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The impact of stronger intellectual property rights on science and technology in developing countries

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Abstract

This paper identifies some effects of the global trend towards stronger protection of intellectual property rights on developing countries, and traces related debates. Pharmaceutics, biodiversity and ethnic knowledge are critical areas of impact. 'Trade-relating' intellectual property might allow developing countries to be compensated, but incentive implementation of optimal compensation in the legislatures seems infeasible. Scientific communities in developing countries are particularly vulnerable to limitations of cooperation and access to information, resulting from stronger intellectual property rights protection, as their efforts to obtain normal science results must be considerable. Consequences of the Bayh-Dole Act and of the patenting of research tools on international scientific cooperation are analysed in this context.

JEL classification: O34, Intellectual property rights, national and international issues; O31, innovation and invention: processes and incentives; O19, international linkages to development; O38, government policy

Keywords: Patents; Development; Access; Intellectual property; Scientific cooperation

1. Introduction

The global trend towards stronger intellectual property rights that has taken place in the past two decades has progressed in different dimensions. Protection has extended from invention to discovery; from mechanical devices to living organisms (Byström et al., 1999; Chakravarthi, 1999); from privately funded research and development to publicly funded scientific and technological results[1]; from information about technology to information about scientific information (David, 2000); from industrial products and technological processes to services and financial and administrative methods (Lerner, 2000), and from 'brick' to 'click' trademarks (Bubert and Büning, 2001). Certain conceptual borders have moved accordingly. Such is the case of the borders between invention and discovery, and between natural and artificial phenomena. Some equilibria have also shifted: research that was usually published is now patented; patenting research has yielded to protection under trade secret (Lerner, 1994); and the world of open science has shrunk in favour of appropriable technology (David, 2000).

Geographically, the trend towards stronger protection of intellectual property rights has extended from developed to developing countries, affecting even pharmaceuticals and medical devices where, for several decades, many developing countries had imposed restrictions on patenting or simply refused to allow it. In some countries where pharmaceutical patents were

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[1] Bayh-Dole Act: Public Law 96-517, 6 (a), 94 Stat. 3015, 3019–3027 (1980).

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previously granted, international firms are now pressing for stronger protection schemes, sometimes involving extraordinary trade secret protection and additional enforcement provisions. Both traditional industrial products and high technology goods have been the target of efforts to strengthen the rights of intellectual property holders.

These legal framework reforms and a rapid evolution of customary government practices have been encouraged by a variety of developments in the economic and political environment of these countries. These include shifts in the international division of labour resulting from the increasing importance of high technology products in trade flows; the rules following the creation of the World Trade Organization (WTO), especially those agreed upon under the Uruguay round; and external pressures connected to the Latin American debt crisis in the 1980s and to financial reform in South East Asian countries in the 1990s (Oh, 2001). A major focus of these pressures has been on South East Asian countries (Maskus, 1997), but their effects have been felt more globally. Even specific national laws of developed countries, like the 1980 Bayh-Dole Act in the United States, allowing universities to appropriate publicly funded research results, have had an impact on the way science is carried out worldwide. The impact is particularly visible in international research collaborations involving academic institutions. At one extreme, specific research contracts in areas such as agriculture are having a wide social impact on developing countries. At the other, the effects of the new intellectual property rights (IPR) environment may be felt by projects linking scientists and teams in high-income countries with their peers in low-income countries, technology transfers, and joint ventures between universities, firms and research labs in these countries. This impact on scientific activities is amplified by the specific manner in which science is carried out in developing countries. As explained below, the effort of developing country scientists to do 'normal science' at the international level resembles in many respects that of 'exploratory research' being done in developed countries, and this makes developing country scientific communities highly sensitive to access limitations.

This paper identifies some actual and potential impacts on developing countries of the trend towards a stronger protection of intellectual property rights, and reviews some of the debates that have taken place in developing countries concerning these changes. It discusses some observations from recent Latin American experience, as illustrative of the new scenario that is emerging in regard to developing countries' participation in international collaborative research in the areas of science and technology.

2. Old debates over IPR in developing countries

Developing countries' policies and academic debate on intellectual property have followed a pendulum-like movement. Soon after the Second World War, a new perspective on the importance of technology in trade and development was created by the work of United Nations programmes (such as the Economic Commission for Latin America) and independent economists from developing countries. These analyses, which centred on technology transfer issues, concluded that developed and developing countries should take a different stance concerning the protection of intellectual property. They often stressed that situations of monopoly and oligopoly in world technology markets prevented developing countries from having fair access to technology (Cruz, 1998).

Some leading economists from industrialised countries argued in the same direction. The works of Edith Penrose, Fritz Machlup and others converged in these policy recommendations. Penrose (1951) maintained that developing countries could not expect any advantage from protecting IPR, for these were concentrated in the hands of residents of developed countries. From the point of view of global welfare, it was argued, industrialised countries would not lose much from the lack of protection in those countries and, overall, welfare would improve with low protection.

In 1970, an analysis of the Chilean experience concluded that "the legal system, in matters related to patents, is, in one way or another, favouring the inhibition of local technological development" (CORFO, 1970, p. 13). Vaitsos (1973) followed Penrose in stressing that the problem with the international intellectual property regime was that patents registered in developing countries were concentrated in the hands of residents of developed countries. He was also aware of monopoly and restrictive practices on the part of foreign patentholders in developing countries. For this author, it was a confusion to equate patent-registration with technology transfers.

Between the 1950s and the middle of the 1980s, developing countries succeeded in maintaining a special status in the international intellectual property system (David, 1993, p. 19). Regional organizations such as the Latin America Free Trade Association (LAFTA), the Andean Pact and others advanced common intellectual property policies along these lines. In 1970, India adopted a patent law with considerable restrictions on patent

holders. The choice of this country in favour of process patents rather than product patents allowed local production of imported products whenever the use of a different process was demonstrated (see, for instance, Ragavan, 2001). This legislation was viewed as a model by other developing countries (SUNS/IPS, 1995), and had the largest impact on the pharmaceutical sector. According to Cruz (1998), when some of those regulations began to be avoided through know–how contracts, many among the larger developing countries (such as India, Brazil and Argentina) set up national offices in charge of controlling technology transfers and contracting. Initiatives to implement regional and sub regional offices dealing with intellectual property and technology transfer were discussed, along the lines of comparable policies in European countries, but they never were consolidated (Cruz, 1998, p. 4).

In the mid-1980s, a shift in this scenario began to occur on the initiative of the United States Government. Responding to the concerns of US-based firms, and sometimes in agreement with other advanced countries, the United States pursued what David (1993) views as "a direct, unilateral course of action", that was chosen instead of renegotiating international intellectual property agreements (Paris or Berne Conventions). First introduced in bilateral agreements, this shift in intellectual property regulation was finally enacted multilaterally in the Uruguay Round of the 1990s, as part of the conditions to join the World Trade Organization.

3. The new, global debates

Within developing countries, the terms of the debate changed beyond what could be expected from simple US pressures. Local interests in favour of enforcing stronger intellectual property protection had emerged, in association with the commercialization of imported goods and, to a lesser extent, with the development of local technology. Products such as software, video films and music are easier to copy than traditional industrial products are to imitate. For this reason, copyright has been the focus of conflict in the less industrialised countries, whereas, in the newly industrialised countries, both in Asia and Latin America, patents and trademarks are also at issue.

In both cases, besides government-to-government pressures, producers in the developed world have formed alliances with local merchants in the developing countries to exert influence over local governments in the direction of a stronger stand on intellectual property, covering both legislation and enforcement. Associations of pharmaceutical firms, software and video importers, backed by producers abroad, as well as domestic musician and author associations have played an important role in IPR policy formation.[2]

The emergence of a small or medium-size scientific and technological capacity in these countries has been a frequent argument in favour of higher protection standards. Nonetheless, statistical time-series on domestic patenting rates in the larger among the developing countries, where a positive reaction would be more likely, do not systematically reflect greater inventive activity in years of higher protection in all countries where legal and enforcement changes have occurred, as is clear in the case of Mexico, referred to below.

On the intellectual debate scene, a similar trend could be observed. Penrose's statement was a good description of the dominant paradigm of thinking about intellectual property in developing countries between the 1950s and the mid-1980s. Since then, however, her ideas have become part of a marginal, though still evolving, paradigm.

The publication of more sophisticated models explaining the global welfare gains resulting from a special IPR status for developing countries reviewed below has not been sufficient to stem the tide favouring an internationally differentiated IPR regime. Nor have the conclusions of van den Klundert and Smulders (1996) who, based on the empirical studies by Baumol and Wolff, and Soete, show that no automatism may be assumed for a developing country to catch up in technology and productivity.

Discussions in the context of the Uruguay round of GATT (1986–1994) prompted academic work evaluating the global welfare effects of extending patent protection worldwide. The policy issue at stake was global unification of IPR protection standards. As expressed by Barton (2003), "the risk that intellectual property rights slow the movement of technological capability to developing nations, suggests that harmonization efforts might most wisely consider one common standard for developed nations and a different one for developing nations" (p. 215).

Chin and Grossman (1990) were among the first to address this question. They developed a model and stated conditions for a possible global welfare loss to occur as a consequence of geographically extending patent protection. The style of north–south modelling for which this paper was the paradigm has been used to provide a

[2] The role of interest groups and trade associations in policies and enforcement of property rights has been developed in detail for the case of France and the USA by Bessy and Brousseau (1997). These groups play a similar role in developing countries.

global welfare rationale for resisting global unification of IPR regimes. But the characterization of research and development (R&D) and diffusion processes has been criticised as insufficiently grounded on empirical information and, therefore, misleading in terms of the critical policy implications that can be drawn from the models.[3]

Deardorff (1992) follows the same line in questioning a universal standard for IPR, with a simple static two-country model, where all inventions take place in one of them. His main conclusion is that, for a wide set of circumstances, it is not optimal to extend patent protection to all countries in the world. His argument is based on the analysis of the trade-off between higher incentives to invention and the distortion of consumer choice by monopoly pricing. At some point the incentives to generate new inventions are offset by the costs of monopoly pricing over existing technologies.

Helpman (1993) analyses the impact of tightening intellectual property rights on terms of trade, production composition, available products and inter-temporal allocation of consumption. For that, he develops a two-region general equilibrium framework partly based on Krugman (1979),[4] and uses alternatively exogenous and endogenous rates of innovation. He limits the technological activity of the less developed region to imitation. Also, as the author explicitly recognises, the two-region division is not adequate to deal with the heterogeneity of less developed countries (Helpman, 1993, p. 1250), but he claims it deals best with newly industrialised countries interacting with developed countries. In different ways, Helpman shows that, in the absence of foreign investment, 'southern' countries tightening intellectual property rights do not obtain benefits. Even when the rate of innovation is responsive to IPR, its initial rise is temporary and does not compensate for the ensuing decline. With foreign investment by multinationals, Helpman shows conditions for which the reallocation of manufacturing, resulting in higher prices for larger fractions of products, brings welfare losses to the less developed region; and he identifies circumstances (no foreign investment and low rate of imitation) where both regions may benefit from relaxation of IPRs.

Lai and Qiu (2001) address the issue asking comparable questions in a setting with both innovation and imitation. They measure the level of protection by the length of patents, and compare two stylised situations that are assimilated to those standing before and after the Trade-Related Intellectual Property Agreements (TRIPs). In a two-region, stationary-state, partial-equilibrium setting they calculate the Nash equilibrium before the agreement, and analyse the impact of increasing the level of protection of southern countries on north, south and global welfare. They propose a way of relating tariff barriers in the north with technological and industrial development in the southern region. One result they obtain is that the higher the protection in the north, the lower the optimal protection in the south.

Other conclusions advanced by Lai and Qiu are not likely to be so robust. Despite some assumptions ensuring the asymmetry of the two regions, the model depicts trade and technology relations between a large and a small-developed country, rather than between one developed and one developing country. Their results depend critically on this structural similarity between the two regions. One surprising and questionable conclusion (due perhaps to the extreme partial equilibrium restrictions they impose) is that, though the south loses when it unilaterally increases its level of protection, global welfare is enhanced, even when the south adopts a level of protection higher than the north's. Assumptions about market size and elasticity of innovation in the south are also critical to obtain this result. Lai and Qiu also address north–south distributional issues of TRIPs in the context of trade. They are discussed below.

Grossman and Lai (2002) follow the same line of discussion, focusing on the incentives of north and south to extend the protection of IPRs, in a non-cooperative scenario. They assume that human capital and labour are the factors of production of inventions. Also, the production function for new inventions is homogenous of degree one and the same in north and south. This would imply that the physical marginal productivity of human capital is larger in the developing country, where there is less human capital. Externalities and scale economies are excluded from the production of knowledge. Since they do not make assumptions about structural differences between the two innovation systems, besides a plausible assumption of a larger human capital stock in the north, they require an ad hoc market-size assumption to predict longer protection of patents in the north.

Several empirical studies have addressed the same or related issues. McCalman (2001) estimates the increase in present value of patent protection granted to foreigners and of patents outstanding abroad for a set of 29 developed and developing countries. A striking result of his calculations, based on imputed patent values, is that all developing and some developed countries in the studied set lose with the application of TRIPs. One of the lat-

[3] For one such critique, see David (1997).

[4] Krugman (1979) analysed a north-south situation where the north led in technology development, but the issue of IPR was not addressed directly.

ter is Canada, a result seen by the author as consistent with Canada's alignment with developing countries in the negotiation of TRIPs. It and the other 'losing' countries would be granting concessions to foreign holders of patents in terms of the scope of patent protection, the enforcement institutions or the acceptance of imports as a working requirement for patents[5] that outweigh, in present value terms, the benefits obtained by their residents as a result of protection granted to their own patents in other parts of the world.

In general, McCalman's 'transfers' from developing countries are associated with stronger enforcement required by TRIPs, rather than with the inclusion of previously excluded sectors. McCalman also calculates the impact of TRIPs on the dead-weight losses associated with granting a patent, and evaluates them to account for close to 20% of gains from trade liberalization. Though calculations based on imputed values may not be precise, McCalman's results are consistent with some theoretical criticisms of the trend towards the unification of intellectual property standards across nations.

4. Changes in the IPR regime and their impacts

Four major changes in the global regime of intellectual property rights and trends related to it appear to be affecting the ways scientific and technological research is conducted in developing countries: (1) the already mentioned Uruguay Round of the General Agreement on Tariffs and Trade, that resulted in the 1994 agreement on trade-related aspects of intellectual property rights (TRIPs) and in the establishment of specific conditions for access to the World Trade Organization, (2) the extension of patent protection to the pharmaceutical sector in most developing countries, following the TRIPs agreement, (3) the 1980 Bayh-Dole and Stevenson-Wydler Acts in the USA, permitting universities, non-profit organizations in general and SMEs to appropriate knowledge resulting from research financed with public Federal funds, and the more recent 1999 Research and Innovation Law in France which seeks the same purpose, and (4) the patenting of research tools and databases. On the other side, many communities and some governments in developing countries are pressing for an increased protection of intellectual property of traditional ethnic knowledge and for indications of origin and the protection of property related to the biodiversity of tropical forests.

The description and economic analysis of these changes has given rise to a vast and still-growing literature on each topic. An array of impacts on the developing countries has been studied, including the implications for their technological research activities. But a comprehensive examination of the effects on the conduct of science and technological research, both within the developing countries and in collaboration with external partners in the public as well as the private sector, is seldom attempted. Although this would be an imposing task were it to be carried out exhaustively, an overview of the emerging picture and some brief analysis of critical aspects of the new IPR scenario in the developing countries are undertaken in the following sections.

5. TRIPs and the WTO

Intellectual property was one of the areas where important agreements were reached during the Uruguay Round of the General Agreement on Tariffs and Trade. The 'trade-related' label given to intellectual property matters actually became a mechanism by which concessions in the IPR area could be compensated for by gains in the trade area. Also, as Khor (2001) puts it, "The linking of issues to the possibility of sanctions under the device of attaching a 'trade related' prefix to the chosen topics was successfully used in the Uruguay Round to inject IPRs ... and investment issues ... into the GATT/WTO system" (p. 1). Others have viewed the possibility of 'trade-relating' additional issues like copyright as an advantage, since negotiations take place in a wider environment where concessions and gains may be balanced across issues and sectors (Correa, 2000).

The African group of countries has tried to put limits on the patenting of living organisms and Venezuela has raised the issue of exempting essential drugs from patenting. Nonetheless, initiatives on the part of developing countries in the WTO negotiations over TRIPs have been scarce. Some of these initiatives relate to biodiversity and geographical origin and, paradoxically, are in favour of strengthening the protection of intellectual property rights (Correa, 2000, p. 1–2).

The most important effect of the TRIPs agreement on developing countries has certainly been the mandate to accept the patenting of pharmaceuticals. Some developed countries such as Italy, and many developing countries, like Brazil, Argentina, India and the Andean countries, had various restrictions on the patenting of drugs. These limitations were justified on the grounds of

[5] Article 27.1 of the TRIPs agreement states that "patents shall be available and patent rights enjoyable without discrimination as to the place of invention, the field of technology and whether products are imported or locally produced".

allowing a national pharmaceutical industry to develop, but the TRIPs agreement forced them to be dismantled. The extension of patents to 20 years, the restriction of conditions under which a government can decide compulsory licensing,[6] and the unification of criteria for non-obviousness and utility testing are other important changes affecting developing countries (Jaffe, 2000). Despite the delayed implementation of certain clauses of the TRIPs agreement, small countries like the Dominican Republic and Honduras have protested against "selective unilateral pressures" on the part of some developed countries, forcing smaller nations into immediate implementation (Correa, 2000, p. 3).

The US made certain concessions in the TRIPs Agreement, as pointed out by Jaffe (2000). Changes in the US national patent statutes are being considered, specifically to switch from the 'first to invent' priority rule to the 'first to file' rule prevalent in Europe, Japan and many other countries, and to mandate the publication of patent applications after 18 months, rather than the current practice of waiting until the patent has been issued.[7] These changes, however, useful in harmonising the laws among the industrialised countries, do not seem to have a sufficient compensatory effect for developing countries. The situation could be viewed as a three-person game, where an alliance of the two strongest would result in exchange of concessions between these two agents, to the detriment of the third.

6. Trade-relating IPR and the international division of labour

IPR were 'trade-related' in the Uruguay Round of GATT that led to the creation of the WTO. 'Trade-relating' IPR has a double effect. On one hand, there is a strengthening of IPR that favours industrialised countries. On the other, there are some international trade compensations favourable to developing countries.

The situation may be analysed considering a simple, stylised model where there is exchange between a small, developing and open economy and the rest of the world. It is centred on analysing the impact of stronger IPR protection in exchange for trade concessions to the small country.

Production in the small country is composed of traditional, manufactured and technology goods. Without losing generality, one can assume that there are exports and imports of all goods. The manufacturing sector makes use of 'technology goods' that have been created by investments to carry out R&D. A large proportion of technology is produced in the rest of the world and it may be assumed that there are spillovers of knowledge so that in a hypothetical situation with no trade related intellectual property rights, the small country is not paying full royalties for the technology it uses in manufacturing activities.[8] The traditional sector is assumed to employ little and low-level technology. Manufactures and traditional goods are assumed to be substitutes.

This hypothetical situation is now compared with another where IPR are stronger and enforced. The cost of production of manufactured goods in the small country is larger: in the first situation industry was not paying full royalties, but trade-relating intellectual property implies the enforcement of that full payment. The income of the rest of the world, which produces most of the technology used in the small country, will increase.

In contrast, the income of the small country will decrease; but even if this reduction is not significant or is partially compensated by trade advantages, the increase in the price of manufactured goods will induce a switch in domestic consumption from manufactured to traditional or imported goods. Domestically produced manufactures will become relatively more expensive than imported manufactures. This will induce a reallocation of resources detrimental to the production of domestic manufactures. These two effects will combine to induce a specialization of the small country in traditional goods.

The sector producing technology goods will be affected accordingly. Domestic research oriented towards the improvement of technology production in the small country is stimulated when the production of local technology is flourishing and there is no interest of foreign R&D investing entities in this activity. However, as most technology is being imported in developing countries, the substitution of imported for domestic technology will be small. Besides, in the short run, there is an income effect related to paying more for expensive technology imports and, in some cases, this might reduce the demand for domestic technology. The global impact on specialization of the small country in the production of traditional goods and away from the production of technology could become permanent, if the technology

[6] Based on the experience of some developed countries, Correa (1999) argues there are important advantages for developing countries to grant compulsory licences.

[7] The de facto situation, however, is that in order to provide inventors with the protection of European national patent laws, US patentees also file ('first') in the latter countries, so that at least the disclosure conditions do not afford them a differential advantage.

[8] This was the case of pharmaceuticals in some developed and many developing countries until the implementation of the TRIPs agreement.

sector follows a dynamic of learning-by-doing, if local technology producers cannot survive the short-run fall in demand for domestic technology or if the contraction in this sector induces emigration of researchers and technology developers.

Trade compensations, granted by developed countries in exchange for more protection of IPR in the developing countries, may balance the developing-country welfare losses.[9] Nonetheless, they may exacerbate those two negative, long run effects on domestic research. First, there is an additional stimulus to allocate investment resources to goods receiving incentives (traditional goods). Their technology content is low,[10] and this will reorient resources away from domestic technology production. If manufactured goods also receive these incentives, the effect will depend on the domestic technology content of manufactured goods and on the elasticity of domestic technology to an increase in the demand for domestic manufactured goods.

Under the assumptions made, and provided the innovation system of the small country fits within them, trade-relating intellectual property will have two main consequences: (a) a deeper international division of labour, and (b) depending upon the reaction capacity of local technology producers of the developing country, either an increase or a decrease of the technology sector of this country.

The decrease in domestic patenting activity by Mexican residents in the period immediately after the tightening of intellectual property rights (after the patent law reforms of 1994)[11] is quite consistent with the latter prediction of the model, although it is also related to the decline in the growth rate of the Mexican economy in those years.

Lai and Qiu (2001) analyse the impact of trade-relating IPR protection on global welfare. In their partial-equilibrium steady-state framework, they obtain the conclusion that if the north's level of protection is an upper bound for the south's own level, "the TRIPs Agreement can be regarded as maximizing global welfare by requiring the south to adopt the north's pre-TRIPs standard . . . It is in this sense that the TRIPs agreement is optimal" (p. 15). But this result is critically dependent on assumptions concerning magnitudes, on ignoring the cost of enforcement and on the very specific use of partial equilibrium conditions they envisage. Lai and Qiu also ask for the incentive compatibility of that agreement with the expected behaviour of the south. To obtain incentive compatibility, they assume that the south's market for the traditional good is larger than the north's, an ad hoc assumption which is not necessarily true unless a restrictive and biased definition of traditional good is adopted. Nonetheless, even if those conditions were met, the long-term consequences of a deeper international division of labour, where the 'south' would specialise in traditional goods, ought to be considered in the analysis. On the other hand, the internal politics of the developing country should be examined. A costly incentive-compatible formula guaranteeing the acceptance of the shift away from the modern sector and towards traditional production is to be devised as a condition for the adoption of a unified IPR standard to be viable and sustainable. Incentive compatibility in the north should also be examined. In fact, there is no guarantee that the legislature of the developed country is willing to grant trade concessions that affect local interest groups, such as agriculture (Cañón and Forero-Pineda, 2004).

Based on similar assumptions, Grossman and Lai (2002) analyse the impact of adopting one patent-length regime for both countries. They show that "The harmonization of patent policies is neither necessary nor sufficient for the efficiency of the global patent regime" (p. 38). If compensations in other areas (such as trade) are possible, their analysis shows that an efficient patent regime is one providing optimal aggregate incentives for innovation to inventors throughout the world. But many efficient solutions are then possible, and "Among combinations of policies that give the same overall incentives for global research, the North fares better, and the South worse, the longer are patents in the South" (p. 4).

7. Patents and trade secrets in the pharmaceutical sector

The most important impact of TRIPs on developing countries has taken place in pharmaceutics. Following India's legislation of 1970, many developing countries either refused patenting of pharmaceutical products or patented processes instead of products in this sector. At the time of the GATT Uruguay round, almost 50

[9] Lai and Qiu (2001) point this out as well.

[10] One could think of a strategy to reorient technology developers towards the improvement of traditional goods. But these changes demand long-run efforts and an institutional environment that is not common in most developing countries.

[11] Domestic patents filed by residents fell from 343 to 148 between 1993 and 1995 in Mexico. In Mexico, patent law was reformed in 1992 and 1994 (Bancomext 2000). In a deeper study on Mexican IPRs experience, Aboites and Cimoli (2002) conclude that "In general, it is argued that the new IPRs framework and the economic reforms do not provide incentives for the upgrading of technological capabilities in the Mexican system" (p. 21). The authors attribute their observation to the fact that existing networks in that country are not stimulated to diffuse technological information towards national agents.

developing countries did not grant pharmaceutical patents (Lanjouw, 1998, p. 1). The approval of TRIPs has reversed this tendency and changes have occurred in most developing countries. Member countries of the WTO are required to grant both product and process patents in the pharmaceutical sector (Correa, 1996). These changes are still debated in several countries, and less-advanced countries have until 2005 to implement intellectual property protection laws for the pharmaceutical sector. The advantages and disadvantages of granting patents for pharmaceuticals, from the point of view of consumers, are well analysed by Lanjouw (1998) in a study about India. This author cautiously postpones a definite conclusion on this issue until the "weakness of the empirical foundations for these claims" is overcome.

One can go a step further in some aspects of the debate. In those countries where change has operated following the TRIPs agreement, granting trade-secret protection in parallel with patent protection is the issue at stake. Trade secret would not cover the product, since the patent is granted in exchange for revelation of knowledge. Instead, trade secret protection would cover the clinical research that is deemed necessary to obtain the approval of sanitary authorities before marketing the product. The debate over the convenience of granting this parallel protection is equally complex. The analysis in terms of constructing a balance between incentives and diffusion has to take into account additional considerations. First, there is a lag between the sale of the product in developed countries and in developing countries. For this reason, multinational companies are usually asking for secret protection of five years instead of ten years, as they usually expect the protection to be in developed countries. Second, keeping under secrecy clinical studies and not permitting their use for further research implies an additional important cost to society. Pharmaceutical companies from developed countries fear the proliferation of small laboratories in developing countries dedicated to the production of no-patent and post-patent generics. If one takes into account that these small laboratories produce drugs for illnesses endemic to intertropical regions, and that there are economies of scope when these two lines of production are combined, there might be negative effects on public health in the developing country.

At this point, some other aspects of the debate over IPR for pharmaceuticals may be settled through simple analysis, but further institutional background is required to set the stage. One of the most recent developments in international regulation of the pharmaceutical sector is the agreement between the WTO and the World Health Organization (WHO) about the principle of price differentiation. The 'common thinking' of these two organizations is that "differential pricing could, and should, play an important role in ensuring access to existing essential drugs at affordable prices, especially in poor countries, while allowing the patent system to continue to play its role of providing incentives for research and development into new drugs" (World Health Organization and World Trade Organization, 2001, p. 1).

This agreement is viewed as an important advance in the consensus between the two international organizations and their member countries. Nonetheless, the question remains whether, in terms of the health of poorer populations and in terms of scientific and technological development and the advancement of their own industrial production, this makes a difference for developing countries.

First, the firm that has developed and patented a drug is granted a monopoly. In the international scene and in the absence of regulation, it usually acts as a discriminating monopoly. As a consequence, the price of the drug in the developing country will tend to a lower level with or without international regulations, guidelines or consensus, simply because this means maximising the extraction of consumer surplus by the discriminating monopoly, when no leakage from one market to the other is possible.[12] The case of Mexico is a good illustration. In the absence of price regulation, and despite an observed leakage of Mexican medications through the US border, Mexican trademark drugs are significantly cheaper than in the neighbouring USA (Bancomext, 2000).

The model presented in the previous section allows analysis of the second issue. The impacts of lowering the price of essential drugs researched and developed in advanced countries and sold in developing countries are manifold. Whether this price differential is the result of regulation or the result of maximising behaviour on the part of discriminating monopolies, local pharmaceutical firms will be affected by stronger IPR, since their own incentives to develop substitutes are diminished. Though some of these local firms could manufacture the drug under a licence or another type of agreement,[13] the threat point of negotiation between the monopolistic

[12] The WHO–WTO agreement precisely commits both organisations to oppose leakage of drugs between countries. This guarantees the textbook condition for monopoly profit maximisation under no price regulation. Situations where the price of drugs is higher in a developing than in the developed country of origin may occur, but should be associated with institutional barriers, costly distribution of the product, strategic pressures or other reasons, rather than with profit maximising.

[13] Correa (1996) argues that there are incentives for manufacturers of drugs to replace local production in their own plants or through licences by imports of finished products (p. 20). Mossinghoff (1999)

owner of the patent and multiple local firms competing for the licence favours the patentee. The income effect of the reduction in the country's expense on drugs is insufficient to counter the negative impact on local research and development. It is not easy to think of mechanisms channelling these savings towards financing local research. In the longer run, as no competition for the production of drugs has much chance to enter the market, any incentive to voluntarily lower the price is depleted, and lobby or scarcity pressures intended to induce the removal of price regulations might increase.

The case of Mexico cited above also illustrates that the situation envisaged by the model is actually possible. A standard Patent and Trademark law protects pharmaceutical products since 1994 and foreign investment in the sector has increased. Nonetheless, there are "few developments of new molecules or new technologies" (Bancomext, 2000) and though local industry is efficient in the production of generics, it "has no research or development of new products" (Bancomext, 2000).

An alternative solution in line with the quoted statement of Barton (2003) would envisage differential intellectual property protection. An implication of Deardorff (1992) is that differential IPR protection, and the ensuing development of local manufacturing and R&D sectors, fosters (imperfect) competition among brand-differentiated products that will set the equilibrium price (in this case of drugs) to levels lower than those set by a discriminating monopoly. Besides, differential IPR protection would diminish the impact of the global strengthening of property rights on the international division of labour and, as shown below, on publicly funded research in developing countries.

Recent debates about the price of pharmaceuticals and about the role of multinational corporations (MNCs) in research, development and testing of new medications seem to be putting too much of a burden on market mechanisms to solve certain health problems. Private firms often impute the deceleration of world investments in HIV/AIDS research to insufficient IPR incentives granted by many governments in the world. On the other hand, developing country governments, international organizations and NGOs are critical of the excessive profits that companies seek. Beyond the conflict of interests, the dispute may be a sign that market mechanisms, such as IPR, are reaching their limits. Perhaps the conflict between health in the tropics and the incentives necessary to elicit research might not find a complete solution within the borders of market incentives and IPR protection. Alternative solutions, where international scientific cooperation plays a leading role should perhaps be envisaged following the experience of other global research networks (Jaramillo et al., 2004).[14]

8. International scientific collaboration and the Bayh-Dole Act

The relationship between technology and science in a national context depends critically on the volume of scientific activity reached by each country. Albuquerque and Bernardes (2003) studied the relationship between scientific publications and patenting activity for 120 countries in different stages of development. Based on a cross-section statistical analysis, they hypothesise that "the existence of thresholds of scientific production that must be overcome to trigger new channels of interactions between the scientific and technological infrastructure" (Albuquerque and Bernardes, 2003, p. 1). The elasticity of patenting to changes in the scientific publication activity increases dramatically once a certain level of scientific publications is reached. This empirical and conclusive observation is not at odds with theoretical work stressing the importance of interfaces between science and technology for the consolidation of a national innovation system.

For this reason, the access of scientists from developing countries to frontier knowledge is critical for their countries to prosper, and for modernization and development strategies to be successful. Conversely, international collaboration with developing country scientists has yielded valuable results for the advancement of human knowledge (Forero-Pineda, 1997). Scientists in developing countries might have regular access to scientific knowledge through publications and through free electronic networks, but this is not sufficient. Database access, permanent two-way exchange, validation of results, periodic in-site training and co-authorships are deemed necessary to ensure an adequate transfer of both codified and tacit knowledge, and to ensure the effective contribution of all partners to common scientific endeavours.

on the contrary cites the example of Brazil where IPR protection for pharmaceuticals, previously inexistent and adopted in May 1996, would explain an increase in investment plans by foreign pharmaceutical companies. The effect actually should depend critically upon the local investment effort, as is apparent in the strategy followed by Italy where the introduction of pharmaceutical patents was coupled with a very aggressive and expensive reconversion of the local pharmaceutical industry.

[14] One example of international collaboration for research related to developing countries is presented in CGIAR (2001).

Both economic and institutional obstacles prevent this access. The governance structures of scientific communities, incentive rules and confidentiality provisions in labs increasingly limit the free flow of scientific knowledge. The readiness and ability of the receptor of this knowledge also strongly influences its transfer. Besides recently tightened national security measures, secrecy and exclusiveness surrounding scientific knowledge are in striking contrast with economic and sociological wisdom calling for a free flow of scientific knowledge.

Recent changes in intellectual property institutions governing the exchange of technology affect international scientific collaboration through the close connection existing between scientific and R&D activities. The extension of intellectual property into the realm of scientific knowledge and production activities has a direct impact on this collaboration. The new scenario of research laboratories in the developed world has definitely changed with regulations and incentives favouring the appropriation of scientific knowledge.[15]

Two major legal changes took place in the USA in 1980. One was the Stevenson-Wydler Technology Innovation Act.[16] The central purpose of this Act was to commit agencies to the full use of the results of research and development being financed by the US Federal Government. It also required public labs and agencies to establish Offices of Research and Technology for this purpose (National Academy of Sciences, 1997, p. 3). The other was the Bayh-Dole Act. It "enables small businesses and non profit organizations, including universities, to retain title materials and products they invent under federal funding".[17] "Bayh-Dole effectively shifted federal policy from a position of putting the result of government-sponsored research directly into the public domain for use by all, to a pro-patent position that stressed the need for exclusive rights as an incentive to industry to undertake the costly investment necessary to bring new products to market" (National Academy of Sciences, 1997, p. 3).

With an almost identical purpose, France approved an Innovation and Research Law in 1999.[18] Its stated purpose is the "transfer of technology from public research to the economy and innovative firms" (Ministère de la Recherche, 2000).

The new academic and public research lab scenario created in the developed countries by these legislative initiatives has potential consequences for international scientific collaboration that are easy to infer. The work environment in the labs of the developed world has changed.[19] In many university research labs that have commercial relations with industry, special secrecy provisions are being implemented. Interest in hosting foreign research scholars is affected by the new environment of secrecy, aimed at protecting the patentability of research in progress. Sharing the latest techniques and results with temporary, visiting scientists is more likely to be restricted. This will be particularly the case where it is found that the exchange visit is sponsored, directly or indirectly by a commercial firm operating in the developing country—although such sponsorship has historically been a significant means of transferring scientific expertise.

Many of the most successful science policies of developing countries are based on international scientific exchanges where a two-way contribution to the advance of knowledge is expected.[20] Important externalities to local scientific communities and society are associated with these exchanges. Mistrust and certain trade secret provisions on the part of developed-country public or academic laboratories directly affect the feasibility of these policies.

Opportunities for scientific networking between scientists in developed and developing countries are narrowed. A climate of suspicion within the labs of developed countries affects the presence of foreign researchers in those teams. Both symmetric uncertainty and asymmetric information on the eventual distribution of benefits in case of a commercial exploitation increase the transaction costs of reaching scientific cooperation agreements. International scientific cooperation is particularly affected, and small developing countries are especially fragile, since they do not have alternative options they can run on their own to develop frontier scientific activities.

Comparable effects should be expected from contracts between private corporations and public or university labs in developing countries. These contracts

[15] Bayh-Dole in the United States and the Innovation and Research Law in France are examples of these new regulations.

[16] Public Law 96-517, 6(a), 94 Stat. 3015, 3019–3027 (1980).

[17] Rautiainen (2001). Subsequent to the 1980 Act, the limitations on licensing publicly funded university inventions to large businesses were removed, first by Presidential Executive Memorandum from the Reagan Administration, and later (in 1984) by amendment of the language of the Bayh-Dole Act. See Sampat (2004) in this issue of Research Policy.

[18] La loi sur l'innovation et la recherche, 12 juillet 1999.

[19] Owen-Smith and Powell (2001) analyse these changes. Exclusive licensing appears to be particularly controversial in the laboratory environment of the United States.

[20] The experience of one such network, the Red Caldas, is analysed in Forero-Pineda (1997).

might be substituting the traditional public financing of research oriented within "a collegiate reputation reward system" based on an ethics of disclosure and on priority in the publication of scientific results (Dasgupta and David, 1994, p. 291) that made international cooperation more feasible.

An additional effect of Bayh-Dole and its European equivalents on international research cooperation should be mentioned. When a university's international research activity is extensive and its reputation in the scientific or technological field is strong, there is a temptation for the institution to adopt aggressive across-the-board negotiating policies concerning the claims to intellectual property arising from research with (supposedly 'weaker') partners in developing countries. Such was the case in at least one unfortunate incident, involving a US public university's participation in an agricultural R&D project with an Andean country: due to the insistence of the university's Technology Licensing Office on the worldwide rights on all patents being assigned to that institution, the proposed cooperative research agreement was not signed.

Other US universities, with a thinner record of international research, tend to have more-flexible intellectual property schemes, and have accepted to share the potential commercial benefits of research with countries or ethnic groups (Zerda-Sarmiento and Forero-Pineda, 2002). This might be explained by transaction costs. When a university in the developed world has few, but strategic international contracts, specific negotiations take place for each contract. When this activity involves a large number of contracts where none has a strategic value for the university, across-the-board rules may be implemented to reduce information and negotiation costs, even if interesting projects are sacrificed. Making exceptions might require setting up a costly procedure to determine when a negotiation is or is not exceptional.

The effectiveness of the Bayh-Dole Act coupled with the Technology Innovation Act in promoting technology transfer from scientific public laboratories to private industry in the US is a matter of debate (see Sampat, 2004). The track record of the French Innovation and Research Law is perhaps too short to make an empirical evaluation. Governments of all industrialised and developing countries might tend to imitate those policies, with the expectation of gaining diffusion and efficient commercial use of publicly funded research. At best, very much as in a Prisoner's Dilemma, if there were gains to this policy when applied in one country, they would tend to deplete as more countries adopt it. In either case, global scientific cooperation suffers and countries having few resources to substitute for the loss of international scientific links are particularly affected.

9. Patenting of research tools and database protection

Basic science research in developing countries has been touched in other forms by the trend towards stronger protection of intellectual property rights. One of them is related to the increasing cost of research tools and databases.

Scientific communities in developing countries are particularly vulnerable to limitations of access to information and to increasing costs of laboratory equipment and materials. In developing countries, the replication of common experiments considered as 'normal science' demands important investments in new equipment, research tools, information, training and scientific networking. These efforts resemble those of 'exploratory research' of industrialised countries in that the setup costs and uncertainties (of being able to replicate results) with local resources are very significant. The proportion of information, equipment and networking expenses (travel and exchange) are generally higher in the budgets of typical research projects of developing countries. Accordingly, high costs of research tools and information may considerably affect scientific activities in these countries. On the other hand, the expected results of scientific projects in developing countries are almost exclusively 'normal science' propositions conforming to dominant paradigms or questioning these paradigms marginally.

The rise in costs of access to scientific techniques may not be a significant proportion of the total costs of carrying out research in large companies or universities in the developed world. But their incidence in reducing the options of scientific collaboration may be too costly for small firms worldwide, and for universities and firms in developing countries. Many transfers of technology and scientific collaboration projects may fail to take place when partners in low-income countries do not have access to these techniques.

Exclusive licensing, under certain pricing policies by the licensee (for instance, with entry fees), may be specially harmful for industries using the technique in small countries, for the same reasons that they affect small industries in developed countries. "What is the effect of the Cetus-Roche licensing policy on small companies? Tom Gallegos, intellectual property counsel for OncoPharm, a small biotechnology company, stated that most small companies cannot afford the fees charged by Roche. He noted that the entry fee for a company that

wants to sell PCR-based products for certain fields other than diagnostics ranges from $100,000 to $500,000, with a royalty rate of 15%. By comparison, a company pays about $10,000 per year and a royalty fee of 0.5–10% for the Cohen-Boyer license. The effect is an inhibition of the development of PCR-related research tools, with consequent reductions or delays in the total royalty stream and possibly litigation" (National Academy of Sciences, 1997, p. 45).

In the case of the now expired Cohen-Boyer restriction enzymes patent in the developing countries, the situation was not as clearly favourable. When the use of research technologies based on this patent began, the impact of even the comparatively modest licensing fees on the research possibilities of developing countries was very important and raised the costs of engaging in biotechnological research. The cost of equipment necessary for the use of this technology was accordingly large for laboratories in these nations. Over the years, both equipment and enzymes became considerably cheaper in real terms, for two reasons. First, the production of both became more competitive with the worldwide appearance of many companies providing the market with slightly or substantially modified alternatives. Second, the restriction enzyme technology was not patented in many developing countries. Networks of public, university and small private laboratories were formed in the developing world, producing substitute enzymes that were exchanged at considerably lower prices. Some of these laboratories in developing countries are currently producing their own enzymes or selling them locally, due to the fact that the patents were never registered there. In some instances, important immunology and biotechnology products have been developed using these non-patented substitutes of Cohen-Boyer. Despite what seems to be a large potential international demand for innovations based on alternative enzymes, these products often do not reach international markets. Laboratories producing them argue that they fear being sued if they reach the larger markets where the basic research technology is patented. These researchers have faced difficulties in negotiations with the owners of some of those licences. The resulting situation is the worst of all worlds.

In the case of other research technologies, the impact of their cost on the research activities of developing countries is larger and has been maintained over the years. Medical researchers involved in epidemiological studies have expressed their concern over the high costs of reagents and kits. They can often lease equipment at low rates, but this equipment is designed to use a specific brand of supplies and the cost of kits becomes a strong limitation for this type of medical research when it is carried out on a large scale.

For similar reasons, database costs are an important factor limiting the access of developing-country researchers to international science. As shown elsewhere, the trend towards granting IPR protection to non-original databases entails increases in the cost of information resources, and affects the more cost-sensitive scientific activities of developing countries (Forero-Pineda, 2004), while the lack of sui-generis protection for databases does not seem to have affected the development of a local database industry in Latin America and the Caribbean region.[21]

10. Biodiversity

One or two decades ago, pharmaceutical MNCs had great interest in using molecules present in plants reputed to be useful in traditional medicine in the humid tropical forests of Latin America and elsewhere. A process of bargaining between MNCs and countries in Central and northern South America ended in the signing of a few 'biodiversity' contracts. The clauses of these contracts have been kept in secret in countries like Costa Rica. Other countries intending to sign similar contracts do not have a basis to negotiate.

Agreements for similar purposes have been signed by Latin American universities and by ethnic groups with US and European universities and research organizations. Partners from high-income countries would have a larger set of possible matches than governments or institutions of developing countries. As a result, the threat point of the former is increased, and the bargained outcome should be giving them a larger share than they would obtain otherwise. On the other hand, many of those contracts were discussed, but never signed because both parts applied inflexible policies that raised transaction costs beyond the value of the projects.

From the standpoint of science and technology policies in developing countries, bargaining is more complex. The interest shown by some developing countries in joint ventures for the research of biodiversity goes well beyond that of obtaining fair shares in the royalties stemming from the exploitation of these results. As the national research programme in biotechnology of one Latin American country puts it, "Besides the incentives to the (local) development of knowledge, the impact over the balance of payments of intellectual property rights that are recognised [by developing countries] and com-

[21] As shown in the analysis of López (2002).

pensatory schemes that should be accorded, for instance by eliminating trade restrictions to their exports, the principle of fostering the participation of national talent and research capacities in generating knowledge is introduced, in the conviction that the [developing country] derives more benefit from this participation than from saving some currency if this right [to participate] is not recognized" (Colciencias, 1993, p. 141).

For many developing countries, building a scientific community and international networks with scientists in frontier labs and universities is of greater importance than obtaining regular flows of royalties. Biodiversity is seen by these countries as a unique opportunity to pursue the first objective. There is awareness that asymmetries of information play a determinant role in the outcome of negotiations concerning biodiversity. And the view that transfers of knowledge and specific technologies are possible only when receptors are peers of the scientists transmitting this knowledge is invoked at the policy-making levels. Policies consistent with this perspective give priority to placing local scientists on the leading committees of research projects and programmes, rather than to obtaining a larger share in royalties.

Nonetheless, these policies are difficult to implement. The case of local researchers directly contacted by international companies or universities to act as herb collectors is common, and the enforcement of legal regulations prohibiting this practice is extremely difficult and costly to enforce. Traditional biologists in these countries have signed research agreements, whereby their only role is to provide biological material to their foreign partners, without any participation on their part in the intelligence of the project, most often based on molecular biology and oriented towards structure analysis. And even if national sources have denied funds for this kind of proposals, they have obtained financial resources from their foreign counterpart. More advanced local labs resent this competition from foreign labs and universities, which they consider unfair.

A related issue has developed in the context of discussions concerning compatibility of the Convention on Biological Diversity and the Trade Related Intellectual Property agreements of the World Trade Organization. Costa Rica, the five Andean Community countries and Brazil are among the countries where national or regional patent legislations demand the revelation of origin, and sometimes verification of licit origin, of the vegetal material used in a product or process to be patented. India is also considering approval of a similar regulation (Vivas, 2001, p. 4). These countries and others, including a few developed countries, have presented proposals for the TRIPs to make explicit the acceptance of these 'revelation of origin' provisions in national legislation and a commitment on the part of all members to a clause demanding previous informed consent of the countries of origin. These clauses have been agreed in Articles 15.1, 15.5 and 15.7 of the Convention on Biological Diversity. The US, the European Union, Canada, Japan and Australia have presented objections to the proposal of including these provisions in the TRIPs (Vivas, 2001, p. 7). The debate has taken place in relation to the revision of Article 27.3b of TRIPs, which presently allows member countries to refuse the patenting of plants and animals, with the exception of micro-organisms and biological processes for the production of plants or animals.

The position of these developing countries could be interpreted in terms of the model presented in the last part of Section 6. It showed how trade-relating intellectual property rights induced an international specialization, likely to deepen the knowledge-production gap. Reforms introducing revelation of origin and demonstration of licit origin could be seen as institutional devices allowing developing countries to counter the general trend towards a specialization in traditional goods induced by trade-relating IPR. Revelation-of-origin and licit-origin clauses are associated with prior consent of the country or ethnic group having title to the genetic material used in the research leading to a patent, according to the Convention on Biological Diversity (Articles 15.1 and 15.5 of CBD). Prior consent implies a fair distribution of benefits between developer and country of origin (Article 15.7). In the presence of learning-by-doing or other externalities related to knowledge production, an excessive specialization of developing countries away from the production of knowledge could be countered if the agreement goes beyond the payment of royalties to the country of origin and if it involves local scientific communities in research.

11. Ethnic knowledge

Traditional knowledge developed over centuries by ethnic groups is increasingly being used for commercial purposes, mostly in agriculture and pharmacy. This use has been the object of abundant litigation and conflict, a trend that has closely followed the interest of companies to appropriate knowledge and the strengthening of intellectual property rights.

The explanation of conflict relating to ethnic knowledge is manifold (see Zerda-Sarmiento and Forero-Pineda, 2002; Zerda-Sarmiento, 2003). The institutions of intellectual property in the modern world are oriented towards ownership by the individual, while knowledge in those ancestral societies is socially constructed and

shared. There are information asymmetries concerning the cultural environment, the value standard and negotiation practices of the other bargaining side. The classic information asymmetry about the effectiveness of this knowledge is *a fortiori* present in these exchanges. There is another information asymmetry affecting commitments and the viability of enforcement of agreements reached. These asymmetries of information significantly increase transaction costs when a regular market exchange is envisioned.

The additional transaction costs related to mistrust result from unsettled past conflicts between potential users and ethnic groups. Many cases have been documented where there has been an appropriation of the ancestral knowledge of ethnic groups through patenting. Protests have resulted in either reversal of patenting decisions, or self-restraint from using the patent after the protest of ethnic groups and ongoing conflicts (Zerda-Sarmiento and Forero-Pineda, 2002, p. 107). These situations may be interpreted as the result of strong information asymmetries and the very high transaction costs of closing a contract when cultural distances are long. In some cases, agreements may simply not be possible. Some ethnic groups may be outside of any value exchange system. In others, even when international firms or universities deal with ethnic groups where exchange is feasible, the magnitude of these costs exceeds the potential commercial value of the products that are to be produced on the basis of that knowledge. As a consequence, valuable knowledge is neither accessed by open science nor used in industry.

The existence of worldwide regulations backed by agreements involving a large number of ethnic groups could lower the transaction costs stemming from those information asymmetries, at least in those cases where exchange may be envisioned.

From an economic point of view, the protection of communal rights over ethnic knowledge could hardly be justified as a marginal stimulus to individual invention. But there are other reasons for advising such a policy: in some cases this could stimulate the commercial use of this knowledge; in others, well-defined property rights would avoid practices identified with 'bio-piracy' and costly judicial reversals as those that have been documented. Beyond these easily computable values, three more solid principles could be invoked for the recognition of intellectual property rights over knowledge that was created by generations of community members: (1) the conservation of living social-knowledge sources, (2) the maintenance of a wide diversity of knowledge-creating systems, and (3) the establishment of sustainable relationships between these communities and the rest of the world. Of course, the traditional framework of intellectual property rights in any of its forms would prove inadequate to satisfy these requirements and new forms of intellectual property institutions ought to be devised.

12. IPRs, north–south models and development policies: concluding remarks

Two final remarks should be made. First, the contribution of the reviewed theoretical work to understanding the impact of stronger IPRs on developing countries should be appraised. Though these models have been useful to analyse the issues of intellectual property in an international context, future work modelling the impact of IPRs on developing countries should consider the dimensions in which developed and developing countries radically differ. Network or local externalities should be accounted for. Economic and institutional barriers preventing a high elasticity of technological activities to IPR protection in developing countries should be made explicit and, ideally, explained. Differences in access to scientific knowledge on the part of technology developers in the two regions should also be directly addressed.

In some of the north–south models, authors remedy the structural inadequacies of their models with the assumption that innovation takes place only in the north, thereby precluding a dynamics of change and development. In other models, technology is produced in both regions, but differences are centred on market size, price levels and numbers of patented products per year, while the significant efforts associated with 'normal science' or routine R&D, which are necessary in developing countries and were mentioned above, are ignored. The conclusions of the north–south models here reviewed do not distinguish between countries in different stages of their development or with differentiated innovation systems, in contrast with the work of Brazilian and Mexican authors, who have analysed empirically the sharp differences between technological development processes in their own countries and in Korea or Taiwan.[22]

But perhaps the main criticism that can be made about the series of north–south models is their focus on an addi-

[22] See Albuquerque (2001) who compares the Brazilian "immature innovation system" with Korea and Taiwan's "catching-up systems"; or Aboites and Cimoli (2002) who state that: "the Mexican economy is some kind of paradox: while sharing several macroeconomic features with Korea (dynamism in exports with a high technological content, economic growth, etc.) its innovative performance is weak" and characterise fundamental asymmetries between Korea and Mexico.

tive welfare function (allowing them to propose trade compensations for welfare losses of the south, ensuing their adoption of tighter IPR protection regimes), and their disregard for other specific effects that are critical when developing countries attempt to build innovation systems as their main development strategy. Understanding the importance of these alternative objectives requires models allowing consideration of structural differences in technology production, path dependence, phases and qualitative change.[23]

The second remark addresses science and technology policy-making in developing countries, in face of international changes in IPR. Parallel to the trend towards a stronger appropriation of knowledge, a change in the attitude of developing countries has taken place. Certain apparently unsuccessful experiences such as the *market reserve policy* adopted in the 1980s by Brazil, showed the limits of this type of nationalist economic development policy. A variety of pressures, most of them connected with debt or with the possibility of trade sanctions by WTO, and difficulties encountered in building coalitions during international negotiation rounds, prompted a shift from proactive technological and development oriented intellectual property policies towards the implicit or explicit acceptance of stronger intellectual property rights in these countries.

In some cases, the negative effects of that trend on the development of the less advanced and developing countries have become more apparent and understandable. But there is no doubt that certain science and technology policies of developing countries have the potential to counter the perverse effects of a tighter appropriation of knowledge worldwide. A few examples show that a favourable insertion of their industries in this new international context is possible. The re-conversion of the pharmaceutical sector of Italy is often cited as an example of successful adaptation to changes in intellectual property rules. Brazil is trying to follow a similar path with some discontinuities and varying degrees of success. But local institutional problems in developing countries[24] often lead to a low-level equilibrium trap, where the interests of government, industrialists and researchers do not converge in effective modernization and innovation system building.

In view of these limitations, niche science and technology strategies[25] might appear to be interesting options. But those may be considered self-limiting development strategies by large and medium-size developing countries. Alternatively, they might best pursue more concerted changes aimed at overcoming the added disabilities of the new IPR regime for their development of greater scientific capabilities and the ability to generate technologies best suited to their special economic and ecological situations. For the latter strategy to succeed, however, will require institutional reforms allowing the allocation of larger human and financial resources to science and technology activities, and a greater capacity for international collaborative actions to preserve the domain of public knowledge.

[23] David (1997) further asks about north-south models: "How informative is the characterization of the processes of technological innovation and diffusion ('transfer') in these models, and of the way those processes may be affected by policies concerned with intellectual property protection and other, infrastructural conditions?" p. 18.

[24] Forero-Pineda and Jaramillo-Salazar (2002) describe the dynamics leading to a low efficiency trap of science and technology activities in developing countries.

[25] Such as those proposed by Davenport and Bibby (1999).

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