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The Intellectual Property Strategy of International Agricultural Research Centres

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Abstract

This paper discusses the main problems, principles, concepts, and solutions that characterise the intellectually property (IP) challenges that the CGIAR Research Centres face. The Centres' IP challenges must be seen against the background of five revolutions. Due to the biotechnology, information and communication technology, and intellectual property revolutions, a management revolution is necessary for the Centres to follow up on their initial success in the Green Revolution. The requisite management revolution would implement the principles of systemic thinking, relational thinking, analysis of incentive problems, bundle thinking, and portfolio thinking. These principles can be applied to IP-related challenges, including technology access and freedom-to-operate issues, relations with the private sector, secrecy versus openness, decisions on IP protection, exclusivity versus non-exclusivity in partnerships, the proper level of investment in IP expertise and information systems, and higher-level initiatives.

1. Strategic Sketch of the CG System [1]

The Consultative Group on International Agricultural Research (CGIAR, or CG for short) System, formed in 1971, is a network of 16 independent Centres, donors, other members, and System-wide services. The CG System performs agricultural research and development (R&D) on behalf of the poor and conserves genetic resources on behalf of humankind. The (co-)sponsors are mostly rich countries, international organisations, and large private charitable foundations.

The historical background to this paper can be interpreted in terms of five "revolutions." The CG Centres played a pivotal role in the massive introduction of high-yielding crop varieties known as the Green Revolution. They could play this role thanks to a global network of transfers of data, genetic resources, technologies, and human capital - transfers unimpeded by intellectual property (IP) obstacles. The biotechnology, information and communication technology (ICT), and IP revolutions, all of which gathered pace in the 1980s and accelerated in the 1990s, have transformed the CG's strategic environment. Centres today face a series of difficult IP-related choices. IP strategy involves management choices concerning formal IP such as patents, plant variety protection (PVP), copyright, trademark, trade secrets, and database protection, as well as informal IP such as knowledge and rights based on contracts such as Material Transfer Agreements (MTAs).

The biotech, ICT, and IP revolutions are closely interrelated. Since 1980, IP protection for inventions involving living things has been strengthened, especially in the United States (US) (Binenbaum et al. 2000:9ff.). This stimulated private investment in agricultural and biotech R&D. Causation runs both ways between the IP and biotech revolutions: biotech has improved technology for enforcement of IP pertaining to living things (Wright 1998). Enhanced IP incentives combined with the expanding technological opportunities afforded by biotech have contributed to the rise of the private sector. While agricultural R&D used to be mainly a public-sector activity, global private agricultural R&D investments have come to exceed those of the public sector (Alston, Pardey & Smith 1998). The ICT revolution intersects with the biotech revolution in areas such as genomics, proteomics, and bioinformatics. In addition, recently developed databases and software are now linking Geographic Information Systems (GIS) to the mapping and conservation of genetic resources, thus enhancing an important set of R&D inputs. Various forms of IP protection pertain to databases and software (Longhorn, Henson-Apollonio & White 2002).

The trend to claim IP over genetic resources has been likened to earlier "enclosures" - historical processes of appropriation of hitherto public goods (Herdt 1999). Both the private and public sectors are contributing to this trend. While IP provides incentives for innovation, it may also hamper subsequent innovation that builds on proprietary enabling technologies. Complementary IP assets often need to be combined for innovation; the dispersion of these among many owners gives rise to a complex of incentive problems dubbed the "tragedy of the anti-commons" (Heller & Eisenberg 1998). Complementarities between IP and other assets in the hands of multiple owners may have encouraged the wave of mergers and acquisitions in the agricultural biotech industry in the 1990s (Graff, Rausser & Small 2002). Thus, currently, the agricultural biotech industry is marked by a high degree of concentration, with half a dozen of multinationals controlling a large proportion of patented technologies.

The public sector has become more territorial. Encouraged by the 1993 Convention on Biological Diversity (CBD), countries are tempted to stake out claims to their genetic resources. A 1994 agreement between the Food and Agriculture Organization (FAO) and CG Centres stipulates that Centres and their clients may not seek IP rights (IPR) over "designated" genetic resources held "in trust" in the Centres' genebanks on behalf of humankind. This "in-trust agreement" aims to reassure countries that their contributed genetic resources won't be appropriated by anyone, but such incentives may not suffice for a continued smooth flow of germplasm to the Centres (Binenbaum and Pardey 2003b). In 2001, 116 nations adopted a draft International Treaty on Plant Genetic Resources. It lists 64 crops and plants whose germplasm will be available to plant breeders in countries that adopt the treaty, in exchange for royalties if the seeds are used to develop commercial varieties. Determining these royalties implies keeping track of breeding pedigree, an issue yet to be re solved. In the US, the 1980 Bayh-Dole Act encouraged federally funded research institutions to seek IP over their inventions. Partly as a consequence, patenting by some universities has increased dramatically (Mowery et al. 2001). Negotiating use rights for publicly help IP can ba as problematic as for IP held by private firms (Binenbaum and Pardey 2003b; Nottenburg, Pardey and Wright 2001).

The biotech, ICT and IP revolutions have necessitated an associated management revolution among all organisations (for-profit and nonprofit, private and public) active in the life sciences. With the rise of the Internet, the costs of initiating and managing inter-organisational partnerships have been greatly reduced. As already pointed out, the need to combine complementary technology-related assets has been partly met in the private sector through mergers and acquisitions. However, indications are that for any player partnerships with several categories of other players (small and large firms, advanced research institutes (ARIs), national agricultural research systems (NARS), and international centres) are essential in order to access complementary assets and optimally develop new technologies. Recent econometric studies (beginning with Clarysse, Debackere and van Dierdonck 1996 and Powell, Koput and Smith-Doerr 1996) show that networks of inter-organisational partnerships has become critical to successful innovation in the life sciences.

The acceleration of technological change in the life sciences and the fragmentation of IP, capabilities, and other assets, mean that it is becoming more and more critical for R&D organisations to have (1) internal and external scanning capability; (2) the ability to absorb the scanned information and use it for research and management purposes; and (3) the ability to effectively partner with other organisations, to innovate collaboratively, and to absorb and use the knowledge thus generated. Organisations need to find out who is doing what, identify and locate technological challenges and opportunities, and make informed R&D and IP choices.

In sum, the ICT, IP, and biotech revolutions imply that for R&D organisations to be successful, their management of partnerships and information systems must meet far higher standards than in the recent past. Thus, these three revolutions require a management revolution. The CG System needs to adapt to this management revolution in order to optimally contribute to the Green Revolution's follow-up.

To understand how and why the CG System needs to change, a historical review is in place. The CG Centres are legal entities, but the CGIAR as such is a network without legal status. System-wide decisions are taken by consensus among sponsors and members. The CG is a conduit for development assistance, linked to NARS partners throughout the developing world. Rooted in pioneering efforts of the 1950s, the CG System started out in 1971 with just a few Centres which focussed on development of high-yielding varieties of a small number major crops - rice, wheat, maize, cassava, pastures. The CG's agenda has been expanded in five major ways. First, soon after its beginning, the CG System ventured into R&D activities other than crop improvement that were equally geared towards increasing agricultural productivity in the developing world. Added research agenda items included, for example, livestock-related research and improvement of irrigation technologies and farming systems. Second, a series of crops - e.g. chickpeas, sorghum, potato, and millets - were added to the CG's plant breeding portfolio, which now includes 27 commodities (CGIAR 2003). Third, an important extension to the CG's research agenda from the early 1980s onwards is natural resource management (NRM). The initial Green Revolution has been criticised for its environmental effects. A general trend since the early 1980s in development aid and in agricultural policy and R&D (Alston, Pardey and Smith 1998) is an increase in attention to NRM. The ideal of a "doubly green revolution", combining agricultural productivity with environmental sustainability (Conway 1999), has now become the norm. This trend is reflected in the CGs' research agendas. Fourth, the CG has become a major player in germplasm conservation. The CG's genebanks are linked to its breeding programs, but also serve an independent genetic resource conservation function on behalf of humankind. Fifth, biotech R&D has become a significant CG activity (Morris and Hoisington 2000).

The current mission statements and budget allocations of the CG and its Centres [2] reflect a remarkable degree of consensus as to the System's mission. This consensus can be summarised as follows. First, the dominant aspect of the System's R&D agenda is still agricultural productivity enhancement intended to benefit the poor. Second, this is augmented by research on sustainability and agricultural systems. Third, the System's genetic resource conservation component is recognised as a separate function that merits a separate funding mechanism.

Crop-varietal improvement, the System's original focus, is still its most important budget item. Eight of the System's sixteen Centres [3] as well as a division of a ninth Centre [4] have a primary mandate in crop improvement. Three Centres focus on social science and policy advice, [5] while the remaining five Centres [6] each have specific research mandates that cannot be summarised under a single heading.

Crops that exhibit large exports in value terms from developing countries to rich countries, such as coffee, cocoa, soybeans and Cavendish bananas, are not included in the CG research agenda (Binenbaum et al. 2003). On the other hand, Naylor et al. (2003) assert that the CG System has under-invested in "orphan crops" - crops that are commercially so unattractive that they are ignored by private-sector R&D. The CG has largely focussed on an intermediate group of staples such as rice, maize, wheat, and potatoes, that are not big foreign exchange earners but do have large domestic markets in poor and rich countries. These are among the crops in which private-sector R&D spending and IP holdings are concentrated; such technology positioning choices matter to IP strategy.

The CGIAR and its Centres began formulating official principles for their IP policies in the early 1990s (CGIAR 2000b). These have been revised several times. Their general thrust has been a reluctance to claim IPR and a commitment to produce global public goods - freely accessible to all. In the 1990s, proliferating IP claims caused CG policymakers to become increasingly concerned about the functioning of the global network of transfers of germplasm, technologies and data. It was only in the late 1990s that the CG System began to seriously address IP. The Central Advisory Service on Intellectual Property (CAS-IP) was established in 1999 and several Centres began investing in IP management activities. As further argued below, these can be considered partial and tentative steps in the management revolution that the CG System may need to undergo.

2. How to Think About IP Strategy?

The management revolution to which the CG Centres may need to adapt consists of the implementation of the principles of systemic thinking, relational thinking, incentive analysis, bundle thinking, and portfolio thinking.

2.1 Systemic Thinking

What discipline(s) study IP strategy? "Law" may seem an obvious answer. IP is a legal category; legal expertise is indispensable to IP strategy. However, "IP" is not the same thing as "IP strategy". IP strategy is closely interrelated with decisions involving technology positioning, funding, public relations, etc. In other words, decision-makers often face nested choices that simultaneously involve IP, technology, funding, etc. Thus, to fully understand IP strategy, technology positioning, funding, etc., we need an academic field that integrates law, technology, finance, etc., in the study of managerial decision-making. That field has a name: strategic management. But most of the strategic management literature, including the part that addresses IP issues, focuses on the for-profit sector.

How does economics fit in? While management studies and economics are often institutionally separate, the former should be viewed as a subset of the latter. Just as economics studies consumer behaviour, it studies managerial decisions. However, management studies and economics have historically evolved to embrace different methodologies. Most economists appear to have a preference for parsimonious modelling based on simplifying assumptions, thus generating testable hypotheses. In contrast, strategic management studies learn from many disciplines and integrate these through systemic thinking. Systemic thinking and its main strengths can be characterised as follows. Systemic thinking attempts not to overlook (1) relevant types of components of systems and (2) relevant types of the interrelationships of these components; by striving for such completeness, it stimulates

Gestalt intuition and thinking on the system as a whole. Systemic thinking thus involves the use of taxonomies and conceptual models (e.g. flow charts). The nature of the problems analysed in this paper requires that we first lay out the taxonomies and interactions that characterise the relevant systems before we even think about mathematical modelling and hypothesis testing.

A number of recent papers address the IP challenges confronting non-profit agricultural R&D (Barton and Berger 2001; Binenbaum et al. 2000; Byerlee and Fischer 2001; CGIAR 1998; Falcon 2001; Nottenburg, Pardey and Wright 2001; Wright 2000). With one possible exception, they were co-authored by economists. These papers convey many interesting insights, but they are all essentially collections of ad hoc observations without a clear analytical framework. Are these papers deficient in that they fail to mathematically develop and empirically test hypotheses? No: their scope would require the (infeasible) testing of large numbers of hypotheses. What they lack is an explicitly systemic perspective, and the present paper is intended to be a step in that direction. According to a methodological view perhaps widely shared among economists, positive economics is about developing and testing hypotheses. In this view, the set of received economic knowledge consists of hypotheses that have not been rejected so far. This methodological principle may lead to a lack of attention to the system into which the hypotheses fit.

Certain paradigms of economics do think in systemic terms, without overly reducing systemic complexity. Especially relevant in the present context is the innovation systems literature (reviewed in Archibugi, Howells and Michie 1999). **[7]** Its approach is to identify categories of players in an innovation system, interactions between them, innovation processes and rules governing these, and economic impacts. Hypothesis generation and testing is embedded in a systemic perspective.

Systemic thinking matters to the IP management of individual CG Centres - even though each of them is only a small player on a global scale - for the following reasons. First, the evolution of agricultural science and technology takes place in a global system. To understand technology positioning and IP matters, it is necessary to understand this system. Second, CG Centres' missions require a public policy perspective. Third, as explained below, the relational nature of IP strategy implies that even a single choice problem considered in isolation has systemic ramifications.

2.2 Relational Thinking and Game Theory

All of the reasons to seek IP protection and all of the options available to deal with the problem of accessing proprietary technology (i.e., technology protected by IP) should be viewed in terms of inter-organisational relations. Relational thinking requires a taxonomy of inter-organisational relations. Relation types include transfers (gift or exchange), adversarial relations (including competition), collusion, coordination, collaboration, catalysis (positive incentives) and discouragement (negative incentives). These types can be combined into a variety of hybrids.

Inter-organisational interactions are games. To understand them requires a balance between hard-nosed game analysis that assumes opportunism and approaches that acknowledge socio-cultural factors. A large body of literature - a brilliant example of which is Dasgupta (1988) - applies game theory to patenting choices. Game theory has begun to incorporate insights from the other social sciences; this is bound to further increase its relevance to IP strategy.

Let me give two examples of the relevance of game theory to IP strategy. First, a branch of game theory called "mechanism design" studies how player A (through nifty bargaining techniques, contract proposals, or auction designs) can induce player B to implicitly (through her actions) reveal the value of an item to B. This helps A to extract maximum value out of his interaction with B. Centres can use this type of insights to answer a question like: How does a Centre that does not have a market evaluation unit know how much an IP asset it owns is worth to a prospective corporate partner? The second example concerns the optimal strategy in repeated Prisoners' Dilemmas (PD). Axelrod (1984) reports that in a tournament of computer programs involving repeated games with PD payoffs, a simple strategy called "Tit for Tat" beat all other strategies. Tit for Tat involved instantly rewarding cooperation and instantly punishing non-cooperation. Such insights into repeated games may help CG policymakers devise optimal strategies vis-à-vis the private sector.

Relational thinking is applicable to all IP problems. A prominent example in is the problem of proprietary inputs: "How can a Centre deal with the apparent need for a technology/set of proprietary inputs?" As a first step, available options must be identified. Analysis can then proceed in terms of relational interactions associated with each option (Binenbaum and Pardey 2003b; Nottenburg, Pardey and Wright 2002):

- Centre (C) may negotiate for a license. The relation type is gift or exchange.
- C may unilaterally access the technology - potentially an adversarial relationship.

- C may contest the IPR either in court or at the IP-granting agency.
- C may attempt to invent around the technology, possibly leading to a valuable asset (in exchange or collaborative relations) that may compete with the original input.
- Note that even when any of the potentially adversarial moves (the second, third or fourth options) are not carried out, they may still play a role as implied, perceived, or explicit threats, in combination with one or more of the other options.
- C may initiate an R&D partnership with the input's owner; use rights to the input may be included as part of the partnership's package deal.
- C may initiate a consortium. The consortium may include other parties interested in the proprietary input, and may focus on the input or have some broader theme.
- If the input is critical and unavailable, C may abandon the R&D program, period.
- C may abandon the R&D program, but catalyse other organisations better able to deal with the input problem to undertake the R&D program instead. This may involve the other organisations' use of any of the first six options.

Funding (another relation type) opportunities might be available in combination with some of the aforementioned options. For example, perhaps the home government of the input's owner might be willing to help subsidize use of the input.

Institutional solutions at a more general level than those mentioned so far may be found, for example through international treaties or lobbying efforts.

Thus, a single choice problem involves a wide variety of relations and institutional solutions, and thus has systemic ramifications. Each option initiates a game. Technological as well as game considerations imply that the most successful players are likely to be those with the best systemic understanding. Not only are players embedded in the system, but the system is embedded in individual choice.

2.3 Costs and Benefits, Incentive Problems, and a Public Policy Perspective

For each option specified in the above example, costs and benefits need to be identified. Consider a two-option problem: whether or not to seek IP for a given output. Taxonomic completeness is important: relevant cost and benefit items should not be overlooked. Section 3.4 lists cost and benefit items that matter to IP choices.

It is due to incentive problems that the application of game theory to IP strategy may be valuable. By overcoming incentive problems, the pursuit of social objectives such as the Centres' mission fulfilment can be greatly enhanced. One type of incentive problems is asymmetric information (exemplified in the revelation mechanism example), the subject of a literature, reviewed in Salanié (1997), which typically employs the assumption of opportunism (Williamson 1985:47).

Other classes of incentive problems are relevant to IP strategy as well. Thus, it is useful to have a checklist of incentive problems. The major groupings here are externalities including public goods, market power, informational asymmetry giving rise to moral hazard, adverse selection or signalling, game dynamics (including hold-ups, commitment problems, punishment strategies, lying, and sabotage), and problems associated with cognitive limitations. A fundamental cause of incentive problems is opportunism or, more generally, divergence of objectives in relations. Dedication to a common purpose, a commitment to veracity and transparency, and other non-opportunistic motivations, may be affected by the setup and dynamics of the relationship (Binenbaum, Pardey and Wright 2001). Such endogeneity of motivation can be accommodated by game theory. Trust - the belief that the other side to a partnership will act in non-opportunistic ways or in accordance with long-term enlightened self-interest - and the projection of trustworthiness may often be key criteria in partner choice and key success factors in partnerships (Nooteboom 2002); this is confirmed by managers in the CG System (David Hoisington, pers.com.; Aart van Schoonhoven, pers. com.; both are senior managers in CG Centres).

In summary, in analysing the CG System's IP strategies, we must find a balance between traditional game theory, which assumes opportunism, and more socially oriented approaches that take into account non-opportunistic motivations.

Policy analysis can benefit from a checklist of incentive problems, as it is easy to overlook policy rationales. The traditional rationale for the CG System's existence appears to be a combination of distributive justice and a public-goods conception of its research products. This story must be amended and extended. IP has raised the appropriateness of research products, thus weakening the traditional rationale. Each type of incentive problem may contribute to market failure and inefficiencies and may thus serve as a rationale for public or non-profit action. The anti-commons is an amalgam of different types of incentive problems. Problems that might prevent complementary

IP assets dispersed among many owners from being combined include, for example, hold-ups, [8] cognitive biases [9] , and informational asymmetries.

In game-theoretic terms, partnerships are cooperative equilibria in repeated games. The Folk Theorem shows that in repeated games with uncertain horizon multiple equilibria are possible, with some being Pareto improvements over others. The CG System may thus have a role in stimulating players to achieve a high equilibrium rather than a low one. It may encourage information sharing, which may be modelled as a Prisoners' Dilemma in which each player can withhold information.

2.4 Bundle Thinking and Portfolio Thinking

Salient principles for IP strategy include bundle thinking and portfolio thinking. According to bundle thinking, technologies come in bundles composed of four elements: (a) codified information; (b) human capital, especially tacit (i.e., un-codified) knowledge; (c) material items embodying the technology; (d) IP - rights to use and benefit from the technology. IP rights are often used to strengthen the IP owner's positions in other elements of the bundles. Bundle thinking implies that the CG's biotech IP issues can only be understood in conjunction with germplasm flows.

Portfolio thinking pertains to IP issues on both the input side and the output side. The problem of proprietary inputs should be addressed not as a series of ad hoc decisions but in an integrated fashion, requiring a complete inventory of proprietary inputs for which Centre researchers perceive there to be a need. This inventory should be subject to frequent review, a relatively low-cost exercise if embedded as an organisational routine. This inventory can be coupled with a stream of information on external sources for the inputs. Similarly, valuable outputs, including inventions, which a Centre owns or otherwise has control over at any time, should be considered jointly. This is only possible with a readily available and regularly updated information system that includes invention disclosures and inventories of other valuable assets. Appropriate information on portfolios of assets and needed inputs greatly facilitates partner selection and partnership design. If there were a well-functioning information system, prospective partners' technologies could be identified as being complements to or substitutes for a Centre's technologies. Centres, being small players, would benefit from pooled information systems - due to powerful economies of scale and scope in information systems - and consideration of joint portfolios of assets and needed inputs, as this would strengthen their bargaining positions in partnerships.

3. IP Strategy Challenges

CG Centres face IP challenges on the input side as well as the output side. The most conspicuous problems involve biotechnology and genetic resources. However, important issues pertain to data, software, and human resources. Centres' IP challenges should be understood in the context of Centres' strengths and weaknesses. Relevant strengths include the Centres' guardianship of genetic resources as well as their high degree of connectivity with NARS, providing links to field-testing facilities in many locations. Many information streams converge on the Centres. Centre scientists have an excellent reputation and are strongly committed to Centre missions.

Weaknesses include the following. Centres are small players in budgetary terms. Their biotech investments, while significant, are dwarfed by those of the private sector. Centres are constrained by politics, stakeholders' conflicting demands, and a consensus-based culture that may inhibit initiative. Centres face an increasing problem with restricted funding: donors insisting on specific uses for their contributions. This reduces flexibility (Binenbaum and Pardey 2003b),

The following subsections discuss some of the CG System's major IP choices.

3.1 Freedom-to-Operate Issues

Freedom-to-operate issues originally motivated the interest in IP in the CG System. Consequently, this is what most of the relevant literature has focussed on so far. [10] Cohen et al. (1999) found that permission to use proprietary inputs in Centres was often either absent or unknown. This report may have caused alarm about IP infringement by Centres; it was this issue that appeared to be the focus of IP concerns in the CG. However, most IPR relevant to developing-world farmers are valid only in developed countries. Problems might arise in technologies destined for crops grown in developing countries unencumbered by IP restrictions, if those crops are exported to countries with strong IP. However, as documented in Binenbaum et al. (2000, 2003), South-North exports in important staple crops that are Centre mandate crops are generally dwarfed by production and consumption in the developing world; these exports are concentrated in a few crops and a few exporting countries. CG Centres that focus on crop breeding are located in the developing world. Thus, it would seem that IPR do not significantly affect the freedom to operate in these Centres (Binenbaum et al., 2000 and 2003). However, bundle thinking implies that this conclusion is incorrect. If IP were separate from other elements of technology bundles, one could access it unilaterally outside of its jurisdiction. But this may not work since one might lack other components of the bundle, such as genetic materials.

Access to materials was rated as relatively problematic among IP-related problems in a recent survey of Centres. It is difficult to obtain germplasm from multinationals. Materials provision by NARS and ARIs is also not without frictions (Binenbaum and Pardey 2002, Falcon 2001); the International Potato Centre (CIP) reports that "the environment specially in developing countries is changing towards more defensive and protectionistic attitudes;" thus, CIP is planning to review its formal IP policy (Marc Ghislain, pers.com; Ghislain is a senior manager at CIP).

In summary, even when the materials are not subject to IP in the locations where they are used in R&D, and the varieties thus developed are not exported to the jurisdictions of the IPR that apply to the materials, then still the materials need to be obtained from their owners. While IPR *per se* often do not limit Centres' access to the materials, they will find themselves in a position as if they had to negotiate for IP.

The recent survey (Binenbaum and Pardey 2002) also showed that critical R&D inputs for the Centres include process technologies like the gene gun. In such technologies, the information and knowledge components of technology bundles are important. Centres typically won't be able to reconstruct such technologies from published patents. In order to effectively use such technologies, partnerships with IP owners that involve transfers of information and human capital may be required.

The relevance of the anti-commons problem to the CG is vividly illustrated by "GoldenRice R ," a type of genetically modified rice with great potential health benefits. About 70 pieces of IP, dispersed among a number of players, pertain to technologies embodied in GoldenRice R . These players must all be persuaded to permit use of their IP for the project to proceed (Kryder, Kowalski and Krattiger 2000).

Patents are the type of IPR, and rights to genetic materials the type of material property rights, that appear to be the greatest impediments to Centres' freedom to operate. This is because patentees have the right to exclude others from using the patented subjected matter in any way, including research. Other types of IP may be less problematic. For example, copyrights are in one sense stronger than patents in that they are granted automatically, internationally (by treaty), and for a longer period, but they allow for "fair use" of the copyrighted materials. PVP, a form of IPR specific to plants, is less restrictive than patents. Most importantly, it allows for the use of protected varieties in breeding programs. The resultant varieties may themselves be protected through PVP and are in no way subject to claims from the owners of progenitors (ancestral varieties). This is called the "breeders' exemption" or "research exemption". An important exception to this rule occurs in countries whose PVP follows the 1991 version of the International Union for the Protection of New Varieties of Plants (UPOV). Under this treaty, PVP extends to "essentially derived" varieties (Godden 1998; Blakeney, Cohen and Crespi 1999).

Material property rights do not prevent any use of properties, unless explicit restrictions apply. MTAs may restrict use of transferred materials, but only the parties to MTAs are bound by them. Restrictive MTAs are a major source of concern among Centre managers (Binenbaum and Pardey 2003b).

There is no simple solution to freedom-to-operate issues. The key lies in a relational approach and in an awareness of all available options (see above). In devising a strategy for inter-organisational relations, it is important to differentiate between relevant categories of players. While public-sector players may create obstacles to the Centres' freedom to operate, on the whole it is the private sector, and in particular the life sciences multinationals, that cause the greatest concern among Centre managers (Binenbaum and Pardey 2003b). One reason is multinationals' 'territorial' behaviour, but a complementary explanation can be found in the Centres' lack of experience in dealing with the private sector.

3.2 Relations with the Private Sector [11]

As uniformly confirmed in interviews, Centre managers are circumspect in their relations with the private sector. Adversarial (e.g. competitive) relations are not a specialty of the CG tradition, while cooperative relations with the private sector are looked at askance by some stakeholders. A cooperative relationship (e.g. exchange, gift, or R&D collaboration) is intended to benefit both sides. Thus sponsors might ask whether their contributions to CG Centres that cooperate with firms are subsidising the latter. And providers of genetic resources may ask: "Why should we be providing germplasm for free, if this multinational is (albeit indirectly) making a profit out of it?" Relations with multinationals thus require discretion and subtlety.

Due to the concentration of IP in the private sector and its territorial behaviour, an active policy involving many types of relations with the private sector is appropriate given the Centres' missions, and IP strategy must be carefully designed to enable this. Centres may discriminate between different types of firms, especially between firms based in poor countries and those based in rich countries, because helping the former may be consistent with their missions. However, in doing so, they need to consider the possibilities of takeovers of local firms by multinationals. **[12]**

Incoming transfers **.** Licensing IP or other components of technology bundles from the owner is often the best way to obtain the desired technology. The item may be licensed at a commercial fee, but often will be transferred at a lower or zero fee. Firms may have a variety of reasons to do so (Binenbaum and Pardey 2003b), many of which can be summarised as "maintaining long-term relationships with Centres."

Competitive and adversarial relations **.** The System's technology positioning in crops that are important in domestic consumer markets in the developing world may imply partly competitive relations with the private sector. However, this may not be a bad thing in terms of the Centres' missions. The System might benefit poor farmers and consumers in developing countries not only by producing public goods but also by countering market power. Conventionally bred Centre varieties may be substitutes for more expensive privately supplied varieties.

Centres' potential to produce or encourage competing technologies may encourage multinationals to cooperate with the Centres to reduce this threat. This is connected to the problem of proprietary inputs. Suppose a Centre faces an uncooperative owner of a proprietary input, while an ARI has the capacity to invent around it. Centres might encourage the ARI to do this. The alternative input could compete with the original one and reduce its value. This need not actually happen: this prospect might deter the input's owner from non-cooperation.

While Centres are naturally reluctant to antagonise other players, they may in exceptional cases decide to take active steps in IP conflicts. CIAT initiated litigation in the US in what it considers to be a case of biopiracy by a US firm. The firm had claimed IP for one of CIAT's in-trust crop varieties (Binenbaum and Pardey 2003b). In another case, a recipient Australian organisation of in-trust germplasm applied for PVP, in violation of the relevant MTA. Aggressive publicity by the 'watchdog' non-governmental organisation (NGO) Rural Advancement Foundation International (RAFI) was followed by a few aggressive steps by the responsible Centre. These actions fell short of legal action, but sufficed to make the recipient withdraw its application (anon. referee; Bragdon 2000:81). **[13]** Thus, a signal was sent that Centres are prepared to act aggressively in defence of their missions.

R&D Collaboration **.** Following the logic of bundle thinking, it often does not make sense to try to get IPR transfers alone. The IPR may not be useful in the absence of other elements of the bundle. It takes time to develop trust and coordination to accommodate transfers of all elements of technology bundles. An R&D collaboration is sometimes the optimal setting to accomplish this.

Outgoing Transfers **.** Technology transfer to developing countries is sometimes hampered by lack of capacity for downstream development and distribution in NARS partners. In such cases, the private sector might be involved with the help of IP. For example, the International Centre for Tropical Agriculture (CIAT), a Centre, has a partnership with Papalotla, a Mexican seed firm. Seeds of tropical forages for cattle farming, developed by CIAT, are expensive to multiply and distribute, and NARS lack the necessary facilities for this. Papalotla does have such facilities. According to the agreement, Papalotla helps fund R&D, registers CIAT as plant variety owner in relevant countries, and licenses the rights to sell the seeds from CIAT. The IPR assure Papalotla that competitors won't free-ride on its investments, and helps Papalotla build long-term relationships with its customers, thus allowing it to follow up its seed sales with extension activities. Farmers can thus be properly informed about the new technology's potential (Binenbaum, Pardey and Wright 2002).

Catalysis. The Centres' uniquely connective position in the global R&D system enables them to serve as a catalyst, e.g. for the local private sector. The Papalotla arrangement helps Papalotla grow, and it has begun conducting R&D itself. The International Institute for Tropical Agriculture (IITA), another Centre, has helped foment a private seed sector in Africa (Binenbaum and Pardey 2003b).

3.3 Secrecy versus Openness Issues

As information and IP are closely related elements of technology bundles, the question of confidentiality versus openness is closely related to IP strategy. With respect to public-sector research organizations that are mandated to promote the public good, commentators tend to voice an ideal of perfect transparency. For example, "One of the missions of public universities. is to generate knowledge, technologies, and products that promote the 'public good'. Pursuing this mission demands that universities practice 'open science', which means that scientists completely disclose all new discoveries to the scientific community" (Maredia et al. 1999:247, quoting Argyres and Liebeskind 1998). However, there are circumstances that justify less-than-perfect transparency. A number of problems might be associated with immediate and complete disclosure of research results. First, disclosure may hamper subsequent IP claims. Second, disclosed information might be used by third parties in ways inimical to the disclosing organization's mission. Third, liability concerns could play a role. The holder to IPR, especially in the life sciences, may find itself liable to impacts in areas such as food safety and 'genetic contamination' by transgenics. Fourth, partner organizations, in particular for-profit ones, may insist on partial confidentiality as a condition for collaboration.

In addition, Centres might occasionally want to withhold information from the public domain to use as a bargaining chip. Secrecy can be entirely informal, but in some jurisdictions - under certain conditions - it is protected by trade secret law. Clearly, this type of bargaining chip would be controversial, and I do not know of any Centre use of it. There is, however, one interesting case of a collaboration (the Biological Control of Locusts project; French acronym: LUBILOSA) in which a Centre (IITA) is involved, where one partner (CAB International) did withhold information for this purpose: "The LUBILOSA programme has maintained a policy of public disclosure of information. The only minor exception to the general policy of complete freedom of information occurred in relation to the technical details of the more sophisticated oil miscible (OF) formulation and a limited amount of information relating to spore storage models. LUBILOSA has made public an estimated 99.5% of the information generated through its research. Maintaining confidence about the technical specifications of the OF formulation does not preclude exploitation of the [simple but robust] SU formulation of the mycoinsecticide by non-commercial producers and artisanal producers in developing countries. CABI Bioscience has maintained [the confidential know-how] as industrial secrets on behalf of LUBILOSA in agreement with its partners" (Dent 2000, pp.8-9; Binenbaum & Pardey 2003b).

The Centres' reliance on reputation in securing other players' cooperation does not allow for an extensive use of secrets as bargaining chips. As in the LUBILOSA case, this strategy should be restricted to rare cases where the information has high value for the partnership, but low value for the Centres' clients. The case of information transferred or generated within a public-private partnership is very different: here, confidentiality may be a necessary condition for the partnership. Confidentiality is one of the costs of getting closer to the private sector.

Conditionality of information provision is another matter. Information can be shared immediately subject to conditions. Practically anyone who wishes to use information supplied by Centres or other units connected to the CG System can be made to agree to certain conditions. Such conditions can include the supply of a wide range of data. Technological data are an important subset of the potentially valuable data that could be collected in this way. Various kinds of organisations can be made to supply information about themselves and their partnerships as a condition for tapping into the CG System's databases. It appears that the potential for this kind of data collection not been tapped, although Centres do have a traditional system whereby recipients of breeding products oblige themselves contractually to supply technical data relating to the products (Binenbaum and Pardey 2003b).

The publication of information can serve as a tool to keep third parties from claiming related IPR. Publication may create "prior art", thus rendering an invention non-patentable. But before publishing patentable information, you better be sure that you don't want to seek a patent yourself, because prior art precludes patenting even if the author of the prior art is the same person as the patent applicant (Adams and Henson-Apollonio 2002). Falcon (2001) points to another risk of defensive publishing: that it may not cover all of the patentable information and that it in fact may provide clues that may enable others to patent, using "surrounding" information.

3.4 IP protection by Centres versus No IP Protection by Centres

Many kinds of products of Centre activity may be subject to IP protection. These include, for example, publications (automatically subject to worldwide copyrights), plant varieties, animal vaccines, pest control methods, enabling technologies that are useful in laboratories and genebanks, genomic information, software, field data, data on organisations and partnerships, and Centre names and logos. Each of these categories can be matched with one or more types of IPR. **[14]**

The System's technology positioning choices have yielded an interesting potential IP portfolio. Due to the aforementioned extensions of the System's research agenda that have not been matched by commensurate funding increases, there is certainly a danger of over-stretching and fragmentation of R&D resources. However, this broad portfolio also creates opportunities. Activities in natural resource management and genomics, together with the more traditional breeding activities, may eventually yield powerfully integrated geo-biological information systems managed by Centres and System-wide services. In addition, the System's and Centres' unique connectivity the worldwide network of inter-organisational partnerships and exchanges could enable them to become foci of collection of information on organisations and their relationships. The System could be a source of information on "Who is working on Which Technology With Whom, In Competition with Whom, How (i.e., institutional and contractual arrangements), and with What Results?" As argued above, public and immediate access to such information systems may well be for the most part in accordance with Centres' missions, but needs to be made subject to conditions. And IP protection could make a big difference in enforcing such conditions. Thus, IP protection can be employed in the service of the open exchange of knowledge (Longhorn, Henson-Apollonion and White 2002).

IP protection must be considered in conjunction with alternative and complementary tactics, such as publishing (in case of defensive purposes) and the use of contracts to protect other elements of technology bundles. Confidentiality agreements may be used to protect knowledge; information transfer agreements, to protect information; and MTAs to protect germplasm.

Consider the following list of pros and cons of IP protection, or, more specifically, patent protection. Most of the cost and benefit items listed are in fact effects on game-like and/or political inter-organisational interactions.

Costs of Seeking IP Protection **.** Falcon (2001:55) rightly points out that, as a practical matter, only a small minority of research findings need to be protected. Costs or risks involved in IP protection include: (1) an often substantial direct IP protection cost; (2) ". a concern that the capability to obtain IPR might skew the research agenda of the centres"; and (3) objections of some CG stakeholders who "view proprietary science arising from public money, or applied to living material, as being inconsistent with the CGIAR mission, or even unethical" (CGIAR 1998, p.7).

Clarification of Rights **.** IPR serve a clarifying role and may reduce transaction costs. This argument is relevant in conjunction with the other motives.

The Defensive Motive **.** The public sector may take out a patent in order to prevent for-profits from appropriating the technology. If this is the prime motive for potential IP protection, other methods of keeping technologies in the public domain, such as publication (see above), need to be considered. However, a Centre's patent application in a developing country, perhaps the location of its headquarters, might be a low-cost method for preventing appropriation by others. This has been confirmed to be the primary motive for one Centre for submitting a patent application.

The Revenue Motive **.** Given widespread misgivings among stakeholders, direct revenues may not become a major motive for Centre patenting anytime soon. The controversial nature of this motive was lead to disagreement among an advisory panel: "For most of the Panel, generating income will never be the main reason for seeking protection. This must be clear, or it will be a constant temptation to divert the energies of the Centres away from their mission. A minority of the Panel believes strongly that significant developments of the Centres should be protected if they offer good prospects of financial reward. The money generated should be used for the mission, and for remunerating sources of germplasm." (CGIAR 1998, p.8).

While direct revenues may not an important motive for IP protection in the Centres, indirect revenues may be more relevant. For example, CIAT was able to free resources for other areas of research by initiating a consortium for rice research, the Latin American Fund for Irrigated Rice (FLAR). FLAR is supported by private- and public-sector organisations connected to rice in Latin America. IP protection plays an important role in reassuring FLAR members that third parties won't free ride on their financial and germplasm contributions (Binenbaum, Pardey and Sanint 2002). IP can be an important partnership asset in agreements that also involve financial contributions. For example, the International Wheat and Maize Improvement Centre's (CIMMYT's) patent related to apomixis (asexual reproduction of plants) played an important role in its R&D partnership with several private firms active in the seed business. Part of this partnership is substantial financial support by the firms. It appears that, when embedded in such a larger partnership, the use of IP to help obtain private-sector funding becomes more acceptable to stakeholders. A plausible motivation for the firms to enter this partnership and contribute funds may be that apomixis may undermine markets for hybrid seeds.

Technology Transfer and Development Incentives **.** IPR "can facilitate technology transfer when a private partner is needed to accomplish this goal" (CGIAR 1998, p.8). This may be the case in important areas like vaccine development and plant variety development (CGIAR 1998, p.13). An example is the CIAT-Papalotla deal. In addition, IP "can be used to attract local investments, as well as to facilitate capital formation in the countries where the Centres are located" (CGIAR 1998, p.8).

The "Bargaining Chip" Motive. When Centres possess IP of interest to for-profits, they might obtain, in return for licenses and other forms of use rights to the IP:

1. use rights to IP or materials ("cross-licensing");
2. other assets;
3. favourable conditions in R&D partnerships; or
4. desirable behaviors, for example in for-profits' dealings with poor countries.

The term "bargaining chip", though widely used, is awkward: bargaining does not always occur. A better term is "partnership assets".

Whatever it is that Centres obtain in return for IP use rights, segmentation will often be a key element of the deal. That is, the contract will differentiate between different uses or destinations of the technology. Low or zero royalties may be obtained if for uses by subsistence farmers or in subsequent non-profit research.

Sentiments among the CGIAR System's stakeholders appear to be largely favourable towards this motive. For example, in an electronic conference on the CG's future, "The notion of the CGIAR's germplasm collection as 'bargaining chips' came up often: the CGIAR should strive to negotiate joint ventures with the private sector, to stimulate it to contribute to the needs of poor farmers and marginal regions. They argued that such a policy would be in the spirit of the CGIAR as an international public goods institution. It was recognised that some exceptions may be necessary to offer exclusive licenses to ensure the full development and delivery of some technologies (e.g. animal vaccines)" (CGIAR 2000a:3). Note that the CGIAR System's germplasm collections are mostly not suitable for primary IP protection, but the bargaining chip motive applies to both materials and IP.

A special issue involves R&D products that are essentially derived from CGIAR properties or in-trust materials:

"In some cases, ownership could be used to obtain access to technologies and/or materials developed and protected by others, but essentially derived from CGIAR properties (e.g., the addition of a single gene to a CGIAR-developed plant variety)" (CGIAR 1998:8).

The Signalling Motive . By obtaining a patent, a Centre may demonstrate its innovative capability and enhance its reputation. This might make the Centre a more attractive partner, quite apart from the value of the patent to the prospective partners.

Undesirable Actions by Others and Liability . The control of a technology (or other type of information) afforded by a patent (or other type of IP) may enable a Centre to prevent others from using the technology (information) for purposes the Centre does not approve of or from actions that raise liability concerns. For example, trademarks (covering Centre names and/or logos) are used for this purpose by some Centres. Trademark protection may help prevent problems like unauthorised statements made in name of a Centre (Binenbaum and Pardey 2003a).

3.5 Exclusivity versus Non-Exclusivity in Partnerships with IP Aspects

An issue that must often be faced in partnerships is that of exclusivity versus non-exclusivity. Disadvantages of exclusivity include the concentration of risk and possible negative effects on relations with the partners' competitors. However, exclusive licensing to a single firm or a group of firms may often be necessary to get the firms on board in a partnership, as it is a source of competitive advantage to them. In most partnerships involving Centres, private sector, and IP, there is some form of exclusivity. This is true for several examples cited above: the CIAT-Papalotla partnership, the CIMMYT apomixis partnership, and the FLAR arrangement. In the case of FLAR, the exclusivity is fairly mild: there is only one member organisation in the consortium per country, which obtains the exclusive rights to FLAR varieties in that country; but each member organisation is itself composed of a group of firms and/or other players, and is intended to be representative of the country's rice sector (Binenbaum, Pardey and Sanint 2002).

3.6 The Level of Investment in Expertise and Information Systems

Most Centres have by now invested in IP management. Some have created IP management positions, others have allocated time of existing managers to IP management, and some pro bono IP services are available from professionals. CAS-IP serves as a System-wide counterpart to these, helps to raise awareness in the System on IP issues, provides IP-related information that is of System-wide use, and provides a liaison so that Centre IP managers can learn from each other. It is difficult for one person plus some administrative support - CAS-IP's size - to do all this.

The quality and impact of IP strategy depends in on the scope and depth of supporting information systems. Relational thinking makes a big difference to a proper assessment of the benefits of information systems. While there is a substantial awareness in the System concerning the importance of technological information systems (including patent databases) the same cannot be said of strategic information of the kind "Who is doing What with Whom, In Competition with Whom, How and with What Results?" Available information should enable managers to continually learn about the problems, risks, and opportunities of partnerships. Such information should include prospective partners' track records in prior partnerships, as well as market analyses and internal laboratory notes and invention disclosures, which help managers assess the available IP assets and their potential value to partners.

Portfolio thinking implies that managers should have access to pooled information from the System and beyond. This would enable them, for example, to identify roles that other Centres could play in prospective public-private partnerships.

IP categories allow for useful taxonomies of technological information systems. For example, a patent can be viewed as a unit of technology. Thus, patent searches initially intended to avoid trouble with proprietary inputs, may simultaneously alert managers to technological opportunities. Properly designed data-sharing mechanisms can substitute for explicitly budgeted investments in information systems. Centres may agree to provide in-kind support for system-wide information systems if they can expect, in return, commensurate improvements in these systems. Nevertheless, the expected allocation of only US$300,000 annually to the System-wide Chief Information Officer's unit seems paltry in relation to the CGIAR combined annual budget - about one-tenth of a percent. In sum, a budget increase for both CAS-IP and the CIO would make sense from a mission optimisation perspective.

3.7 Overall Strategy and Higher-level Initiatives

Centre or stakeholders can initiate institutional innovations that may help the System's IP strategies. There may be scope for IP clearinghouse mechanisms (Graff et al. 2001; Graff and Zilberman 2001). Many people in the nonprofit and for-profit sectors support the CG's mission. Combined with the System's network connectivity and its reputation for excellence, this might enable the continuation of an innovation system - that of global nonprofit agricultural R&D - that still is mostly non-proprietary. The viability, efficiency, and scope of such an innovation system are illustrated by Open Source approaches in software development (Lerner and Tirole 2000, 2002). Critical to such a system is the leadership of a small group respected in the R&D community (Tuomi 2003). Centres could perform this role.

If the Centres succeed in becoming global foci of relevant information as well as germplasm and research products, this might suffice to ensure continued supplies of germplasm to their genebanks. NARS will be more forthcoming in their supply of genetic resources if they perceive to receive great benefits from the Centres in return. Such incentives would be especially powerful if (by some new international agreement) Centre genebanks (or some other responsible body) would have the authority to withhold information, germplasm, and/or research products in response to especially blatant non-cooperation from a NARS. With strong enough Centres, such a threat would probably very rarely, if ever, have to be carried out. This is another possible mechanism through which increased investment in the CGIAR could contribute to agro-biodiversity conservation for the benefit of humankind and its future generations.

4. Concluding Comments

The CG System needs to adapt to the management revolution that is taking place in response to the biotech, ICT, and IP revolutions. This is necessary to maintain and enhance the Centres' freedom to operate, to boost their stagnant budgets, and to make each dollar invested in the System more productive in meeting the System's objectives. The requisite management revolution consists of applying the principles of systemic thinking, relational thinking, bundle thinking, and portfolio thinking, and of providing sufficient investment in IP expertise and especially in ICT expertise and user-friendly systems that supply information on a far wider range of variables than is commonly considered necessary for nonprofit R&D management

The principles outlined in this paper imply that IP strategy is useful in a number of ways, the most salient of which are the following. First, the System needs exchange assets and partnership assets to access and leverage other organisations' technologies, IPR, money, people, etc. The System has the potential to create such exchange/partnership assets because of its strengths of network centrality - connecting it to NARS in particular - germplasm collections, and scientific reputation. Exchange/partnership assets may include *inter alia* data - including for example genomic, geo-biological, and relational data -, software, enabling technologies, plant varieties, pest control methods, and animal vaccines. IP strategy can be used to convert potential strengths into exchange/partnership assets. For example, data may be made readily available to the public but subject to certain conditions such as the provision of other data in return. Second, bundle thinking implies that access to IP may be problematic even for use in jurisdictions where the IP is not valid. The IP owner will likely own elements of technology bundles other than IPR. Thus, the IP owner will often need to be dealt with as if the IP were valid in the relevant jurisdiction. Third, IP protection may play a role in technology transfer to developing countries, in the process contribution to the viability of the local private sector. Fourth, while the Centres are more constrained in certain respects - e.g. in obtaining IP protection, or in obtaining funding in return for valuable assets - than other players are, they need IP strategy to find solutions that involve other players - for example, IP ownership by allies, or partnerships that include funding arrangements but make such arrangements more acceptable to stakeholders. Thus, such constraints imply that a greater, not a lesser, awareness of IP strategy is necessary in the System. Fifth, transaction costs are a major issue for the Centres. According to our recent survey of the Centres (Binenbaum and Pardey 2002), access to IP, information and materials is generally possible and licensing fees - if Centres have to pay them at all - are generally affordable. The main problem in accessing technology is costly and time-consuming negotiations. This problem is exacerbated if some negotiators are not sufficiently familiar with IP. Some negotiations and similar hassles are probably inevitable in partnerships; however, such transaction costs are often minimized by clearly delineating current and future IP ownership - or at least procedures that will determine future IP ownership - at an early stage. Sixth, as the FLAR example shows, IP strategy can be employed to design consortia and other partnerships that tap supplementary funding sources. Seventh, IP ownership may allow Centres control of uses of technology so that these are in accordance of Centre missions. Eighth and finally, IP strategy can be employed to help the System play a leading role in the continuation of the innovation system that consists of the System and its nonprofit partners - a system characterised by a minimal use of proprietary mechanisms and a maximum degree of openness and unimpeded flows of information, genetic resources, technologies, and human capital.

This paper's message for economists is: systemic thinking is worthwhile for understanding innovation strategy. Theoretical modelling and empirical hypothesis testing certainly have their place, but these parsimonious approaches should be embedded in taxonomic and systemic structures of concepts, assumptions, and real-world phenomena. Remarkably, individual choices can only be understood at the systemic level. In the traditional analysis of competitive markets, you can work with an actor who responds to a price and otherwise does not take systemic features into account. This picture is somewhat complicated, though mostly still intact, in textbook analyses of market power. But in the individual choices that matter to the topic at hand, such as the set of options to deal with the need for a proprietary technology, the system is fully present in all its irreducible complexity. Embracing parsimony as the only valid methodology would destroy our understanding of this situation.

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[1] Helpful comments from an anonymous referee, Phil Killicoat's research assistance, and information and insights from Marc Ghislain, Dave Hoisington, and Aart van Schoonhoven are gratefully acknowledged. Binenbaum & Pardey (2003b) contains a more detailed overview of the relevant players.

[2] All of which are easily accessible on the Web, with www.cgiar.org providing all the necessary links.

[3] CIAT, CIMMYT, CIP, ICARDA, ICRISAT, IITA, IRRI, and WARDA.

[4] INIBAP, which is part of IPGRI, has a networking role in *Musa* improvement.

[5] IFPRI, IPGRI and ISNAR.

[6] CIFOR, ICLARM (World Fish Centre), ICRAF (World Agroforestry Centre), ILRI, and IWMI.

[7] The literature on innovation systems (e.g. McKelvey 1996) is strongly connected to the modern evolutionary economics tradition which builds on Nelson & Winter (1982).

[8] P layer A may improve its bargaining position by waiting until others have agreed to combine their assets, which then still need to be combined with A's assets.

[9] Heller & Eisenberg (1999) cite studies that indicate that organisations tend to rate their own capabilities higher than their prospective partners do, giving rise to difficulties in reaching a deal.

[10] A recommended reference is Nottenburg, Pardey & Wright (2002).

[11] This section is partly based on Binenbaum & Pardey (2003b).

[12] This theme surfaced in two case studies, Binenbaum, Pardey & Wright (2002) and Binenbaum, Pardey & Sanint (2002).

[13] See website of ETC (RAFI's current name): www.etcgroup.org/documents/news_plantbreeders.pdf

[14] Blakeney, Cohen & Crespi (1999) and Longhorn, Henson-Apollonio & White (2002) are primers on relevant forms of IP. For a review of the Centres' IPR inventory, see Binenbaum & Pardey (2003a).

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