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# *Do Intellectual Property Rights Stimulate R&D and Productivity Growth? Evidence from Cross-national and Manufacturing Industries Data*

## INTRODUCTION

THROUGH DOMESTIC AND INTERNATIONAL LEGISLATIVE REFORMS, various countries are adopting new and stronger intellectual property protections. Canada is among them. In recent years, Canada has undertaken (and is expected to undertake further) actions to revise its laws. For example, through Bill C-32, Canada has amended its *Copyright Act*, and through Bill S-17, it will update its *Patent Act* to conform with its obligations under the *Agreement on Trade-Related Aspects of Intellectual Property Rights* (TRIPs), of the World Trade Organization (WTO). Canada has also become a signatory to treaties of the World Intellectual Property Organization (WIPO), for example the *Copyright Treaty* and the *Performances and Phonograms Treaty* in 1997. More recently (in May 2001), Canada became a signatory to WIPO's *Patent Law Treaty* (PLT). Both the PLT and the TRIPs Agreement are major (and complementary) international initiatives. Whereas the TRIPs Agreement largely focuses on substantive laws, the PLT focuses mainly on procedural laws and formalities and seeks to simplify and harmonize administrative practices. Differences in these laws and practices across countries (or jurisdictions) are viewed as imposing significant *transaction costs* on inventors interested in obtaining global patent protection. In the future, further intellectual property (IP) reforms are expected in Canada in light of new technological developments (related, for example, to the Internet, telecommunications, software, biotechnology, etc.).[1]

These changes in intellectual property laws come with some costs; for instance, *infrastructural* costs (of rewriting national laws and providing the means for enforcement and administration), static *deadweight* losses (in terms of the deviation of markets from competitive structures), and rent transfers (from consumers and rival producers to rights holders). Offsetting these costs, it is argued, are the benefits of IP reform — namely the stimulation of research and development (R&D), innovation, and ultimately productivity growth. In policy debates, arguments are often made that strengthening and clarifying intellectual property laws is vital to Canada's domestic economic progress and international competitiveness. It is also argued that these changes will help Canada become a major player in the emerging international digital economy.

However, outside of these debates, a severe shortage of evidence exists as to the effects of intellectual property rights (IPRs) on R&D and productivity growth, among other things. The purpose of this study, therefore, is to help enhance the debate by providing some quantitative estimates of the benefits of IP protection to national economies, such as Canada. The plan of the study is to examine the extent to which various kinds of IPRs can explain productivity growth, *directly* and *indirectly*. The different kinds of IPRs considered here include: patent rights, copyright, trade-mark rights, parallel import protection, software protection, prevention of piracy, and enforcement mechanisms (statutory and actual execution of laws).[2] These kinds of rights can impact on potential output *directly* by affecting the technical efficiency of production, or *indirectly* by stimulating factor accumulation (particularly R&D capital) by enhancing the returns to investment (or rather the *ability to appropriate* those returns). These two channels by which IPRs can affect productivity (technical efficiency of production and R&D accumulation) have been stressed in academic and policy debates. The institutionalists would emphasize the important role of the legal environment in which markets operate. The *new growth* and/or *knowledge-based economy* adherents would emphasize the role of R&D, inventions and technology as the primary *engines* of growth. The focus in the study is to develop quantitative measures of different kinds of IPRs and determine the extent to which technical efficiencies and R&D investments are functions of these different kinds of IPRs.

The outline of the study is as follows: the next section provides a brief literature review of the few studies that investigate the impact of IPRs on economic growth and R&D. The third section, entitled *Conceptual Framework*, develops a model of how IPRs may affect productivity growth directly and indirectly. It derives the empirical growth rate equation and R&D investment equation that will be estimated. The fourth section, entitled *IPR Indexes*, discusses indexes for the different kinds of IPRs. The fifth section, entitled *Data*, discusses two sample datasets: a national sample and a manufacturing industries sample. In both samples, the unit of analysis is the country. The sixth section, entitled *Empirical Results*, presents the empirical results and discusses their implications for the Canadian macro-economy. The *Conclusion* summarizes the results of this study and suggests extensions for future work.

## BRIEF LITERATURE REVIEW

CURRENTLY, THERE IS STILL QUITE A CONTROVERSY about whether IPRs matter for productivity growth, directly or indirectly. The theoretical literature is divided over the welfare and efficiency effects of stronger intellectual property regimes, and empirical works are few and far between. For example, in a theoretical study, Takalo and Kanniainen (2000) find that a strengthening of patent rights can delay the introduction of new technology to the market (i.e. raises the value of waiting for the innovator). Bessen and Maskin (2000) develop a model of sequential and complementary innovation in which patent protection reduces innovation and social welfare. In an international (North-South) setting, Helpman (1993) argues that weak IPRs in the South may actually be welfare-enhancing for that region, while stronger IPRs in the South may not necessarily benefit the North (consumers, for example, would forgo the benefits of cheaper imitated imports). On the other hand, theoretical studies by Diwan and Rodrik (1991) and Taylor (1994) reveal that stronger IPRs may enhance global welfare and productivity.

Though not always explicit about it, a large number of theoretical studies on IPRs actually deal with patent rights and inventive activity. Landes and Posner (1987, 1989) provide a theoretical analysis of non-patent IPRs, such as trade-marks and copyright. Essentially, trade-mark protection encourages economic efficiency by reducing search costs for consumers (allowing them to recognize quality products through symbols or names). Furthermore, firms or intellectual property owners invest in promotional expenditures to attract consumers, and in expenditures aimed at maintaining the quality of their products and services. If they were unable to link their investments and products to their trade-marks, they would have less incentive to invest in those quality-promoting investments. However, there are occasions where trade-mark protection can be too broad (e.g. when 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. Copyright over original and derivative works also stimulates creativity by increasing the odds of appropriating the benefits of the creations. Copyright can also complement other rights, such as patent rights, where the ideas are not protectable but the expression is — e.g. pure computer and mathematical algorithms. There may also be situations where stronger copyright may be adverse to economic efficiency — namely, where those rights reduce the incentive of rivals to create, or the owner's incentive to produce new creations. Each creator is part of an intertemporal chain of creators. Thus, stronger protection of expressions affects subsequent generations of creators (who themselves would like to build on previous works).

In terms of empirical work, a survey by Levin, Klevorick, Nelson and Winter (1987) of U.S. firms finds that patent protection is not the most important means for firms 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 stimulate innovation. On the other hand, case studies conducted in developing countries indicate that IPRs are considered very important for 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 alternative means of appropriation, if any). Another interesting case study is that of Korenko (1999) who finds that, in Italy's pharmaceutical industry, a strengthening of local intellectual property rights helped expand domestic R&D and market share (rather than create a situation where foreign firms crowded out domestic).

As far as econometric evidence is concerned, two studies show that patent rights contribute to economic growth, but they emphasize different mechanisms. Gould and Gruben (1996) focus on how this effect depends on the degree of *openness* of countries in their external trading, while Park and Ginarte (1997) emphasize that patent rights stimulate factor accumulation (human capital, R&D capital, and physical capital) which, in turn, directly influences economic growth.

Few econometric works exist because, until recently, measures or indexes of patent rights have been limited. Moreover, because available IPR indexes relate exclusively to patent rights, empirical growth studies have not been able to assess the impact on growth of other kinds of IPRs, such as copyright and trade-marks. Thus, the present study develops and incorporates indexes of other types of IPRs and tests their role in explaining productivity growth.

In a related study, Siwek (2000) examines the importance of copyright industries for U.S. economic growth. Rather than using indexes of copyright protection, the author's strategy is to separate groups of IP-based industries (computer software, motion pictures, music, publications, etc.) from traditional manufacturing industries. The study finds that copyright industries account for 4.94 percent of U.S. gross domestic product (GDP) and that this share is growing fast. Copyright industries also account for 3.24 percent of all jobs and employment growth in this group is three times the national average. Two criticisms can be made: first, the study does not show how sensitive copyright industries are to copyright legislation and enforcement. Even if it may be presumed that copyright industries seek copyright protection, it would still be useful to know to what degree. For example, what is the *elasticity* of demand for copyright protection with respect to the strength of protection? This is important for policy purposes if the objective of strengthening copyright protection is to stimulate the output of copyrightable works — which lead to increased productivity. A second related criticism is that the study does not explicitly show that copyright laws and enforcement are directly or indirectly responsible for the growth of IP-based industries (or of other industries).

## Conceptual Framework

In this section, two equations are derived for empirical estimation, the first to capture the direct effects of IPRs on productivity growth and the second to capture the indirect effects on growth via the effects of IPRs on R&D. The two equations are derived in turn.

### Productivity Growth

This sub-section builds on Mankiw, Romer and Weil (1992). Assume the following Cobb-Douglas production function:

$$(1)\quad Y = K^{\alpha} R^{\beta} (AL)^{1-\alpha-\beta},$$

where $Y$ denotes output, $K$ physical capital, $R$ intangible (R&D) capital, and $L$ labour. The technical efficiency of production is denoted by $A$, and is assumed to be a function of environmental and institutional factors. Holding other environmental and institutional factors constant, let

$$A = A(IPR) = a\, IPR^{\gamma},$$

where $IPR$ denotes intellectual property rights and $\gamma$ the elasticity of technical efficiency with respect to the level of $IPR$.

Therefore:

$$(1)'\quad y = k^{\alpha} r^{\beta} (IPR)^{\gamma(1-\alpha-\beta)},$$

where $y = (Y/aL)$, $k = (K/aL)$, $r = (R/aL)$. That is, output and the reproducible inputs are expressed in terms of efficiency labour units.

Physical and R&D capital accumulation is given by:

$$(2)\quad \dot{K} = I_K - \delta K \text{ and}$$

(3) $\dot{R} = I_R - \delta R$ ,

where $I$ denotes investment and $\delta$ the geometric rate of depreciation. In efficiency units, the equations of motion are:

(2)' $\dot{k} = i_k - (n + g + \delta)k$

(3)' $\dot{r} = i_r - (n + g + \delta)r$ ,

where $g = \dot{a}/a$ and $n = \dot{L}/L$ are the rates of growth of technical efficiency and of the labour force, respectively. Let:

$i_k = s_k y$
$i_r = s_r y$ ,

where $s_k$ and $s_r$ are the respective savings rates from output.

In the steady state,

(4)' $k^* = \frac{s_k\, y}{(n + g + \delta)}$

(5)' $r^* = \frac{s_r\, y}{(n + g + \delta)}$ .

Substituting equations (4)' and (5)' into equation (1)', taking the logs of both sides and rearranging yields:

(6) $\ln y^* = \phi_1 \ln s_k + \phi_2 \ln s_r + \phi_3 \ln(n + g + \delta) + \gamma \ln IPR$ ,

where $\phi_1 = \alpha/(1 - \alpha - \beta)$, $\phi_2 = \beta/(1 - \alpha - \beta)$, and $\phi_3 = -(\alpha + \beta)/(1 - \alpha - \beta)$.

While equation (6) gives the steady-state level of output, the dynamic behaviour of output can be derived from time-differentiating equation (1)' and linearizing around the steady state:[3]

(7) $\frac{d \ln y(t)}{dt} = -\lambda\,(\ln y(t) - \ln y^*)$ ,

where $\lambda = (1 - \alpha - \beta)(n + g + \delta)$.

Solving the differential equation (7) backwards to time 0 yields:

(8) $\Delta \ln y(t) = \ln y(t) - \ln y(0) = (1 - e^{-\lambda t})(\ln y^* - \ln(y(0)))$.

Substituting equation (6) into equation (8), and using the definition of $y = Y/aL$, and assuming that $\ln a(0)$ is distributed randomly across countries (that is, $\ln a(0)$ = constant $c$ + error $\varepsilon$), yields the equation to be estimated:

$$\text{(9)} \quad \begin{aligned} &\Delta \ln\left(\frac{Y(t)}{L(t)}\right) = c + \Omega_0 \ln\left(\frac{Y(0)}{L(0)}\right) + \Omega_1 \ln(s_k) + \Omega_2 \ln(s_r) \\ &+ \Omega_3 \ln(n + g + \delta) + \Omega_4 \ln(IPR) + \varepsilon \end{aligned} ,$$

where $\Omega_0 = -(1 - e^{-\lambda t})$, $\Omega_1 = -\Omega_0\phi_1$, $\Omega_2 = -\Omega_0\phi_2$, $\Omega_3 = -\Omega_0\phi_3$, and $\Omega_4 = -\Omega_0\gamma$.

From estimates of the $\Omega$s, the implied values of $\alpha$, $\beta$ and $\gamma$ can be determined.[4]

## R&D Model

THIS SUB-SECTION BUILDS ON LICHTENBERG (1987).[5] First, the optimizing demand for R&D is characterized, and secondly, the optimizing supply of R&D. The two equations are then solved to obtain the equilibrium rate of R&D investment in the steady state.

On the demand side, it is assumed that there are many *identical* competitive firms that demand R&D output. Thus, in the aggregate, firms maximize the following function:[6]

$$\text{(10)} \quad \max_{\dot{R}, R} \; V = \int_t^{\infty} [Y(R, \ldots) - p_R I_R] \, e^{-\int_t^s \rho_u \, du} ds ,$$

subject to equation (3) above, where $Y$, as before, denotes output, $R$ the stock of R&D capital, $V$ the firm value, $\rho$ the real interest rate, and $p_R$ the price of R&D capital. The necessary condition for value maximization is:

$$\frac{\partial Y}{\partial R} = (\rho + \delta) p_R - \dot{p}_R .$$

This is the standard condition where the marginal product of R&D capital appears on the left-hand side, while the user cost of R&D capital is on the right-hand side.

In the steady state,

$$(11) \quad p_R = \frac{\frac{\partial Y^*}{\partial R^*}}{\rho + \delta}.$$

On the supply side, it is also assumed that there are many identical competitive firms. In the aggregate, firms choose the quantity of R&D output, $I_R$, to maximize the present discounted flow of profits:[7]

$$(12) \quad \max_{I_R} \; \Pi = \int_t^{\infty} [\theta \, p_R \, I_R - c(I_R, R)] \, e^{-\int_t^s \rho_u \, du} ds,$$

where $\theta$ is a measure of the appropriability (of revenues or sales of R&D output, given by $p_R I_R$). In the absence of imitation, $\theta = 1$; under perfect imitation, $\theta = 0$. It is assumed that $\theta = \theta(IPR)$.

In equation (12), $c(I_R,R)$ is the cost function for R&D output. The cost of producing R&D output depends positively on the quantity of output produced, $I_R$, and negatively on the stock of existing R&D knowledge capital, $R$. That is, the past stock of R&D capital generates intertemporal externalities.[8] As to how firms treat these externalities, there are two possibilities: if firms are small, it would be reasonable to assume that they would treat nationwide (or sector-wide) $R$ as given. However, if they are sufficiently large, they would likely take into account the contribution of R&D output to future cost reductions. For now, it will be assumed that R&D producers are sufficiently small. This would be consistent with the assumption that they also treat $p_R$ as given. It is assumed that $c_1 > 0$, $c_{11} > 0$, $c_2 < 0$, $c_{22} > 0$, and $c_{12} < 0$.

The necessary condition for profit maximization is:

$$(13) \quad p_R = \frac{1}{\theta} \frac{\partial c}{\partial I_R},$$

which holds for each period. Combining equation (13) with the demand-side condition of equation (11) yields, in the steady state:

$$(14) \quad \frac{\partial c}{\partial I_R} = \frac{\theta \left(\frac{\partial Y^*}{\partial R^*}\right)}{\rho + \delta},$$

where the left-hand side represents the marginal cost of producing R&D and the right-hand side represents the discounted marginal return to R&D (adjusted for the degree of appropriability).

$c(I_R,R)$ will be specified as a Cobb-Douglas function:

(15) $c(I_R,R) = \Psi\, I_R^{\sigma 1} R^{-\sigma 2}$,

where $\psi$ is a parameter. Note that when $\sigma_1 - \sigma_2 = 1$, the R&D cost function exhibits *constant* returns to scale. This specification addresses an aggregation matter: the marginal cost of R&D ($\partial c/\partial I_R$) in equation (14) is *independent* of the number of firms. Moreover, as long as the ratio of gross R&D investment to R&D stock ($I_R/R$) is the same across countries or sectors, the cost of R&D production per stock of R&D is the same as well. In preliminary analyses, the assumption that $\sigma_1 - \sigma_2 = 1$ could not be rejected in the data.

From equation (15), the partial derivative $\partial c/\partial I_R$ can be calculated, and from equation (1), $\partial Y^*/\partial R^* = \beta Y^*/R^*$. Substituting these expressions into equation (14) yields:

(16) $$\left(\frac{I_R}{Y}\right)^{\sigma_1 - 1} = \frac{\beta\theta(IPR)}{\sigma_1\psi(\rho+\delta)}\left(\frac{R}{Y}\right)^{\sigma_2 - 1}.$$

Let $\theta(IPR) = \theta_0\, IPR^{\mu}$. Substituting this into equation (16), taking logs of both sides and rearranging yields:

(17) $$\ln(s_r) = \eta_0 + \eta_1 \ln(R_Y) + \eta_2 \ln(IPR) + \varepsilon,$$

where

$\eta_0 = \log\,[\beta\theta_0/(\sigma_1\psi(\rho + \delta))] = \text{constant}$

$\eta_1 = (\sigma_2 - 1)/(\sigma_1 - 1)$

$\eta_2 = \mu/(\sigma_1 - 1)$

and where $s_r$ is the ratio of R&D to output (as defined earlier) and $R_Y$ is the ratio of the stock of R&D to output. The error term reflects random disturbances in the R&D investment rate and deviations from the steady-state conditions which yielded this equation.

Equation (17) is the basic R&D equation to be estimated in the empirical section. Note that some parameter restrictions can be formulated. First, in order for the R&D cost function to exhibit the property of being increasing in $I_R$ (at an increasing rate), it is necessary that $\sigma_1 > 1$. Secondly, if this function is decreasing in $R$, it is necessary that $\sigma_2 > 0$. Thirdly, if the cost function exhibits constant returns to scale in $I_R$ and $R$ (i.e. $\sigma_1 - \sigma_2 = 1$), then these restrictions altogether imply that $\eta_1 < 1$. If the intertemporal externality effect is not very large, it is also possible that $\eta_1 < 0$. The reason is that in general, an increase in the stock of R&D knowledge, $R$, has ambiguous effects on R&D investment. On the one hand, a higher stock of $R$ reduces the cost of producing each unit of R&D output; on the other hand, it reduces the marginal productivity of R&D capital (and reduces the market's demand for R&D output). If $\sigma_2 < 1$, the cost reduction effect will not outweigh the reduction in marginal productivity. From estimates of $\eta_1$ and $\eta_2$, the implied values of $\sigma_1$, $\sigma_2$, and $\mu$ can then be obtained.[9]

## IPR INDEXES

THIS SECTION DESCRIBES THE VARIOUS INDEXES of intellectual property rights used in the study. In total, eight different kinds of indexes are used. Three of them cover standard statutory rights: patent rights, copyright and trade-mark rights. Two of them deal with aspects of IPRs that have been the subject of much recent policy debate: software protection and parallel import protection. Finally, the remaining three examine different aspects of IP enforcement; for example, piracy rates (which tend to be high in regions where enforcement is lax or ineffective), enforcement mechanisms and enforcement in practice.

### PRELIMINARY REMARKS

MULTIPLE INDEXES OF IPRS ARE EXAMINED in order to get a broad perspective on the state of IP rights in a country. Individual intellectual property owners (or potential owners) may be heterogeneous as to what kinds of IPRs they value. By way of analogy, consider the surveys that rank cities according to quality of residential life (surveys on best places to live). What do people look for in a city: school quality, low crime, low taxes, scenic views, quality of air? How do people rank these different characteristics? Obviously, residents would want all of these good characteristics, but how would they prioritize them? What weights would they attach to the different characteristics? Likewise, what do inventors, artists, writers, producers, etc., look for? Ease of application, no compulsory licensing, no working requirements, strong penalties for infringement, expansion of rights into new areas (software, biotechnology, Internet commerce, folk dances, etc.)? Again, how would they prioritize and weight different IP law features? Of course, a major difference between rating IP systems and rating cities is that, in the latter, the surveys are attempting to measure something about *quality*. The rating of IP systems, in contrast, is not about measuring the quality of IP regimes, but rather their *strength*. 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 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 these regimes protect the rights of intellectual property owners.[10] The empirical section then determines whether certain efficiency factors (like productivity and innovation) are influenced by the strength of those IP rights.

Another important remark is that the indexes largely measure statutory levels of protection (the laws on the books) rather than actual practice, although this study does incorporate a few variables that help to assess actual enforcement of laws. Nonetheless, a common concern is that IP indexes only measure perceived protection — not real protection. However, as will be discussed later, 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 enforce their laws. Moreover, enforcement aside, statutes can play a role. For instance, empirical results will show that even perceived (statutory) protection has real effects. This might be due to, among other things, a *signalling* effect. The laws on the books may affect agents' expectations or confidence levels, and thus influence their investment and other decisions.

Related to the issue about perceived vs. actual protection is the practice of judging the accuracy of index values according to certain a priori views. Of course, it is useful to incorporate information based on experiences and expert opinion. Indexes and expert opinion should be viewed not as substitutes but as complements. However, a common pitfall is to judge whether a country's IP index value is too low or too high according to the country's level of economic development, the prior assumption being that richer countries should have stronger levels of IP protection. In general this is the case, but there are instances where it is not (some rich countries have weak IP systems, while some poor countries have strong systems). In such cases, other factors are not held constant (for example, richer economies with weak IP systems may have good educational systems to compensate, or poorer economies with strong IP systems may follow poor fiscal and monetary policies which offset the effects of IPRs). In all cases, it should be understood that IPR indexes are not measures of economic development. They may be important determinants of development, but are not themselves indicators of it. The approach in constructing these IP indexes should be to let the chips fall where they may, with minimal (if any) reliance upon a priori views about the economic consequences of IPRs.

Legal features are chosen to measure the strength of intellectual property regimes. If there is ambiguity or uncertainty as to whether a feature contributes to the strength of IP rights, it is not incorporated (for example, priority rules: first-to-file vs. first-to-invent). Another 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.[11] Furthermore, the information has to be widely available across countries.[12]

## OVERVIEW

THE EIGHT MEASURES OF IPRS considered in this study cover the gamut of statutory and enforcement provisions, piracy and enforcement experiences.

For each of the three basic IP instruments (patents, copyright and trade-marks), the index consists of four sub-categories: coverage, duration, restrictions and membership in international treaties. Enforcement can also be included as a sub-category (as in Ginarte and Park, 1997). However, since the enforcement provisions are available for the enforcement of all three types of rights (patents, copyright and trade-marks), it would be useful to separate it out and treat it as a distinct index.

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 substantive and procedural laws of these international agreements. Note that, for signatory nations, there may be some *double-counting* in that a nation gets credit for having certain legal features in national law, but those features may be part of an international law treaty to which the nation is a signatory and for which the nation already gets credit for being a member of that particular treaty. However, membership in an international treaty in and of itself provides some value-added information, particularly about the willingness of particular nations to adhere to shared international principles such as non-discrimination.

The following sub-section provides further details about each of the measures of IP protection. The acronym to be used in the empirical section is given in parentheses. Appendix 1 provides a quick summary of the legal features included in each type of IPR index and of how the indexes are scored.

## DESCRIPTION OF INDEXES

### Patent Rights (*Pat4*)

The measure of patent rights is taken from Ginarte and Park (1997) and Park and Wagh (2002).[13] The index of patent rights ranges from 0 (weakest) to 4 (strongest). The value of the index is obtained by aggregating four 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 sub-index ranges from 0 to 1 and indicates the fraction of legal features in that sub-index available in the particular country. For example, a value of 0.33 for membership in international treaties indicates that a country is a signatory to one-third of the international treaties listed under that sub-index. A value of 0.5 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. Finally, several conditions exist under which authorities can revoke or restrict patent rights. The value for the restrictions category indicates the fraction of those restrictions which are not exercised in the country.

### Copyright (*Copyrig*)

This index varies also from 0 to 4. Each of its four categories is scored out of one. The score is again the fraction of features that are available. The *coverage* category includes works that are among the primary victims of piracy, such as literary, dramatic, artistic, musical, cinematographic works, etc. 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 restrictions category includes rights to resale (*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 creations. It also covers extended collective licensing schemes. Collective licensing societies are organizations of authors and performers. These societies are somewhat common in Europe. Their extended licensing schemes are deemed to weaken copyright since they can at times interfere with the freedom of contract of individual rights holders (see Campbell and Cotter, 1997); moreover, the licensing schemes may typically permit more liberal reproduction of works by photocopy or by broadcasting. For instance, organizations that obtain authorization from a collecting society to photocopy some author's work may in some cases be entitled to photocopy that author's published works in the same field not represented by the collective society. Also, authorization to record works in a broadcast may also include authorization to record works of non-represented rights holders that happen to be in the same broadcast.

The copyright restrictions category also incorporates compulsory licensing. One kind of compulsory licensing is for private use and another is for government use. Private individuals may apply for a compulsory licence in some jurisdictions if (typically) a foreign work is not available locally after it has been published elsewhere for some specified period of time (e.g. six months or a year). Some countries provide explicitly for compulsory licensing (e.g. the United States for satellite broadcasting) and mechanical licensing (for musical works, etc.). These are treated as private use. Government use (e.g. by a ministry of culture) is typically for educational purposes, local technological development or judicial and administrative uses (such as proof in legal proceedings).

Major international copyright treaties include the Berne Convention, the Rome Treaty, the Universal Copyright Convention (UCC) and the Phonogram Convention. The Berne Convention is the oldest international copyright treaty, providing for effective and uniform global protection. The basic underlying principles are national treatment, automatic protection and independence of protection (independent of whether protection exists in the country of origin of the work). The Rome Treaty offers protection for *neighbouring rights* (rights of performers). The UCC provides minimum legal obligations for each contracting state, emphasizing rights and protections that ensure an author's economic interest. The Phonogram Convention focuses on strengthening rights of producers of phonograms (given the increased piracy of records and tapes, at the time of its signing). This convention, unlike the Rome Treaty, does not provide substantive rights; as long as phonograms are protected, the mode of protection is left to domestic law (see Leaffler, 1997, p. 451).

### Trade-marks (*Tmark*)

The trade-mark index also varies from 0 to 4. It is the sum of scores from four categories (again coverage, duration, restrictions and membership in international treaties). Each category is scored out of 1 (indicating the fraction of available provisions). The coverage category lists three types of marks: service marks, certification marks and collective marks.[14] Countries vary as to whether these types of marks can be granted trade-mark protection. Service marks are words, names, symbols or devices that identify services. Certification marks are words, names, symbols or devices that certify the origin (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.

As for the duration of trade-mark protection, the international norm is 10 years. Again, the duration score is the ratio of the statutory length of protection to ten years; if the statutory length exceeds 10 years, the maximum score of 1 is given. The restrictions category indicates whether countries require proof of use at the time of trade-mark rights renewal (e.g. demonstrate commercial use); whether there are linking requirements (e.g. linking foreign trade-marks 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. It does not protect any trade-mark rights but facilitates their acquisition in member states. The Nice Agreement governs the international classification of goods and services for the purposes of registering trade-marks. Official documents and publications refer to these classes. However, countries can use this international classification as their principal system of classification or alongside their own national classification system. The Paris Convention also contains provisions on trade-mark rights. They deal with the use of registered marks and of well-known marks.

### Parallel Import Protection (*Parallel*)

Parallel imports refer to the importation of legally manufactured products by agents other than those who have exclusive distribution rights. The right to prevent parallel imports is essentially the international equivalent, or extension, of domestic vertical restrictions. Domestically, wholesalers may grant retailers exclusive dealerships to help solve free-rider problems (whereby other distributors, such as parallel traders, free ride on the promotion and other marketing activities of authorized dealers).[15]

Countries also vary in how they treat parallel importation. Under a national exhaustion system, parallel imports are not permitted; under an international exhaustion system, they are. Under a regional system, parallel importing is permitted within the region, but it is not permitted from outside the region. Based on these different policy regimes, the International Intellectual Property Alliance (1998) has undertaken a survey of whether IPR owners can be protected against parallel imports. This index has three values: 1 if yes, 0 if no; 0.5 if probably yes.

### Software Rights (*Software*)

In light of the prominent developments in the computer industry (particularly software) and the related impact on economies, it would be useful to incorporate the effects of software protection. The above measures do not explicitly, if at all, incorporate computer software in their coverage categories. A separate index would be required. Software protection is available in several forms, depending on whether it is the idea (technical effect) or expression for which protection is sough. Agents can thus use patents or copyright, or a combination of them. Software can also be protected under existing trade secret laws. Hence, this index is the sum of three components: trade secrecy, copyright and patents. Each of these components gets a score: 1 if such protection is available, 0 otherwise. In the case of software patentability and software copyrightability, a score of 0.5 is given if the protection is possibly available but is not clear from existing statutes. In total, this *Software* index varies from 0 to 3.

### Piracy Rates (*Piracy*)

Software laws may look good on the books, but in practice piracy may be rampant. Piracy may be rampant because laws do not exist and/or are not effectively enforced. But piracy occurs even in systems where laws exist and are enforced. That is, holding laws and enforcement constant, piracy may rise because agents become more adept at copying — they are better educated or have access to better technology (e.g. digital reproductive technologies or exchange mechanisms such as *Napster*). Like lax laws and enforcement, these copying skills provide greater opportunities for piracy, which all together determine the equilibrium level of piracy. But as a *complement* to the statutory provisions (in the *Software* index), it would be useful to look at measured rates of piracy. The idea is that piracy would be more prevalent in regimes where the laws are not very effectively enforced (if at all, since copying may even be encouraged or tolerated by policy authorities), but subject to the understanding that piracy in and of itself is not a measure of the lack of law enforcement.[16]

### Enforcement Provisions (*Enf-GP*)

This index is the fifth component in the Ginarte and Park (1997) index of patent rights, separate from the rest of the components. 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 this category. While litigation, arbitration and settlement comprise different enforcement routes should infringement occur, patent holders may have recourse to a number of statutory provisions that 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 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 to also 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 IP owners may have to prove that others are infringing on their ideas, expressions or symbols, shifting the burden of proof can be a powerful enforcement mechanism.

### Enforcement in Practice (*Enf-USTR*)

At present, no scientifically conducted studies have been done on how laws are actually enforced in practice. The closest available are reports filed with the United States Trade Representative (USTR) concerning intellectual property enforcement in various countries. A major limitation is that these reports are biased towards the views of U.S. firms (of what constitutes effective and adequate enforcement). Another limitation is that some complainants may have ulterior motives for filing complaints; for example, to seek assistance in penetrating foreign markets because they are not able to compete against local firms on price, product quality or some other factor alone. A third limitation is that because the reports are descriptive and qualitative in nature, any attempt to construct quantitative indexes based on them is likely to depend subjectively on the author's interpretation of the nature of complaints.

On the other hand, having no measure at all of enforcement in practice would be a serious omission. Thus, notwithstanding these limitations, an index is developed to reflect the experience of IP enforcement as documented in these reports (see USTR, *National Trade Estimates*). It can then be compared to, and used in conjunction with, the other, largely statutory, IP indexes.

The index focuses on the execution of laws. Laws may be ineffectively implemented: i) because of a *lack of willingness* on the part of policy authorities to provide or enforce them (because, for whatever reason, they do not agree with a strong intellectual property policy), or ii) because of a *lack of capacity* to enforce laws effectively. This may arise because of a lack of resources, training and experience.

As was discussed earlier for the *Piracy* index, IP violations occur not only because of weak laws and enforcement, but also because imitators or infringers are very capable of copying. Therefore, it is important to control for the capacity of a nation's "imitative" sector to make copies. In nations where the capacity for imitation is low, weak enforcement may not be an important factor for innovators. The weak imitation capacity itself acts as a protection against such practice. On the other hand, even if strong laws exist (on the books) and enforcement is strong (that is, the authorities are both willing and able to protect rights), there will always be some infringement (even in regions where IP laws and rights are strong, such as in the United States). Thus, the level of infringement activity is not, in and of itself, a good indicator of whether laws are lax or ineffective, particularly if the laws exist and the court system enforces them (in which case the system is working well). While lax laws and poor enforcement do contribute to IP infringement, there are other factors driving IP infringement activity [including the capacity for imitation, such as the level of technology (for copying) and the quantity of innovations and creations].

Thus, for purposes of this index (which attempts to measure the actual enforcement of IP laws), the focus will be on how authorities enforce or carry out the laws in practice — not on the actual extent of infringement activity. This particular index looks first at whether enforcement mechanisms are available or adequate; secondly, whether laws are enforced; and thirdly, how effectively. For instance, if enforcement measures are not available or inadequate, the enforcement of laws will not be effective. Thus, countries in this situation would score 0. Countries would also score 0 if they have the enforcement mechanisms, but are not applying their laws (as a policy choice or because certain other policy choices make enforcement ineffective, such as weak fines or sentences). However, if countries are deemed to be enforcing the laws, but not effectively because of barriers to enforcement (e.g. resource constraints) or delays in policy implementation (that is, an intellectual property law goes into effect six months or a year later), they would score 0.5. Essentially, countries should score a half point if they are trying to enforce the laws (but are less successful because their capacity to enforce needs to be strengthened). Countries without enforcement problems would score 1. Note that complaints about the lack of laws (other than enforcement provisions) are not counted in this index since the previous indexes (*Pat4*, *Copyrig*, *Tmark*, etc.) already incorporated information about the absence of laws.

## Sample Statistics

TABLE 1 SHOWS THE VALUES of the various indexes by country, for roughly the period 1987-94. Thus, the TRIPs provisions are not incorporated.

The mean patent rights score is 2.51 (with a coefficient of variation of 0.27). The mean level for copyright and trade-marks is 2.89 and 2.88, respectively (with coefficients of variation of 0.17 and 0.24, respectively). The country with the strongest measured patent rights is the United States (with a level of 3.69), while the weakest is Venezuela (with a score of 1.13). Canada's patent rights level is average, with a score of 2.50. For copyright, the country with the strongest measured regime is France (score of 4.00) and the weakest is Singapore. Canada's copyright level of 2.96 is slightly above the average (of 2.89). For trade-marks, the countries with strongest measured regime are France, Switzerland and the United Kingdom (with scores of 4.00), while the weakest are Mauritius and India (with scores of 1.28). Canada's trade-mark level of 3.08 is also slightly above the average (2.88).

**TABLE 1**

**INTELLECTUAL PROPERTY RIGHTS, VARIOUS MEASURES**

| | PAT4 | COPYRIG | TMARK | PARALLEL | SOFT-WARE | PIRACY | ENF-GP | ENF-USTR | MANUF. SAMPLE |
|---|---|---|---|---|---|---|---|---|---|
| Australia | 2.59 | 2.87 | 3.08 | 0.50 | 2.50 | 34.00 | 1.00 | 1.00 | Yes |
| Austria | 3.40 | 3.33 | 3.42 | 0.50 | 2.00 | 44.00 | 1.00 | 1.00 | Yes |
| Belgium | 2.90 | 3.50 | 3.67 | 0.50 | 1.50 | 44.00 | 1.00 | 0.50 | Yes |
| Brazil | 1.78 | 2.93 | 2.42 | 0.00 | 2.00 | 70.00 | 0.67 | 0.00 | |
| Canada | 2.50 | 2.96 | 3.08 | 1.00 | 3.00 | 43.00 | 0.67 | 1.00 | Yes |
| Chile | 2.41 | 2.50 | 2.17 | 0.00 | 1.50 | 65.00 | 0.33 | 0.00 | |
| Colombia | 1.18 | 2.75 | 2.50 | 0.00 | 1.50 | 72.00 | 0.67 | 0.00 | |
| Denmark | 3.31 | 3.67 | 3.67 | 0.50 | 2.50 | 41.00 | 0.67 | 1.00 | Yes |
| Egypt | 1.66 | 2.17 | 2.83 | 1.00 | 2.00 | 85.00 | 0.33 | 0.00 | |
| Finland | 2.57 | 3.28 | 3.67 | 0.50 | 2.50 | 46.00 | 1.00 | 1.00 | Yes |
| France | 2.97 | 4.00 | 4.00 | 1.00 | 2.50 | 48.00 | 1.00 | 1.00 | Yes |
| Germany | 2.79 | 3.54 | 3.17 | 1.00 | 3.00 | 40.00 | 1.00 | 1.00 | Yes |
| Greece | 1.82 | 3.10 | 2.83 | 1.00 | 2.00 | 81.00 | 0.67 | 0.50 | Yes |
| India | 1.16 | 2.75 | 1.28 | 0.50 | 2.00 | 76.00 | 0.33 | 0.00 | |
| Ireland | 3.16 | 2.88 | 2.70 | 1.00 | 2.50 | 70.00 | 0.00 | 0.50 | |
| Israel | 2.90 | 2.45 | 3.12 | 0.00 | 2.00 | 69.00 | 0.67 | 0.50 | |
| Italy | 3.12 | 3.42 | 3.42 | 1.00 | 2.50 | 57.00 | 1.00 | 0.50 | Yes |
| Japan | 2.94 | 3.10 | 2.50 | 0.50 | 3.00 | 49.00 | 1.00 | 1.00 | Yes |
| Kenya | 2.07 | 2.63 | 2.53 | 0.00 | 0.50 | 78.00 | 0.67 | 0.00 | |
| Korea | 3.07 | 2.80 | 2.25 | 0.50 | 3.00 | 72.00 | 1.00 | 0.50 | Yes |
| Mauritius | 2.56 | 2.07 | 1.28 | 0.00 | 0.50 | 86.00 | 0.33 | | |
| Mexico | 1.91 | 2.66 | 2.00 | 0.00 | 2.00 | 70.00 | 0.33 | 0.00 | Yes |
| Netherlands | 3.31 | 3.10 | 3.67 | 0.50 | 2.50 | 57.00 | 1.00 | 1.00 | Yes |
| New Zealand | 2.92 | 2.82 | 2.45 | 0.00 | 2.50 | 38.00 | 0.67 | 1.00 | Yes |
| Norway | 2.93 | 3.00 | 3.42 | 1.00 | 2.50 | 52.00 | 0.67 | 1.00 | Yes |
| Pakistan | 1.99 | 2.43 | 1.78 | 0.00 | 0.50 | 92.00 | 0.00 | 0.00 | |
| Peru | 1.53 | 2.70 | 2.50 | 0.00 | 2.00 | 78.00 | 0.33 | 0.00 | |
| Philippines | 2.66 | 2.68 | 2.50 | 0.00 | 1.50 | 90.00 | 0.00 | 0.00 | |
| Portugal | 2.15 | 3.50 | 3.67 | 0.50 | 1.50 | 58.00 | 0.33 | 0.50 | Yes |
| Singapore | 2.57 | 1.93 | 2.50 | 0.00 | 2.50 | 57.00 | 0.67 | 0.00 | |
| South Africa | 2.90 | 2.03 | 2.75 | 0.50 | 2.00 | 55.00 | 0.67 | 0.00 | |
| Spain | 2.83 | 3.65 | 3.75 | 1.00 | 2.50 | 69.00 | 1.00 | 0.50 | Yes |
| Sri Lanka | 2.79 | 2.40 | 2.50 | 0.50 | 1.50 | | 0.33 | | |
| Sweden | 3.07 | 3.67 | 3.67 | 0.50 | 3.00 | 50.00 | 1.00 | 1.00 | Yes |
| Switzerland | 3.19 | 3.03 | 4.00 | 0.50 | 2.00 | 42.00 | 0.67 | 1.00 | |
| Thailand | 1.38 | 2.18 | 2.75 | 0.00 | 1.00 | 83.00 | 0.67 | 0.00 | |
| Turkey | 1.79 | 2.42 | 2.75 | 1.00 | 1.00 | 87.00 | 0.00 | 0.00 | |
| United Kingdom | 3.24 | 3.47 | 4.00 | 1.00 | 3.00 | 36.00 | 0.33 | 1.00 | Yes |
| United States | 3.69 | 3.35 | 3.17 | 1.00 | 3.00 | 28.00 | 1.00 | 1.00 | Yes |
| Uruguay | 2.10 | 2.55 | 2.67 | 0.00 | 1.50 | 81.00 | 0.33 | | |
| Venezuela | 1.13 | 2.12 | 1.92 | 0.00 | 2.00 | 70.00 | 1.00 | 0.00 | |

**TABLE 1** (CONT'D)

**INTELLECTUAL PROPERTY RIGHTS, VARIOUS MEASURES**

| | PAT4 | COPYRIG | TMARK | PARALLEL | SOFT-WARE | PIRACY | ENF-GP | ENF-USTR | MANUF. SAMPLE |
|---|---|---|---|---|---|---|---|---|---|
| Mean | 2.51 | 2.89 | 2.88 | 0.46 | 2.06 | 61.58 | 0.63 | 0.50 | |
| Standard Deviation | 0.67 | 0.51 | 0.70 | 0.40 | 0.70 | 17.59 | 0.33 | 0.44 | |
| Minimum | 1.13 | 1.93 | 1.28 | 0.00 | 0.50 | 28.00 | 0.00 | 0.00 | |
| Maximum | 3.69 | 4.00 | 4.00 | 1.00 | 3.00 | 92.00 | 1.00 | 1.00 | |

Notes: *Pat4* is an index of patent rights (without an enforcement component).
*Copyrig* and *Tmark* are indexes of copyright and trade-mark rights.
*Parallel* is an index of parallel import protection.
*Software* is an index of software intellectual property rights.
*Piracy* refers to the percentage of software piracy.
*Enf-GP* is the enforcement component of the Ginarte and Park (1997) patent index.
*Enf-USTR* is a qualitative index of effective enforcement based on reports to the USTR.
*Manuf. Sample* indicates that the country is both in the national sample and in the manufacturing industries sample.

As for parallel import protection, 12 out of 41 countries provide measures (including Canada), 15 do not, while the rest provide uncertain or partial protection. As for software protection, 7 countries provide measures (trade secrecy, patents and copyright): Canada, Germany, Japan, Korea, Sweden, the United Kingdom and the United States. Thailand and Turkey provide the weakest level of protection in this regard. Most are providing some protection, but not completely or certainly. Piracy rates average about 62 percent. The lowest rate is in the United States (28 percent) and the highest in Pakistan (92 percent) followed by the Philippines, Turkey, Mauritius and Egypt. Canada's is among the lowest (with a piracy rate of 43 percent).

On measures of enforcement, the *Enf-GP* index, indicates that countries are about evenly dispersed in terms of those that have full protection (1.00), near full protection (0.67), near incomplete (0.33), and incomplete (0.00). The *Enf-USTR* index indicates that 15 out of 38 countries score high on enforcement experiences [largely the Organisation for Economic Co-operation and Development (OECD) countries], 8 countries have a medium score and 15 have a low score. The latter tend to be the less developed economies. Canada's level of enforcement in practice is rated very good (*Enf-USTR* score of 1.00) while its statutory level is near full protection (*Enf-GP* of 0.67). A comparison of *Enf-GP* and *Enf-USTR* can show where statutory levels and perceived experiences differ; for example, Kenya and Brazil score relatively high on statutory provisions but low on practice. The United Kingdom does the opposite: score low on statutory protection, but high on experience. The United Kingdom (during this sample period) did not provide preliminary injunctions and burden-of-proof reversals. Ireland also scores low statutorily, but it rates high on actual enforcement experience. Overall, there are more overestimates (19) than underestimates (10), where overestimate means that the *Enf-GP* score exceeds the *Enf-USTR* score. As the next section shows, the raw correlation between the two is 0.531 in one sample and 0.321 in another (consisting primarily of OECD economies).

As the next section also explains, the two different samples employed in the empirical analysis are a cross-country macro-economy sample and a cross-country manufacturing industries sample. The far-right column of Table 1 indicates whether a country is in both samples.

## DATA

TWO DATASETS ARE USED to examine the role of IPRs in productivity growth and R&D activities. Each has advantages and disadvantages. The main advantage of the national (macro-economy) sample is that it has more countries. But the disadvantage is that it averages across industries in each country, thus suppressing sectoral variations. The manufacturing sample allows for sectoral variations to be reflected, but it does not have as much cross-country variation. Fewer countries are in this sample because detailed manufacturing data are only available for a subset of the national sample.

In order to facilitate the description of the data, let:

$Y$ : Output
$L$ : Labour (or number of workers)
$YL$ : Output per Worker
$\Delta\ln(YL) = \ln(YL_{1995}) - \ln(YL_{1980})$ : Long-term Growth Rate
$s_K = (I_K/Y)$ : Physical Capital Investment per Output
$s_R = I_R/Y$ : R&D Capital Investment per Output
$R$ : Stock of R&D Capital
$n = \dot{L}/L$ : Growth Rate of Labour.

The stock of R&D capital is obtained as follows:

$$(18)\quad R(t) = I_R(t) + (1-\delta)\,R(t-1)$$

$$(19)\quad R(0) = \left(\frac{1+\iota}{\iota+\delta}\right) I_R(0)\,.$$

The initial stock, $R(0)$, is obtained by backward recursive substitution of equation (18), where $\iota$ is an historical average of the growth rate of investment $[1 + \iota(t) = I_R(t)/I_R(t-1)]$.[17] A 10-percent geometric depreciation rate is assumed.

## NATIONAL SAMPLE

IN THIS SAMPLE, there are 41 nations (as listed in Table 1). The measure of output ($Y$) is GDP. Data on GDP, number of workers ($L$), and investment rates ($I_K$) are taken from the *Penn World Tables* (Version 5.6a). The data are already in real 1985 U.S. dollars (at purchasing power parity) and go up to 1992. For 1995 data, the World Bank *Development Indicators* were used to update the investment rates, number of workers and GDP.[18] The R&D data ($s_R$) are from the various issues of the UNESCO's *Statistical Yearbook*.

To obtain the stock of R&D, the flows of R&D investment were first derived (by multiplying the $s_R$ figures by the GDP), and then the perpetual inventory method, using equations (18) and (19), was applied.

## MANUFACTURING SAMPLE

THIS SAMPLE CONSISTS OF 21 COUNTRIES and 18 manufacturing industries. Appendix 2 provides a list of these industries. The manufacturing production and investment data are from the OECD STAN database. For each industry, the output measure refers to production, the labour measure refers to the number of employees, and the physical capital investment rate refers to the ratio of investment to production. The output data are in real 1990 U.S. dollars at purchasing power parity. The exchange rate data are taken from the STAN database. Deflators can be derived from real and nominal value-added figures; however, deflator data are still missing for some countries, in which case GDP deflators from the International Monetary Fund's *International Financial Statistics* were used as a replacement.

The R&D data are from the OECD's *Basic Science and Technology Indicators* (1997 edition). The industry-by-industry R&D figures are called the BERD (Business Enterprise Research & Development) data. Here, $s_R$ is the ratio of privately funded BERD to production, while $s_G$ is the ratio of publicly funded BERD to production. Appendix 2 also indicates how the BERD sectoral codes match with the sectoral codes used in the STAN database.

## SAMPLE STATISTICS

TABLE 2 SHOWS SAMPLE STATISTICS for the national sample over the period 1980-95. Part A presents basic descriptive measures. The long-term growth rate varies from –0.388 (Peru) to 0.989 (Korea). GDP per worker is highest in the United States ($38,554) and lowest in Kenya ($1,905). The United States has the highest R&D investment rate and largest stock of R&D capital. Uruguay has the lowest R&D investment rate and lowest stock of R&D capital. The highest rate of physical capital investment is undertaken by Singapore and the lowest by Egypt. Canada's GDP per worker is the second highest in this sample ($37,157), but its national R&D investment rate (1.55 percent) is the 13th highest. Within the OECD, Canada's R&D investment rate is 11th out of 21 countries. The disparity between Canada's relatively high GDP per worker and medium rate of R&D can be reconciled by the fact that GDP per worker captures both relatively recent developments (occurring at about the time of the 1980-95 sample period) as well as longer term (historical) factors. For instance, Canada enjoys a high level of institutional development (that has been attained and maintained for a relatively long period of time), which other economies do not enjoy, or have not enjoyed, to the same extent. There are also offsetting factors in Canada that can compensate for relatively average R&D investment rates and thereby contribute to a relatively high level of GDP per worker (such as high human capital, open trade, and a large capital stock per worker). Thus, these factors need to be taken into account when trying to understand why Canada's GDP per worker is fairly high despite the fact that the country has quite average levels of intellectual property protection and R&D investment rates (compared to other countries). Moreover, as will be discussed in the next section, Canada's productivity performance is somewhat weaker when looking at data on manufacturing GDP (instead of overall, aggregate GDP). Among OECD economies, Canada ranks 10th (over the sample period) in terms of average manufacturing GDP per worker.[19] It turns out, as the empirical results show, that intellectual property rights matter more significantly for manufacturing productivity.

Part B of Table 2 shows the correlation among these variables and the IPR variables. R&D is positively correlated with all the IPR variables, except the piracy rate, with which it has a negative correlation. GDP per worker and the stock of R&D capital are also positively correlated with the IPR variables (except piracy, with which they have a negative correlation).

Note that the growth rate has a positive correlation with GDP per worker. But this is the unconditional correlation; once other factors are controlled for (as in the regression analysis), their (conditional) correlation is negative. Essentially, all the simple correlations are as expected. What is of interest is how the IPR measures correlate among themselves:

- Patent rights are positively correlated with *Enf-USTR*. Apparently, the countries in which there is least concern about enforcement in practice are those where patent statutes are strong, and vice versa: the countries with the poorest enforcement experience are those with weak or nonexistent laws. Patent rights are also positively correlated with trade-mark rights and copyright. Thus, countries that protect patent rights well also protect other forms of intellectual property.

## Table 2

## Sample Statistics, 41 Nations

| | Mean | Std Dev. | Min | Max |
|---|---|---|---|---|
| *Growth* | 0.223 | 0.267 | –0.388 | 0.989 |
| *GDP/Worker* | 21,181 | 10,892 | 1,905 | 37,157 |
| *RDY* | 1.179 | 0.879 | 0.074 | 3.059 |
| *IY* | 20.96 | 6.623 | 7.812 | 39.49 |
| *RDStock* | 2.3E+10 | 4.4E+10 | 9.5E+07 | 7.5E+11 |

**Correlation Matrix**

| | Growth | GDP/W | RDY | IY | RDStock | Pat4 | Copyrig | Tmark | Parallel | Software | Piracy | Enf-GP | Enf-USTR |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Growth* | 1.000 | | | | | | | | | | | | |
| *GDP/Worker* | 0.213 | 1.000 | | | | | | | | | | | |
| *RDY* | 0.247 | 0.708 | 1.000 | | | | | | | | | | |
| *IY* | 0.552 | 0.562 | 0.399 | 1.000 | | | | | | | | | |
| *RDStock* | 0.123 | 0.379 | 0.619 | 0.261 | 1.000 | | | | | | | | |
| *Pat4* | 0.216 | 0.722 | 0.705 | 0.372 | 0.343 | 1.000 | | | | | | | |
| *Copyrig* | 0.055 | 0.619 | 0.528 | 0.137 | 0.454 | 0.535 | 1.000 | | | | | | |
| *Tmark* | 0.019 | 0.697 | 0.557 | 0.199 | 0.261 | 0.629 | 0.722 | 1.000 | | | | | |
| *Parallel* | 0.277 | 0.517 | 0.417 | 0.136 | 0.391 | 0.402 | 0.536 | 0.553 | 1.000 | | | | |
| *Software* | 0.131 | 0.711 | 0.644 | 0.471 | 0.483 | 0.568 | 0.501 | 0.446 | 0.509 | 1.000 | | | |
| *Piracy* | –0.004 | –0.806 | –0.682 | –0.401 | –0.439 | –0.681 | –0.585 | –0.629 | –0.338 | –0.672 | 1.000 | | |
| *Enf-GP* | 0.037 | 0.607 | 0.518 | 0.436 | 0.344 | 0.371 | 0.441 | 0.436 | 0.179 | 0.514 | –0.591 | 1.000 | |
| *Enf-USTR* | 0.181 | 0.828 | 0.776 | 0.371 | 0.471 | 0.739 | 0.689 | 0.648 | 0.499 | 0.635 | –0.802 | 0.531 | 1.000 |

Notes: *GDP/worker*: Gross domestic product per worker in 1995 (in constant 1985 US$).
*Growth*: Growth of GDP per worker over the period 1980-95.
*RDY*: National R&D as a percentage of GDP (average for 1980-95).
*IY*: Physical capital investment as a percentage of GDP (average for 1980-95).
*RDStock*: Stock of R&D capital in 1980 (in constant 1985 US$).
For the rest of the variables, see notes to Table 1.

- The piracy variable is negatively correlated with the two enforcement variables. Thus, piracy rates are lowest in countries that have strong enforcement mechanisms and practices. The USTR enforcement measure also correlates well with the Ginarte and Park measure of enforcement provisions.
- Parallel import protection is also positively correlated with other IPR variables, except piracy.

Table 3 presents statistics for the manufacturing sample over the period 1980-95. Part A focuses on the macro variables of interest. The mean and standard deviation for the IPR variables are not repeated since they vary only by country, not by industry. The mean and standard deviation are broken down by industry. (The unit of analysis here is the industry, not the country.) The industry-wide average long-term growth rate is 0.182, as the first line (TOTAL) shows.

The highest growth rate of output is in the Office Equipment Industry (which includes computers), followed by Radio-TV. The lowest growth rate is in the Food and Beverages sector, followed by Chemicals (non-drug). The highest rate of R&D investment is in Chemicals (drugs), followed by Office Equipment. About 10 percent of output in Chemicals (drugs) goes to R&D. The lowest rate of R&D investment is in Fabricated Metals, followed by the Wood Industry. The stock of R&D is also the largest in the Aircraft industry, followed by the Office Equipment and Radio-TV industries. The lowest stock of R&D capital is in the Wood industry, followed by Shipbuilding and Textiles.

Part B of Table 3 examines the correlation among these variables and IPRs. The growth rate (of output per worker) is positively correlated with R&D. The stock of R&D is also positively correlated with the growth rate. Patent rights, enforcement, and software are all positively correlated with the growth rate. That is, the fastest growing industries are associated with countries in which those types of IPRs are strongest. The same industries in countries where those kinds of IPRs are weakest tend to have the slowest growth rates. In contrast, the correlation between growth rates and copyright, trade-marks, and parallel import protection is negative.

Private R&D is positively correlated with all IPR measures, except piracy and trade-marks. It is expected that the correlation of private R&D with piracy would be negative, but not with trade-marks (although it is small in absolute value). The correlation with copyright is also small (0.065) in contrast to patent rights which have a correlation of 0.234 with private R&D. The correlation between private and public R&D is 0.156. The stock of R&D is positively correlated with growth, public R&D and private R&D, and negatively with copyright and trade-marks. Now, among the IPR variables, patent rights are negatively correlated with parallel importation. That is, parallel import protection is not necessarily accorded in countries with strong patent regimes.

**TABLE 3**

**SAMPLE STATISTICS, MANUFACTURING INDUSTRIES ACROSS 21 COUNTRIES**

| A) MEAN (STANDARD DEVIATION) | *GROWTH* | *PRIVATE RDY* | *R&D STOCK* |
|---|---|---|---|
| Total | 0.182 | 1.741 | 3,659 |
| | (0.697) | (3.117) | (10,529) |
| Food | –0.194 | 0.230 | 1,973 |
| | (0.534) | (0.177) | (3,739) |
| Textiles | 0.042 | 0.231 | 356 |
| | (0.643) | (0.183) | (830) |
| Wood | 0.155 | 0.137 | 220 |
| | (0.469) | (0.105) | (469) |
| Printing | 0.181 | 0.226 | 430 |
| | (0.458) | (0.234) | (659) |
| Chemicals (non-drug) | –0.088 | 1.883 | 10,721 |
| | (0.696) | (1.670) | (18,076) |
| Chemicals (drug) | 0.354 | 10.59 | 6,648 |
| | (0.38) | (5.44) | (9,660) |
| Petroleum | –0.469 | 0.613 | 2,573 |
| | (1.181) | (0.463) | (5,761) |
| Rubber | 0.083 | 0.84 | 1,073 |
| | (0.567) | (0.668) | (2,046) |
| Non-metallic Minerals | 0.071 | 0.657 | 1,332 |
| | (0.604) | (0.548) | (2,569) |
| Metals: Iron | 0.399 | 0.545 | 2,091 |
| | (0.592) | (0.398) | (4,193) |
| Metals: Non-ferrous | 0.318 | 0.570 | 672 |
| | (0.618) | (0.516) | (1,283) |
| Fabricated Metals | 0.330 | 0.091 | 3,446 |
| | (0.661) | (0.054) | (10,143) |
| Office Equipment | 0.962 | 6.91 | 11,924 |
| | (1.132) | (3.94) | (29,192) |
| Radio-TV | 0.633 | 5.581 | 10,126 |
| | (0.396) | (2.71) | (19,077) |
| Electrical | 0.067 | 2.017 | 5,000 |
| | (0.702) | (1.21) | (7,956) |
| Shipbuilding | 0.564 | 1.415 | 323 |
| | (0.753) | (1.339) | (653) |
| Motor Vehicles | 0.224 | 2.236 | 7,770 |
| | (0.650) | (1.60) | (11,238) |
| Aircraft | 0.156 | 3.85 | 12,058 |
| | (0.759) | (1.66) | (23,209) |

**TABLE 3** (CONT'D)

**SAMPLE STATISTICS, MANUFACTURING INDUSTRIES ACROSS 21 COUNTRIES**

| B) CORRELATION MATRIX | *GROWTH* | *PRIVRDY* | *RDSTOCK* | *PAT4* | *COPYRIG* | *TMARK* | *PARALLEL* | *SOFTWARE* | *PIRACY* | *ENF-GP* | *ENF-USTR* |
|---|---|---|---|---|---|---|---|---|---|---|---|
| *Growth* | 1.000 | | | | | | | | | | |
| *PrivRDY* | 0.224 | 1.000 | | | | | | | | | |
| *RDStock* | 0.168 | 0.367 | 1.000 | | | | | | | | |
| *Pat4* | 0.446 | 0.234 | 0.319 | 1.000 | | | | | | | |
| *Copyrig* | –0.021 | 0.065 | –0.034 | 0.335 | 1.000 | | | | | | |
| *Tmark* | –0.067 | –0.003 | –0.199 | 0.354 | 0.804 | 1.000 | | | | | |
| *Parallel* | –0.168 | 0.021 | 0.118 | 0.169 | 0.451 | 0.471 | 1.000 | | | | |
| *Software* | 0.287 | 0.218 | 0.282 | 0.454 | –0.031 | –0.101 | 0.321 | 1.000 | | | |
| *Piracy* | –0.528 | –0.149 | –0.297 | –0.546 | –0.202 | –0.299 | –0.035 | –0.311 | 1.000 | | |
| *Enf-GP* | 0.287 | 0.078 | 0.131 | 0.475 | 0.231 | 0.129 | 0.169 | 0.282 | –0.143 | 1.000 | |
| *Enf-USTR* | 0.442 | 0.177 | 0.179 | 0.566 | 0.222 | 0.375 | 0.215 | 0.536 | –0.731 | 0.321 | 1.000 |

Notes: *Growth*: Growth of real industrial output per worker over the period 1980-95.
*PrivRDY*: Privately funded industrial R&D as a percentage of industry output (average 1987-95).
*RDStock*: Stock of privately funded industrial R&D in 1987 (in millions of constant 1990 US$).
For the other variables, see notes to Table 1.

Software rights are positively correlated with patent rights, but negatively with copyright and trade-marks. This suggests that software rights might be driven largely by patent rights since the software variable is a mixture of copyright and patent rights (and trade secrecy), yet the level is high primarily in countries where patent rights are strong. It could be that countries with strong copyright protection are strong in fields other than software (sound recordings, books, etc.). Not surprisingly, piracy and software are negatively correlated. Enforcement and piracy are also negatively correlated. Both enforcement variables are weakly correlated with each other (in contrast with the national sample). Thus, the deviation between perceived and actual protection is wider in the manufacturing sample. The correlation between *Enf-GP* (which measures statutory enforcement provisions) and *Enf-USTR* (which measures enforcement experience) may have been higher in the national sample which includes developing countries. Among these, countries that do not provide adequate statutory IP enforcement are also not likely to carry out laws adequately.[20]

## EMPIRICAL RESULTS

THIS SECTION PRESENTS ESTIMATES of the productivity growth equation (9) and the R&D investment rate equation (17).

### NATIONAL SAMPLE

COLUMN 1 OF TABLE 4 PRESENTS the growth rate equation without IPR variables. This is similar to the augmented model of Mankiw et al. (1992), except that the R&D variable replaces their human capital variable.[21] The secondary school enrolment rate was tried but found not to be significant at conventional levels (coefficient of 0.16 and standard error of 0.12). This first regression serves as a basis of comparison against previous empirical growth studies that omit IPRs. Thus far, the results are fairly comparable: 58.8 percent of the data is explained. From the coefficient of initial income (1980), one can find the speed of convergence, $\lambda$, estimated to be 0.024 [ln(0.7)/15; see the formula for $\Omega_0$ in equation (9), where t = 15 years (from 1980-95)]. This implies that deviations from the steady state are closing at a rate of 2.4 percent per year. This is faster than the rate found by Mankiw et al. (1992) (without controlling for R&D), but it is closer to what they get for the OECD sample. As for the other implied parameters, $\alpha = 0.36$ [0.425/(0.299+0.833)] and $\beta = 0.084$ [0.099/(0.299+0.833)], both of which are in the ballpark of previous findings.

Given no major departures from previous growth studies, the next step is to examine the consequences of incorporating IPR variables. In columns 2 to 8, each of the different IPR variables is reported to be statistically insignificant. Hence, at the national level, there appears to be no appreciable *direct* effect on

**TABLE 4**

**NATIONAL GROWTH EQUATION ESTIMATES**

| | DEPENDENT VARIABLE: GROWTH = LN($YL_{1995}$) – LN($YL_{1980}$) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) |
| C | 4.521 | 4.545 | 4.853 | 4.495 | 4.610 | 3.462 | 4.352 | 4.439 | 0.820 | 6.828 |
| | (0.662) | (0.621) | (0.616) | (0.668) | (0.604) | (1.001) | (0.724) | (0.725) | (1.690) | (0.601) |
| $YL_{1980}$ | –0.299 | –0.298 | –0.283 | –0.284 | –0.314 | –0.256 | –0.299 | –0.248 | –0.184 | –0.560 |
| | (0.053) | (0.059) | (0.053) | (0.061) | (0.052) | (0.061) | (0.054) | (0.069) | (0.066) | (0.051) |
| $S_K$ | 0.425 | 0.425 | 0.403 | 0.421 | 0.417 | 0.412 | 0.449 | 0.454 | 0.488 | 0.233 |
| | (0.142) | (0.144) | (0.125) | (0.144) | (0.143) | (0.143) | (0.129) | (0.157) | (0.216) | (0.057) |
| $S_R$ | 0.099 | 0.103 | 0.119 | 0.104 | 0.098 | 0.131 | 0.077 | 0.142 | 0.147 | 0.098 |
| | (0.035) | (0.032) | (0.037) | (0.033) | (0.037) | (0.038) | (0.039) | (0.051) | (0.061) | (0.026) |
| *NGD* | –0.883 | –0.895 | –1.083 | –0.925 | –0.887 | –0.876 | –0.762 | –0.929 | –0.979 | –0.313 |
| | (0.189) | (0.209) | (0.211) | (0.211) | (0.199) | (0.174) | (0.221) | (0.198) | (0.278) | (0.195) |
| *Pat4* | | –0.018 | | | | | | | | |
| | | (0.103) | | | | | | | | |
| *Copyrig* | | | –0.355 | | | | | | | |
| | | | (0.214) | | | | | | | |
| *Tmark* | | | | –0.096 | | | | | | |
| | | | | (0.126) | | | | | | |
| *Parallel* | | | | | | | 0.157 | | (0.172) | 0.215 |
| | | | | | | | (0.121) | | (0.216) | (0.086) |
| *Software* | | | | | 0.039 | | | | | |
| | | | | | (0.109) | | | | | |
| *Piracy* | | | | | | 0.188 | | | 0.703 | –0.059 |
| | | | | | | (0.122) | | | (0.288) | (0.051) |
| *Enf-GP* | | | | | | | | –0.208 | | |
| | | | | | | | | (0.141) | | |
| *Enf-USTR* | | | | | | | | –0.156 | | |
| | | | | | | | | (0.173) | | |
| Adjusted $R^2$ | 0.588 | 0.577 | 0.613 | 0.583 | 0.579 | 0.591 | 0.597 | 0.568 | 0.459 | 0.911 |
| Number of Observations | 41 | 41 | 41 | 41 | 41 | 40 | 41 | 38 | 19 | 21 |

Notes: *YL* denotes GDP per worker (in real 1985 US$) and LN denotes logarithms (base *e*).
$S_K$ is the physical capital investment rate; $S_R$ is the R&D capital investment rate, *NGD* is ($n + g + \delta$) (see text).
For definitions of IPR variables, see text or notes to Table 1.
All right-hand-side variables (except the constant C) are logged.
Heteroskedastic-consistent standard errors are in parentheses.
For values of *Parallel*, *Enf-GP* and *Enf-USTR*, a value of 1 was added to avoid taking logs of zero.

productivity growth from intellectual property protection or enforcement. However, piracy has significance almost at conventional levels (*p*-value of 0.071).

Because the number of observations is rather small, the IPR variables have been considered one at a time, so as not to lose many degrees of freedom. Also, a few IPR variables take on the value 0. Hence, before logging them, a value of 1 was added — ln($IPR + 1$). Since these variables are indexes, it is the ranking that matters. Absolute scores or values have no particular meaning.

However, the fact piracy has near significance induces one to look further. Thus, in columns 9 and 10, the 41-country sample is split between developed and less developed countries. Basically, the sample is sorted in descending order of GDP per worker, and then divided roughly in half. The results in column 9 show that piracy is contributing positively to the growth of less developed countries (LDCs). For this smaller sample, the output elasticities of physical and R&D capital are $\alpha = 0.42$ and $\beta = 0.13$, respectively. Likewise, the implied elasticity of output with respect to piracy is 1.72. (This is obtained from the fact that the estimated elasticity of technical efficiency with respect to IPRs is $\gamma = 3.82$ (0.703/0.184), while the elasticity of output with respect to piracy is $(1 - \alpha - \beta)\gamma$.) However, less than half the variation in the data is explained by the model (adjusted $R^2 = 0.459$). The model explains the data better for the richer half of the sample (adjusted $R^2 = 0.911$). The implied output elasticities of physical capital and R&D capital are lower ($\alpha = 0.26$ and $\beta = 0.11$). Thus, the less developed economies' output is more sensitive to resource accumulation, as might be expected. Another big difference is that parallel import protection stimulates growth in the richer half. Parallel import protection may matter less for LDCs because they have fewer innovative (and creative) outputs.

Given the weak direct effects of IPRs on growth, it is useful to look at some secondary or indirect benefits of IPRs via their effects on R&D. The first column of Table 5 shows the estimation results of the R&D equation for the 41-nation sample.[22] The model explains about 69 percent of the variation in R&D investment rates. As the theory predicts, the coefficient on the initial stock of R&D (as a ratio to GDP) is less than one, and is statistically significant at better than conventional levels. The patent rights index and the enforcement provisions are both significant at conventional levels. From these estimates, the implied R&D cost function elasticities are $\sigma_1 = 2.30$ and $\sigma_2 = 1.30$. Given the coefficient on *Pat4*, the implied elasticity of the appropriability function (with respect to patent rights) is $\mu = 1.90$. This implies that the appropriability function is convex. The ability to capture revenue increases with each *unit* increase in IPRs at an increasing rate. This implies that halfway measures are not very effective instruments for appropriation; starting from no protection to some halfway point of protection does not raise appropriability as much as going from that halfway point of protection to full protection of patent rights. Halfway measures leave much room still for imitation and infringement.

In column 2 of Table 5, the *Enf-GP* variable is replaced by *Enf-USTR*. This variable is statistically quite significant (*p*-value of 0.01). Its presence reduces the importance of *Pat4* (*p*-value rising to 0.057). Each of columns 3, 4 and 5 shows that copyright, trade-mark rights, and parallel importation individually contribute positively to R&D investment. But in effect, what are they

**TABLE 5**

**NATIONAL R&D EQUATION ESTIMATES**

| | Dependent Variable: LN($S_R$) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) |
| C | –9.565 | –8.077 | –9.732 | –9.871 | –8.601 | –9.555 | –8.829 | –0.645 | –8.140 | –8.950 |
| | (0.737) | (0.548) | (1.071) | (1.149) | (0.935) | (0.896) | (0.956) | (2.148) | (1.003) | (0.395) |
| *RDStock/GDP* | 0.232 | 0.167 | 0.277 | 0.303 | 0.272 | 0.266 | 0.284 | 0.182 | 0.149 | 0.184 |
| | (0.061) | (0.045) | (0.075) | (0.068) | (0.073) | (0.062) | (0.071) | (0.066) | (0.085) | (0.045) |
| *Pat4* | 1.464 | 0.866 | | | | 1.487 | | | 0.878 | 0.999 |
| | (0.264) | (0.439) | | | | (0.340) | | | (0.477) | (0.527) |
| *Copyrig* | | | 1.334 | | | –0.295 | | | | |
| | | | (0.605) | | | (0.689) | | | | |
| *Tmark* | | | | 1.175 | | 0.252 | | | | |
| | | | | (0.456) | | (0.480) | | | | |
| *Parallel* | | | | | 0.982 | 0.308 | | | | |
| | | | | | (0.439) | (0.429) | | | | |
| *Software* | | | | | | | 0.638 | 0.118 | | |
| | | | | | | | (0.263) | (0.280) | | |
| *Piracy* | | | | | | | | –1.601 | | |
| | | | | | | | | (0.409) | | |
| *Enf-GP* | 1.118 | | | | | | | | 0.939 | 0.509 |
| | (0.572) | | | | | | | | (0.658) | (0.475) |
| *Enf-USTR* | | 1.291 | | | | | | | 2.001 | 1.494 |
| | | (0.469) | | | | | | | (0.791) | (0.549) |
| Adjusted $R^2$ | 0.688 | 0.747 | 0.411 | 0.470 | 0.429 | 0.618 | 0.447 | 0.578 | 0.580 | 0.812 |
| Number of Observations | 41 | 38 | 41 | 41 | 41 | 41 | 41 | 39 | 17 | 21 |

Notes: All variables are defined in previous tables.
All right-hand-side variables (except for the constant term C) are logged.
Heteroskedastic-consistent standard errors are in parentheses.

picking up? Once patent rights are controlled for, these variables lose (statistical) significance, as the results in column 6 show. Patent rights remain a significant explanatory factor. This seems intuitive — namely, that for R&D, the legal variable that matters most is patent rights. Copyright, for any expressive aspects, or protections for trade names or symbols, seem to be a secondary element in the consideration of inventors.

In column 7, the software protection variable also helps to explain R&D, but as the results in column 8 show, once piracy is controlled for — as a proxy for actual experience — the software variable is insignificant. Piracy exerts a significant negative influence on national R&D investment.

Columns 9 and 10 show the results of splitting the sample again between poorer and richer nations. In the poorer economy sample, patent rights exert a weak influence on R&D. Lagged R&D knowledge stock also has a weak but positive influence on R&D investment (at conventional levels of significance). These variables do not vary as much in this sample. Since there are fewer past inventions, the stock of past R&D capital is small and similar in size. Piracy rates tend to be high and patent rights low. What little there is in the way of statutory patent protection has essentially no impact on the R&D activities of developing economies. The strengthening of enforcement in practice would have a much more important impact on R&D investment. Overall, the model explains 58 percent of the data.

In the richer economy sample, the model explains about 81 percent of the data. Both enforcement in practice and patent rights have the expected signs and are statistically significant explanatory factors. Thus, these two forms of IPRs have the strongest indirect effect on productivity growth, via their influence on R&D capital formation.

The fact that *statutory* patent provisions help stimulate R&D is of interest, since a common criticism of the statutory patent protection variable is that it does not measure *actual* practice. Here, the evidence seems to suggest that the laws on the books can stimulate R&D. This would be consistent with the idea that laws act as a *signal*. They might work by revealing something about the attitude of public authorities towards the protection of intellectual property and promote confidence among agents to invest in risky ventures like R&D.

## MANUFACTURING SAMPLE

THE REGRESSION ANALYSES ARE REPEATED for the manufacturing industries sample, and are reported in Tables 6 and 7. With 21 countries and 18 sectors in the sample, there are potentially 378 observations; however, for each sector, about 10-14 observations were actually available per sector.

The growth equation results differ somewhat from those of the national sample. Here, some of the IPR variables do have significant direct effects on productivity growth. In column 1 of Table 6, patent protection is seen to affect productivity directly. The implied elasticities are $\alpha = 0.43$, $\beta = 0.14$, and $\gamma = 4.5$ (1.606/0.357), indicating that the explanatory variables have larger effects in the manufacturing sample (in comparison to the aggregate, national sample).

The results in columns 2 and 3 show that copyright and trade-mark rights do not have any direct effect on growth. Column 4 results show that parallel importation has a negative effect on growth. This differs from the national sample (see Table 4, column 10). It appears that among manufacturing industries, parallel import protection might be establishing too much market power by, among other things, limiting the diffusion of new goods. This might explain why its effect on growth is negative. In column 5, software rights are seen to

**TABLE 6**

**MANUFACTURING GROWTH EQUATION ESTIMATES**

| | Dependent Variable: *Growth* = $LN(YL_{1995}) - LN(YL_{1980})$ | | | | | | |
|---|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) |
| C | 3.964 | 6.414 | 6.728 | 6.372 | 8.417 | 3.783 | 4.965 |
| | (1.008) | (0.948) | (0.940) | (0.878) | (0.862) | (0.876) | (1.311) |
| $YL_{1980}$ | –0.357 | –0.415 | –0.418 | –0.408 | –0.341 | –0.382 | –0.340 |
| | (0.067) | (0.071) | (0.071) | (0.070) | (0.064) | (0.064) | (0.068) |
| $S_K$ | 0.275 | 0.135 | 0.125 | 0.096 | 0.329 | 0.223 | 0.299 |
| | (0.092) | (0.099) | (0.099) | (0.102) | (0.101) | (0.088) | (0.096) |
| $S_R$ | 0.089 | 0.152 | 0.151 | 0.154 | 0.095 | 0.073 | 0.052 |
| | (0.021) | (0.022) | (0.022) | (0.022) | (0.020) | (0.019) | (0.019) |
| *NGD* | –0.287 | –0.284 | –0.314 | –0.268 | –0.391 | –0.316 | –0.368 |
| | (0.107) | (0.113) | (0.117) | (0.114) | (0.107) | 0.113) | (0.114) |
| *Pat4* | 1.606 | | | | | | 1.029 |
| | (0.254) | | | | | | (0.307) |
| *Copyrig* | | –0.121 | | | | | –0.518 |
| | | (0.375) | | | | | (0.503) |
| *Tmarks* | | | –0.380 | | | | –0.149 |
| | | | (0.332) | | | | (0.408) |
| *Parallel* | | | | –0.507 | | | –0.138 |
| | | | | (0.248) | | | (0.264) |
| *Software* | | | | | 0.447 | | 0.084 |
| | | | | | (0.217) | | (0.266) |
| *Piracy* | | | | | –0.827 | | –0.279 |
| | | | | | (0.162) | | (0.188) |
| *Enf-GP* | | | | | | 1.318 | 1.025 |
| | | | | | | (0.245) | (0.283) |
| *Enf-USTR* | | | | | | 1.855 | 0.887 |
| | | | | | | (0.293) | (0.377) |
| Adjusted $R^2$ | 0.517 | 0.406 | 0.409 | 0.415 | 0.508 | 0.553 | 0.612 |
| Number of Observations | 238 | 238 | 238 | 238 | 238 | 238 | 238 |

Notes: *YL* denotes real industrial output per worker in constant 1990 US$.
All other variables are defined in previous tables.
All right-hand-side variables (except for the constant term C) are logged.
Heteroskedastic-consistent standard errors are in parentheses.

affect productivity positively and significantly, while piracy rates are seen to affect it negatively and significantly. In column 6, the two enforcement variables are seen to affect productivity quite strongly.

When all eight IPR variables are entered together in the model (see column 8), it is patent protection, enforcement provisions and enforcement in

**TABLE 7**

**MANUFACTURING R&D EQUATION ESTIMATES**

| | Dependent Variable: *GROWTH* = LN($S_R$) | | | | | | |
|---|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) |
| C | 7.669 | 7.102 | 8.254 | 8.416 | 8.027 | 7.087 | 5.782 |
| | (0.860) | (1.025) | (0.714) | (0.596) | (0.735) | (0.781) | (1.099) |
| *RDStock/ GDP* | 0.789 | 0.803 | 0.808 | 0.807 | 0.794 | 0.771 | 0.773 |
| | (0.037) | (0.034) | (0.033) | (0.033) | (0.038) | (0.036) | (0.037) |
| *Pat4* | 0.612 | | | | | | –0.230 |
| | (0.260) | | | | | | (0.417) |
| *Copyrig* | | 1.209 | | | | | 1.465 |
| | | (0.498) | | | | | (0.891) |
| *Tmark* | | | 0.324 | | | | –0.537 |
| | | | (0.272) | | | | (0.532) |
| *Parallel* | | | | 0.384 | | | –0.080 |
| | | | | (0.240) | | | (0.345) |
| *Software* | | | | | 0.578 | | 0.343 |
| | | | | | (0.205) | | (0.341) |
| *Piracy* | | | | | –0.038 | | 0.071 |
| | | | | | (0.183) | | (0.290) |
| *Enf-GP* | | | | | | 1.038 | 0.845 |
| | | | | | | (0.310) | (0.344) |
| *Enf-USTR* | | | | | | 0.518 | 0.576 |
| | | | | | | (0.234) | (0.389) |
| Adjusted $R^2$ | 0.850 | 0.851 | 0.848 | 0.849 | 0.851 | 0.858 | 0.863 |
| Number of Observations | 265 | 265 | 265 | 265 | 265 | 265 | 265 |

Notes: All variables are defined in previous tables.
All right-hand-side variables (except for the constant term C) are logged.
Heteroskedastic-consistent standard errors are in parentheses.

practice that matter (directly to productivity growth). All other IPR variables, including software and parallel import protection, have less significance.

Table 7 presents the results of estimating the R&D equation for the manufacturing sample. In column 1, the implied R&D cost function elasticities are much higher: $\sigma_1 = 5.74$ and $\sigma_2 = 4.74$. The elasticity of the appropriability function is $\mu = 2.9$ (0.612/0.211), again showing a convex relationship between appropriability and patent rights. The model explains about 85 percent of the data.

Column 2 results show that copyright also matters for R&D, but again they may be picking up the effects of omitted variables: patent rights and enforcement. In columns 3 and 4, trade-mark rights and parallel import protection have weakly significant positive effects on R&D investment rates.

Column 5 focuses on the role of software protections (statutory rights and piracy). For this sample, software statutes are an important explanatory factor but variations in piracy rates do not explain variations in R&D. Piracy rates are relatively low and less varied in the OECD region. Column 6 once again shows that enforcement variables are strongly significant for R&D.

In column 7, when all eight IPR variables are entered together, only the two enforcement variables have explanatory power (in addition to the lagged stock of R&D to GDP). Unlike the national sample which aggregates all sectors, the signalling aspect of intellectual property *statutes* appears weaker in the manufacturing sector. What makes the manufacturing sector particularly different is worth examining further, but one possibility is that manufacturing R&D outputs might be of higher value than the national average (and thus very attractive to imitators). Thus, those intellectual assets are most worth fighting for, in which case the most essential kind of IPRs is enforcement — whether through litigation, settlement, injunctions, etc. Consequently, manufacturing R&D investment rates tend to be influenced most by IPR *enforcement* provisions and practice.

To summarize, in the national sample, patent rights and enforcement variables affect productivity growth *indirectly* via their effect on R&D capital accumulation; in the manufacturing sample, IPRs can affect growth *directly* and *indirectly*. In manufacturing, productivity is directly affected by patent statutes, enforcement provisions, and enforcement in practice; however, manufacturing R&D is not directly affected by intellectual property statutes (once enforcement factors are controlled for). The patent statutes variable on its own likely picks up the enforcement effects.

## SENSITIVITY TESTS

THUS FAR, ESTIMATION HAS BEEN BY THE OLS (ordinary least squares) method. The growth model assumes no correlation between the residual and the investment rates. Mankiw et al. (1992) provide defences for this. In the case of the R&D model, however, a legitimate concern is the potential endogeneity between R&D investment and IPRs. Ginarte and Park (1997), for instance, study the determinants of patent rights, among which is the R&D intensity of countries. The idea is that countries that conduct relatively more R&D have a greater incentive to provide and protect patent rights. Other important determinants of patent rights are output per worker and economic freedom. Thus, in Table 8, two-stage least square (2SLS) estimates of the R&D model are provided. The reduced-form equation, and hence the instruments for patent rights (the *Pat4* variable), include the constant term, the lagged stock of R&D (as a ratio of GDP), GDP per worker, and an index of economic freedom (see Gwartney and Lawson, 2002). In Table 8, column 1 presents the results for the

**TABLE 8**

**R&D EQUATION TWO-STAGE LEAST SQUARE ESTIMATES**

| | Dependent Variable: LN($S_R$) | |
|---|---|---|
| | (1) | (2) |
| C | –10.049 | 4.329 |
| | (0.853) | (2.051) |
| *RDStock/GDP* | 0.243 | 0.708 |
| | (0.069) | (0.062) |
| *Pat4* | 2.452 | 2.473 |
| | (0.545) | (0.986) |
| Adjusted $R^2$ | 0.566 | 0.821 |
| Number of Observations | 41 | 262 |
| Hausman $\chi^2(3)$ | 2.10 | 3.44 |
| [*p*-value] | [0.552] | [0.328] |

Notes: Column 1 presents the results for the national sample, and column 2 for the manufacturing sample. In each case, the instruments for *Pat4* include the constant term, the log of the ratio of *RDStock* to *GDP*, the log of the index of economic freedom (average for 1980-95), and the log of *GDP per worker* in 1980.
The index of economic freedom is obtained from Gwartney and Lawson, 2002.
Hausman $\chi^2(3)$ refers to the Hausman test-statistic (with three degrees of freedom) for testing the null hypothesis of exogeneity of *Pat4*.
All other variables are as defined previously.
Heteroskedastic-consistent standard errors are in parentheses.

national sample and column 2 for the manufacturing sample. For both the national and manufacturing samples (comparing column 1 of Table 8 to column 1 of Table 5, and comparing column 2 of Table 8 to column 1 of Table 7), the 2SLS estimates are similar for the lagged R&D stock variable, but the OLS method underestimates the impact of patent rights on R&D. However, as the Hausman test results indicate, the null hypothesis that *Pat4* is exogenous cannot be rejected.

Another possibility is that the errors from the two equations (growth and R&D) are correlated. Hence, Table 9 presents the results of estimating the two equations jointly with the SUR (seemingly unrelated regression) method. Columns 1 and 2 show the results for the national sample, and columns 3 and 4 for the manufacturing sample. Comparisons should be made to column 2 of Table 4, and column 1 of Table 5 (in the case of the national sample) and to column 1 of Table 6 and column 1 of Table 7 (in the case of the manufacturing sample). The results are fairly similar (except that the magnitude of the effect of R&D on growth is smaller in the SUR estimates of the national sample, and the statistical significance of the effect of *Pat4* on R&D is weaker in the SUR estimates of the manufacturing sample). The important result, though, is that

**TABLE 9**

**SUR ESTIMATES OF THE GROWTH-R&D SYSTEM OF EQUATIONS**

| | NATIONAL SAMPLE | | MANUFACTURING SAMPLE | |
|---|---|---|---|---|
| | DEPENDENT VARIABLE | | | |
| | *GROWTH* | LN($S_R$) | *GROWTH* | LN($S_R$) |
| | (1) | (2) | (3) | (4) |
| C | 4.413 | –9.840 | 3.949 | 7.666 |
| | (0.591) | (0.658) | (0.577) | (0.629) |
| $YL_{1980}$ | –0.303 | | –0.360 | |
| | (0.046) | | (0.041) | |
| $S_K$ | 0.416 | | 0.275 | |
| | (0.089) | | (0.083) | |
| $S_R$ | 0.079 | | 0.083 | |
| | (0.036) | | (0.021) | |
| *NGD* | –0.889 | | –0.291 | |
| | (0.211) | | (0.104) | |
| *RDStock/GDP* | | 0.284 | | 0.770 |
| | | (0.052) | | (0.025) |
| *Pat4* | 0.037 | 1.618 | 1.624 | 0.315 |
| | (0.114) | (0.289) | (0.217) | (0.297) |
| $R^2$ | 0.624 | 0.655 | 0.527 | 0.831 |
| Number of Observations | 41 | 41 | 238 | 238 |
| B.P. $\chi^2(1)$ | | 1.002 | | 0.356 |
| [*p*-value] | | [0.317] | | [0.551] |

Notes: Results in columns 1 and 2 are obtained from the national sample, and those in columns 3 and 4 from the manufacturing sample.
The dependent variable *Growth* and all other variables are as defined in previous tables.
B.P. $\chi^2(1)$ refers to the Breusch-Pagan test-statistic (with one degree of freedom) for testing the null hypothesis of independent equations (that the disturbance covariance matrix is diagonal).
Standard errors are in parentheses.

the Breusch-Pagan test for testing the null hypothesis of no correlation between the error terms of the two equations cannot be rejected.

## IMPLICATIONS FOR CANADA

IT IS NOT EASY TO GENERATE SPECIFIC ESTIMATES of the impact of IPRs on productivity for Canada since the estimates obtained thus far represent an *average* across industries and countries. To get country-specific estimates, time-series observations are needed (or a panel dataset) for two reasons: there is a limited number of manufacturing sectors per country per cross section of time (namely 18 at most), and the IPR variables do not vary by sector (or vary within a country). Thus, this sub-section focuses on the *average* cross-industry, cross-country estimates and evaluates Canada's productivity response to a strengthening of patent rights based on those estimates.

A large number of empirical results have been presented so far, but they all centre around two equations: the productivity growth equation and the R&D equation. The two can be combined [substitute the R&D equation (17) into the growth equation (9)] to obtain the sum of the direct and indirect effects of IPRs on productivity. Note that it would not be useful to calculate the effects of patent rights on the long-run productivity growth rate since, in these models, the long-run growth rate is pinned down by exogenous factors (such as the exogenous growth rate of technical efficiency, $g$, and the labour force growth rate, $n$). In other words, shocks to the growth rate will only be temporary. However, shocks can have permanent effects on the *level* of output per worker. Thus, the focus should be on the steady-state level of GDP per worker. From equation (9), let $\Delta \ln(Y/L) = 0$ and rearrange to obtain the following partial derivative:

$$\text{(18)} \quad \frac{\partial \ln(\frac{Y}{L})}{\partial \ln(IPR)} = \frac{\Omega_2}{-\Omega_0}\frac{\partial \ln(s_r)}{\partial \ln(IPR)} + \frac{\Omega_4}{-\Omega_0} = \frac{\Omega_2}{-\Omega_0}\eta_2 + \frac{\Omega_4}{-\Omega_0},$$

where, from equation (17), $\partial\ln(s_r)/\partial\ln(IPR) = \eta_2$. The last term on the right in equation (18) gives the direct effect of IPRs on long-run output per worker. The second last term gives the indirect effect (from the effect of IPRs on the R&D investment rate, and then the effect of the R&D investment rate on output per worker). The total effect or total value of the right side of equation (18) indicates the *elasticity* (the percentage by which long-run output per worker will increase per 1-percent increase in IPRs).

Using estimates from the manufacturing sample (from Table 6, column 1 and Table 7, column 1), the estimate of $\eta_2$ is 0.612, and the value of the right side of equation (18) is 4.64 (0.089*0.612/0.357 + 1.606/0.357). That is, a one percent strengthening of patent rights raises long-run GDP per worker by 4.64 percent, most of which is due to the direct effect of patent rights on productivity. That is, the direct effect dominates in magnitude.

Consider then an increase in Canada's level of patent rights by 0.33 points (from 2.50 to 2.83). This is equivalent to half the sample standard deviation of *Pat4* (see Table 1). For Canada, this change represents a 13.4 percent increase in the level of patent rights. Thus the steady-state manufacturing R&D investment rate is expected to increase by 12.2 percent (0.612*13.4) and long-run manufacturing GDP per worker to increase by 62.3 percent (4.64*13.4). Given that the sample period is 15 years, this long-term 62.3 percent increase in GDP per worker translates into a 3.28 percent annual rise in *trend* manufacturing output.[23] Now Canada's *potential* increase in long-run GDP could be higher or lower (since this estimate is based on *average* cross-country, cross-industry estimates). How well-off Canada is in relation to other nations depends on whether the change in patent rights is unilateral or whether other countries are strengthening their rights as well (see Park, 2000, for a study of the effects of patent reform on worldwide income distribution).

Now, the effect of this patent reform on Canadian GDP per worker *as a whole* (that is, on aggregate GDP per worker rather than on manufacturing GDP per worker) is smaller. From column 10 of Table 5, the estimate of $\eta_2$ is 0.999. Combining this with estimates from column 2 of Table 4, the overall elasticity (of long-run output per worker with respect to patent rights) is 0.345 (0.103*0.999/0.298, where the *direct* effect is ignored since it is not statistically significant). Hence, a half standard deviation increase in patent rights (which in Canada's case represents a 13.4 percent rise) should raise long-run GDP per worker by 4.63 percent (13.4*0.345) over a 15-year period (or an annual average increase of 0.3 percent). Thus, patent reform may potentially have a large impact on Canadian manufacturing but a modest effect overall on the Canadian economy.

## CONCLUSION

THERE IS MUCH CONTROVERSY about the effects of intellectual property rights on economic growth and development. Theoretical analyses can and have shed light on the mechanics or principles by which IPRs affect innovation, productivity and welfare. Eventually, however, empirical work is needed to test some of the assumptions made in the theoretical models, or to estimate some of the functional relationships specified therein. Yet, empirical work lags considerably behind theoretical work in the field of IPRs. Thus, policymakers faced with making choices under uncertainty and imperfect information have very little empirical evidence on which to base their decisions.

A specific policy issue (or option) confronting Canada in the near future is whether to admit newer forms of technologies as patentable subject matter, for example innovations in the areas of business methods, online (e-commerce) transactions, biotechnology, finance, databases, etc. Canada is confronted with this issue because as these new types of innovations emerge, decisions have to be made as to whether to recognize them as inventions. Yet, even if they fit the definition of inventive material, is intellectual property rights protection over them sensible? Several of Canada's trading partners (such as the United States, Japan and Europe) have proceeded to recognize some or all of these innovations as inventions and are providing IP protections. Should Canada follow their example? Will failure to do so disadvantage Canada in terms of competitiveness, innovation and standard of living?

These are challenging questions. The present study has sought to help fill some gaps in empirical work, to provide *pieces* of evidence that can be put together with previous and new research in order to assess the economic effects of IPRs. Using two separate samples of data and various indexes of IPRs, the study examined the extent to which different kinds of IPRs can affect the technical efficiency of production and the rate of R&D capital formation.

In the 41-nation sample, the results show that IPRs do not stimulate productivity growth directly, but do indirectly by stimulating R&D investments. What matters most about IPRs are the mechanisms for enforcement and the level of enforcement effectiveness, rather than the substantive provisions alone (patent rights, software rights, copyright, etc.). However, for the richer subset of the 41-nation sample, substantive patent rights do matter, even after controlling for enforcement effectiveness. In the manufacturing sample, IPRs contribute to productivity growth directly and indirectly by stimulating R&D. But again, different kinds of IPRs matter. Patent protection and enforcement are important for raising the technical efficiency of production, while it is the enforcement component that primarily explains R&D investments. Other kinds of IPRs (e.g. copyright, trade-marks, parallel import protection, software and piracy) matter when examined individually (without other IPR variables), but they would then be picking up the effects of omitted variables (namely enforcement levels). That is, once patent rights and/or enforcement levels are controlled for, copyright and trade-marks have no statistically significant effect on productivity growth. Thus, the results indicate on balance that IPRs — particularly those governing the enforcement of those rights and their execution — contribute significantly to productivity growth.

A related point is that the *kinds* of IPRs targeted by policy do matter. IPRs should not be treated as a homogenous (unidimensional) concept. Of the different kinds of IPRs, it is (perhaps expectedly) patent protection and enforcement levels that are conducive to R&D activity and productivity. It is instructive to note that software rights are not significant once patent rights and enforcement are controlled for. Thus, in view of the recent policy debate about what to do in response to changing technological developments (related to the Internet, the computer information age, and so forth), these results might suggest that it is not so much the protections aimed at emerging areas that matter but rather the age-old concern with effective enforcement and implementation of laws, particularly for patent rights as traditionally understood.

Overall, there are several areas where this research could be extended:

1) The first would be to examine copyright and trade-mark-related *output*. The results show that R&D is patent-sensitive, rather than copyright-, trade-marks-, or other IP-sensitive. This does not imply that copyright, trade-marks or other non-patent IP instruments do not matter for *other*

valuable economic activity. Thus, future work could explore other types of economic activity (in other words, possible left-hand-side variables other than R&D) that might be more specifically a function of copyright or trade-mark rights; for example, promotion, marketing and advertising investments, education, community development and cultural activities.

2) It would also be useful to obtain time-series observations on non-patent IPRs [as was done with the Ginarte and Park (1997) patent rights index]. This will require looking back through legislative history to identify changes in statutes, and studying past reports or documentation about actual experiences. Having a time-series dimension would allow for a panel data analysis. With more observations, one could estimate the growth and R&D models industry by industry. In this study, with just a cross-sectional dimension and about 10 to 14 observations per industry, it was difficult to provide industry by industry results, and determine which type of industry would be more dependent on IPRs.

3) Another useful extension would be to construct measures of *effective* intellectual property by industry. In principle, IP laws vary by country but do not vary by industry within a country, except in coverage (for example, a country may not provide protection for biotechnological innovations, surgical methods, pharmaceuticals or software). By excluding certain patentable subject matter, the legislation does provide a tacit amount of preferential protection across sectors. But in theory, IPR laws are national in scope. However, in practice, there are important inter-industry differences in the level of IPRs that firms can enjoy, and they are measurable. This is important because different kinds of inventions may require different levels of protection for the inventors to recoup their R&D costs. For some inventions, existing rights may be too weak (say for chemical inventions), while for others they may be too strong (say for business methods). For example, the 20-year patent protection period may be sufficient for certain types of innovations for purposes of recouping costs, but may be inadequate for others (due, say, to a lengthy marketing approval process which consumes many years of the 20-year patent duration). Another reason why firms in different industries may enjoy different *effective* levels of IP protection is that the process for obtaining rights and enforcing them may differ. For example, due to differences in technological complexity, firms in some industries may take longer to obtain a patent. The search and examination process may be more involved so that patent *pendency* is longer. It may also be more difficult to detect and prove infringement, and thus enforce property rights, in certain technological fields. The ability to procure and enforce IP rights may also be a function of the degree of competition in the sector.

4) Finally, it would be useful to estimate the *costs* of strengthening intellectual property rights and enforcement (e.g. infrastructure costs, cost of rewriting and implementing new legislation). This study focused on estimating the *benefits* of strengthening intellectual property protection in terms of the contribution of IPRs to overall national and manufacturing productivity growth. A remaining issue concerns the *returns* to such a policy — the cost of increased IP enforcement vs. the potential productivity gains.

## APPENDIX A

### INTELLECTUAL PROPERTY RIGHTS – SUMMARY OF CRITERIA AND MEASUREMENT

THIS APPENDIX REVIEWS THE KEY CRITERIA under each type of IPR index and the method for scoring the strength of protection. It is likely that no one index captures the overall nature of IP protection in a region; but together, the various indexes should provide a general picture.

### *PAT4*

THIS IS THE INDEX OF PATENT RIGHTS without the enforcement category. The original index has five categories (including enforcement). The remaining four categories are:

| | | |
|---|---|---|
| (1) Membership in International Treaties | Signatory | Not Signatory |
| – Paris Convention and Revisions | 1/3 | 0 |
| – Patent Cooperation Treaty | 1/3 | 0 |
| – Protection of New Varieties (UPOV) | 1/3 | 0 |
| (2) Coverage | Available | Not Available |
| – Patentability of Pharmaceuticals | 1/7 | 0 |
| – Patentability of Chemicals | 1/7 | 0 |
| – Patentability of Food | 1/7 | 0 |
| – Patentability of Plant and Animal Varieties | 1/7 | 0 |
| – Patentability of Surgical Products | 1/7 | 0 |
| – Patentability of Micro-organisms | 1/7 | 0 |
| – Patentability of Utility Models | 1/7 | 0 |
| (3) Restrictions on Patent Rights | Does Not Exist | Exists |
| – "Working" Requirements | 1/3 | 0 |
| – Compulsory Licensing | 1/3 | 0 |
| – Revocation of Patents | 1/3 | 0 |
| (4) Duration of Protection | Full | Partial |
| | 1 | $0 < f < 1$ |

where $f$ equals the duration of protection as a *fraction* of the full (potential) duration. Full duration is either 20 years from the date of application or 17 years from the date of grant (for grant-based patent systems).

### *COPYRIG*

THIS IS AN INDEX OF COPYRIGHT, based on statutory provisions:

| | | |
|---|---|---|
| (1) Membership in International Treaties | Signatory | Not Signatory |
| – Berne Convention | 1/4 | 0 |
| – Rome Treaty | 1/4 | 0 |
| – Universal Copyright Convention | 1/4 | 0 |
| – Phonogram Convention | 1/4 | 0 |
| (2) Coverage | Available | Not Available |
| – Literary, Dramatic, Artistic, ... | 1/5 | 0 |
| – Performance Rights | 1/5 | 0 |
| – Sound Recordings | 1/5 | 0 |
| – Cinema | 1/5 | 0 |
| – Broadcasting | 1/5 | 0 |
| (3) Restrictions on Copyright | Does Not Exist | Exists |
| – Limit Re-sale (droit de suite) | 1/4 | 0 |
| – Extended (collective) | | |
| Licensing Schemes | 1/4 | 0 |
| – Compulsory Licensing: | | |
| Government Use | 1/4 | 0 |
| Private Use | 1/4 | 0 |
| (4) Duration of Protection | Full | Partial |
| – Literary, Dramatic, Artistic, ... | 1/4 | $0 < f < 1/4$ |
| – Performance Rights | 1/4 | $0 < f < 1/4$ |
| – Sound Recordings | 1/4 | $0 < f < 1/4$ |
| – Cinema | 1/4 | $0 < f < 1/4$ |

where $f$ equals the duration of protection as a *fraction* of the international standard of 50 years, times 1/4. The duration of protection varies by kind of work covered. Each kind has equal weight in the overall duration score. If the duration of a work exceeds the 50-year norm, a maximum score of 1/4 is assigned.

### *TMARK*

THIS IS AN INDEX OF TRADE-MARK RIGHTS, based on statutory provisions:

| | | |
|---|---|---|
| (1) Membership in International Treaties | Signatory | Not Signatory |
| – Madrid Treaty | 1/3 | 0 |
| – Nice Treaty | 1/3 | 0 |
| – Paris Convention | 1/3 | 0 |
| (2) Coverage | Available | Not Available |
| – Service Marks | 1/3 | 0 |
| – Certification Marks | 1/3 | 0 |
| – Collective Marks | 1/3 | 0 |
| (3) Restrictions on Trade-mark Rights | Does Not Exist | Exists |
| – Renewal Proof of Use | 1/4 | 0 |
| – "Linking" Requirements | 1/4 | 0 |
| – Restricted Licensing | 1/4 | 0 |
| – Lack of Protection for Well-known Marks Due to Non-use | 1/4 | 0 |
| (4) Duration of Protection | Full | Partial |
| | 1 | $0 < f < 1$ |

where $f$ equals the duration of protection as a *fraction* of the full duration (of 10 years, the international norm).

### *PARALLEL*

THIS REFERS TO 'PARALLEL IMPORT' PROTECTION for intellectual property (books, computer programs, phonograms, videos, etc.), as rated by the International Intellectual Property Alliance (1998).

The index = 1 if YES, country provides parallel import protection,
0.5 if PROBABLY YES,
0 if NO.

### *SOFTWARE*

THIS INDEX MEASURES the intellectual property protection for software. The patent and copyright indexes above do not explicitly include software in their coverage category. Hence, a special index can be created for this particular type of innovation or creative expression (and/or as an extension to the indexes above).

Software rights can be protected by three sources: (a) trade secrecy; (b) patent; and (c) copyright. Thus,

$$\text{Software index} = \underset{(x_1)}{\text{trade secret}} + \underset{(x_2)}{\text{patent}} + \underset{(x_3)}{\text{copyright}},$$

where $x_1 = 1$ if trade secrecy protection exists (0 otherwise);
$x_2 = 1$ if patent protection exists for software, 0.5 if partial protection exists, and 0 otherwise; and
$x_3 = 1$ if copyright exists for software, 0.5 if partial protection exists, and 0 otherwise.

Information on software patent and copyright provisions is contained in *International Computer Law* (Matthew Bender, 1999), Chapter 3B. Information on trade secret protection is contained in Hemnes, DiMambro and Moore (1992).

### *PIRACY*

THESE ARE AVERAGE RATES of computer software piracy in 1994, estimated by the Business Software Alliance and Software Publishers Association (1996). The number of pirated copies is estimated to be the difference between the estimated number of software installations and the estimated number of software shipments. The piracy rate is then the number of pirated copies as a fraction of software installations.

### *ENF-GP*

THIS IS THE ENFORCEMENT CATEGORY of the Ginarte and Park (1997) index, as separated from the aggregate index. Since the same enforcement features are available for patent rights enforcement as well as for other types of intellectual property rights enforcement, it is useful to look at this category as a separate index. This index can represent the statutory provisions for enforcing IPRs.

| Enforcement | Available | Not Available |
|---|---|---|
| – Preliminary Injunctions | 1/3 | 0 |
| – Contributory Infringement | 1/3 | 0 |
| – Burden-of-proof Reversal | 1/3 | 0 |

### *Enf-USTR*

THIS INDEX IS A QUALITATIVE MEASURE of the effectiveness of IPR enforcement in practice. It is based on reports filed with the United States Trade Representative documenting the experience of IP enforcement in countries outside the United States.

The reports describe complaints, if any, about enforcement procedures and/or about the failure of the proper authorities to carry out the laws on the books. The failure to enforce may be due to some inability on the part of authorities to carry out those laws or to a conscious policy choice. The absence of substantive laws (other than enforcement provisions) is already incorporated in the previous indexes, and thus complaints about the lack of substantive laws are not incorporated here. Thus, the index is given by:

*Enf-USTR* = 0 if enforcement measures are not available or are inadequate (e.g. weak deterrents);
0.5 if enforcement measures are available but not effectively carried out (due to lag in policy implementation or resource barriers);
1 otherwise.

## APPENDIX B

### MANUFACTURING INDUSTRIES SAMPLE

**TABLE B-1**

**LIST OF COUNTRIES IN THE SAMPLE**

| | | |
|---|---|---|
| Australia | Germany | New Zealand |
| Austria | Greece | Norway |
| Belgium | Italy | Portugal |
| Canada | Japan | Spain |
| Denmark | Korea | Sweden |
| Finland | Mexico | United Kingdom |
| France | Netherlands | United States |

**TABLE B-2**

**LIST OF INDUSTRIES IN THE SAMPLE (FOR EACH COUNTRY)**

| SECTOR | LINE NUMBER FROM: STAN DATABASE | DSTI DATABASE |
|---|---|---|
| 1. Food, Beverages, Tobacco | 3100 | 04 |
| 2. Textiles, Apparel, Leather | 3200 | 07 |
| 3. Wood Products & Furniture | 3300 | 12 and 40 |
| 4. Printing & Paper Products | 3400 | 13 and 14 |
| 5. Chemicals (non-drugs) | 3512x | 18 |
| 6. Chemicals (drugs) | 3522 | 19 |
| 7. Petroleum | 3534A | 16 |
| 8. Rubber & Plastics | 3556A | 20 |
| 9. Non-metallic Mineral Products | 3600 | 21 |
| 10. Metals: Iron & Steel | 3710 | 23 |
| 11. Metals: Non-Ferrous Metals | 3720 | 24 |
| 12. Fabricated Metal Products | 3800 | 25 |
| 13. Office & Computing Equipment | 3825 | 28 |
| 14. Radio, TV, & Communication Equipment | 3832 | 32 |
| 15. Electrical Apparatus (excl. communication equip.) | 383X | 29 |
| 16. Shipbuilding | 3841 | 36 |
| 17. Motor Vehicles | 3843 | 34 |
| 18. Aircraft | 3845 | 37 |

Notes: STAN is the OECD Industrial Activity Database.
DSTI is the OECD Science & Technology Indicators Database.

## ENDNOTES

1 See *IP Policy Initiatives*, www.strategis.ic.gc.ca.
2 Other kinds of IPRs (not explicitly treated in this study) are trade secret protection, geographic indications, industrial designs, etc.
3 Here, for simplicity, IPRs and the legal environment are held constant.
4 That is: $\alpha = \Omega_1/(-\Omega_0 - \Omega_3)$, $\beta = \Omega_2/(-\Omega_0 - \Omega_3)$, and $\gamma = -\Omega_4/\Omega_0$.
5 See also Howe and McFetridge (1976) for a model of R&D expenditure behaviour. The underlying basis is similar: investment in R&D proceeds to the point at which the marginal rate of return to R&D equals the marginal cost of funds.

6 An equivalent way to model the decision problem is to posit an aggregate (representative) firm that behaves competitively and maximizes equation (10) subject to equation (3).

7 In this specification, neither the variety nor the quality of products resulting from R&D (or inventive) activity is explicitly treated.

8 A comparable specification is found in Romer (1986), except that knowledge spillovers occur in the production function. A firm's investment generates learning by doing (which affects the future marginal productivity of capital). As in this model, knowledge spillovers operate at the economy-wide (or sector-wide) level.

9 With constant returns to scale (i.e. $\sigma_1 - \sigma_2 = 1$), $\eta_1 = (\sigma_1 - 2)/(\sigma_1 - 1)$. Thus, $\sigma_1 = (2 - \eta_1)/(1 - \eta_1)$, $\sigma_2 = 1/(1 - \eta_1)$, and $\mu = \eta_2 /(1 - \eta_1)$.

10 A further distinction might be made between incumbent and entrant. The indexes tend to measure the strength of existing rights holders. For example, if existing IP owners exercised a very broad scope over their rights, the laws may make it difficult for new inventors to obtain intellectual property protection. This might be interpreted as a failure on the part of the system to provide intellectual property rights to entrants. However, this distinction is not pursued here. Perhaps the solution is to develop different indexes for different classes of inventors and creators.

11 For example, incorporating *derivative works* adds no variability because all countries in the sample provide protection for these works in their copyright laws.

12 For instance, only few countries specify the level of punishment or penalties for IP violations (length of sentences, amount of fines, etc.). Most countries indicate that infringement can be punishable as a civil or criminal offence, but are not explicit enough to allow for comparisons of punishment levels across countries.

13 The authors obtained information on national patent laws from Baxter (2000) and WIPO (2000).

14 Since all jurisdictions with trade-mark laws allow words, names, symbols, devices, or any combination, to be trade-marked, it was not necessary to list these under the coverage category. In some cases, colour, sounds, fragrances, or 3-dimensional objects can be registered, but cross-country variations in the protection of these are small.

15 For a further discussion of the welfare effects of parallel import protection, see Maskus, 2000.

16 For example, the murder rate is highest in the United States. But this does not necessarily indicate that criminal law enforcement in that country is the weakest in the world.

17 Because the sample period is relatively short, $\iota = 0$ is assumed if this method produces negative values for $\iota$.

18 To obtain 1995 GDP figures, GDP growth rates from the *Development Indicators* were used to extrapolate the 1992 figures taken from the *Penn World Tables*.

19 More specifically, a weighted average of manufacturing GDP, where the weights are the shares of each manufacturing industry in total manufacturing output.

20 At least the two enforcement variables are not negatively correlated, which would mean that countries with strong laws on the books are the ones that least carry out their laws.

21 For the variable $NGD = \ln(n + g + \delta)$, the exogenous technical efficiency growth rate is assumed to be 2 percent ($g = 0.02$), as in Mankiw et al. (1992), and $\delta = 10$ percent.

22 The value of the left-hand-side variable is the average for 1987-95, while the value of the stock of R&D to output is for 1987.

23 Let $x$ be the annual (average) trend rate of increase. Then $(1 + x)^{15} = 1 + 0.623$, so that $x = 0.0328$, or 3.28 percent.


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## BIBLIOGRAPHY


Baxter, J.W., J.P. Cent, J.M. Sinnott and W.J. Cadre (eds.). 2000. *World Patent Law and Practice*. New York: Matthew-Bender.

Bessen, James, and Eric Maskin. 2000. *Sequential Innovation, Patents, and Imitation*. Working Paper No. 00-01. Cambridge, MA: Massachusetts Institute of Technology, Department of Economics.

Business Software Alliance and Software Publishers Association. 1996. *1995 Software Piracy Survey*. Washington, D.C.

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

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

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

Gould, D., and W. Gruben. 1996. "The Role of Intellectual Property Rights in Economic Growth." *Journal of Development Economics* 48: 323-350.

Gwartney, James, and Robert Lawson (with W.G. Park and C. Skipton) (eds.). 2002. *Economic Freedom of the World Annual Report*. Vancouver, B.C.: Fraser Institute.

Helpman, Elhanan. 1993. "Innovation, Imitation, and Intellectual Property Rights." *Econometrica* 61, 6: 1247-1280.

Hemnes, T.M., M.G. DiMambro and M.L. Moore (eds.). 1992. *Intellectual Property World Desk Reference: A Guide to Practice by Country, State, and Province*. Boston, MA: Kluwer Publishers.

Howe, J.D., and D.G. McFetridge. 1976. "The Determinants of R&D Expenditures." *Canadian Journal of Economics* 9: 57-71.

International Intellectual Property Alliance. 1998. "Parallel Import Protection in 107 elected Countries." *Conference on Exhaustion of Intellectual Property Rights and Parallel Importation in World Trade*. Geneva: International Trade Law Association.

Korenko, George G. 1999. "Intellectual Property Protection and Industrial Growth." *Journal of World Intellectual Property* 2, 1: 47-75.

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

——. 1989. "An Economic Analysis of Copyright Law." *Journal of Legal Studies* 30: 265-309.

Leaffler, Marshall A. (ed.). 1997. *International Treaties on Intellectual Property*. 2nd ed. Washington, D.C.: The Bureau of National Affairs Inc.

Levin, R., A. Klevorick, R. Nelson and S. Winter. 1987. "Appropriating the Returns from Industrial Research and Development." *Brookings Papers on Economic Activity* 3: 783-820.

Lichtenberg, Frank R. 1987. "The Effect of Government Funding on Private Industrial Research and Development: A Reassessment." *Journal of Industrial Economics* 36: 97-104.

Mankiw, G., D. Romer and D. Weil. 1992. "A Contribution to the Empirics of Economic Growth." *Quarterly Journal of Economics* 107: 407-437.

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

Park, Walter G. 2000. *International Patenting, Patent Rights, and Technology Gaps.* Working Paper, American University, Department of Economics, Washington, D.C.

Park, Walter G., and Juan Carlos Ginarte. 1997. "Intellectual Property Rights and Economic Growth." *Contemporary Economic Policy* 15: 51-61.

Park, Walter G. and Smita Wagh. 2002. "Index of Patent Rights." In *Economic Freedom of the World Annual Report*, James Gwartney and Robert Lawson (eds.). Vancouver, B.C.: Fraser Institute.

Romer, Paul M. 1986. "Increasing Returns and Long-Run Growth." *Journal of Political Economy* 94, 5: 1002-1037.

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

Siwek, Stephen E. 2000. *Copyright Industries in the U.S. Economy: 2000 Report*. Prepared for the International Intellectual Property Alliance. Washington, D.C.: Economist Incorporated.

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

Taylor, M. Scott. 1994. "Trips, Trade, and Growth." *International Economic Review* 35, 2: 361-381.

UNESCO. Various issues. *Statistical Yearbook*. Paris.

United States Trade Representative (USTR). *National Trade Estimates: Report on Foreign Trade Barriers*. Washington, D.C.: Office of the United States Trade Representative <serial>, 1987-1995.

World Intellectual Property Office (WIPO). 2000. *IPLEX CD-ROM (Legislative Texts in the Field of Intellectual Property)*. Geneva.

## OTHER REFERENCES

Geller, Paul E. (ed.). 2000. *International Copyright Law and Practice*. New York: Matthew-Bender Publications.

Horowitz, Ethan (ed.). 2000. *World Trademark Law & Practice, vols. A, B*. New York: Matthew Bender Publications.

Louwers, Ernst-Jan, and Corien E.J. Prius (eds.). 1999. *International Computer Law*. New York: Matthew-Bender Publications.

UNESCO. 2000. *Copyright Laws and Treaties of the World*. Paris.