents per R&D dollar. But post 1980, national labs reached parity with universities in patenting activity. The citation rates for national laboratories either rose or remained constant. The study does find, however, that the more successful labs were those where turnover of contractors was high and where exclusive licensing was not the norm. It would be useful to examine if the conclusions of this study can be generalized to other national laboratories (say of the Defense Department or NIH).

Thus, the debate continues as to whether it is economically desirable to allow publicly funded innovations to be patentable. This will be an important issue for developing nations where the public sector is more actively involved in national R&D activities than the U.S. has been. A policy judgement has to be made whether technology transfer is enhanced or not with a Bayh-Dole type Act in their own economies. Both type I and II errors could arise, where it is either a mistake not to let those inventions be patented or a mistake to let them be patentable.

4. Empirical Results

4.1 Overview of Results and Methodology

This empirical section examines the effects of the determinants of R&D discussed in previous sections, for example, intellectual property rights (IPRs), fiscal incentives, and public R&D funding (through grants and subsidies). The following remarks are an overview. We begin with a look at the effects of public R&D and different kinds of IPRs: patents, copyrights, and trademarks. To take into account the endogeneity between public and private R&D that was discussed in previous sections we use instrumental variables estimation. We then take into account individual (country) effects. This analysis finds that once patent rights are controlled for, the other kinds of IPRs matter insignificantly. We then introduce the fiscal incentives variable (i.e. the B-index), and find that its effects are as predicted, but not very significant statistically once patent rights are controlled for. The level of significance is about 7-8%. Next, we introduce the human capital variables (scientists and engineers per 10,000 workers and tertiary education enrollment rates), and find that these variables are important explanatory variables for private R&D. Finally, we ask what the effects of private and public R&D (and indirectly the effects of fiscal incentives, patent rights, and human capital) are on total factor productivity (TFP), domestic innovation (as measured by domestic patenting), and on technology inflows (as measured by foreign patenting and foreign direct investment inflows). In other words, we try to get at the overall economic benefits of these determinants of R&D. The benefits are that they stimulate R&D which in turn stimulates innovation and technology inflows, and which in turn stimulate TFP. We find that human capital can directly stimulate TFP, but fiscal incentives, public funding, and patent protection stimulate TFP indirectly by stimulating the determinants of TFP such as domestic and foreign patent capital.

The estimating equation is based on the R&D supply and demand model of section 2. Essentially, we substitute equation (3) into equation (4) (to eliminate p) and aggregate across firms. In steady-state, the stock of private R&D capital per worker is a function of public R&D capital per worker, physical capital per worker, human capital per worker, and the policy environment (e.g. level of intellectual property protection and fiscal incentives):[23]

$$(14)\ \ln\left(\frac{R_p}{L}\right) = \alpha_0 + \alpha_1 \ln\left(\frac{R_g}{L}\right) + \alpha_2 \ln\left(\frac{K}{L}\right) + \alpha_3 \ln(IPR) + \varepsilon$$

The factor resources (such as physical capital and human capital) have the effect of augmenting the marginal productivity of private R&D capital; human capital can also reduce the cost of doing R&D by increasing the supply of scientists and engineers. Intellectual property rights have two opposing effects on R&D: on the one hand, they increase the degree of appropriability of the returns to R&D; on the other hand, they increase the cost of R&D for rivals and/or follow-on inventors. Fiscal incentives (such as an R&D tax credit) can have a positive effect on steady-state R&D depending

[23] Details are in Park (2001).

on the extent to which they reduce the marginal effective cost of conducting R&D. Public R&D funding can affect and be affected by private R&D, as was discussed in the previous section.

The stocks of public and private R&D capital are determined as follows:

(15) R(t) = I(t) + (1 -) R(t-1)

$$(16)\ R(0) = (\frac{1+\gamma}{\gamma+\delta})\, I(0)$$

that is, by the perpetual inventory method (where R could refer to either public or private R&D capital). The initial stock R(0) is obtained by rolling equation (15a) backwards in time, and assuming that R&D investment, I(t), grows at the average rate . We set equal to the sample period average investment growth rate ((t+1) = I(t+1)/I(t) - 1), for t = 1980, ..., 1995). If is negative, we set to zero, or otherwise the initial values of R&D stock are implausibly high.

4.2 Data

The R&D and scientists and engineers data are from Unesco's *Statistical Yearbook* (various issues) and the OECD's *Basic Science and Technology* database. The B-index data are from Warda (1996), and GDP, labor, and stock of physical capital per worker from Summers et. al. (1996) *Penn World Tables* (and updated using the World Bank's *World Development Indicators (WDI)*). Tertiary education and foreign direct investment data are from the World Bank *WDI*. Government spending and price index data are from the International Monetary Fund's *International Financial Statistics* (various issues). Intellectual property index data are from Park (2001) and Ginarte and Park (1997), and patenting data from the World Intellectual Property Office (WIPO) *Industrial Property Statistics*.

4.3 Econometric Analyses

(A). R&D and Intellectual Property

First, in Table 7, the basic R&D investment equation is estimated, using government spending per worker to instrument for public R&D capital per worker. (This has been a good instrument in the past since public R&D spending is a percentage of government spending. It is therefore correlated with overall spending, yet government spending overall is not determined by private R&D spending.) There are four parts to this table. In part A, the intellectual property rights variable focused upon is patent rights, in part B copyrights, and in part C trademark rights. In part D, all three IPR variables are entered jointly. For each of these four parts, a regression is run on the sample as a whole, then on each of the four regions separately.

For all regions, patent protection is an important explanatory variable. A 1% strengthening of patent rights increases the long run stock of private R&D capital by 1.773%. Public R&D capital per worker is also a very important explanatory variable, even after controlling for simultaneity. A 1% increase in the long run stock of public R&D capital per worker is associated with a 0.58% increase in the long run stock of private R&D capital per worker. There likely is some crowding out (or stimulation of inframarginal private R&D), which may be why the coefficient is less than unity. Physical capital per worker is also important. Its presence raises the marginal productivity of R&D capital and hence the demand for private R&D. The model explains about 79% of the data.

For all regions, copyrights are also an important explanatory factor as is trademark rights. But when all three IPR variables are entered together, patent rights and copyrights are statistically significant at conventional levels, but the trademark rights is not significant, and exerts a negative (but weak) effect on private R&D. It may be that trademarks create transactions costs (while also protecting intellectual assets, such as reputation) by making it more difficult for rivals to develop differentiated names, symbols, and other marks. Ideas for coming up with marks and symbols are easier when a field of business or research is new, and beyond some point it becomes more difficult to be novel.

For region 1 (largely OECD minus Japan and Korea), patent protection, copyrights, and trademarks when entered individually along with the other regressors are significant; however, when they are entered together, patent rights and trademark rights remain statistically significant, but copyrights have a strong, negative effect on private research (see Part D). Under Part A, copyrights appear to have a positively significant effect in region 1, but here it is likely proxying for patent rights. One reason copyrights have a negative effect in region 1 may be that the duration is excessive (50 years plus). Moreover, copyrights pertain more to artistic creations rather than to R&D. But to the extent that copyrights protect particular aspects of research output – namely the expressive part – rival researchers may find this a hindrance. Someone else's proprietary expressions are protected while the rest of society enjoys little, if any, spillover benefits from those creations. As for the other determinants of private R&D capital, public R&D capital is a significant explanatory variable, as is the physical capital.

For region 3 (East Asia), there are fewer observations (namely 20), so that the statistical inferences should be taken with some care. Patent rights, copyrights, and trademark rights each have a significant effect on Asian private R&D, but with rather large quantitative estimates. When considered jointly, it is only the copyright variable that dominates. One possibility is that the Asian Tigers largely developed through imitation, and therefore strong patent rights would have worked against them. Secondly, it is conceivable that the particular areas of R&D they conducted were more sensitive to copyright protection, for example, electronics, computers, telecommunications, and textiles. Physical capital is an important determinant of private research, but public research has exerted a statistically insignificant effect. One explanation is that in Japan and Korea, the share of public funding is relatively small (about 22-24%), and yet they are among the leading private R&D-nations. In contrast to them, this region also includes Thailand and the Philippines where the share of public R&D is much high (63-73%) but the degree of private R&D activity is much lower. Hence the relationship between government and private R&D has a tendency to be negative in this region, but not statistically significantly so, since there are only a few country observations to detect this.

The finding might also reflect the Asian economies relying upon industry's own initiatives for investing in private R&D. Certainly the Asian governments have played some role in promoting their industries, but it is apparently more on the production side (rather than research), for example in providing export subsidies and promoting domestic industry.

Next, in region 2 (LAC), when the IPR variables are examined individually (along with the other determinants), patent protection is positively significant, copyright not significant, and trademark negatively significant for LAC R&D. When entered jointly, the same qualitative results are obtained. Thus despite the fact that IPR violations have occurred in this region (primarily against U.S. intellectual assets), as well as imitative activities, patent protection has been important to private research in Latin America. What this suggests is that private R&D levels in LAC would have been higher had patent protection levels been higher. In this sense, opportunities for greater domestic R&D were forgone due to imitative activities and IPR infringements. Thus patent reform is likely to have an important effect on the future growth of private R&D in LAC. As for why trademark rights have had a negative effect on R&D, it might be that trademark rights imposed transactions costs. Certainly, foreign firms operating in LAC have pushed for stronger trademark protection for themselves, but the results here suggest that for domestic research, trademark rights have discouraged R&D. The benefit to the individual firm is outweighed by the costs imposed on other firms. This is not to say that trademark protection is not important for overall welfare, but that for private R&D, the net effect is negative. This effect may work indirectly, by first increasing the cost of production for a firm (that does not own the trademark), thereby reducing profits and output, and ultimately its investments in capital, including R&D capital.

What is also interesting for LAC is that despite the relatively heavy involvement of the government sector in research, public R&D capital has had an insignificant effect on private R&D. One possibility is that public R&D was neither directed at helping private industry commercialize the latter's research output nor invested in generic, enabling technologies that could raise the marginal productivity of private research. In other words, this is a finding that suggests inefficient use of resources. Considering the evidence for other regions, it does not appear that public R&D is inherently bad for private research, through net crowding out effects or misallocations of resources. It suggests that perhaps the spending was not directed in the appropriate places. More on this is discussed later in section 5.

Finally, for region 4, intellectual property rights variables have weak effects on private research. Patent rights matter but modestly, with a significance level of 7-8%. Public R&D, on the other hand, is an important determinant of private R&D in this region. Thus the results for region 4 are in direct contrast to that for the LAC region. Like LAC, this region has had low levels of private research activity, but perhaps the technological capability is less. Because this is so, there is less role for a patent system. Such a system is useful to the degree that there is something to protect. On the other hand, the results suggest that public R&D in this region might have been more targetted to specific uses (as it was in Israel). Like LAC, the government share of R&D funding is very high. The private sector is fairly small with less developed capital markets, and thus the probability that public R&D would fund what the private sector would have funded on its own is rather slim. The stock of public R&D capital is then likely to have raised the marginal productivities of private research.

In Table 8, we control for individual effects, namely country effects. There could be omitted individual country heterogeneity not observed; for example, innovative capacity, quality of environment for research, and quality of policy institutions. In column 1, the random effects estimates are provided for the R&D equation with all three IPR variables entered jointly (along with the other regressors). The equation is estimated for the sample as a whole (i.e. all the regions pooled). Public R&D capital per worker, physical capital per worker, and patent rights are significant explanatory factors. However, copyrights and trademark rights exert statistically weak influences on private R&D capital per worker. The table indicates nonetheless that the random effects results are not consistent since the null hypothesis of no correlation between the individual effects and the explanatory variables can be rejected. In remainder of this paper, we shall therefore focus on the *fixed effects* estimates.

Thus, without the copyright and trademark rights variables, the fixed effects estimates are reported in column 2. The presence of individual effects has certainly reduced the magnitude of the effect of patent rights on private R&D, while the elasticities of the public R&D and physical capital variables are not too different from what were shown in Table 7. In columns 3 and 4, the sample is split between LAC (region 2) and the rest of the sample (regions 1, 3, and 4). In this case, public R&D and physical capital continue to be important for the non-LAC region but not important to explaining private R&D in LAC. More interestingly, the patent variable's statistical significance has been reduced with the modelling of fixed effects. This has largely to do with the fact that the sample is dominated by OECD economies whose patent protection levels are high and have converged during the past decade or so. For a developing area like LAC, patent rights are relatively more important to the region's private R&D activity (as the significance level is somewhat higher). Thus, to reconcile with the results in column 2, patent rights better explain variations in private R&D for the world at large, rather than within regions.

Columns 5 and 6 show the results of splitting the sample between the OECD and non-OECD countries. The OECD includes the U.S., Canada, Australia, New Zealand, Japan, Korea, Europe, and Turkey. The results indicate more explicitly that patent protection does not help to explain R&D among OECD nations due to the fact that their patent protection levels are fairly high and exhibit little variability between countries. This is not to say that patent rights and patent institutions are not important for R&D. As the results in column 2 (where all countries are pooled) indicate, patent rights matter in explaining worldwide R&D. Thus once countries have attained high levels of patent protection and acquired strong property rights institutions, other factors (such as public R&D funding) appear to better explain between-country variations in R&D. Thus, in line with that explanation, patent rights matter significantly to non-OECD countries, as shown in column 6.

(B). R&D and Fiscal Incentives

Next, in Table 9, the fiscal incentives variable, the B-index, is introduced into the private

R&D equation. Note that the sample size drops to 52, since few countries have provided fiscal incentives, such as R&D tax credits. In column 1, we examine a bivariate regression, where the B-index is the only regressor. This has the expected sign (negative) and is statistically significant at conventional levels. The lower the B-index value, the more generous the fiscal incentives. Firms can break even on an investment in R&D with a lower present value stream of before-tax revenues. The model explains only 18% of the data, however.

Once the other regressors are controlled for (including patent protection, public R&D), the B-index's significance level falls. It is statistically significant at about the 7% level. For this smaller group of countries, which consists mostly of the OECD countries, the quantitative effect of the patent rights variable is higher (exceeding unity). The quantitative effect of public R&D is lower with an elasticity of 0.433 (compared to what is shown in Table 8). The model now explains 81% of the data.

A question of interest is whether perhaps fiscal incentives interact with public R&D funding or with patent protection. The idea is that both fiscal incentives and something else are needed to stimulate private R&D. In column 3, we examine the interaction between fiscal incentives and public R&D capital per worker. The interaction between the two is of no statistical significance. The other regressors, including the B-index variable (un-interacted), have qualitatively and quantitatively the same effects on private R&D. In column 4, we examine the interaction between fiscal incentives and patent protection. Again their interaction is of no statistical significance. This suggests that each type of policy (public R&D funding, fiscal incentives, and patent protection) has perhaps its own "niche" effects. Public R&D is perhaps best at stimulating generic, basic R&D; fiscal incentives at R&D that is less basic but not applied enough; and patent protection at applied, industrially applicable, R&D. Though these are speculative remarks, the available evidence and theoretical reasoning seem to suggest that for knowledge that is fundamental, private agents would not find it profitable to pursue, not even if an R&D tax credit is provided, since the deduction in taxes over some time period probably will not be sufficient to compensate or match the extent of spillovers. Hence fiscal incentives will inadequately enable the private agent to appropriate the rewards to that kind of R&D. Given that applied R&D tends to generate fewer spillovers than basic R&D and since the applied R&D becomes more focused on solving a particular problem, firms could probably do well in appropriating most of the returns to applied R&D through intellectual property protection (or through trade secrecy). Here, it takes some additional investments to take it to market, and a patent right may be most suitable. The more basic the R&D is, the more likely that patent protection will be too strong from a social point of view. Patent protection will likely increase the cost of R&D to rivals and follow-on inventors, so that the net effect of patent protection will be to reduce or slow the rate of private R&D. Thus for R&D that is not too applied and not too basic, fiscal incentives might be the appropriate policy. In short, all three mechanisms have a role but they need not be interactive – that one cannot work without the other policy or policies.

(C). R&D and Human Capital

In Table 10, we examine the role of the human capital variables (number of scientists and engineers per 10,000 workers and tertiary education enrollment rates).[24] Column 1 shows the effect of adding both human capital variables into the model. Both are statistically significant explanatory variables. One interpretation could be that the scientists and engineers variable represents the quantity of inputs into R&D production (such that the more of them there are the lower the cost of R&D – i.e. a supply shift), and that the education variable represents the quality of inputs into R&D production (i.e. skill level). The statistical significance of patent rights falls to the 7% level. Thus once the R&D model incorporates all the inputs into R&D generation, the role of the background institutions fades somewhat. Note that public R&D funding remains significant at conventional levels.

In columns 2 and 3, the sample is split between LAC and non-LAC. Since few observations exist for LAC and since the panel is very unbalanced for both samples, we focus on the two key variables of interest for this subsection: the *supply of scientists and engineers* and *tertiary education*. In order to provide a side-by-side comparison between LAC and non-LAC countries, we use the same RHS variables for both samples. As column 4 shows, tertiary education plays an important role in private R&D capital accumulation in LAC, but the supply of scientists and engineers does not. The size and share of the scientific sector may be too small in LAC to have a noticeable influence on R&D accumulation. In contrast, in the non-LAC sample, both tertiary education and the supply of scientists and engineers are important inputs into private R&D capital accumulation.

In columns 4 and 5, the sample is split between the OECD and non-OECD. In both sub-samples, tertiary education is an important determinant of private R&D, while the supply of scientists and engineers is strongly important for the OECD and moderately important for the non-OECD. Just as the bulk of world R&D is conducted in the OECD, most of the world's supply of research scientists and engineers resides in the OECD.

(D). Effects on Total Factor Productivity

In Table 11, we shift our attention to the effects of R&D and R&D policy on total factor productivity (TFP). The TFP measure assumes that capital's share of national income is 30%.[25] The TFP is in real 1990 U.S. dollars. Under column 1, TFP is regressed against a constant and the patent rights variable. Patent protection weakly determines TFP (with a significance level of about 7%). Only 2% of the data is explained. This finding is similar to that of Park and Ginarte (1997). There it is argued that property laws do not directly affect productivity but rather the determinants

[24] In preliminary investigation, we find that average years of tertiary education do not significantly explain private R&D behavior. It was hypothesized that this variable might capture the amount of training or higher learning, but apparently the enrollment rate variable used here appears to better capture the rates of "investment" in human capital.

[25] $TFP = GDP/(K^{0.3}L^{0.7})$, where K denotes capital and L labor. The value of capital's share in output is assumed to be 0.3. This is a customary assumption in the literature, but there are grounds for why the share could be higher or lower, say to due to market power, measurement error, and so forth. To enable comparison with most studies, we shall also maintain this assumption.

of productivity like capital (including R&D capital and human capital). Without property rights, the rate of capital accumulation would be inefficiently low. Patent laws make up part of the environment in which firms and innovators operate. But as to the ultimate source of their efficiency – or productivity of inputs – one looks to factors that augment them (rather than affect the degree of appropriability of their returns).[26]

In column 2, TFP is regressed on the B-index (of fiscal incentives). Again, the sample size is smaller, and 18% of the data is accounted for. Here fiscal incentives are seen to stimulate TFP; the negative coefficient arises because a lower value of the B-index indicates greater fiscal generosity. As will soon be seen, this significance of this variable diminishes once other regressors are controlled for.

Next, we introduce the stocks of domestic and foreign patent capital per worker as determinants of TFP. A number of economic growth theory models assume that TFP is a function of the stocks of inventions. As the total stock of inventions is unobservable – or rather since we largely observe inventions for which inventors file patent applications – we shall use the stocks of patent applications as proxies for the stocks of inventions. This may be reasonable to do since inventors tend to file for patents for their *valuable* inventions. Of course not all inventions will be granted a patent; some will be rejected, but nonetheless the data on patent applications are used not to count inventions that are patented but to get an idea of the stock of available inventions.

The stocks of patent capital are constructed in the same manner as the stocks of R&D and physical capital, using the perpetual inventory method (assuming a 10% rate of depreciation). Domestic patents refer to patent applications by residents; foreign patents refer to patent applications by non-residents. The latter represent foreign inventions brought to the domestic economy. The reason stocks are used and not flows is that the stocks capture knowledge developed in the past (but not too far in the past) that are still productive or are important to output, whereas flows assume that only innovations in that time period affect productivity. The depreciation rate of stocks reflect the rate of obsolescence of past technologies.

As the bottom of Table 11 shows, for the average economy, the stock of foreign patent capital is nearly three times that of domestic patent capital (i.e. 6.82 per 1,000 workers versus 2.34 respectively). Thus for most countries, the technologies they have access to are from abroad, reflecting the global diffusion of knowledge. Most of the foreign patent capital comes from the U.S.,

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[26] This would be a plausible explanation if we could separate the technological efficiency of an input from the efficiency effects due to the degree of ownership of the input. For example, the efficiency of a computer literally depends on its properties (memory, speed, disk space, and software installed). The fact that the ownership rights to the computer is uncertain affects how it is used and taken care of. With clear ownership rights, the owner of the computer has an incentive to invest in additional software, memory, and plug-ins. The analogy then is that TFP is affected by those investments which augment the computer's productivity rather than the laws governing ownership rights. The latter are already reflected in the extent to which investments are made.

Japan, Germany, France, and the U.K. (with Korea approaching the top five list). Thus for each of these countries, one finds the reverse: that its stock of domestic patent tends to be larger or as large as its stock of foreign patent capital.

The results in column 3 continue to show that patent protection does not matter directly to TFP. Both the stocks of domestic patent capital and foreign patent capital, however, matter significantly to TFP. Both the scientists and engineers and tertiary education variables are statistically significant. Overall, 65% of the data are explained. In columns 4 and 5, the sample is split again between LAC and non-LAC. The lack of observations may explain why the model does not explain TFP in LAC, but the few observations are also a reflection of the fact that there is not a great deal of patent capital in LAC, whether domestic or foreign – not to mention scientific personnel. Thus rather than indicate the lack of importance of these factors, the results might suggest that a certain threshold quantity of resources is needed in order for those resources to have a measurable effect on TFP. In contrast, for the non-LAC sample, the human capital variables and patent capital variables all exert a statistically significant influence on TFP. In columns 6 and 7, the sample is split between the OECD and non-OECD. The results support the view that the results for LAC are likely due to the lack of variability in the data and small sample size. Domestic patent knowledge and tertiary education are important determinants of TFP for both the OECD and non-OECD samples. The main differences are that foreign patent knowledge is not important for the OECD (as the OECD accounts for most of the world's patentable knowledge) and that the supply of scientists and engineers is not important for the non-OECD (as non-OECD countries have a small share of the world's supply of research scientists and engineers).

In columns 8 - 10, we show the results of accounting for the effects of information and communications technology (ICT). The ICT index is "constructed as a principal-component index based on the number of telephone lines, personal computers, mobile phones, fax machines, and internet hosts per capita" (see Lederman and Xu (2001)). Essentially, these types of "infrastructure" are an important determinant of TFP. They complement domestic and foreign knowledge capital and the supply of scientists and engineers (see column 8). However, the ICT variable matters most to the non-OECD (see column 10). Moreover, for the non-OECD, the presence of the ICT variable reduces the impact and significance of domestic patent knowledge capital. This may be partly due to the fact that the inventive level of domestic patents in the non-OECD is not relatively high, such that *tangible* technology infrastructure matters more than intangible ideas to TFP.[27]

(E). Effects on Domestic Patenting

Next, having analyzed some of the determinants of TFP, we turn to the behavior of one of the determinants, namely domestic patent capital. This enables us to examine whether some

[27] Note that the tertiary education variable is dropped from columns 8 - 10. We find that this variable is correlated with the ICT index among non-OECD nations. When entered jointly, it is the education variable that emerges as statistically significant. Thus, one possibility is that the ICT variable proxies for human capital as embodied in technology.

variables have indirect influences on TFP via their influences on domestic patent accumulation. In Table 12, we present estimates of an equation for the stock of domestic patent capital. Such an equation can be derived from a Romer (1990) growth model, as shown in Park (2000). Note that we do not model or estimate foreign patent capital accumulation. We will treat this as an exogenous factor with respect to domestic TFP. Foreign patenting behavior will likely depend on both domestic (destination) and foreign (source) characteristics, for which a more complete model needs to be specified.

In column 1, we first analyze the impact of fiscal incentives. The results indicate that the B-index is not statistically significant. Note also that for the smaller sample of countries that is represented here, public R&D is weakly (negatively) significant. Domestic innovations depend much more strongly on private R&D.

For the sample as a whole (see column 2), both public and private R&D capital are seen to be strong determinants of domestic innovation. But patent rights are not directly significant to domestic patent capital accumulation. The reason is that the influence of patent rights is already incorporated in the private R&D variable. Because of spillovers associated with research and development, and the difficulty of appropriating the returns to R&D, firms' R&D are influenced by the level of protection. But once they have innovated, firms may be less dependent on patent protection as a means for appropriation. As the Levin et. al. (1987) study pointed out, firms could also depend upon reputation and lead time advantages. In this sense, patent protection gives an incentive to do the original *applied* R&D, but at the post-R&D stage, the innovation phase may be rather specialized so as to prevent spillovers and leakages, or at least make it less difficult to exclude others from copying.[28]

In column 2, both the scientists and engineers and tertiary education variables are also controlled for. Tertiary education is statistically insignificant at conventional levels but the scientists and engineers variable is strongly significant. One reason is that the kind of human capital that is relevant to domestic innovations is specialized human capital, as embodied in scientific personnel.

In columns 3 and 4, estimates for the split sample (LAC vs. non-LAC) are provided. Again due to sample size problems, a parsimonious specification is adopted. As before, in order to provide a side-by-side comparison between LAC and non-LAC countries, the same RHS variables are used for both samples. The results show that private R&D and scientists and engineers do not explain domestic patent capital in LAC. Again, the level of patenting activity in LAC is low, and exhibits little variability among the smaller LAC countries (outside of Argentina, Brazil, and Mexico). In contrast, private R&D strongly explains (and the supply of scientists and engineers modestly explains) domestic patent capital in the non-LAC region. Column 5 shows the results for the non-OECD countries (which includes LAC and several other developing economies). The usefulness of this sub-sample is that it provides greater variability in the data than in the LAC sample. In this

[28] However, as shown in Park (2000), patent protection still plays an important role in the "filing" of patents. This means that patent rights are valuable if patent laws are strong enough.

instance, the research variables (private R&D stock and scientists and engineers) do modestly help explain the stock of domestic patent knowledge capital.

(F) Effects on Foreign Direct Investment (FDI)

Lastly Table 13 examines the effects of R&D policies on foreign direct investment (which help influences the overall level and rate of capital formation in the local economy, and which in turn affects local production possibilities). First, column 1 shows that domestic private R&D and domestic patent rights strongly influence FDI, while domestic public R&D does not. Column 2 shows that, after controlling for the human capital variables, patent rights remain an important determinant of FDI. Tertiary education is also an important determinant. Private and public R&D are weakly positive influences on FDI. Columns 4 and 5 provide a side-by-side comparison between LAC and non-LAC. Breaking the sample down like this shows that education matters to the FDI inflows in the non-LAC region, but not in the LAC region, while patent protection matters to the FDI inflows in the LAC region, but not in the non-LAC region. The results for the non-OECD sample (see column 5) mimic those for the LAC sample. Patent protection is a significant determinant of FDI inflows. There is as yet very little theoretical and empirical work on the relationship between FDI and intellectual property that can help interpret these findings. Hence these findings should be treated as preliminary. However, for the non-OECD countries, perhaps the results are not surprising since the bulk of world FDI is conducted by OECD nations (and the bulk of world multinational firms are from the OECD). The results suggest that FDI flows from OECD to non-OECD depend importantly on the security of intangible property rights and protection of such assets.

To summarize, public funding, fiscal incentives, and intellectual property rights each have a noticeably positive effect on private R&D. When considered jointly, some effects dominate others; in particular, we find that patent rights are more relatively more important to private R&D activities than copyrights and trademark rights. Likewise, fiscal incentives tend to show modest effects on private R&D, once patent protection and public R&D funding are controlled for. However, the quantitative and qualitative effects of these policies further diminishes when one controls for human capital variables. Human capital is largely responsible for conducting R&D, so the results should not be surprising. In this sense, resources such as physical capital and human capital are the primary determinants of private R&D, but the policy environment is important for the efficient functioning of this R&D input-output relationship. In this regard, fiscal incentives, public support, and institutions protecting property rights play an important “infrastructural” role. Moreover, the benefits of R&D policy are also manifested in total factor productivity and the determinants of total factor productivity. What we largely find is that human capital and the stock of technological innovations (as represented by the stocks of patent capital, domestic and foreign) are the primary determinants of TFP. But technological innovations are themselves determined by private R&D capital and human capital. Private R&D capital in turn is a function of fiscal incentives, public R&D capital, and patent protection. Thus, important interrelationships exist whereby an R&D policy regime has an influence on the course of a nation’s total factor productivity.

These findings were based on the pooled data. Some region by region comparisons were done which showed some heterogeneity in experience with R&D policies. But the pooled data capture more variation in the data and more likely yields a sense of the underlying relationships between policy and the trends in R&D and productivity.

5. Implications for the LAC Region

One hesitates to prescribe country-specific policy recommendations based on the case study experiences of the U.S. and on cross-country (pooled) empirical results. The results are suggestive, however, of some important links among R&D and policy incentives and institutions. In this section, we explore the implications for the Latin America and Caribbean (LAC) region in two ways: the first is to see what the empirical magnitudes imply for LAC's potential R&D and total factor productivity growth. Hence a few policy simulations are conducted (using the empirical estimates) to examine the effects on R&D and TFP of changes in R&D policy.[29] The second is to assess future R&D policy options facing LAC, and their suitability in this region. For instance, are there important regional attributes that need to be taken into account?

5.1 Policy Effects

The results of the simulation analyses are presented in Table 14. The analyses are conducted for region 2 only. We use the estimated equations to predict the effects of changes in the independent variables on R&D and TFP. These effects should be interpreted as a steady-state comparison (since the model was solved for in steady-state). First, it should be noted that we mix coefficient estimates from different tables, since we were not able to estimate a complete set of R&D and TFP equations with all the R&D policy variables included, primarily because the number of observations for the fiscal incentive variable was few. The bottom of the table indicates the formulae and where among Tables 7 - 13 the coefficient estimates come from. Secondly, these coefficient estimates are averages for the sample as a whole. They will most likely differ by country (if only we had individual country time series observations). We did control, however, for individual fixed effects.

We examine, one by one, the effect of a half standard deviation increase in patent rights, the B-index, and public R&D capital per worker. Each of these changes has a direct effect on private R&D capital per worker and an indirect effect on TFP, via its influence on private R&D and/or domestic patent capital; that is, each of these changes influences private R&D, which in turn influences patenting, which in turn affects TFP.

Let us first consider what happens if LAC economies strengthen their patent regimes. According to Table 1, one standard deviation of the patent rights index for the LAC region, during the sample period, is 0.56. Thus, half of that is 0.28. We therefore assume that each LAC economy increases its patent rights index by 0.28 points. This represents a different effort level to each

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[29] None of the equations involve explicit expectations of future variables, for which a more careful analysis of "regime shifts" is required.

country. For some, it is a relatively large percentage increase, and for others a relatively small percentage increase. For example, this 0.28 increase is approximately a 30.4% increase for Nicaragua, 25% for Guatemala, but only 8% for Argentina and 9% for Brazil and Chile. Using the elasticity estimate of 0.4, each 1% increase in PAT increases private R&D per worker by 0.4%.[30] Thus, the first column in Table 14 reports the predicted percentage growth in private R&D per worker in each country. Nicaragua and Guatemala enjoy the greatest increases in private R&D, followed by Costa Rica. The lowest rate of increase is in Argentina, of 3.4%. For Argentina, this represents an increase in private R&D spending of 32 cents per worker per year in real 1990 U.S. dollars (=3.4% of $9.3, see Table 1), or $3.2 million per 10 million workers per year. We also need to put the 0.28 point increase in patent rights in perspective. What does it amount to? It approximately amounts to adding a feature to the laws; for example, getting rid of compulsory licensing, allowing preliminary injunctions, or allowing two subject areas to be patentable (chemicals and food).

The next column of Table 15 shows the effect of this same 0.28 increase in patent rights on TFP. The effects range from a 0.07% to 0.23% increase in total factor productivity. For the LAC region, the sample period TFPs range from $13 for Bolivia to $20.09 for Mexico (all in real 1990 U.S. dollars).

Next, we consider the effect of a half standard deviation change in the B-index (which is equal to 0.061; see Table 5). Here, we only have data for two LAC countries: Brazil and Mexico. Assume that their B-indexes are lower by 0.061 points. This increase in generosity of R&D tax incentives results in a 6.9% increase in private R&D per worker in Brazil and 7% in Mexico. It also leads to a 0.24% increase in both Brazil's and Mexico's TFP.

A half standard deviation increase in public R&D funding per worker (equal to $9.9) has more varying effects. We should qualify that public R&D was not found to explain private R&D significantly in the LAC region (recall Table 7). Thus the predictions here apply if LAC initially scales back some public R&D programs or agencies (through a once-off stock-shift policy). Note that for this experiment we eliminated some countries (Bolivia, El Salvador, Nicaragua, and Uruguay). For these countries, the $9.9 change is a very large percentage of their existing (sample) public R&D funding rate, and thus the results would not be very reliable (given that the model is a linear approximation). The effect on private R&D is greatest for Ecuador (representing a 42.3% growth) and least for Brazil. For Brazil, the $9.9 change represents a negligible 0.4% increase in public R&D funding per worker. The elasticity estimate used here is 0.66 (see column 2, Table 8): a 1% increase in the rate of public R&D funding increases the rate of private R&D funding by 0.66%. The growth in private R&D spending per worker ranges from 0.2% to 27.9%. The effect on TFP is also quite varied, ranging from an increase of 0.1% in Argentina, Brazil, Mexico, and Venezuela to 1.77% in Ecuador. The mechanisms underlying the change in TFP are that public R&D stimulates private R&D; then both public and private R&D stimulate domestic patenting (with

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[30] The 0.4 value is an average of the coefficient estimates of the patent rights index (PAT) from columns 2 and 3 of Table 8.

an elasticity of 0.282 and 0.216 respectively). Domestic patent capital in turn stimulates TFP (with an elasticity of 0.09).

The last two columns of Table 14 show what happens when both an increase in patent strength and an increase in public R&D funding occur jointly. As the model is linear, the joint effect is simply the sum of the individual policy effects. No significant interaction effect was detected in the empirical analysis.

These simulations show that half-standard deviation changes in the underlying R&D regimes have a relatively large impact on private R&D spending and total factor productivity. For instance, in Chile, a half-standard deviation increase in public R&D funding per worker could potentially result in a 1.9% increase in private R&D spending per worker. This translates into 32 cents per worker in real 1990 U.S. dollars (= 1.9% of $16.6, see Table 1) or $1.92 million per 6 million workers per year. Overall, smaller changes occur with patent reform. However, one cannot really compare which of these policies has the greater return since the simulations do not tell us how much it costs to change each policy by half a standard deviation (for example, administrative costs, costs on rival producers and on taxpayers). It might be the case that increasing public R&D funding by $1.92 million per year is economically more costly than rewriting patent laws to add one or two new features. These laws may only require say an executive order. Or it might very well be the case that the change in patent laws requires a new infrastructure (e.g. enforcement mechanisms and training of judges, etc.) while providing fiscal incentives may, for some countries, be administratively straightforward to implement. The implementation costs of policies should be the subject of future analysis.

5.2 Policy Evaluation

Though R&D activity has intensified recently in parts of LAC, the region as a whole still lags the OECD and parts of Asia. Yet the LAC region has several other challenges to cope with; for example, balance of payments crises, government budgetary deficits, inflation, tax reform in general, financial markets reform, capital controls, credit rationing, vestiges of an import-substitution (or inward-oriented) trade regime, and political instability. These problems may overshadow the concern that LAC's knowledge-based economy lags behind that of the OECD – though these problems are not unconnected, since a strong technologically performing economy is likely to be better at weathering economic crises. However, R&D policies and R&D investments require a long term focus, which may be difficult to maintain amid short run macroeconomic fluctuations. Another "connected" matter is that the efficiency of R&D policies and investments will depend on a supportive environment for innovation. Where markets are underdeveloped, tightly regulated, and institutions deficient and unstable, there is limited potential for the effects of policies like fiscal incentives and R&D grants to be realized if at all. The disincentive to invest due to a poor market environment will likely outweigh that of even a well-designed policy that worked elsewhere in the world (without such underlying problems). Thus, reform of an innovation sector – to correct for market failures in R&D – should be part and parcel of a larger effort to improve the efficiency of markets. Well-defined property rights will go some ways towards enabling firms to collateralize their wealth and enhance their ability to raise funds.

To develop its knowledge-based economy, LAC will need to continue to improve its innovation system and the environment in which innovation takes place. Certain policies proved useful in other parts of the world. How appropriate are they for LAC? No doubt interregional differences in technological needs and capabilities exist. What impact do these differences have on the suitability of the various policies for stimulating R&D? There are no clear cut answers to this. In some cases, certain policies may be optimal regardless of historical or spatial factors. In other cases, there may be no need for LAC to replicate the exact system prevailing elsewhere (i.e. the "harmonization" issue). The above discussion alluded to the fact that fiscal policies (such as an R&D tax credit, R&D grant, or subsidy) work best in an environment where institutions are stable, credible, and supportive. Thus we start with the institution of intellectual property rights, and the case for strengthening them in LAC.

(A) Imitation vs. Innovation

Several arguments have been voiced in favor of a cautious approach to strengthening IPRs in LAC. Cornea (2000, p.5) expresses the views of many when he argues that: "[The Trade-Related Intellectual Property Rights (TRIPS)] Agreement . . . ignores the profound differences in economic and technological capabilities between the North and the South . . . ." The traditional labels attached to the LAC region are that it is a net technology importer, an assembler, an adaptor, or imitator of Northern technologies. To this date, the vast majority of intellectual properties in LAC are owned by non-residents. Consequently, in short, it is argued that stronger IPRs would make the LAC region worse off.[31] Technological inputs would be more expensive for producers, goods more expensive for consumers, royalties to foreigners increased, and LAC's international terms of trade decreased.[32] Technological catch up by LAC economies may be hampered due to its inability to acquire technologies cheaply (by imitation). It is also argued that one reason LAC countries agreed to join international treaties on intellectual property (such as TRIPS) was pressure – namely to avoid trade sanctions – not because they saw inherent economic benefits from IPRs.

There are two criticisms of the views above. The first has to do with endogeneity. LAC's R&D capabilities may be lower and LAC may be characterized as "imitative" precisely because policies and institutions were not in place to support innovation or to give appropriate incentives for agents to "switch" from the "imitative" sector to the "innovative" sector. Also, by minimizing or restricting the outflow of royalty payments, future inward FDI flows are discouraged. The second

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[31] Not to mention welfare losses to the world since goods cannot be produced (or imitated) in the *lower-wage* LAC region.

[32] As Buscaglia (2000) points out, "in most Latin American countries, the same government agency that registers patents also regulates direct foreign investment and technology transfer." This means that governments seeking to minimize the flow of royalty payments abroad have an interest in keeping intellectual property rights weak.

criticism is that an economy based on imitation and infringement for technological catch-up is likely to be pursuing that goal inefficiently. As the results of this study show, weak IPRs distort R&D decisions. They ultimately discourage technology inflows (foreign direct investment, foreign patenting) and domestic innovation (local R&D and patenting).

Some practical issues should also be considered. If individuals or firms, say, in a developing nation have the capacity to infringe, they typically have the capacity to innovate. While duplicating cassette tapes or video tapes is a simple task, certain other activities like reverse engineering a patented technology requires some technical sophistication. Thus nations (such as Brazil, India, or China) that succeed in producing and distributing patent-infringing goods usually reveal a capacity to innovate but also reveal an environment where the relative economic rewards of infringement are greater than that from innovation (say because the punishment is too weak and/or the protection afforded innovative works too low). In other words, the net social gain from innovation may be positive, but the private incentives to infringe are greater than those to innovate. Another practical factor is that the patent-infringing sectors are not always competitive, but oligopolistic. Several studies find that weaker patent protection does not necessarily result in lower prices.[33]

Here it is instructive to look at the experiences of other countries. Korea had the reputation of being a major IPR-violating nation. After strengthening its IPR system in the late 1980s, Korea turned into one of the top world patenting nations and one of the leading nations in semiconductor research and production. On the other hand, India is the world's fourth leading supplier of bulk pharmaceutical products but provides weak patent protection for pharmaceutical innovations.[34] This has led to a number of repercussions. First, India conducts very little basic R&D in pharmaceuticals. Secondly, India lost a number of scientists and engineers to foreign countries (*brain drain)*. Ironically, the first person to patent a genetic innovation is an Indian national, Ananda Chakrabarty, who filed his patent in the U.S. Thirdly, weak pharmaceutical patent laws discourage research on treatments for the health of the local population and environment. Likewise, the argument goes, there is much potential for LAC economies to become more innovative, to give incentives for agents to invest in their human capital and technical skills, to retain its skilled workforce, and to encourage them and others to conduct research that is relevant to LAC's needs. Due to its rich natural resources, some see LAC's comparative R&D advantage in biotechnology, agriculture, and pharmaceuticals. As the Levin et. al (1987) study pointed out, these are the kinds of sectors that are dependent upon patent protection. Thus, a strengthening of IPRs in LAC may help contribute to the development of these sectors in LAC.

(B) Policy Harmonization

Does strengthening IPRs, however, require LAC to proceed all the way to full harmonization of laws with the rest of the world (or among LAC countries only, as in a free trade area)? In general,

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[33] See Sherwood (2000).

[34] This is adapted from material on the *Pharmaceutical Manufacturer's Association* web site.

full harmonization is not necessary for world economic efficiency, and may even be counterproductive.[35] This is one area where LAC countries should preserve some degree of flexibility in designing laws and rules that best fit their social and economic objectives (subject to encouraging the desired level of innovative activity).

But first, what are the benefits of harmonization? Differences in laws and regulations across countries impose transactions costs on firms engaging in trade or technology transfers. It would be much simpler to conduct international business if agents were to deal with one basic legal code rather than several from different countries (sometimes conflicting). An argument against harmonization is uncertainty: along which aspects of patent laws should nations harmonize? There are controversies in the literature over which of the various aspects of patent laws are best for economic welfare or efficiency. For example, is a broad or narrow scope of protection the more conducive to technological change? It is possible, therefore, for the international community to converge on inferior standards.

While harmonized patent systems are not *a priori* optimal for each and every nation, a globally harmonized patent system might, in a world of increased trade and technological interdependence, produce trade and transactions benefits which may offset any efficiency losses nations incur by deviating from what is optimal for their own specific national innovation needs. There is some similarity with the European Monetary Systems adoption of a single currency. While this is a subject beyond the scope of this paper, the parallel is instructive. For instance, there is no a priori reason member nations should have the same currency.[36] The argument in favor of it is that a single currency would reduce transactions costs (for example, exchange rate conversion costs) and facilitate trade. The same type of arguments may apply to the international harmonization of IPRs. Thus, to the extent that harmonization's strength lies in reducing international transactions costs, harmonization efforts should be kept modest. This means that the ideal approach to harmonization is to select minimal features of IPR laws on which to incorporate uniformly into national laws. These rules should directly focus on removing barriers to trade, reducing transactions costs, and increasing transparency in decision-making. Secondly, harmonization efforts could focus on developing a *shared infrastructure*, such as a single international authority to process and examine international IPR applications. This prevents the duplication of searches and examinations by different jurisdictions.

(C) Public R&D Funding

We next evaluate the role of public R&D funding. The empirical results indicated that public R&D in the aggregate stimulates private R&D (even after taking endogeneity into account).

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[35] See Grossman and Lai (2001).

[36] If anything, given the relative lack of labor mobility in the EMS, each member nation should have its own currency. The currency fluctuations would substitute for labor mobility in insulating each member from outside economic shocks.

However, at the regional level, public R&D was found not to explain private R&D in LAC. Indeed, case histories reveal that public R&D policies and programs in the LAC region have not been very successful at developing the innovation base in Latin America. As Agapitova et. al. (2001) describe in the case of Colombia, the national innovation system operates incoherently, the scientific base is poor, and there is limited information sharing between the private sector and the publicly funded research sector. Mani (2001) describes in the case of Brazil that despite past efforts, the stock of scientific and technological human capital is low (as measured by the density of scientists and engineers).

As Melo (2001) describes, the LAC region has a history of heavy government involvement in R&D, through the creation of government science and technology agencies and public R&D labs. Nearly 80% of R&D has been funded by the public sector and performed at the laboratories of state-owned enterprises (SOEs). Thus how does one reconcile the apparent lack of success of public R&D in LAC with the positive experiences of other regions? There are two possibilities. The first is that a *joint hypothesis* might be involved - that the experience in LAC is not a test of the efficacy of public R&D but the efficacy of public R&D in an environment of heavy regulation, infant industry protection, and inward trade-orientation. It is quite probable that the experience is actually a test of the import substitution model. Brazil, for instance, tried its hand at protecting and developing its domestic personal computer industry through the *Informatics Law* (1980s), but the lack of foreign competition might have adversely affected computer innovation rather than public R&D support crowding out or failing to stimulate private R&D. In an environment of protected markets, public R&D funding may be used to further the market power of incumbent firms. Thus, it is important to separate the effects of public R&D from the effects of the domestic policy regime.

Another possible explanation for why public R&D would not succeed is that it failed the test of *cost-benefit analysis*. That is, public funding is productive up to a point, beyond which the marginal social gains fall short of the marginal social costs. Currently the size of the public research sector in LAC may be too "large" from a social welfare point. In many LAC economies, the government share of R&D is high (around 70-90% for many countries). Thus too much resources might have been allocated to the public research sector, and not enough to the private sector (or to academia). This may be why a matching grant system might be useful in that government funding is provided only if the private sector puts up funds of its own. This helps avoid a situation where there is too much (or too little) government R&D or private R&D.

The fact that LAC has a history of heavy government involvement in R&D suggests at least that the infrastructure for public support is there. It would be useful to channel the experience and capacities to forging greater links with industry and academia. University-industry-government collaboration has had some successes in the U.S. and in the U.K. One metaphor for these links is *science parks* - although in practice these "science parks" are also a physical attribute in that firms do locate near national laboratories and universities. As the U.S. experience with Bayh-Dole Act seems mixed, it would be useful to experiment with technology transfer agreements, limited intellectual property rights (including the rights to license non-exclusively), and then to strengthen and expand those rights according to how the experiment progresses. Melo (2001, p. 42) points out that in LAC the quality of universities varies, and questions whether they have much to offer local industry. The universities are not seen as technological partners. This is perhaps the current status; however, again there is an endogeneity issue. With the right incentives and with focused policies on commercialization, the universities could respond to market signals and potentially become more valuable commercial partners later on.

(D) Fiscal Incentives

We turn now to the policy of introducing fiscal incentives to stimulate R&D, and whether they would be suitable for LAC. Here, more questions are raised than can be answered.

Thus far in the debate, much concern has been expressed about the degree of stimulus that fiscal incentives have. If the stimulus is small, this would mean that governments lose (or forgo) more tax revenues than the amount of R&D that is stimulated by the fiscal incentives. There is also concern that the amount of R&D stimulated may be over-estimated since some of that R&D might have been undertaken without fiscal incentives (i.e. inframarginal R&D). In the context of LAC, revenue considerations and sustainability issues (i.e. whether the government's present value or intertemporal budget constraint can be satisfied) are important given LAC's experiences with budgetary debt and deficits.

First, the share of revenues lost or forgone is likely to be small initially since the R&D sector in LAC is still a small percentage of GDP. Secondly, the above concern ignores any potential multiplier effects of fiscal incentives; that is, the R&D that is stimulated, even if smaller than the tax revenue forgone, increases productivity and output, which in turn contributes to future tax revenues. Thirdly, we pointed out earlier that a comparison of the fiscal revenues forgone to the R&D stimulated is not a good way to evaluate the efficiency of the policy. One needs to compare the R&D that is stimulated to the socially desired level, and determine if the gap between social marginal rates of return and private has been narrowed or eliminated.

Nonetheless, there are two other reasons for concern about the efficacy and suitability of fiscal incentives in the LAC region. First, this study finds that fiscal incentives have a modest effect on private R&D once patent rights and public R&D funding are controlled for. Secondly, the priority for LAC may be tax reform in general, before the introduction of new R&D tax measures. When the prevailing tax system is already quite distorted, the marginal incentive effects of new fiscal measures are likely to be weak or offset by these other factors. This is a theme echoed in Shah (1995). Financial, tax, and credit policy reforms may have to take precedence. Under this view, the LAC region may not be prepared for a system of fiscal incentives, such as are in operation elsewhere in the world.

Furthermore, in LAC where the R&D sector is small, the new R&D investments may come from the ranks of startup firms, whose initial startup costs are high but revenues low. Thus, they are not likely to have sufficient taxable income early on to take advantage of R&D tax incentives, such as an R&D tax credit. Allowing for "carryforwards" will help them use the credits later on but due to the time value of money, the credits will be worth less. Another factor that will diminish the value of those credits will be inflation, which is another consideration in light of the use of seignorage revenues in the past in the LAC region to finance the public sector.

Despite what advocates have argued about tax incentives being administratively less complex than direct public funding, there are some executive and administrative decisions to make about the definition of R&D, whether to define it stringently (so as to incorporate R&D that is of high-technology caliber) or loosely (to include minor inventive research). Will multinationals be eligible for R&D tax credits? Should the credit be based on the volume of R&D or on the incremental part (vis-à-vis some previous level)?

Defining R&D will be quite important in light of the practice of re-labeling expenditures as R&D in the OECD countries. Thus, an opportunity for tax reductions (or evasion) might arise by labeling ordinary investment (or consumption) expenditures as R&D. In the U.S., many start up firms may have had excessive incentives to compensate employees with stock options, since they are tax deductible, and thus firms have been able to avoid taxes. To deal with this, the U.S. has resorted to an alternative minimum tax (to ensure that these companies pay some tax). Thus the potential for excessive use of tax credits (along with relabelling) should be considered.

In the end, fiscal incentives may work best if they could address the kinds of research that public R&D and IPRs cannot. We mentioned that public R&D's comparative advantage might be basic, generic R&D. Here direct funding, subsidies, and cost sharing (matching grants) could be adopted for purposes of stimulating that kind of R&D. Patent protection's comparative advantage may be in stimulating applied, innovative research. There may be a grey area where R&D is not basic enough for research labs and academic centers to be working on but not near enough to the commercial phase for firms to have an interest in pursuing. But if governments do specify the kinds of research that qualify for a tax credit, there might again be instances of relabelling or re-definition of firms' R&D activities.

6. Conclusions

The focus of this study has been on the mechanisms by which research and development activities in the Latin America and Caribbean (LAC) region may be enhanced. Investments in R&D are an important part of building the knowledge base of an economy. This study has concentrated on three primary mechanisms for stimulating R&D: (1) Intellectual Property Rights; (2) Fiscal Incentives; and (3) Public R&D Funding (for example, subsidies and grants). Partly due to lack of data for the LAC region alone and partly due to the wish to incorporate information and experiences widely, we examined the effects of these three mechanisms using cross-country data over time; we also surveyed case studies and literature on specific countries (primarily the U.S., Israel, the U.K., Canada, and Sweden). The idea has been to draw lessons for LAC from these cross-country and non-LAC country analyses, though of course direct applications to LAC will be imperfect given economic, social, and other heterogeneities between countries.

In this concluding section, we shall highlight the main points. First, relative to other regions, LAC has not conducted much national R&D (whether as a percentage of GDP, labor supply, or in absolute terms). What little it has conducted, most of it was financed by the government. In recent years, a number of LAC countries have increased their national R&D (with a larger share performed and financed by the private sector), but the overall level still lags that of the OECD countries.

The study finds that private R&D is an important function of an economy's level of intellectual property rights, but we find that patent protection is the most important. Copyrights and trademark rights positively explain R&D, but not when patent rights are controlled for, indicating that these variables likely picked up the effects of the omitted variable (patent rights). Public R&D funding is also an important determinant of private R&D, but it should be pointed out that there should be a "balance" or appropriate mix of public and private R&D. Too much public R&D relative to private could signal a misallocation of resources. It should also be pointed out that the positive contribution of public R&D is picked up at the macroeconomic level. Some microeconomic analyses of government grant programs find some degree of crowding out of private research by government research; they also find that some government programs fund inframarginal private R&D (i.e. projects that were profitable to the private sector and which the private sector would have undertaken without public support). We also found fiscal incentives to be an important determinant of private R&D, but to have modest effects once patent rights and public R&D funding are controlled for. A few concerns about the use of fiscal incentives to stimulate R&D have been that firms might reclassify certain expenditures as R&D just to take advantage of tax breaks, that firms may not have any taxable income to benefit from R&D tax credits effectively (and that carryforward provisions may help but not to the extent desired), and that with incrementally-based tax credit systems the marginal effective credit rate may be negative (discouraging R&D investment). In the context of LAC, we also pointed out that possibly a greater priority than fiscal incentives for R&D may be tax reform in general, for fiscal incentives for R&D will likely work less effectively when there are many pre-existing distortions. Also, fiscal budgetary concerns in LAC region are legitimate. The fiscal incentives offered to firms will require authorities to forgo tax revenues, which in other regions may not pose a budgetary problem, but in LAC it may. If fiscal incentives have a powerful "multiplier effect", this budgetary issue would not be significant, but the empirical results do not predict a powerful effect of fiscal incentives on private on R&D (and ultimately on output growth and future tax revenue growth).

In addition to studying the above mechanisms for stimulating R&D, we also found that human capital variables, such as the supply of scientists and engineers and tertiary education enrollment rates, strongly and positively explain private R&D. Human capital plays an important role in increasing the productivity of research and in helping to lower the cost of R&D. The human capital variables are also important determinants of domestic and foreign patenting, and direct foreign investment. That is, they encourage domestic innovation (and hence domestic patenting) and encourage foreigners to bring their technologies to the local market. Overall, we find that patent protection, public funding, and human capital are important to private R&D, and ultimately to total factor productivity. The causal mechanisms are as follows: patent rights, public funding, and human capital stimulate private R&D. Private R&D and public R&D in turn stimulate domestic and foreign patenting, which in turn contribute to the stocks of domestic and foreign-generated knowledge capital, which in turn are important determinants of total factor productivity.

The study does, however, qualify that reforming IPRs to stimulate R&D and economic development need not require harmonization of laws with other regions. The purpose of harmonization should be more trade-related – to reduce transactions costs. It should be realized that harmonization is likely to be inefficient, and that countries would be making tradeoffs (to better facilitate international trade). The study has also stressed the importance of endogeneity or feedback effects. Critics of IPR reform argue that reform measures ignore the fundamental differences in technological capabilities between the North and the South and suggest that the benefits of IPR reform are one-sided – favoring the North. What this study has stressed is that those very technological capabilities are a function of R&D policies, incentives, and institutions, and must not be treated as exogenous.

Thus in terms of overall policy recommendations for LAC, the analyses in this study support strengthening local patent regimes (but not necessarily harmonizing them vis-à-vis the rest of the world) and investing in scientific and technological education and supply. The analyses support a more balanced allocation of resources between public and private R&D, at least compared to the current disproportionate mix in LAC. R&D subsidies or matching grants should help alleviate the imbalance. The analyses were somewhat more ambivalent about the use of fiscal incentives for R&D investment. The theory and empirical evidence were not strongly supportive (at least in this panel data study). The potential for fiscal incentives to stimulate R&D is more likely to be realized after general tax reforms are carried out.

We end by suggesting two extensions to this study:

1) Should policymakers focus more on the Research or Development part of R&D? This can only be answered theoretically since the aggregate data used do not allow us to distinguish between them. Future micro-level studies should be better able to disentangle the roles of each. Theoretically, the research part generates much more knowledge spillovers, but the development part is closer to the market phase of innovation. At another level, the distinction may not be very fruitful. For technological progress, it is difficult to have one without the other. The development phase is dependent on the stock of basic research; but basic research (if it is to generate valuable spillovers) must be forward-looking and avoid traveling on dead-end paths; that is, paths on which research does not yield results useful for either applied work or future basic research.

2) Attention should also be on improving the practical aspects of policy. To this date, certain firms have more experience, skill, knowledge, or connections to avail themselves of intellectual property protection, government R&D grants, or tax incentives. As a case in point, a survey of British firms finds that a vast majority of firms did not know how to manage their patent portfolio. 70% of them invested in R&D only to find that someone else had patented the technology.[37] A more

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[37] See Chapter 4 in Stewart (1999).

comprehensive search of databases would have helped avoid conducting duplicative R&D. Firms in developing countries, and typically small firms in industrialized countries, are not as skillful at playing the patent game or the R&D grant game. The policy authorities need to improve awareness of the opportunities for grants, tax breaks, and of the means to seek IPRs. Certainly, rational, profit-seeking firms should find it in their best interest to be informed. However, the information failure may be on the part of the authorities to provide it. Thus further analysis of how to improve public knowledge of R&D policies may prove useful.

7. References:

Agapitova, Natalia, Holm-Nielsen, and Vukmirovic, Goga (2001), "Science and Technology in Colombia: Status and Perspectives, World Bank manuscript.

Baily, Martin and Lawrence, Robert (1992), "Tax Incentives for R&D: What do the Data Tell Us?" *Council on Research and Technology*, Washington, D.C.

Baxter, J. W., Cent., J. P., Sinnott, J. M., and Cadre, W. J. (e's.), (2000) *World Patent Law and Practice*, Matthew-Bender, N.Y.

Bessen, James and Maskin, Eric (2000), "Sequential Innovation, Patents, and Imitation," MIT Department of Economics Working Paper No. 00-01.

Bloom, Nick, Griffith, Rachel, and Van Reenan, John (2000), "Do R&D Tax Credits Work? Evidence from a Panel of Countries 1979-97," *Journal of Public Economics* forthcoming.

Buscaglia, Eduardo (2000), "Can Intellectual Property in Latin America be Protected?" in Clarisa Long (ed.) *Intellectual Property Rights in Emerging Markets*, Washington, D.C. American Enterprise Institute.

Campbell, Dennis and Cotter, Susan (ed.) (1997) *Copyright Infringement*, Boston: Kluwer Law International.

Cordes, Joseph (1989), "Tax Incentives and R&D Spending: A Review of the Evidence," *Research Policy*, Vol. 18, pp. 119-133.

Correa, Carlos M. (2000), *Intellectual Property Rights, the WTO and Developing Countries: The TRIPS Agreement and Policy Options*, London, ZED Books Ltd.

David, Paul, Hall, Bronwyn, and Toole, Andrew (2000), "Is Public R&D a Complement or Substitute for Private R&D? A Review of the Econometric Evidence," *Research Policy*, Vol. 29, pp. 497-529.

Diwan, Isaac and Rodrik, Dan. (1991), "Patents, Appropriate Technology, and North-South Trade," *Journal of International Economics*, Vol. 30, pp.27-47.

Eisner, Robert, Albert, Steven, and Sullivan, Martin (1984), "The New Incremental Tax Credit for R&D," *National Tax Journal*, June, Vol. 37, pp. 171-83.

Feldman, Maryann and Kelley, Maryellen (2001), "Winning an Award from the Advanced Technology Program: Pursuing R&D Strategies in the Public Interest and Benefitting from a Halo Effect," *Advanced Technology Program, National Institute for Standards and Technology, Economic*

Assessment Office. (Http://www.atp.nist.gov/eao/absracts-eao.htm).

Geller, Paul E. (ed.), (2000) *International Copyright Law and Practice*, Matthew-Bender, NY.

Gilbert, Richard and Shapiro, Carl (1990), "Optimal Patent Length and Breadth," *Rand Journal of Economics*, Vol. 21, No. 1, Spring, pp. 106-112.

Ginarte, Juan Carlos and Park, Walter G. (1997) "Determinants of Patent Rights: A Cross-National Study," *Research Policy*, Vol. 26, pp. 283-301.

Grossman, Gene and Helpman, Elhanen (1991), *Innovation and Growth in the Global Economy*, MIT Press, Cambridge.

Grossman, Gene and Lai, Edwin (2001), "International Protection of Intellectual Property," unpublished manuscript.

Hall, Bronwyn (1993), "R&D Tax Policy During the Eighties: Success or Failure?" *Tax Policy and the Economy*, Vol. 7, pp. 1-36.

Hall, Bronwyn and Van Reenan, John (2000), "How Effective are Fiscal Incentives for R&D? A Review of the Evidence," *Research Policy*, Vol. 29, pp. 449-469.

Helpman, Elhanen (1993), "Innovation, Imitation, and Intellectual Property Rights," *Econometrica*, Vol. 61, No. 6, pp. 1247-1280.

Henderson, Rebecca, Jaffe, Adam, and Trajtenberg, Manual (1998), "Universities as a Source of Commercial Technology: A Detailed Analysis of University Patenting 1965-1988," Review of Economics and Statistics, Vol. 80, No. 1, pp. 119-127.

Horowitz, Ethan (2000) (ed.) *World Trademark Law & Practice*, Vols. A, B., Matthew Bender Publications, NY.

Jaffe, Adam and Lerner, Joshua (2001), "Reinventing Public R&D: Patent Policy and the Commercialization of National Laboratory Technologies," *Rand Journal of Economics*, Vol. 32, No. 1, pp. 167-198.

Klemperer, Paul (1990), "How Broad Should the Scope of Patent Protection Be?" *Rand Journal of Economics*, Vol. 21, No. 1, Spring, pp. 113-130.

Korenko, George, G. (1999) "Intellectual Property Protection and Industrial Growth," *Journal of World Intellectual Property*, Vol. 2, No. 1, pp. 47-75.

Laidlaw, Frances (1997), "Acceleration of Technology Development by the Advanced Technology

Program: The Experience of 28 Projects Funded in 1991," *Advanced Technology Program, National Institute for Standards and Technology, Economic Assessment Office.* (Http://www.atp.nist.gov/eao/absracts-eao.htm).

Landes, W. and Posner, R. (1987), "Trademark Law: An Economic Perspective," *Journal of Law and Economics*, Vol. 30, pp. 265-309.

Landes, W. and Posner, R. (1989), "An Economic Analysis of Copyright Law," *Journal of Legal Studies*, Vol. 30, pp. 265-309.

Lederman, Daniel and Xu, L. Colin (2001), "Comparative Advantage and Trade Intensity: Are Traditional Endowments Destiny?" World Bank Discussion Paper, August 2001.

Levin, R., Klevorick, A., Nelson, R., and Winter, S. (1987) "Appropriating the Returns from Industrial R&D," *Brookings Papers on Economic Activity*, Vol 3., pp. 783-820.

Leyden, Dennis and Link, Albert (1992), *Government's Role in Innovation*, Kluwer Academic Publishers, Boston, MA.

Link, Albert (1996) (ed.), *Evaluating Public Sector Research and Development*, Praeger Publishing, Westport, CT.

Mani, Sunil (2001), "Government, Innovation and Technology Policy: An Analysis of the Brazilian Experience during the 1990s," United Nations University INTECH, Discussion Paper No. 11.

Mansfield, Edwin (1986), "The R&D Tax Credit and Other Technology Policy Issues," *American Economic Review*, Vol. 76, No. 2, pp. 190-194.

Mansfield, Edwin (1994), *Intellectual Property Protection, Foreign Direct Investment, and Technology Transfer*, International Finance Corporation Discussion Paper No. 19. Washington, D.C.: World Bank.

Mansfield, Edwin (1985), "Public Policy Toward Industrial Innovation: An International Study of Direct Tax Incentives for Research and Development," in Kim B. Clark, Robert Hayes, and Christopher Lorenz (eds.), *The Uneasy Alliance: Managing the Productivity and Technology Dilemma*, Harvard Business School Press, Boston, MA.

Maskus, Keith E. (2000) *Intellectual Property Rights in the Global Economy*, Washington, D.C.: Institute of International Economics.

McFetridge, Donald and Warda, Jacek (1983), *Canadian R&D Incentives: Their Adequacy and Impact*, Canadian Tax Paper No. 70, Canadian Tax Foundation, Toronto.

Melo, Alberto (2001), “The Innovation Systems of Latin America and the Caribbean,” *Inter-American Development Bank*, Working Paper No. 460.

Merges, Robert P. and Nelson, Richard R. (1994), "On Limiting or Encouraging Rivalry in Technical Progress: The Effect of Patent Scope Decisions," *Journal of Economic Behavior and Organization*, Vol. 25, pp. 1-24.

Mowery, David, Nelson, Richard, Sampat, Bhaven, and Ziedonis, Arvids (1998), “The Growth of Patenting and Licensing by U.S. Universities: An Assessment of the Effects of the Bayh-Dole Act of 1980,” University of California, Haas Business School, Working Paper.

National Science Foundation (2000), *Latin America: R&D Spending Jumps in Brazil, Mexico, and Costa Rica*, NSF 00-316, Division of Science Resources Studies, NSF Arlington, VA. (Author, Derek Hill).

Park, Walter G. (2000), “International Patenting, Patent Rights, and Technology Gaps,” Department of Economics, American University Working Paper.

Park, Walter G. (2001), “Do Intellectual Property Rights Stimulate R&D and Productivity Growth? Evidence from Cross-National and Manufacturing Industry Data,” forthcoming *Industry Canada* Conference Volume on *Intellectual Property and Innovation in the Knowledge-Based Economy*.

Park, W. and Ginarte, J. (1997), “Intellectual Property Rights and Economic Growth,” *Contemporary Economic Policy*, Vol. 15, pp. 51-61.

Romer, Paul (1990), “Endogenous Technological Change,” *Journal of Political Economy*, Vol. 98, No. 5, pp. S71-S102.

Scotchmer, Suzanne and Green, Jerry (1990), “Novelty and Disclosure in Patent Law,” *Rand Journal of Economics*, Vol. 21, No. 1, Spring, pp. 131-146.

Shah, Anwar (1995) (ed.) *Fiscal Incentives for Investment and Innovation*, Oxford University Press.

Sherwood, Robert (1990), *Intellectual Property and Economic Development*, Westview Press, Boulder, CO.

Sherwood, Robert M. (1997), "Intellectual Property Systems and Investment Stimulation: The Ratings of Systems in Eighteen Developing Countries," <u>IDEA: Journal of Law and Technology</u>, Vol. 37, No. 2, pp. 261-370.

Sherwood, Robert M. (2000), “The TRIPS Agreement: Benefits and Costs for Developing Countries,” *International Journal of Technology Management*, Vol. 19, No. 112, pp. 57-76.

Silber, Bonnie (1996), "Survey of Advanced Technology Program 1990-1992 Awardees: Company Opinion About the ATP and its Early Effects," *Advanced Technology Program, National Institute for Standards and Technology, Economic Assessment Office.* (www.atp.nist.gov/eao/abstracts.)

Summers, Robert, Heston, Alan, Nuxoll, Daniel, and Aten, Bettina (1996), *Penn World Tables, Mark 5.6a*, National Bureau of Economic Research, Cambridge, MA.

Takalo, Tuomas and Kanniainen, Vesa (2000), "Do Patents Slow Down Technological Progress? Real Options in Research, Patenting, and Market Introduction," *International Journal of Industrial Organization*, Vol. 18, pp. 1105-1127.

Trajtenberg, Manuel (2001), "Government Support for Commercial R&D: Lessons from the Israeli Experience," Tel Aviv University, Department of Economics, Working Paper.

Wallsten, S. J. (2000), "The Effects of Government-Industry R&D Programs on Private R&D: The Case of the Small Business Innovation Research Program," *Rand Journal of Economics*, Vol. 31, No. 1, pp. 82-100.

Warda, Jacek (1996), "Measuring the Value of R&D Tax Provisions," in *Fiscal Measures to Promote R&D and Innovation*, OECD/GD(96)165, Organization for Economic Cooperation and Development, Paris.

Table 1 cont'd	R&D as % of GDP	% R&D financed by Gov't	Privately % R&D R&D per Worker	Publicly % R&D R&D per Worker	Sci& Engin. per 10000 Workers	School Enroll. Tertiary %Gross	Patent Rights Index	Copy-Rights Index	Trade-Mark Index
Mean	0.28	76.7	6.3	25.1	8.36	17.0	2.00	2.84	2.55
Std Dev.	0.14	13.7	6.0	19.8	4.93	7.5	0.56	0.26	0.30
Min	0.09	52.2	0.0	5.5	0.58	1.0	0.92	2.37	2.17
Max	0.56	100.0	19.9	73.1	17.88	28.8	3.19	3.17	3.00
Region 3:									
Hong Kong	0.30				1.53	10.3	2.31		
Japan	2.59	22.0	481.8	94.1	83.04	29.3	3.94	3.85	3.25
Korea	1.70	24.8	299.2	84.5	33.20	34.8	3.76	3.80	3.25
Malaysia	0.24	53.1			2.34	7.2	2.67		
Philipp.	0.16	63.6	2.7	4.8	2.85	26.6	2.67	2.68	2.50
Singapore	0.69	39.0	106.7	61.2	38.30	18.4	2.90	2.35	2.92
Thailand	0.30	73.4	4.6	13.0	2.19	17.9	1.94	2.60	3.17
Mean	0.85	46.0	179.0	51.5	15.22	17.8	2.88	3.06	3.02
Std Dev.	0.86	19.1	185.9	36.5	20.56	9.1	0.67	0.64	0.29
Min	0.16	22.0	2.7	4.8	0.58	1.0	1.94	2.35	2.50
Max	2.59	73.4	481.8	94.1	83.04	34.8	3.94	3.85	3.25
Region 4:									
Egypt	0.28	90.0	1.7	15.2	17.67	17.6	1.99	2.50	3.17
India	0.69	86.2	2.8	17.5	3.43	6.0	1.56	2.83	1.37
Israel	2.07	50.6	270.2	241.0	120.99	34.2	3.57	3.12	3.78
Kenya	0.79	81.7	2.9	12.9	0.77	1.2	2.65	3.05	2.95
Malawi	0.01				0.73	0.6	3.19		
Mauritius	0.53	36.3	29.8	16.8	4.83	2.9	2.89	2.40	1.62
Pakistan	0.35	100.0	0.0	14.7	2.04	2.7	1.99	2.43	1.78
S. Africa	1.17	35.0	72.1	38.1	9.40	16.0	3.57	2.70	3.42
Sri Lanka	0.18	81.3	1.8	7.8	4.15	4.0	3.04	2.73	2.83
Tunisia	0.02				10.70	8.0	1.90		
Turkey	0.60	68.2	15.4	32.7	4.95	11.7	1.80	2.42	2.75
Zambia	0.01	61.0	0.1	0.1	1.35	1.9	3.52		
Mean	0.56	69.0	39.7	39.7	18.09	12.2	2.64	2.69	2.63
Std Dev.	0.57	21.5	79.7	67.9	30.82	10.6	0.73	0.26	0.80
Min	0.01	35.0	0.0	0.1	0.58	0.6	1.56	2.40	1.37
Max	2.07	100.0	270.2	241.0	120.99	34.8	3.57	3.12	3.78
All Regions:									
Mean	0.98	59.1	146.9	91.7	24.31	23.1	2.77	3.41	3.39
Std Dev.	0.92	21.7	194.2	101.3	25.26	15.5	0.94	0.75	0.93
Min	0.01	22	0	0.1	0.58	0.6	0.92	2.35	1.37
Max	2.90	100	653	482.2	120.99	77.3	4.52	5.00	5.00

Notes:
Data are averages from 1980-1995. R&D Spending figures are in real 1990 U.S. dollars.

Table 2. Sample Correlations

All Regions:	Pat	Copy	TMark	RD/GDP	Govt%	RDp/L	RDg/L	Educ	S&E
Pat	1								
Copy	0.720	1							
TMark	0.723	0.863	1						
RD/GDP	0.765	0.670	0.676	1					
Govt%	-0.732	-0.553	-0.561	-0.685	1				
RDp/L	0.741	0.658	0.662	0.937	-0.725	1			
RDg/L	0.669	0.633	0.633	0.796	-0.453	0.767	1		
Educ	0.571	0.570	0.558	0.559	-0.498	0.586	0.642	1	
S&E	0.667	0.457	0.542	0.786	-0.561	0.744	0.736	0.618	1

Region 1:	Pat	Copy	TMark	RD/GDP	Govt%	RDp/L	RDg/L	Educ	S&E
Pat	1								
Copy	0.530	1							
TMark	0.528	0.817	1						
RD/GDP	0.654	0.358	0.510	1					
Govt%	-0.394	-0.196	-0.394	-0.592	1				
RDp/L	0.639	0.349	0.487	0.912	-0.722	1			
RDg/L	0.574	0.338	0.292	0.698	-0.221	0.669	1		
Educ	0.332	0.101	0.003	0.247	-0.302	0.308	0.416	1	
S&E	0.577	0.047	0.137	0.762	-0.406	0.726	0.674	0.518	1

Region 2:	Pat	Copy	TMark	RD/GDP	Govt%	RDp/L	RDg/L	Educ	S&E
Pat	1								
Copy	0.216	1							
TMark	0.187	0.801	1						
RD/GDP	0.461	-0.227	-0.354	1					
Govt%	-0.538	-0.600	-0.465	-0.056	1				
RDp/L	0.609	0.222	-0.090	0.584	-0.737	1			
RDg/L	0.068	-0.696	-0.770	0.654	0.480	0.161	1		
Educ	0.114	-0.433	-0.124	0.278	0.400	-0.186	0.359	1	
S&E	0.436	-0.201	0.075	0.245	-0.111	0.097	-0.011	0.443	1

Region 3:	Pat	Copy	TMark	RD/GDP	Govt%	RDp/L	RDg/L	Educ	S&E
Pat	1								
Copy	0.797	1							
TMark	0.432	0.593	1						
RD/GDP	0.863	0.783	0.561	1					
Govt%	-0.878	-0.655	-0.445	-0.856	1				
RDp/L	0.870	0.789	0.557	0.978	-0.846	1			
RDg/L	0.796	0.631	0.606	0.760	-0.783	0.800	1		
Educ	0.732	0.607	0.234	0.664	-0.555	0.601	0.400	1	
S&E	0.824	0.513	0.472	0.866	-0.808	0.877	0.825	0.504	1

Region 4:	Pat	Copy	TMark	RD/GDP	Govt%	RDp/L	RDg/L	Educ	S&E
Pat	1								
Copy	0.424	1							
TMark	0.545	0.415	1						
RD/GDP	0.520	0.661	0.472	1					
Govt%	-0.639	-0.022	-0.146	-0.508	1				

RDp/L	0.563	0.533	0.495	0.880	-0.536	1			
RDg/L	0.537	0.606	0.555	0.900	-0.378	0.862	1		
Educ	0.390	0.420	0.704	0.746	-0.306	0.784	0.842	1	
S&E	0.548	0.612	0.599	0.849	-0.348	0.886	0.969	0.878	1

Notes:
Pat, Copy, and TMark are the indexes of patent rights, copyrights, and trademarks respectively. RD/GD ratio of R&D to GDP, RDp/L private R&D per worker, RDg/L public R&D per worker, Govt% percentage R&D funded by government, Educ tertiary school enrollment (%gross), and S&E number of scientists and engineers per 10,000 workers. Regional groupings are as in Table 1.

Table 3. Alternative Intellectual Property Measures (Sherwood Ratings)

	Region	Patents	Copyrights	Trademarks	Sherwood Overall Score:
		Points Deducted for:			
Australia	1	-3	-4	-3	83
Austria	1	-10	-7	-1	69
Argentina	2	-13	-4	0	39
Brazil	2	-10	-4	-1	49
Chile	2	-5	-2	-1	62
Costa Rica	2	-16	0	-3	54
Ecuador	2	-9	-5	-3	42
El Salv	2	-1	-5	-7	43
Guatemala	2	-14	-10	-7	13
Mexico	2	-1	-7	0	69
Nicaragua	2	-15	-10	-7	17
Panama	2	-7	-3	-8	36
Paraguay	2	-15	-10	-7	22
Peru	2	-9	-3	-1	61
Uruguay	2	-14	-8	-5	48
Korea	3	-6	-3	-1	74
India	4	-11	-5	-4	46
Pakistan	4	-14	-8	-5	49
	Mean	-10	-5	-4	49
	Std Dev.	5	3	3	19
	Min	-16	-10	-8	13
	Max	-1	0	0	83

Correlation between:

		Sherwood's Indexes:			
		Patent	Copyright	Trademark	Overall
	Patent	0.369			0.624
Park's Indexes:	Copyright		-0.075		0.556
	Trademark			0.292	0.632

Table 4. International R&D Tax Credit Regimes

	Current R&D Depreciation Method	Capital R&D Depreciation Method	Carryforward Provision	Tax Credit Rate	Base for Tax Credit
Australia	150%	3 years	3-10 years	None	--
Austria	105%	accelerated	5 years	None	--
Belgium	100%	3 years	5 years	None	--
Brazil	100%	like investment	4 years	None	--
Canada	100%	100%	3-10 years	20%	Volume
Denmark	100%	100%	5 years	None	--
France	100%	3 years	5 years	50%	Incremental
Germany	100%	3 years	1-5 years	None	--
India	100%	100%	?	None	--
Ireland	100%	100%	?	> 100%	?
Italy	100%	accelerated	None	None	--
Japan	100%	accelerated	5 years	20%	Incremental
Korea	100%	20%	?	10-25%	Incremental
Mexico	100%	3 years	?	None	--
Netherlands	100%	like investment	8 years	12.5-25%	Volume
Norway	100%	like investment	10 years	None	--
Portugal	100%	?	?	None	--
Singapore	capitalize	like investment	?	> 100%	?
S. Africa	100%	25%	?	None	--
Spain	capitalize	100%	3-5 years	15-30%	Incremental
Sweden	100%	30%	?	None	--
Switzerland	100%	like investment	2 years	?	?
Taiwan	100%	like investment	4 years	15-20%	Volume
U.K.	100%	100%	5 years	None	--
U.S.A.	100%	3 years	3-15 years	20%	Incremental

Notes: Depreciation Methods of 100% (or more) indicate that R&D is fully expensed. Under R&D capital expenditures, the number of years refer to the duration of the straight-line depreciation method. Under Base for Tax Credit, 'Volume' refers to the fact that the tax credit applies to total R&D, while 'Incremental' refers to the fact that the tax credit applies to the excess of R&D over some base (usually past R&D or moving average of past R&D). '?' refers to unclear information.

Source: Hall and Van Reenan (2001), OECD (1996)

Table 5. Index of Fiscal Incentives - The "B-index"

	Region	1980	1985	1990	1995
Australia	1	1.010		0.805	0.893
Austria	1	0.950			0.932
Belgium	1	0.970			1.011
Canada	1	0.840		0.657	0.714
Denmark	1	1.000			1.000
Finland	1				1.008
France	1	1.020		0.941	0.923
Germany	1	1.050		1.027	1.051
Greece	1				1.009
Ireland	1				1.000
Italy	1	1.030		1.033	1.051
Netherl.	1				0.906
New Zeal.	1				1.131
Norway	1	1.040			1.017
Portugal	1				1.017
Spain	1	0.850			0.658
Sweden	1	0.950		1.040	1.015
Switzerl.	1				1.003
U.K.	1	1.000		1.000	1.000
U.S.A.	1	0.950		0.972	0.893
Brazil	2	1.030			
Mexico	2	0.960			1.015
Hong Kong	3	1.000			
Japan	3	0.980		1.003	1.014
Korea	3	1.010		0.805	0.893
Singapore	3	0.410			
Turkey	4				1.000

B-Index Summary Statistics:	Mean	Std. Dev.	Min	Max
	0.953	0.122	0.410	1.131

B-Index Correlations with:	R&D as % of GDP	% R&D financed by Gov't	Privately Financed R&D per Worker	Publicly Financed R&D per Worker	Patent Rights Index	Copy-Rights Index	Trade-Mark Index
	0.249	0.125	0.181	0.115	0.139	0.278	0.086

Source: Warda (1996)

Table 6. Matching Grant Program: The U.S. Advanced Technology Program (ATP)

Forty-Two Competitions: 1990 - 2001

Number of Proposals Received:	4696
Number of Awards:	581
– *Joint Ventures*	*(31.8%)*
– *Individual Projects*	*(68.2%)*
Industry Commitment (in nominal terms):	$1.8 Billion
ATP Matching Funds (in nominal terms):	$1.8 Billion
Awards per project range:	$441,000 - $31,000,000

Technology Areas:

Information Technology	24%
Electronics & Photonics	23%
Advanced Materials & Chemistry	22%
Biotechnology	19%
Manufacturing	12%

Leading States by Number of Awardees:

California	146
Massachusetts	54
Michigan	43
New York	38
New Jersey	28
Texas	25

Source: ATP web site (www.atp.nist.gov)

Table 7. Private R&D, Public R&D, and Intellectual Property

Dependent Variable: Private R&D Capital per Worker, RD_p/L

PART A	All Regions	Region 1	Region 2	Region 3	Region 4
Constant	-8.996	-11.30	-0.635	-8.361	-5.859
	(1.208)	(2.035)	(2.794)	(4.644)	(2.585)
RD_g/L	0.580***	0.597***	-0.189	0.704*	0.834***
	(0.111)	(0.153)	(0.224)	(0.498)	(0.246)
K/L	0.680***	0.765***	-0.364	0.307	0.401
	(0.116)	(0.217)	(0.285)	(0.448)	(0.279)
PAT	1.773***	2.953***	1.099***	4.857***	1.356*
	(0.255)	(0.456)	(0.341)	(0.905)	(0.791)
Adj. R^2	0.79	0.72	0.18	0.85	0.67
No. of Observ.	168	80	35	20	32

PART B	All Regions	Region 1	Region 2	Region 3	Region 4
Constant	-9.729	-17.03	-7.444	-21.96	-6.937
	(1.349)	(2.491)	(6.206)	(2.464)	(3.564)
RD_g/L	0.734***	0.714***	0.209	-0.199	0.911***
	(0.120)	(0.183)	(0.423)	(0.265)	(0.253)
K/L	0.676***	1.429***	0.587	1.450***	0.559**
	(0.129)	(0.225)	(0.806)	(0.209)	(0.279)
COPY	2.278***	1.848***	-0.675	5.858***	1.127
	(0.499)	(0.692)	(2.803)	(0.501)	(2.072)
Adj. R^2	0.78	0.59	0.05	0.95	0.64
No. of Observ.	156	80	24	20	32

Table 7 cont'd

PART C	All Regions	Region 1	Region 2	Region 3	Region 4
Constant	-8.259	-16.25	-10.04	-31.48	-5.814
	(1.369)	(2.257)	(5.027)	(7.973)	(2.753)
RD_g/L	0.849***	0.704***	0.177	-1.021	0.928***
	(0.125)	(0.171)	(0.313)	(0.759)	(0.251)
K/L	0.715***	1.298***	1.127**	1.922***	0.585**
	(0.139)	(0.218)	(0.572)	(0.536)	(0.308)
TMARK	0.851**	2.225***	-3.426***	9.146***	-0.198
	(0.405)	(0.558)	(1.286)	(3.065)	(0.674)
Adj. R^2	0.75	0.63	0.19	0.74	0.64
No. of Observ.	156	80	24	20	32

PART D	All Regions	Region 1	Region 2	Region 3	Region 4
Constant	-10.63	-10.11	-9.529	-23.64	-6.986
	(1.152)	(2.184)	(4.002)	(3.752)	(3.736)
RD_g/L	0.469***	0.561***	-0.456	-0.304	0.737***
	(0.100)	(0.135)	(0.355)	(0.318)	(0.238)
K/L	0.674***	0.608***	0.863*	1.529***	0.518**
	(0.112)	(0.212)	(0.522)	(0.356)	(0.313)
PAT	2.089***	2.906***	1.427***	-0.162	1.609*
	(0.266)	(0.476)	(0.378)	(1.405)	(0.894)
COPY	1.762***	-2.588***	0.532	5.794**	0.494
	(0.518)	(0.977)	(2.407)	(1.717)	(2.227)
TMARK	-0.751*	2.885***	-4.134***	0.877	-0.726
	(0.401)	(0.793)	(1.172)	(2.152)	(0.725)
Adj. R^2	0.84	0.75	0.56	0.95	0.66
No. of Observ.	156	80	24	20	32

Notes: RD_g/L denotes *public* R&D capital per worker (in real 1990 U.S. dollars), K/L physical capital per worker, and PAT, COPY, TMARK denote the indexes of patent rights, copyrights, and trademark rights respectively. Estimation is by instrumental variables estimation. The instrument for RD_g/L is real national government spending per worker. All variables are in natural logarithms, and standard errors are in parentheses. ***, **, and * denote significance levels of 1%, 5%, and 15% respectively.

Table 8. R&D, Intellectual Property, and Individual (Country) Effects

Dependent Variable: Private R&D Capital per Worker, RD_p/L

	R.E. (1)	F.E. (2)	LAC F.E. (3)	Non-LAC F.E. (4)	OECD F.E. (5)	Non-OECD F.E. (6)
Constant	-7.271	-7.374	-6.982	-6.728	-8.668	-4.463
	(1.259)	(1.475)	(5.778)	(1.417)	(1.662)	(2.68)
RD_g/L	0.779***	0.641***	0.237	0.690***	0.537***	0.76***
	(0.089)	(0.101)	(0.354)	(0.099)	(0.152)	(0.147)
K/L	0.614***	0.660***	0.453	0.605***	0.823***	0.323
	(0.117)	(0.149)	(0.604)	(0.153)	(0.189)	(0.275)
PAT	0.702***	0.390***	0.410*	0.470*	0.352	0.385**
	(0.190)	(0.161)	(0.224)	(0.348)	(0.481)	(0.187)
COPY	0.267					
	(0.757)					
TMARK	-0.124					
	(0.572)					
Adj. R^2	0.89	0.57	0.19	0.66	0.61	0.56
No. of Obs.	156	168	36	131	88	80
^{2}	34.3					
[p-value]	[0.00]					

Notes: All variables are as defined in Table 7. R.E. denotes random effects estimation and F.E. fixed effects. ^{2} is the Hausman test statistic for testing the null hypothesis of no correlation between the individual effects and the explanatory variables. ***, **, and * denote significance levels of 1%, 5%, and 15% respectively. LAC refers to region 2 (Latin America and the Caribbean).

Table 9. R&D and Fiscal Incentives

Dependent Variable: Private R&D Capital per Worker, RD_p/L

	(1)	(2)	(3)	(4)
Constant	0.169	-6.283	-6.351	-6.651
	(0.087)	(1.849)	(1.895)	(1.836)
RD_g/L		0.433*	0.417*	0.421*
		(0.232)	(0.240)	(0.228)
K/L		0.442**	0.434**	0.416**
		(0.193)	(0.199)	(0.190)
PAT		1.732***	1.702***	2.055***
		(0.369)	(0.384)	(0.434)
B-index	-2.604**	-1.158*	-1.127*	-5.627*
	(1.108)	(0.638)	(0.656)	(3.363)
B-index			-0.369	
• RD_g/L			(0.962)	
B-index				3.479
• PAT				(2.571)
Adj. R^2	0.18	0.81	0.81	0.82
No. of Observ.	52	52	52	52

Notes: B-index is the log of the index of fiscal incentives (see Table 5). All other variables are as defined in Table 7 and are in logs; • denotes multiplication (in the two interaction variables). Estimation is by fixed effects regressions. Standard errors are in parentheses. ***, **, and * denote significance levels of 1%, 5%, and 15% respectively.

Table 10. R&D and Human Capital

Dependent Variable: Private R&D Capital per Worker, RD_p/L

	(1)	LAC (2)	Non-LAC (3)	OECD (4)	Non-OECD (5)
Constant	-5.254	-8.466	-3.748	-3.081	-5.733
	(1.727)	(2.152)	(0.258)	(0.256)	(0.580)
RD_g/L	0.481***				
	(0.111)				
K/L	0.288*				
	(0.193)				
PAT	0.321*				
	(0.188)				
S&E	0.203**	0.819	0.399***	0.321***	0.391*
	(0.102)	(0.925)	(0.104)	(0.098)	(0.268)
EDUC	0.276***	1.323***	0.556***	0.608***	0.759***
	(0.109)	(0.519)	(0.101)	(0.095)	(0.239)
Adj. R^2	0.62	0.23	0.58	0.73	0.27
No. of Observ.	164	37	128	84	80

Notes: S&E denotes the log of scientists and engineers per 10,000 workers and EDUC the log of the tertiary school enrollment rate (as a gross – i.e. regardless of age – percentage of relevant age group). All other variables are as defined in Table 7. Estimation is by fixed effects regressions. Standard errors are in parentheses. ***, **, and * denote significance levels of 1%, 5%, and 15% respectively. LAC refers to region 2.

Table 11. Effects on Total Factor Productivity (TFP)

Dependent Variable: log TFP = log (GDP per worker) - 0.3* log (K/L)

	(1)	(2)	(3)	LAC (4)	Non-LAC (5)
Constant	6.514	6.992	6.235	6.702	6.138
	(0.057)	(0.023)	(0.073)	(0.549)	(0.069)
A_d			0.091***	0.184	0.075***
			(0.019)	(0.170)	(0.019)
A_f			0.044***	-0.037	0.039***
			(0.013)	(0.225)	(0.013)
PAT	0.104*		-0.061		
	(0.057)		(0.049)		
B-Index		-0.699**			
		(0.299)			
S&E			0.066**	-0.003	0.063**
			(0.027)	(0.153)	(0.026)
EDUC			0.124***	0.042	0.135***
			(0.024)	(0.198)	(0.023)
Adj. R^2	0.02	0.18	0.65	0.24	0.71
No. of Observations	212	53	163	25	138

Sample Statistics:

	Mean	Std. Dev.	Min	Max
TFP	838.2	364.4	185.0	1627.5
A_d	2.34	3.27	0.0007	19.08
A_f	6.82	9.94	0.0183	54.61

Notes: A_d denotes the stock of domestic patents per 1,000 domestic workers, A_f the stock of foreign patents per 1,000 domestic workers, and ICT denote information and communications technology. All other variables are as defined in previous tables. Estimation is by fixed effects regression. All of the RHS variables (except the constant) are in logs. ***, **, and * denote significance levels of 1%, 5%, and 15% respectively. LAC refers to region 2.

/... continued

Table 11 continued ... /

	OECD (6)	Non-OECD (7)	All Countries (8)	OECD (9)	Non-OECD (10)
Constant	6.146 (0.082)	6.179 (0.129)	6.377 (0.073)	6.378 (0.086)	6.338 (0.076)
A_d	0.168*** (0.033)	0.076*** (0.029)	0.065*** (0.019)	0.162*** (0.038)	0.041* (0.026)
A_f	0.028* (0.020)	0.053*** (0.021)	0.045*** (0.015)	0.060*** (0.024)	0.052*** (0.020)
S&E	0.065** (0.029)	0.042 (0.046)	0.106*** (0.026)	0.098*** (0.033)	0.080** (0.041)
EDUC	0.122*** (0.029)	0.124*** (0.039)			
ICT			0.009*** (0.003)	0.004 (0.003)	0.022*** (0.007)
Adj. R^2	0.80	0.52	0.55	0.75	0.46
No. of Observations	84	78	181	87	94

Table 12. Effects on Domestic Patenting

Dependent Variable: log of the stock of domestic patent capital per 1,000 domestic workers, A_d

	(1)	(2)	LAC (3)	Non-LAC (4)	Non-OECD (5)
Constant	0.752	0.039	-2.263	-0.581	-2.364
	(0.066)	(0.552)	(1.142)	(0.383)	(0.697)
RD_p/L	0.296**	0.216**	-0.282	0.368***	0.264*
	(0.155)	(0.113)	(0.200)	(0.094)	(0.140)
RD_g/L	-0.414	0.282**			
	(0.304)	(0.139)			
PAT		-0.335*			
		(0.229)			
B-Index	-0.546				
	(0.787)				
S&E		0.288**	-0.209	0.179*	0.382*
		(0.122)	(0.451)	(0.109)	(0.208)
EDUC		-0.172			
		(0.122)			
Adj. R^2	0.21	0.27	0.12	0.32	0.20
No. of Observ.	52	151	32	136	80

Notes: All variables are as defined in previous tables. Estimation is by fixed effects regression. All of the RHS variables (except the constant) are in logs. ***, **, and * denote significance levels of 1%, 5%, and 15% respectively. LAC refers to region 2.

Table 13. Effects on Foreign Direct Investment

Dependent Variable: log of Foreign Direct Investment (FDI) Inflows as a % of GDP

	(1)	(2)	LAC (3)	Non-LAC (4)	Non-OECD (5)
Constant	-1.591 (0.705)	-4.390 (1.261)	-3.623 (3.837)	-1.842 (1.582)	-2.850 (0.875)
RD_p/L	0.737** (0.297)	0.492* (0.305)	-0.101 (0.361)	0.516* (0.294)	0.062 (0.268)
RD_g/L	-0.478 (0.365)	0.553* (0.345)			
PAT	1.857*** (0.563)	1.578*** (0.614)	2.384*** (0.894)	-0.688 (1.215)	2.013*** (0.769)
S&E		-0.030 (0.324)			
EDUC		0.884*** (0.336)	0.607 (1.138)	0.917*** (0.354)	0.460 (0.503)
Adj. R^2	0.18	0.28	0.33	0.28	0.20
No. of Observ.	169	155	33	122	74

Notes: All RHS variables are as defined in previous tables. All of the variables (except the constant) are in logs. Estimation is by fixed effects regression. ***, **, and * denote significance levels of 1%, 5%, and 15% respectively. LAC denotes region 2.

Table 14. Simulated Effects of R&D Policy on TFP and Private R&D

The Effects on Private R&D Spending per worker and on Total Factor Productivity (TFP) of a one-half standard deviation change in:

	Patent Rights		B-Index		Public R&D funding per worker		Joint Effect: Patents and Public R&D	
	% Change in RDp/L:	% Change in TFP:	% Change in RDp/L:	% Change in TFP:	% Change in RDp/L:	% Change in TFP:	% Change in RDp/L:	% Change in TFP:
Argentina	3.4	0.07			0.9	0.05	4.3	0.1
Bolivia	4.7	0.09						
Brazil	3.6	0.07	6.9	0.13	0.2	0.01	3.8	0.1
Chile	3.6	0.07			1.9	0.11	5.5	0.2
Colombia	4.2	0.08			4.6	0.26	8.8	0.3
Costa Rica	6.1	0.12			24.7	1.43	30.8	1.5
Ecuador	4.0	0.08			27.9	1.62	32.0	1.7
El Salv	3.8	0.07						
Guatemala	10.1	0.20			19.9	1.15	30.0	1.3
Mexico	3.8	0.07	7.0	0.14	0.6	0.04	4.4	0.1
Nicaragua	11.8	0.23						
Peru	4.0	0.08			2.8	0.16	6.8	0.2
Uruguay	4.2	0.08						
Venezuela	3.8	0.07			0.8	0.05	4.6	0.1

Notes:

a. A one-half standard deviation in Patent Rights in LAC (Region 2) is 0.28, in the B-index is 0.061, and in Public R&D spending per worker is 9.9. See Table 1.

b. The following formulae were used (based on the coefficients in the tables/columns indicated):

1. Patent Rights:
log RDp/L = 0.4 log PAT
log TFP = [0.4 * 0.216 * 0.09] log PAT
from Table 8, cols. 2, 3; Table 12, col. 3; and Table 11, col. 3.

2. B-Index:
log RDp/L = -1.158 log B-Index
log TFP = [1.158 * 0.216 * 0.09] log PAT
from Table 9, col. 2; Table 12, col. 2; and Table 11, col. 3.

3. Public R&D Funding:
log RDp/L = 0.66 log RDg/L,
log TFP = [0.66 * 0.216 * 0.09 + 0.282 * 0.09] log RDg/L
from Table 8, col. 2; Table 12, col. 2; and Table 11, col. 3.

4. Joint Effects refer to an increase in both patent rights and public R&D funding, each by a half standard deviation.

(All variables are as defined in previous tables; see, for example, notes to Table 2)

Table 14 Annex. Simulated Effects of Scientists and Engineers (S&E) on TFP and Private R&D

The Effects on Private R&D Spending per worker and on Total Factor Productivity (TFP) of a one-half standard deviation change in:

	S&E		Joint Effect: S&E and B-index		Joint Effect: S&E and Patent Rights		Joint Effect: S&E and Public R&D	
	% Change in RDp/L:	% Change in TFP:	% Change in RDp/L:	% Change in TFP:	% Change in RDp/L:	% Change in TFP:	% Change in RDp/L:	% Change in TFP:
Argentina	2.9	1.37			6.3	1.4	3.8	1.4
Bolivia	6.7	3.15						
Brazil	3.6	1.72	10.5	1.9	7.2	1.8	3.9	1.7
Chile	4.7	2.23			8.3	2.3	6.6	2.3
Colombia								
Costa Rica	3.1	1.49			9.2	1.6	27.8	2.9
Ecuador	9.4	4.46			13.5	4.5	37.4	6.1
El Salv								
Guatemala					10.1	0.2	19.9	1.2
Mexico	7.6	3.60	14.6	3.7	11.4	3.7	8.2	3.6
Nicaragua	8.1	3.81						
Peru	3.1	1.46			7.1	1.5	5.9	1.6
Uruguay	2.8	1.32						
Venezuela	9.4	4.45			13.2	4.5	10.3	4.5

Notes:

These simulations are a continuation of Table 14, adapted to allow for an increase in scientists and engineers per 10,000 workers (S&E) by one-half the sample standard deviation.

a. A one-half standard deviation in S&E in LAC (Region 2) equals 2.47

b. The following formulae were used (based on the coefficients in the tables/columns indicated):

log RDp/L = 0.203 log S&E, column 1, Table 10
log Ad/L = 0.216 log RDp/L + 0.288 log S&E, column 2, Table 12
log TFP = 0.09 log Ad/L + 0.066 log S&E, column 3, Table 11

where Ad/L is the stock of domestic patent capital per 1,000 workers.

c. Joint Effects refer to a simultaneous increase in the indicated variables, each by a half standard deviation.

(All variables are as defined in previous tables; see, for example, notes to Table 2)