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DOES INTELLECTUAL PROPERTY PROTECTION SPUR TECHNOLOGICAL CHANGE?

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Abstract

Of the diverse factors motivating technological change, one factor that has received increasing attention in the recent past has been the protection of intellectual property rights. Given fairly recent changes in the international policy ethos where a regime of stronger intellectual property protection has become a *fait accompli* for most developing countries, it is of some significance to ask whether more stringent protection of intellectual property does indeed encourage innovation. And this is the question which this paper examines, utilising cross-country panel data on R&D investment, patent protection and other country-specific characteristics spanning the period 1981-1990. The evidence unambiguously indicates the significance of intellectual property rights as incentives for spurring innovation.

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Does Intellectual Property Protection spur Technological Change?

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A distinctive characteristic of modern economic growth has been the significant role played by technological change. Of the diverse factors motivating technological change, one factor that has received increasing attention in the recent past has been the role of intellectual property protection. Given the shift in the ownership distribution of innovations away from individuals and towards large corporations in 'recent decades'[1], intellectual property protection has arguably become an even more important stimulus than hitherto; for such protection augments both the means and the incentive to undertake expensive innovation. While there has been an on-going debate on whether strong(er) intellectual property protection encourages or retards the rate of technological change and, by implication, that of economic growth, policy-makers have in any case moved towards a regime of stronger intellectual property protection in recent times, as evidenced by the agreement on Trade Related Intellectual Property issues (TRIPs) under the GATT-WTO[2] in April 1994.

That the inventor be given protection for his invention was a principle recognized as early as the fifteenth century, when the very first patents were granted by the city state of Venice. The motives cited were the natural right of the inventor to the fruits of his labour, the benefits accruing therefrom to society at large, society's compensation (therefore) of the costs incurred by him, and the fillip this would provide to inventive propensities (Mandich, 1948). This is not to imply, however, that opposition to such protection did not also exist right from the early times. Some argued even then, for instance, that such protection mimicked prohibitive tariffs (insofar as the protected products could not be imported freely, hindering trade) and ought not to be granted (Schiff, 1971)[3]. That this issue has continued to remain controversial into the present times would be understating the case; one of the important reasons for this being the lack of cumulative empirical evidence. Evenson (1990) categorises the attempts to examine the incentive effects of IPRs on innovation into two - studies of (firm) behaviour (see the following section; references in Evenson 1990; Lanjouw and Cockburn 2000; and Sakakibara and Branstetter 2001), and studies on the intrinsic value of protection (see the references cited in Evenson 1990; and Schankerman 1998). To these categories we may add (or else widen the first category to include) attempts to estimate aggregate or economy-wide response (Gould and Gruben 1996). The evidence is thin and mixed, to say the least. Evenson himself opines that the (weak) evidence "... does not imply that intellectual property rights are of little value as inducements to innovate. It attests to the relevance of the process of imitation".

This paper seeks to analyse empirically the influence that intellectual property protection might have on innovation and technological change. We study this relationship at the economy-wide level, using cross-country data on the strength of intellectual property rights, technological change and other relevant country-specific controls. Our evidence shows unambiguously, that intellectual property protection (proxied by an index of patent rights) has a strong positive effect on technological change (proxied by R&D investment expenditures), and therefore on economic growth. This has obvious implications for developing countries, which have been confronted by an international policy ethos favouring the strengthening of intellectual property rights under the recent TRIPs agreement almost as a *fait accompli*. We provide some evidence that conforming with the agreement may not be fruitless in the longer run. Of course, needless to add, the strengthening of IPRs must occur not just on the statute books but in reality. Only then would stronger IPRs provide the right incentives for innovation.

Section 2 briefly considers the pros and cons of weak protection versus strong protection in the global context, and the implications this might have for the relation between intellectual property protection and technological change. Section 3 delineates the estimation model. Section 4 briefly discusses the data and samples used for estimation, and the appropriate estimation procedure in our context. Section 5 then presents the estimation results while section 6 outlines some broad conclusions.

Strong protection or Weak protection?

When considering the process of technological change, two important characteristics of innovations ought to be kept in mind. First, innovations are non-rival goods. That is, use of a particular innovation by a producer does not preclude other entrepreneurs from using it. Second, innovations are partially non-excludable goods. This implies that the innovator is often unable to completely prevent others from unauthorisedly using the innovation (Romer, 1990). It is these two properties of innovations that form the basis of the argument in favour of intellectual property protection, which serves to decrease the degree of non-excludability of innovations by assigning to the inventor the property rights over his innovation for a given period of time. How strong should the protection given be, however, is a difficult and complex question to settle in practice. We briefly discuss below the various arguments for and against the strong protection of intellectual property.

Arguments favouring weak protection

One of the more obvious benefits supposed to accrue from the weak protection of intellectual property (as in developing countries), is to keep the market prices (of products made from or using protected technology) low. Second, a related positive is claimed to be the cheap acquisition of technology. Underlying these arguments appear to be the suppositions that protected products have no close substitutes or competition, that the menu of products available would be the same irrespective of the protection regime (i.e. strong or weak), and that there are no offsetting costs to the countries in question (Sherwood, 1990). Third, there are several instances of patent abuse involving inadequate disclosure in developing countries, where important bits of knowledge have been withheld from the patent applications, without which even those skilled in the art would not be able to replicate the inventions after the expiry of the patent (Roffe, 1974). Fourth, strong protection, by creating a monopoly, may induce the producer to accumulate 'sleeping patents' in an effort to preserve market share (Gilbert and Newbery, 1982). In which case, strong protection will only serve to limit the rate of technological change. Although, whether a producer would want to preserve market share with *extant* technology would depend upon whether or not he can do better by innovating (Park, 1997).

In a global context, Deardorff (1992) demonstrates that as patent protection spreads (to developing countries, for instance), the gains from protection in the form of monopoly profits to inventors taper off as diminishing returns set in, and at some point could fall short of the costs arising from distorted consumer choice due to monopoly pricing. Again, Chin and Grossman (1990) show that the globally efficient degree of protection may not be evenly welfare-maximising. Thus, in the South or innovation-importing countries, welfare may be negative. Grossman and Helpman (1991) show that stronger protection (or production subsidies) would cause the global rate of technical innovation to fall. Finally, Helpman (1993) shows that strong protection will increase the rate of innovation only in the short term as it raises profitability; in the long term it lowers the innovation rate as the producers tend to produce the older products.

Arguments favouring strong protection

On the other hand, there is evidence which suggests that strong protection stimulates innovative activity, at least in some industries such as pharmaceuticals and chemicals. Thus, Levin et.al. (1987), in a survey of 650 American R&D executives who had been asked to rank order alternative means of protecting products and processes across 130 industries, found that for the pharmaceuticals and chemicals industries the executives placed great emphasis on patent protection. This result is supported by Mansfield (1986), who questioned a hundred R&D executives across different U.S. industries about what percentage of their inventions over the period 1981-1983 would not have been made had it not been for the availability of patents. The survey responses revealed that 60% of the inventions in pharmaceuticals and about 40% in chemicals would not have been developed in those circumstances (see Evenson 1990 for a summary of similar evidence). This evidence is in consonance with Segerstrom (1991) who shows that government incentives to innovation unambiguously increase inventive intensity, although welfare increases only if innovation intensity exceeds a threshold. It is not, however, necessarily in agreement with Segerstrom, Anant and Dinopoulos (1990), who show that stronger protection may either increase or lower inventive activity.

Second, 'strong' protection is often necessary because even with this ‘strong’ protection competition begins to gnaw away the profits fairly quickly. Lesser (2000) notes that the commercial life of a new (crop) variety in the U.S. is only about 7 years and has been declining due to competition (and is not the statutory 20 years). Mansfield (1985), using a survey of 100 U.S. firms spanning 13 manufacturing industries, reports that the average time lapse till the point where information on new products or processes is leaked to rival firms was only about a year for products and 15 months for processes.

Third, foreign direct investment and the transfer of technology from the North to the South may be adversely affected, at least in certain industries, if adequate protection is wanting in the South. Taylor (1993, 1994) shows that weak protection in the South (to facilitate unintended technology transfers, for instance), would evoke a defensive response from inventors in the North, which may ultimately eliminate the gains from weak protection. Lai (1998) qualifies this statement by showing that the relationship between protection (in the South) and innovation (in the North) depends on whether imitation or ‘multinationalization’ (i.e. foreign direct investment) is the mode of international production transfer. If imitation is the mode of production transfer, stronger protection will lower the rate of innovation and the rate of technology transfer; but if multinationalization is the channel, the effect on innovation and the rate of technology transfer from the North to the South will be just the opposite. Diwan and Rodrik (1991) demonstrate that when the structure of demand in the South differs markedly from that in the North, (strong) protection in the South will stimulate invention (in the North), leading to net gains for the South. By implication, given the existence of considerable taste differentials between developing and developed countries (as in pharmaceutical and agricultural products), the South may lose considerably by not granting adequate protection.

Fourth, strong protection by the South may be necessary if it is to prevent rampant piracy of intellectual property and consequent retaliation by the North (for some piracy estimates see Gadbaw and Richards 1988). It was the loss of this potential profit which originally motivated the North (particularly the United States) to bargain hard to bring intellectual property issues within the purview of the GATT/WTO; for the dispute settlement mechanism in this forum was reasonably effective, whereas there was no such mechanism in the WIPO[4] (Sherwood, 1990). Moreover, by linking intellectual protection with trade, the North gained insofar as it could use trade sanctions to counter piracy[5]. This can be prevented, however, if the root cause of piracy - namely, weak protection - is remedied.

Thus, we find that a host of arguments can be adduced for and against the strong protection of intellectual property rights. From the arguments per se and the empirical evidence, one is hard put to decide on the appropriate degree of protection. Nor is the theoretical literature much help in this regard. It is the purpose of this paper, therefore, to empirically examine the relationship between intellectual property protection and the rate of technological change.

The Estimation Model

In doing so we do not wish to deduce the relationship from a more general relationship such as that between economic growth and protection (as do Gould and Gruben 1996), because economic growth is a very complex and ill-defined process, at least relatively speaking. In other words, the relationship between protection and technological change does not follow very easily from findings relating to the relationship between protection and economic growth. Therefore, it might be more convincing to dwell on the behaviour of technological change per se, the variable on which protection is supposed to have a more direct impact.

Capturing technological change

To proceed with the estimation we must first clarify what constitutes technological change. At one level technological change may be interpreted to refer not to the change in technology *in existence* (i.e. known to society at any given point in time), but rather to the change in technology *in use*? Obviously, the latter cannot occur without the former. However, the former can and does occur independently of the latter. Thus, many new innovations may exist and yet not be commercially exploited because, for instance, they may be economically unviable. To the extent that they are not yet employed, they do not cause any change in the extant technology of production, and hence do not influence economic growth. By the same token, only when they are exploited in the market can the technology of production be said to have changed, with possible ramifications for economic growth. Therefore, it is this phenomenon of the adoption or economic exploitation of innovations that ought ideally to be emphasized, rather than the phenomenon of the generation of innovations per se. In actual fact, however, this distinction may not be practicable.

We propose to represent technological change, therefore, by *research and development investment as a proportion of gross national product* (RDI)[6]. While all of research and development expenditure does not necessarily fructify into inventions and innovations, such investment has the virtue of being more closely related to inventive activity than is, say, non-residential physical capital investment, while at the same time being more 'all-encompassing' than still another possible proxy, namely patent applications.

The explanatory variables

Countries differ widely in the strength of protection that they provide to intellectual property. While a comprehensive evaluation of the relative strengths of protection would require dwelling on each of several instruments such as patents, trademarks, copyrights and trade secrets (South Centre, 1997)[7], differences in patent laws across countries are considered the most important and are perhaps the most dramatic. The protection offered may differ along several dimensions. Thus, patent laws across countries differ with respect to coverage. While some countries allow both product and process patents in a broad range of activities, some disallow product patents for innovations in certain areas such as pharmaceuticals, chemicals and food products (e.g. India). Second, patent laws differ with respect to the duration of protection. Patent duration in most western European nations has been 20 years, whereas in other countries it has varied between 5 and 17 years (e.g. India, Pakistan, Sri Lanka, Jordan, US). Further, while some countries measure patent life from the patent application filing date (e.g. Nigeria, Jordan, Thailand), others measure it from the publication date (India, Korea, Austria, Australia), while still others measure it from the grant date (Pakistan, Mexico, Portugal, Canada, Iceland, US). Third, enforcement procedures may differ depending on whether or not countries allow for preliminary injunctions in the case of an alleged infringement, and on who carries the burden of proof. Fourth, while some countries allow pre-grant opposition to a patent application (e.g. Japan), others allow only post-grant opposition (e.g. western European countries). Fifth, in some countries patentees may face a higher risk of loss of protection (once granted) on account of 'non-working' of the patent or else compulsory licensing. And so on. There are many other differences that one could list. While the TRIPs agreement of 1994 allows for a process of gradual harmonisation of the protection laws across the member countries, and this process is indeed underway, many of these differences still obtain in large measure. These differences are captured by Ginarte and Park (1997) in an index, which we use as the *index of protection* (IP) variable[8]. The index incorporates five aspects of patent laws: extent of coverage, membership in international patent agreements, provisions for loss of protection, enforcement mechanisms, and duration of protection. It ranges from zero to five with higher values of the index indicating stronger patent protection.

Several control variables are considered. R&D investment, and investment in general, have been found to be pro-cyclical for various reasons - the availability of internal funds for activities for which loans are usually not available (Hall 1992; Himmelberg and Petersen 1994), and demand pull forces indicating profitability being two of the most important (Geroski and Walters 1995). This may be captured by introducing (current) GDP as a regressor (Guellec and Ioannidis 1997; Geroski and Walters 1995; Barro 1991; Kamien and Schwartz 1982; Nadiri 1980). Using this variable as a regressor, however, does not tell us much about the mechanism of causation. Also, it is a nonstationary variable, and it does not make sense to use nonstationary variables to explain movements in stationary variables such as RDI[9]. To remedy this (at least relatively[10]), we propose to use instead two separate variables. To represent the internal funds available for R&D investment we use *gross domestic savings as a proportion of GDP, lagged one period* (S(-1)), whereas to capture the demand-pull factors we use the *ratio of current per capita GDP to per capita GDP lagged one period* (? GDPPC)[11].

Countries that have factor bundles that contain relatively more human capital will tend to innovate and hence invest at a faster rate than countries having factor bundles with lower proportions of this resource, because this input is central to research and development (Romer 1990). In other words, it is an enabling factor. Given that in certain skills (e.g. in communications) the returns are higher if others are also skilled, increases in human capital tend to induce higher rates of investment (Romer 1991). In cross-country analysis we must also allow for the fact that more educated countries are better able to absorb the innovations made elsewhere (Nelson and Phelps 1966). We do not consider literacy rates apt for this purpose, because these are usually based on criteria such as whether the respondent can sign his name, or whether he can identify a given number of characters of some language etc., which are not particularly cogent indicators of his skill level. Nor would primary school enrolment rates serve the purpose, because too many countries have already achieved 100% enrolment at this level and hence there would be insufficient variation in this variable.(Barro, 1991). Besides, ideally we ought to use a stock measure of human capital rather than a flow measure. Therefore, we represent the human capital variable by the Barro-Lee (2000) data on the *average number of years of formal schooling of the population equal to or over age 15* (EDU).

Political instability is an important factor influencing investment decisions. Countries with unstable political, and hence economic, climates witness a drying up of productive investment. Even localized political conflicts that tend to be long drawn out can stifle investment in those regions within countries or at the very least divert scarce resources away from R&D towards the control and resolution of that conflict. We propose to represent this factor by a relatively comprehensive ‘state failure’ dummy. Using data on genocides and politicides, revolutionary wars, ethnic wars, and abrupt régime changes towards autocratic rule compiled by the Center for International Development and Conflict Management (see Esty et.al. 1998), we construct a *political instability dummy* (ID) for each country which equals 1 in years exhibiting one or more of these phenomena and equals 0 otherwise.

The I-O literature points out that lending institutions are reluctant to lend for R&D activities simply because such ventures tend to be highly risky with uncertain expected rates of return. Therefore, R&D investment tends to get financed mainly from internal funds (Hall 1992; Himmelbery and Petersen 1994). Hence, as we argued above, the importance of savings. Even so, the *real lending rate of interest* (RLR) may be used as an additional control variable, perhaps to reflect the opportunity cost of internal funds if not the actual cost of borrowed funds used for R&D (Guellec and Ioannidis 1997).

Finally, it has been argued that the trade orientation of a country can be of importance in determining its propensity to innovate. The conjecture (sometimes implicit) is that relatively open economies tend to face relatively more competition, not having access to sheltered markets, and are compelled to invest relatively more in R&D (Edwards 1992; World Bank 1987; Krueger 1978; Bhagwati 1978; and Lewis 1955). Measuring the degree of openness of an economy, however, has proved a fairly thorny exercise. The alternative measures used in the literature have been exports shares, trade shares (i.e. exports plus imports as a share of GDP), effective tariff rates, real exchange rate distortions, black market exchange rate premiums and still other measures. All of these measures may be shown to be deficient in one respect or another. Some, however, are better than others and one that seems to be preferred is the black market exchange rate premia (Gould and Gruben 1996). We, therefore, use the black market exchange rate premia to construct a *black market premium dummy* (BMPD), which equals 0 for relatively open economies or those whose black market premium is less than the median of the sample countries, and 1 for the relatively closed economies or those whose black market premium is more than the median[12].

The above discussion leads us to the following estimation model:

$$RDI_t = f(S_{t-1}, ?\,GDPPC_t, EDU_t, BMPD_t, ID_t, RLR_t, IP_t) \qquad (1)$$

where the different variables are as defined above. What we are interested in is the 'long term' relationship between intellectual property protection and research and development investment, and it appears reasonable that yearly data would not be appropriate to capture it. Surely, yearly changes in research and development investment cannot be expected to reflect the response of innovation to changes in the strength of protection, not only because changes in the latter are rather occasional, but also because innovation decisions tend to be relatively long term decisions. It would be more plausible, therefore, to estimate this relationship using data averaged over longer periods than a single year. Such averaging would reduce, if not eliminate, the yearly variations in R&D investment on account of 'short run' causes. Over how many periods should the data be averaged, however, is not à priori clear. Following the lead of earlier researchers studying long-term macro-relationships using panel data (e.g. Islam 1995), we use quinquennial data to estimate this relationship. Partly, we are forced to do this, because data on some variables such as education (EDU) and the index of protection (IP) are only available on a quinquennial basis (see the data section below).

Data, Samples and Estimation Issues

Data and Samples

Data on the variables discussed above were collected from several different sources (see Appendix 3). The maximum sample size was 32 countries (listed in Table 1). The major constraining factor for the sample period was the short series for R&D investment, which was available only from 1981 to 1990 for a respectable number of countries. But for this constraint, the sample period could have been longer. While data on most variables were available on a yearly basis, those for EDU and IP were only available quinquennially. Atleast for variable IP this is understandable, because changes in patent laws and their enforcement are few and well-spaced so that it becomes difficult to capture changes in protection levels on a yearly basis. The summary statistics pertaining to the variables are listed in Appendix 1.

Data on all the variables were available for only 29 countries for the period 1981-1990[13]. Since we propose to use five-year averages, this implies that we have only two data points for each country, 1985 (or the average for 1981-85) and 1990 (or the average for 1986-90), for a total of 58 observations. Estimations using this sample constitute 'Exercise 1'. If we are prepared to drop variable RLR from the initial general model, on grounds that earlier work on R&D shows internal funds to be the really significant source of funds for such investment, then our sample size becomes 31 countries (now including Jordan and Pakistan). Estimations using this larger sample constitute 'Exercise 2'. Many researchers have used literacy rates (LIT) in lieu of the human capital variable that we have defined above. While we have reservations about the use of literacy rates to represent skill levels (which we briefly voiced above), doing so expands our sample of countries by another (Nigeria). Estimations based on this expanded sample of 32 countries constitute 'Exercise 3'.

Estimation Issues

A large menu of alternative methods obtains for the estimation of panel data models with individual country effects. A significant issue that arises in this context is whether such effects ought to be treated as 'fixed' or 'random'. In a lot many applications the former approach is adopted, which requires estimating the individual effects as parameters. It is not clear à priori, however, that it ought to be the automatically preferred approach. Indeed, it has been shown (Nerlove 1967, 1971; Maddala 1971; Nickell 1981) that OLS estimates (either ignoring or) treating individual effects as constants to be estimated gave "'exceedingly poor estimates' of the system parameters. These studies point out that the advantage of the 'random effects' model follows from the fact that estimating a fixed effects model implies not only substantially fewer degrees of freedom *but also rules out all information that may be available by directly comparing individual units*. This is particularly egregious when the number of individual units in a panel substantially exceeds the number of time periods (as in our samples, where the number of countries outnumber the number of time periods by a factor of as much as 15[14]); for, in such a situation, we must make efficient use of the information across individual units, to estimate that part of the behavioural relationship under study which contains variables that (are hypothesized to) differ substantially across the units. For these reasons we prefer to use a random effects model for studying our relationship. Specifically, the econometric model estimated is of the type:

$$y_{it} = \bar{ß}_1 + ß_k x_{kit} + \mu_I + e_{it} \qquad i = 1, \ldots, N;\ t = 1, \ldots, T$$

where $\mu_I \sim N(0,\ s_{\mu}^{2})$

$e_{it} \sim N(0,\ s_{e}^{2})$

$E\mu_I e_{ijt} = 0$, œ i, j and t,

$E\mu_I \mu_j = 0$, i … j,

$Ee_{it}e_{js} = 0$, i … j, t … s. (2)

where the regressand y_{it} refers to R&D investment for the i^{th} country in the t^{th} year, while x_{kit} refers to the k^{th} regressor for the i^{th} country in the t^{th} year. All variables are taken in (natural) logs. All variables are stationary. Estimation yields feasible GLS estimates of the model parameters, which are discussed below.

Estimation Results

In Table 1 we categorize the list of countries in our data set into five groups, based on the average strengths of intellectual property protection obtaining in these countries over the period 1981-1990. We also note the share of GNP that they devote to R&D[15]. From these data there appears to be a monotonic positive relation between RDI and the strength of intellectual property protection. Thus, countries with the lowest level of protection invest less than 1/3 of 1% of their GNP on research and development activities. At the other extreme, countries with the highest level of protection invest almost 6 times as much on R&D. Of course, no firm conclusion can be reached unless we allow for various control factors that impinge on R&D investment. This is what we do in the following exercises.

Intellectual property protection and technological change: Exercise 1

Table 2 reports the 'random effects' GLS estimates using a sample of 29 countries for which data were available for all the variables discussed above. Model (1) sets out the results of the 'complete' model, i.e. equation (1) above. Note, that in this analysis, we move from a relatively general model to a relatively specific one (Charemza and Deadman 1997). In doing so, we may use various model selection tests such as the 'root mean squared error' (R.M.S.E) and the 'Schwarz criterion' (SC). We must emphasize, however, that one cannot afford to be doctrinaire about the model selection procedure adopted, for the simple reason that theory is just not well-defined enough to guide us in starting from 'the' complete model. More often than not, the available data may be the binding constraint. Interestingly, this criticism applies as much to general-to-specific modelling as to specific-to-general modelling where researchers start off with a 'base model' and then add variables one by one; for theory may not be particularly helpful in guiding us to 'the' base model either. We bear these reservations in mind as we proceed.

Model (1) results show that internal funds have a strong and significant positive influence on R&D. This supports earlier findings in the I-O literature which point to the importance of internal funds for investing in such uncertain ventures as research and development for which financial institutions are quite unwilling to lend. Relatively educated countries, ceteris paribus, invest significantly more in research and development; indeed, a skilled manpower base is a pre-requisite to R&D activities. The strength of intellectual property protection is positively and significant associated with R&D, supporting the hypothesis that we had set out to test. Thus, countries which provided stronger protection tended to have larger proportions of their GDP devoted to R&D activities.

Both the political instability dummy as well as the real lending rate, however, have the wrong sign, although insignificant. Model (2), therefore, drops RLR because theory suggested this to be relatively unimportant in explaining R&D (internal funds mostly financing such activity, as we pointed out). Variable ID still has the wrong sign, so model (3) drops this variable too. The results show that the conclusions we reached above about the importance of internal funds, education and the strength of intellectual property protection remain unaffected. Additionally, the trade orientation variable BMPD is now marginally significant (using a one-tail test) - economies which are relatively open tend to face greater competition and therefore spend more on R&D. In model (4) we further drop the demand variable ? GDPPC, which had the right sign but was insignificant in model (3). The internal funds variable, education, the index of protection as well as the trade orientation variable all continue to be significant[16]. (All these conclusions would still be valid were we to reverse the model selection procedure and move from the 'base model' (4) to a more general model (3); and indeed even (2) and (1), except that we should eschew (2) and (1) because in these models variables ID and RLR appear with the wrong signs.) Model (4) has the lowest root mean squared error and also minimizes the Schwarz criterion[17].

Intellectual property protection and technological change: Exercise 2

The received literature on R&D emphasizes the significance of internal funds for such risky investments as R&D, for which creditors are generally unwilling to lend. If, therefore, we were to start with a model that excludes the variable RLR, i.e.

$$RDI_t = f(S_{t-1}, ?\,GDPPC_t, EDU_t, BMPD_t, ID_t, IP_t) \qquad (3)$$

our sample size rises to 31 countries (now including Jordan and Pakistan) or 62 observations. The 'random effects' GLS estimates based on this larger sample are reported in Table 3. Model (1) results reveal lagged savings to have a significant positive influence on R&D. The trade orientation variable is strongly negatively related to RDI, indicating the importance of international competition in encouraging research and development activities. Intellectual property protection continues to have a strong positive association with R&D, as in the previous exercise.

But the political instability dummy again has the wrong sign, although it is insignificant. Model (2), therefore, drops this variable. All of our previous results - from model (1) - remain unchanged. Models (3) and (4) further drop the education variable EDU and the demand variable ? GDPPC, respectively, which have the right sign but are insignificant in model (2). We find that the sequence of dropping these variables (i.e. which variable we drop first) does not affect the qualitative results. Finally, model (5) drops both EDU and ? GDPPC. The internal funds variable, the trade orientation variable and the index of protection all continue to be significant[18]. (Again, these conclusions would remain valid if we were to move from the 'base model' (5) to the more general model (2) by adding variables. They would also be valid in the case of model (1), but as before we should eschew this model where variable ID appears with the wrong sign.) Model (5) has the lowest root mean squared error and also minimizes the Schwarz criterion.

Intellectual property protection and technological change: Exercise 3

Some researchers use literacy rates (LIT) rather than the number of schooling years (EDU) to define the human capital variable. While we prefer to use the latter as a measure of skill levels, using literacy rates instead expands our sample of countries by one more (Nigeria). The simple correlation coefficient between the 'education' and 'literacy' variables was 0.74, supporting the substitution of 'LIT' for 'EDU' only partially. Table 4 reports the random effects GLS estimates based on this larger sample of 32 countries or 64 observations. (In this exercise we continue to exclude variable RLR.) Model (1) results, based on the following equation

$$RDI_t = f(S_{t-1}, ?\, GDPPC_t, LIT_t, BMPD_t, ID_t, IP_t) \qquad (4)$$

reveal lagged savings to have a strongly positive influence on R&D activities. So also do literacy levels, providing support to our results in exercise 1. The protection of intellectual property rights appears to strongly encourage R&D, as in both the previous exercises.

The political instability dummy ID once again has the wrong sign, and is also significant. This variable is, therefore, omitted from model (2). The literacy variable is now insignificant, although only marginally so (at the 10% level using a one-tail test). This should not distract us from the plausible effects found for education in the previous two exercises, in view of the 'modest' correlation between 'literacy' and the 'education' variables reported above. Also, the demand variable is now positively significant. Model (3) further omits the trade orientation variable BMPD, which has the right sign but is insignificant in model (2). This leads to no further changes in the results found in model (2). Finally, model (4) drops both LIT and BMPD. We find that the internal funds variable, the demand variable, and the index of protection all continue to be significant[19]. (Even if we move from the 'reference model' (4) to the more general model (2) by progressively adding the relevant variables, the same conclusions hold.) Model (4) has the lowest root mean squared error, although not the

Schwarz statistic.

Conclusions

This paper set out to establish an empirical relation between the protection of intellectual property rights and technological change (and hence between the former and economic growth). We found evidence to support the claim that the former encourages the latter insofar as intellectual property protection was found to have a strong positive association with R&D investment. This relation continued to hold even when several pertinent control variables were allowed for. Results may have been even more pronounced if we had reliable, quantifiable evidence on the *implementation* aspect of intellectual protection across countries, for many developing countries may appear to have strong protection laws on their statutes but are rather remiss in their implementation. Our results imply that the lack of an incentive structure can be a significant mitigating factor for technological change even when other constraints such as internal funds, availability of skills and trade orientation may not be binding.

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Table 1
Strength of Intellectual Property Protection and R&D investment, 1981-1990

0 # IP* < 1		**1 # IP < 2**		**2 # IP < 3**		**3 # IP < 4**		**4 # IP # 5**	
Country	**RDI***	**Country**	**RDI**	**Country**	**RDI**	**Country**	**RDI**	**Country**	**RDI**
Indonesia	0.303	Venezuela	0.352	Iceland	0.812	Nigeria	0.542	Austria	1.276
		Mexico	0.397	Singapore	0.660	Sri Lanka	0.185	Italy	1.110
		India	0.772	Canada	1.419	Australia	1.222	Netherlands	2.081
		Thailand	0.257	Jamaica	0.058	Norway	1.516	USA	2.719
		Jordan	0.231	Mauritius	0.352	Spain	0.612		
		Portugal	0.415	Finland	1.720	UK	2.229		
		Pakistan	0.926	Ireland	0.870	S. Africa	0.882		
						Sweden	2.822		
						S. Korea	1.421		
						Denmark	1.389		
						France	2.233		
						Japan	2.704		
						Belgium	1.614		
Av. RDI	0.303		0.479		0.842		1.490		1.797

Note: * IP - Index of Protection; RDI - Share of R&D investment in GNP

Table 2
Exercise 1 - Random Effects Estimates; Dependent Variable: RDI

Variable	**(1)**	**(2)**	**(3)**	**(4)**
S(-1)	0.628	0.669	0.623	0.616
	(2.174)	(2.308)	(2.175)	(2.168)
? GDPPC	0.120	0.162	0.176	
	(0.534)	(0.711)	(0.783)	
EDU	1.093	0.965	0.900	0.948
	(2.435)	(2.193)	(2.063)	(2.205)
IP	0.600	0.579	0.506	0.475
	(2.111)	(2.035)	(1.846)	(1.766)
BMPD	-0.182	-0.210	-0.222	-0.236
	(-1.120)	(-1.202)	(-1.368)	(-1.452)
ID	0.521	0.448		
	(1.101)	(0.947)		
RLR	0.167			
	(1.380)			
Intercept	-5.473	-4.674	-4.293	-4.315
	(-4.723)	(-4.684)	(-4.657)	(-4.7120
R.M.S.E.	2.024	1.656	1.274	1.203
SC	0.060	0.059	0.055	0.053
F(H_0: all slopes 0)	5.770	6.329	7.159	8.696
$\bar{R}^2$	0.390	0.385	0.383	0.392
Observations	58	58	58	58

Note: All variables are in (natural) logs; T-statistics are in parentheses

Table 3
Exercise 2 - Random Effects Estimates; Dependent Variable: RDI

Variable	(1)	(2)	(3)	(4)	(5)
S(-1)	0.344	0.372	0.377	0.338	0.344
	(1.672)	(1.734)	(1.944)	(1.612)	(1.816)
? GDPPC	0.087	0.164	0.155		
	(0.443)	(0.807)	(0.804)		
EDU	0.252	0.191		0.207	
	(0.842)	(0.634)		(0.692)	
IP	0.943	0.806	0.890	0.806	0.897
	(3.232)	(2.889)	(3.409)	(2.892)	(3.432)
BMPD	-0.546	-0.375	-0.381	-0.394	-0.400
	(-2.208)	(-1.617)	(-1.676)	(-1.715)	(-1.780)
ID	0.857				
	(1.661)				
Intercept	-2.796	-2.602	-2.354	-2.492	-2.224
	(-3.506)	(-3.298)	(-3.113)	(-3.212)	(-3.010)
R.M.S.E.	1.218	0.932	0.766	0.866	0.701
SC	0.0498	0.052	0.045	0.0487	0.042
F(H_0: all slopes 0)	4.156	4.566	5.061	5.361	6.151
$\bar{R}^2$	0.247	0.239	0.230	0.243	0.233
Observations	62	62	62	62	62

Note: All variables are in (natural) logs; T-statistics are in parentheses

Table 4
Exercise 3 - Random Effects Estimates; Dependent Variable: RDI

Variable	**(1)**	**(2)**	**(3)**	**(4)**
S(-1)	0.629	0.889	0.885	0.939
	(3.210)	(4.146)	(4.134)	(4.371)
? GDPPC	0.198	0.392	0.414	0.560
	(1.030)	(1.762)	(1.871)	(2.551)
LIT	0.049	0.037	0.038	
	(1.976)	(1.252)	(1.268)	
IP	1.132	0.795	0.876	0.843
	(3.782)	(2.671)	(3.101)	(3.262)
BMPD	-0.070	-0.073		
	(-1.025)	(-0.904)		
ID	1.368			
	(4.062)			
Intercept	-3.945	-4.304	-4.396	-4.373
	(-5.413)	(-5.373)	(-5.542)	(-5.622)
R.M.S.E.	0.815	0.833	0.804	0.766
SC	0.057	0.075	0.071	0.077
F(H_0: all slopes 0)	9.403	7.055	8.350	10.829
$\bar{R}^2$	0.467	0.345	0.348	0.362
Observations	64	64	64	64

Note: All variables are in (natural) logs; T-statistics are in parentheses

Appendix 1
Means and Standard Deviations of the Variables

Variable	Mean	Standard Deviation
RDI	1.205	0.807
S(-1)	20.701	8.762
? GDPPC	808.900	864.290
EDU	6.989	2.278
LIT	87.973	17.757
IP	2.940	0.977
BMPD	0.500	0.504
ID	0.159	0.367
RLR	3.953	7.966

Appendix 2

Definitions of Variables

RDI: Research and Development expenditure as a percentage share of GNP (%)

S(-1): Real Savings share of GDP (at 1985 international prices), lagged one period (%)

? GDPPC: Real GDP per capita (chain index in 1985 international prices) as a proportion of the previous period real GDP per capita (US $$)

EDU: Average number of schooling years in population over 15 (years)

LIT: Total literacy rate in population over 15 (%)

IP: Index of patent protection

BMPD: Black market exchange rate premium dummy

ID: Political instability dummy

RLR: Real lending rate of interest (%)

Appendix 3

Data Sources

RDI: World Bank 2000

S(-1): Penn World Tables 5.6a (also see Summers and Heston 1991)

? GDPPC: Penn World Tables 5.6a (also see Summers and Heston 1991)

EDU: Barro-Lee 1996

LIT: World Bank 2000

IP: Ginarte-Park 1997

BMPD: Pick's Currency Yearbook and World Currency Yearbook (various years)

ID: Esty et.al. 1998

RLR: World Bank 2000

Notes:

1. Thus, in the United States, the share of all patents issued to individual inventors was 91% in 1901; but by the early 1980s this had reduced to under 19% (Scherer and Ross 1990).

2. GATT - General Agreement on Tariffs and Trade; WTO - World Trade Organisation.

3. Thus, the Dutch government repealed the existing patent law in 1869, whereas the Swiss government could not enact a patent law because successive referendums in the late-19th century defeated such a proposal.

4. World Intellectual Property Organisation.

5. In fact, the U.S. repeatedly used its trade laws 'super 301' and 'special 301' in its bilateral dealings with some nations.

6. R&D data were available as proportions of GNP and not GDP; the discrepancy should be of the second order of smalls.

7. In addition, the protection of geographical indications, integrated circuits and industrial designs may also be considered subsequent to the TRIPs agreement of 1995 (South Centre, op.cit.); but this falls outside the sample period for this study.

8. An alternative index is that constructed by Rapp and Rozek (1990), and used by Gould and Gruben (1996). The Rapp and Rozek index is based on a comparison of individual countries' patent laws with the guidelines proposed by the US Chamber of Commerce's Intellectual Property Task Force in *Guidelines for Standards for the Protection and Enforcement of Patents*. It ranks countries from zero to five, with the former signifying an absence of patent protection laws and the latter full conformity with the proposed standards. The Ginarte-Park index is superior in many respects, as it looks into various facets of patent protection in greater detail, and therefore makes for greater variation in the index or protection even amongst the developed countries.

9. This is precisely another problem with the Gould and Gruben (1996) study, in that they try to explain

a stationary variable such as the growth rate of GDP using a nonstationary variable such as GDP.

10. Ideally, we ought to estimate a vector autoregression model to take care of the related endogeneity problem. This, however, would require long time series of data, which are just not available.

11. To jump ahead for a moment, since all variables are measured in logs, the ratio of current to lagged per capita GDP will translate into a change in (log) GDP between periods; hence the use of the operator '? ' for this variable.

12. The black market exchange rate premium itself is calculated as (BMR - OR)/OR, where BMR is the black market exchange rate and OR is the official exchange rate (both measured in local currency per US dollar).

13. Even so, for Austria, Mexico, and Indonesia (1981-85 only), we had to use the real deposit rate in lieu of the real lending rate.

14. In the econometric studies cited above, the number of cross section units were assumed to exceed the number of time periods only by a factor of 2.5.

15. See endnote 6.

16. The (F-distribution variant of the) LM-statistic for the null hypothesis H_0: S(-1) = 0 is LMF = 30.504; for the null hypothesis H_0: EDU = 0, LMF = 30.242; for the null hypothesis H_0: BMPD = 0, LMF = 37.707, and for the null hypothesis H_0: IP = 0, LMF = 35.098. In all four cases, the LM statistics comfortably exceed the critical value F(1, 53) = 7.161 at the 1% level.

17. It also happens to have the highest adjusted R^2, but we do not use this statistic for model selection because it is quite unreliable in many situations. We report it here only for those who might be interested.

18. The (F-distribution variant of the) LM-statistic for the null hypothesis H_0: S(-1) = 0 is LMF = 16.742; for the null hypothesis H_0: BMPD = 0, LMF = 17.916, and for the null hypothesis H_0: IP = 0, LMF = 7.478. In all three cases, the LM statistics comfortably exceed the critical value F(1, 58) . 7.103 at the 1% level.

19. The (F-distribution variant of the) LM-statistic for the null hypothesis H_0: S(-1) = 0 is LMF = 16.268; for the null hypothesis H_0: ? GDPPC = 0, LMF = 30.280; and for the null hypothesis H_0: IP = 0, LMF = 22.930. In all three cases, the LM statistics comfortably exceed the critical value F(1, 60) . 7.080 at the 1% level.