The Intellectual Property Strategy of International Agricultural Research Centres

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This paper targets policymakers and their advisors as well as academic economists. It seeks to combine methodological lessons for economists and non-economists with analysis of real-world issues and policy advice. It advocates systemic thinking and indicates principles for systemic analysis without fully developing such an analysis (which would require a book-length treatment). It tackles issues that arouse great passions and require the transcendence of disciplinary boundaries; systemic thinking may help us overcome our emotional biases and professional narrowness.

The generation of plant breeders, other agronomic experts, and their managers who did pioneering work in the early years of the International Agricultural Research Centres and the latter years of their predecessor institutions may today feel nostalgic. Gone forever are the halcyon days of the Green Revolution, when they did not need to worry about intellectual property, multinationals that constitute formidable concentrations of assets and resources of all sorts, national governments overly protective and possessive of their genetic resources, universities demanding something in return for sharing their most prized inventions, tedious legalities, and a multitude of related hassles and headaches. How can we historically interpret these changes? How can we usefully formulate the problems and opportunities confronting the relevant decision-makers? What are the missions, strengths and weaknesses of the Centres and the nonprofit global innovation system in which they are embedded? We must consider all of these questions as we address the question of primary interest to this paper: What are the main problems, principles, concepts and solutions that characterise the intellectual property challenges that the Centres currently face? This paper is not intended to be a normative exercise in the sense of endorsing or criticising the Centres' strategies. This is because I take their missions as given. An attempt at identifying their missions and finding optimal intellectual property

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[1] This paper builds on a series of papers that were produced in the IFPRI IP Project with funding from the Swedish International Development Agency and the European Union. Those papers include Binenbaum et al. (2000; 2003); Binenbaum & Pardey (2003a; 2003b); Binenbaum, Pardey & Sanint (2002); and Binenbaum, Pardey & Wright (2001, 2002). I owe a great debt of inspiration to my co-authors, but am solely responsible for the present paper. Thanks are due to Phil Killicoat for research assistance. Provision of information and insights from Marc Ghislain, Dave Hoisington, and Aart van Schoonhoven is gratefully acknowledged.

strategies given those missions can be regarded as a positive exercise (even though such an exercise is shrouded in uncertainty and subjective historical interpretation of ongoing processes).

1. Strategic Sketch of the CG System

1.1 The CG System's Environment: A Tale of Five Revolutions[2]

The historical background to this paper lends itself well to being interpreted and narrated in terms of five "revolutions." This rather grandiose term should not be used lightly, but each of the broad historical trends highlighted here is so dramatic and fast-paced as to be truly revolutionary.

The Consultative Group on International Agricultural Research (CGIAR, or CG for short), formed in 1971, and its research centres (CG Centres), played a pivotal role in the widespread introduction of high-yielding crop varieties known as the Green Revolution. They could play this role thanks in part to a global network of transfers among institutions active in agricultural research and development (R&D) of data, genetic resources, technologies, and human capital. These transfers were 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 drastically changed the strategic environment for the CG Centres. In the new environment – still in flux today – all Centres face a series of difficult choices relating to IP.

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 (Binenbaum et al. 2000:9ff.). This has stimulated private investment in agricultural and biotech R&D. The direction of causation between the IP and biotech revolutions runs both ways: biotechnology has yielded improved technological means for enforcement of IP pertaining to living things (Wright 1998). The improved IP incentives combined with the expanding technological opportunities afforded by biotech have contributed to the ascendancy 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,

[2] This subsection is partly based on Binenbaum & Pardey (2003b) which contains a more detailed overview of the relevant players in agricultural R&D.

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 *in situ* genetic resources, thus enhancing an important set of inputs into agricultural R&D. 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 playing an active role in this trend. While IP provides incentives for incentives, it may also hamper subsequent innovation that builds on the technologies protected by it. Complementary IP assets often need to be combined for innovative activities; the dispersion of these among many owners gives rise to a complex of incentive problems that has been called the "tragedy of the anticommons" (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 ag-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. Partly as a consequence of the 1993 Convention on Biological Diversity (CBD) countries may be 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 so-called "designated" genetic resources held "in trust" in the Centres' genebanks on behalf of humankind. This "in-trust agreement" thus aims to reassure countries that their contributed genetic resources won't be appropriated by anyone; such incentives may however not be sufficient to guarantee a continued smooth flow of genetic materials to the Centres (Binenbaum & Pardey 2003b). In 2001, a draft International Treaty on Plant Genetic Resources was adopted by 116 nations. It lists 64 crops and plants that are to be included in a pool of genetic resources which will be freely 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 pedigrees, an issue yet to be resolved. In the United States, the 1980 Bayh-Dole Act encouraged federally funded research institutions to seek IP over their inventions. Partly as a consequence of this Act, patenting by some universities has increased dramatically (Mowery et al. 2001). Negotiating use rights for publicly held intellectual property can be more problematic than for IP held by private firms: public agencies like universities may be hamstrung by regulations or bureaucracies, or royalty-sharing arrangements with faculty (Binenbaum & Pardey 2003b; Nottenburg, Pardey & 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 that all players, even the largest firms, still need partnerships with all of the categories of players (other large firms, smaller firms, advanced research institutes, national agricultural research systems (NARS), and international centres) to access complementary assets and optimally develop new technologies. The core insight from econometric studies conducted in the mid-1990s (Clarysse, Debackere & van Dierdonck 1996; Powell, Koput & Smith-Doerr 1996) that networks of inter-organisational partnerships have become critical to successful innovation in the life sciences, even for the largest players, still seems equally relevant to the life sciences today and is corroborated by large amounts of more recent, albeit more anecdotal evidence.

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 technologically innovative organisations to have (1) internal and external scanning capability; (2) the ability to absorb the scanned information and render it useful 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 and information thus generated. Organisations need to find out who is doing what, identify and locate technological challenges and opportunities, and make informed research agenda and IP choices.

In summary, the combined effect of the ICT, IP, and biotech revolutions is that for R&D organisations in the life sciences to be successful, they must meet far higher standards in their management of partnerships and information systems than, say, two decades ago. Thus, these three revolutions have necessitated a management revolution. The CG System and Centres may need to undergo this management revolution in order to continue playing a significant role in the Green Revolution's follow-up.

1.2 History, Mission, Research Agenda

The CG System is a network of sixteen independent Centres, their donors, additional members, and a set of System-wide services. The sponsors and co-sponsors are (mostly) rich countries, international organisations, and a small number of private charitable foundations. Additional members are mostly developing countries.

Rooted in pioneering efforts dating back to the early post-World-War-II years, the CG System started out in 1971 with just a few Centres which focussed on development of high-yielding varieties of a small set of major crops – rice, wheat, maize, cassava, and pastures – for developing countries. Such productivity improvements, if implemented, generate a mix of producer surplus and consumer surplus, and thus may help both poor farmers and poor consumers.[3] The CG System thus is essentially a conduit for development assistance – it has been from its beginning and still is. The System is linked to NARS partners throughout the developing world.

The CG's agenda has been expanded in five major ways. First, soon after its beginning, the CG System began to encompass R&D activities other than crop-varietal 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 that was added from the early 1980s onwards is natural resource management

[3] One criticism of the initial Green Revolution has been its neglect of the poorest farmers. The System has attempted to address this criticism by making poverty alleviation and enhancement of nutrition and food security for the poor - rather than productivity increases – more explicitly the objective of CG research. In order to assist CG priority setting in this regard, socio-economic impact assessment has become an integral part of the CG research agenda.

(NRM). The initial Green Revolution has been criticised for its unintended environmental effects. A general trend since the early 1980s in agricultural policy and agricultural R&D (Alston, Pardey & Smith 1998) as well as in development assistance is an increase in attention to NRM. It is now the mainstream view in agricultural research policy for the developing world that the research agenda should encompass some kind of environmental sustainability. A "doubly green revolution", combining agricultural productivity with environmental considerations (Conway 1999), has now become the norm among relevant stakeholders. This trend is reflected in the CG System's missions and research agendas. Fourth, the CGIAR has developed a major genetic resource conservation component. Its *ex situ* germplasm collections, originating from an impressive range of agro-ecological environments, comprise a significant contribution to worldwide efforts to conserve agro-biodiversity. The CG's genebank activities are closely interconnected with its breeding programs, but they also serve an independent genetic resource conservation function on behalf of humankind including its future generations. Efforts are underway to fund this role of the CG System through a separate mechanism. Fifth, biotechnology has become a significant component of the CG System's activities (Morris & Hoisington 2000).

The current mission statements and budget allocations of the CGIAR and of all of the Centres[4] 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 into the sustainability of 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 the most important activity category in the System in budgetary terms. Eight of the System's sixteen Centres[5] as well as a subsidiary organisation of a ninth Centre[6] have a primary mandate in crop improvement. Three of the other Centres focus on social science, policy advice, and management issues[7] that relate to the System's mission, while the

[4] All of which are easily accessible on the Web, with www.cgiar.org providing all the necessary links.
[5] CIAT, CIMMYT, CIP, ICARDA, ICRISAT, IITA, IRRI, and WARDA.
[6] INIBAP, which is part of IPGRI, has a networking role in *Musa* improvement.
[7] IFPRI, IPGRI and ISNAR.

remaining five Centres[8] each have idiosyncratic applied 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 so-called "orphan crops" – crops that are commercially so unattractive that they are ignored by private-sector R&D. In budgetary terms, the CG has largely focused on an intermediate group of important staple crops, in particular rice, maize, wheat, and potatoes, that are not big foreign exchange earners but do have large domestic markets in the developing world. Such technology positioning choices matter to IP strategy. The crops that receive the most R&D funding in the CG System are also important crops in domestic markets in rich countries, albeit in different varieties. These are among the crops in which the R&D spending and IP holdings of multinationals are concentrated.

There is a mostly clear division of labour among the Centres, each of which has a unique mandate. Each is an independent and legally incorporated organisation with one headquarters campus plus activities in several countries. Since the CG's beginning, there have been collaborations and exchanges among Centres. However, Centres are often each other's competitors on the funding market, and in the late 1990s there was a perception that collaboration between Centres' was suboptimal. To encourage more inter-Centre collaboration (and to tap into new funding sources), a new funding mechanism was designed: competitive grants for so-called Global Challenge Programs, which require participation of more than one Centre (Binenbaum & Pardey 2003b).

The CGIAR as such is not a legal entity but rather a network. System-wide decisions are taken by consensus among sponsors and members. A number of units provide system-wide services. Most of these units, including two that are relevant in the present context – namely the Central Advisory Service on Intellectual Property (CAS-IP) and the CGIAR Information Officer (CIO) – are now being integrated into a newly created CGIAR System Office (CGIAR 2002).

[8] CIFOR, ICLARM (also known as the World Fish Centre), ICRAF (also known as the World Agroforestry Centre), ILRI, and IWMI.

1.3 IP Policies (Introduction)

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 thus only in the late 1990s that the CG System and Centres began to seriously address IP. 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? [9]

The requisite management revolution should, of course, be underpinned by sound abstract reasoning and applied analysis. But where in the academic literature can we find the conceptual tools required to develop an analytical foundation for the Centres' IP strategy design? This question is not easily answered. We need to combine insights from several disciplines and we need to find or develop some sort of framework for integrating these insights.

2.1 Systemic Thinking

What academic discipline(s) study IP strategy? "Law" may seem an obvious answer. It is true that IP is a legal category, and legal expertise is indispensable in IP strategy design. 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.

[9] The ideas of this section are based on section 2.2 of Binenbaum (2002) and are being worked out more fully in a companion paper (Binenbaum 2003).

There is a literature on strategic management of nonprofits, but it appears to have somewhat neglected IP issues.

How does economics fit in? While there is an institutional separation in many universities between management studies and economics, the former should be viewed as a subset of the latter. Just as economics studies consumer behaviour, it studies managerial decision-making. 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, the field of strategic management endeavours to incorporate insights from many disciplines. It integrates those insights not through mathematical models but 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 completeness in this sense, it stimulates *Gestalt* intuition and thinking on the system as a whole, and is capable of integrating many disparate insights and details. Systemic thinking thus involves the use of taxonomies and conceptual models (e.g. flow charts). To be sure, systemic thinking can be fully mathematical, as in general equilibrium theory; but due to the simplifying assumptions necessary to render completely mathematical systems, this sort of approach does not appear to be relevant in the present context.

The present paper owes much to the style of reasoning common in business strategy case studies. It is eclectic, incorporating any relevant insights. It perceives organisations' strategic outlook in terms of internal strengths and weaknesses and external threats and opportunities.

A number of recent papers address the IP challenges confronting nonprofit 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 perhaps deficient in that they fail to mathematically develop and empirically test hypotheses? No, that wouldn't work: the scope of their discussions would require the (excessively costly or infeasible) testing of large numbers of hypotheses. What they lack is an explicitly systemic perspective. According to a methodological view that is perhaps widely shared among economists, the point of positive economics is to develop and test hypotheses. In this view, the set of received economic knowledge consists of hypotheses that have not been rejected so far. However, there is a danger in this methodological principle, which is that economists may pay insufficient attention to the system into which the hypotheses fit. They may not sufficiently appreciate the value of work that focuses on taxonomic and systemic features.

In summary, a major element that is missing in existing contributions by economists on IP challenges facing nonprofits involved in agricultural R&D is a systemic perspective.

In fact, certain schools of thought of (what is recognised as) 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 & Michie 1999).[10] 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 technology and underlying scientific knowledge 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 in the following subsection, 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

Any rationale of IP strategy is ultimately based on inter-organisational (and interpersonal) interactions. 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) can and should be viewed in terms of inter-organisational relations. (This is illustrated below.) Relational thinking requires a taxonomy of inter-

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

organisational relations. Relation types include transfers (gift or exchange), adversarial relations (including competition), collusion, coordination, collaboration, catalysis (provision of positive incentives) and discouragement (negative incentives). These relation types can be combined to form 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 give pride of place to cultural and social aspects of behaviour. Game theory has begun to incorporate insights from the other social sciences.

Let me give two examples of the relevance of game theory to IP strategy. Suppose a Centre (say C) is in possession of a piece (say P) of IP of clear importance to a prospective partner, a firm (say F). Consider the design of a collaborative agreement between C and F. C contributes *inter alia* P, and F contributes *inter alia* money. But <u>how much</u> money will F contribute? Well, that is determined in negotiations. But how can C know in those negotiations how much to ask for? Clearly, C must have some idea of P's value to F. This situation can be reduced to a game model where C sells (use rights to) P to F. At the core of such a model is an informational asymmetry, and C needs to find a mechanism for revelation of the other side's information. In case F has competitors, the mechanism may be an auction; but revelation mechanisms can also be found in successive offers in bargaining models. The difference could be one (to put this point in stark terms) of a 100-million dollar project with a proper revelation mechanism, or a 1-million dollar project without one. The value of a revelation mechanism could be as much as $99 million more to be used for R&D in this project.

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. This and other insights from game theory are applicable in organisational strategy without explicitly modelling game-like situations.

Relational thinking is applicable to all IP problems. A prominent example in is the problem of proprietary inputs. This problem is better formulated as "How can a Centre deal with the apparent need for a technology/set of proprietary inputs?" rather than "How to access a technology/set of proprietary inputs?" because the former formulation leaves open more options. As a first step, available options must be identified. Analysis can then proceed in terms of relational interactions associated with each option (for further discussion, see Binenbaum & Pardey 2003b and Nottenburg, Pardey & Wright 2002).

First, the Centre may negotiate with the input's owner for a license. The relation type is gift or exchange.

Second, the Centre may unilaterally access the technology. This may lead to a adversarial relationship; repercussions might ensue.

Third, the Centre might be able to contest the IPR either in court or at the IP-granting agency.

Fourth, the Centre may attempt to invent around the technology. This may result in a valuable asset in exchange or collaborative relations with other organisations. It may also lead to a reduction in value of the original technology and hence a loss to its owner.

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.

Fifth, the Centre may initiate a bilateral or multilateral R&D collaboration (another relation type) with the input's owner; use rights to the input may be included in the partnership. Segmentation is likely to be important.

Sixth, the Centre may initiate a consortium (another relation type) and participate in it. The consortium may include other parties that would like to access the proprietary input, and may either focus on this particular input or have some broader theme. Note that the consortium can also be used for accessing other proprietary inputs and for R&D.

Seventh, the Centre may abandon the R&D program if the input is both critical and inaccessible, and do nothing.

Eighth, the Centre may abandon the R&D program, but catalyse (another relation type) other—nonprofit or for-profit—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.

Finally, specific 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.

Thus, a single seemingly simple problem necessitates consideration of a wide variety of relations and institutional solutions, and thus has systemic ramifications. Essentially, each option initiates a game, and any further analysis is bound to benefit from game-theoretic insights. This is true not only for the non-cooperative approaches, but also for the cooperative approaches (for example, the fourth and fifth options).

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

The above example illustrates the first two steps of dealing with an ill-defined choice problem: finding a correct formulation of the problem (one that does not preclude relevant options) and listing all options. A next logical step is cost-benefit reasoning: assessing costs and benefits associated with options.

Consider a two-option problem: whether or not to seek IP for a given output. This problem can be analysed in terms of the costs and benefits of IP protection. Again, taxonomic completeness is important: relevant cost and benefit items should not be overlooked. (This point bears repetition in view of the preference many economists have for "parsimonious" approaches.) A list of cost and benefit items that matter to Centres' IP choices is provided below. The point to be made here is that most of the items in that list refer to positive or negative effects IP choices have on inter-organisational interactions. Game theory, balanced with or integrated with insights from the social sciences, provides the tools for understanding such interactions.

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 fulfillment can be greatly enhanced. One category of incentive problems is asymmetric information. The above example about a revelation mechanism hints at the value of game theory in solving incentive problems such as those connected to asymmetric information. This class of incentive problems is the subject of a literature, summarized and reviewed in Salanié (1997), which typically employs the assumption of opportunism (Williamson 1985:47).

Other classes of incentive problems are potentially relevant to IP strategy as well. For this reason, 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 signaling, game dynamics (including holdups, 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 & 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.).

In summary, in analysing the CG System's IP strategies and consequently its inter-organisational relations, we must find a balance between traditional game-theoretic approaches that assume 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. For example, 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. Because of the IP revolution, this story must be amended and extended. IP has raised the appropriability 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 nonprofit action. The anticommons 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,[11] cognitive biases[12], 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 public sector, say, the CG System, may thus have a role in stimulating the players

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[11] Player 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.

[12] 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.

to achieve a high equilibrium rather than a low one. It may encourage the multilateral exchange of information, which can be viewed as a Prisoners' Dilemma in which each player has an incentive to withhold information.

2.4 Bundle Thinking and Portfolio Thinking

A full systemic perspective on IP strategy encompasses technological as well as inter-organisational connections. Salient principles regarding technological connections 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 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 ideally be addressed not as a series of ad hoc decisions but in an integrated fashion, by considering the set of needed proprietary inputs as a whole. This requires 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 it is embedded as an organisational routine. This inventory can then be coupled with a stream of information on external sources for the inputs. Similarly, on the output side, all valuable technology-related items, including inventions, that 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. Given a well-functioning information system, technologies of prospective partners can be identified as being complements to or substitutes for a Centre's technologies.

As individual Centres are small players, their missions would benefit from pooled information systems and consideration of joint portfolios of assets and needed inputs.

3. IP Strategy Challenges

The CG Centres' IP challenges include issues 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.

The CG Centres' IP challenges should be understood in the context of the Centres' strengths and weaknesses. These can be summarised as follows.

The strengths pertain to the System's appeal to clients and donors as well as to prospective partners. For prospective partners, the Centres' guardianship of genetic resources as well as their high degree of connectivity with NARS are attractive. They provide links to field-testing facilities in a large number of 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 biotechnology investments, in particular, while significant, are dwarfed by those of the private sector. Centres are further constrained by politics, stakeholders' sometimes conflicting demands, and a consensus-based culture that may inhibit bold initiatives. Centres face an increasing problem with restricted funding: donors insisting on specific uses for their contributions. This reduces the Centres' flexibility (Binenbaum & Pardey 2003b),

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

3.1 Freedom-to-Operate Issues

Apparently, this is the set of issues that originally motivated the interest in IP in the CG System. Consequently, this is what most of the relevant literature has focussed on so far.[13]

In 1998, a report was published (Cohen et al. 1999) that found that permission to use proprietary inputs in Centres was often either absent or unknown. This report may have caused alarm about IP infringement through use of proprietary inputs in the Centres. Thus, it was this issue that appeared to be the focus of IP concerns in the CG System. 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, and these exports are concentrated in a few crops and a few exporting countries. The 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. However, bundle thinking implies that this conclusion is incorrect. If IP were separate from the other complements of technology bundles, you could access it unilaterally outside of its jurisdictions. But this may not work since you might lack other components of the bundle – in particular genetic materials.

Access to materials was rated as relatively problematic among IP-related problems in a recent survey of the Centres. In particular the provision of breeding materials by multinationals to Centres is highly problematic. Materials provision by NARS and by advanced research institutes is also not without frictions (Binenbaum & Pardey 2002, Falcon 2001); for example, a manager at the International Potato Centre (CIP) reports that "the environment specially in developing countries is changing towards more defensive and protectionistic attitudes"; in view of this tendency, CIP is planning to review its formal IP policy (Marc Ghislain, pers.com.).

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

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

obtained from their owners. While it is not the IPR *per se* that limit Centres' access to the materials in many cases, they will find themselves in a position as if they had to negotiate for permission to use IP. It is thus unsurprising that rights to genetic materials are routinely covered in discussions of (or even, not quite correctly, considered to be a subset of) IPR in the life sciences.

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 process technologies, the codified information and human capital components of the technology bundles are important. It may not be very useful for a Centre to try to reconstruct such technologies from the cryptic descriptions in patents. In order to most effectively use such technologies, partnerships with the IP owners that include the supply of additional information and the exchange of scientific personnel may be required. The Centre will find it helpful to secure its own IPR, or more generally, control over valuable assets, in preparation for such partnerships (see next subsection).

The relevance of the anticommons problem to the CGIAR's work is vividly illustrated with the example of "GoldenRice^{R}," a type of rice with beta-carotene genetically engineered into it. GoldenRice^{R} has the potential for a great nutritional and health impact. About 70 pieces of IP, dispersed among a number of players, pertain to technologies embodied in GoldenRice^{R}. All or most of these players must be persuaded to give permission to use their IP or related items for this project to proceed (Kryder, Kowalski & Krattiger 2000). While these pieces of IP are for the most part not valid in the developing world (Binenbaum et al. 2000, 2003), the owners simultaneously possess other elements of the relevant technology bundles.

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 (or, more correctly, the right to sue to exclude) others from using the patented subjected matter in any way, including research. Other types of IP or material property are apparently 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. Plant variety rights, a *sui generis* form of IPR specific to plants, are generally less restrictive than patents. Most importantly, they allow for the use of protected varieties in breeding programs. The resultant varieties may themselves be protected through plant variety protection 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 plant variety rights follow the 1991 version of the International Union for the Protection of New Varieties of Plants (UPOV). Under this treaty, plant variety rights extend to “essentially derived” varieties. That is, you may not take protected variety A, insert a gene into it, and sell the resultant variety without the consent of A’s owner. However, UPOV 1991 (the strongest version of plant variety protection) safeguards the use of protected varieties to obtain non-essentially-derived varieties, thus leaving the breeders’ exemption intact for the most part (Blakeney, Cohen & Crespi 1999).

Material property rights do not prevent any use of properties after they have been transferred, unless explicit legal or contractual restrictions apply. Material transfer agreements (MTAs) may restrict use of transferred materials, but only the signatories to MTAs are bound by them. Restrictive MTAs are a major source of concern among Centre managers (Binenbaum & Pardey 2003b).

How to solve freedom-to-operate issues? There is no simple solution. 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 & Pardey 2003b). It is important to note this, because multinationals have made well-publicised donations of intellectual property and (hitherto) confidential information. The reason for this may reside in multinationals generally behaving in ‘territorial’ ways, but an alternative or complementary explanation can be found in the Centres’ tradition of dealing with a multitude of nonprofit players – they are far less experienced in dealing with the private sector. Let us, then, pay a bit of special attention to the Centres’ relations with the private sector.

3.2 Relations with the Private Sector[14]

What kinds of relations are appropriate between CG Centres and the private sector? What are the strategic IP implications of the answer to this question?

Centre managers are understandably 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 often looked at with suspicion by some of the System's traditional stakeholders. A cooperative relationship (e.g. exchange, gift, or R&D collaboration) is generally intended to benefit both sides. Thus sponsors might ask whether their contributions to CG Centres that cooperate with, say, multinationals, are subsidising the latter. Even more problematic may be the attitudes of providers of genetic resources, e.g., "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.

However, 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. In their interactions with the private sector, Centres will likely discriminate between different types of firms, especially between firms based in developing 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.[15]

Incoming transfers. Transfers of IPR as well as the other components of technology bundles from firms to Centres are important to the Centres. Often, licensing or acquiring a bundle element from the owner is the only or best way to obtain the desired technology. The item may be sold or licensed at a commercial fee, but often will be transferred at a lower or zero price. Firms may have a variety of reasons to do so (Binenbaum & Pardey 2003b). Many of these considerations can be summarised as "maintaining long-term relationships with the Centres" and relate to the Centres' strengths listed above.

Transfers are often most effectively organised as a part of partnerships that encompass other relation types, such as R&D collaboration, as well

[14] This section is partly based on Binenbaum & Pardey (2003b).
[15] This theme surfaced in two case studies, Binenbaum, Pardey & Wright (2002) and Binenbaum, Pardey & Sanint (2002).

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 imperfect substitutes for more expensive transgenic varieties, thus forcing multinationals to reduce the latter's prices and benefiting farmers.

The potential for Centres to produce or encourage the production of competing technologies and products may encourage multinationals to cooperate with the Centres to reduce this threat. This is also connected to the problem of proprietary inputs. Suppose that Centres face an uncooperative owner of a proprietary input. Suppose that an advanced research institute has the capacity to invent around it. The Centres and donors might encourage the ARI to do this and supply the alternative input to the Centres. The alternative input would 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 United States in what it considers to be a case of biopiracy by a U.S. firm. The firm had claimed IP for what CIAT considers to be one of its in-trust crop varieties (Binenbaum & Pardey 2003b). In another case, a recipient Australian organisation of in-trust germplasm applied for plant variety protection, in violation of the relevant material transfer agreement. A few aggressive steps by the responsible Centre, short of formal legal action, were sufficient to make the recipient withdraw its application (Bragdon 2000:81). A small number of actions of this kind may suffice to signal to partners and other players that Centres are prepared to act aggressively in defence of their missions if necessary. They may thus play an indirect role in an appropriate "sticks and carrots" or "Tit for Tat" (see above) approach.

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. A partnership involving 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 perform the latter roles, and intellectual property may play a role in this. For example, the International Centre for Tropical Agriculture (CIAT), a Centre, has entered a partnership with Papalotla, a private 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 the necessary R&D, registers CIAT as plant variety owner in countries where it plans to sell the seeds, and licenses the rights to sell the seeds from CIAT. The IP protection provides assurance to Papalotla that competitors won't free-ride on its investments in this project. The IP protection also helps Papalotla to engage in long-term relationships with its customers, thus allowing it to follow up its seed sales with extension activities. Farmers can thus be properly informed so that they can realise the potential of the new technology (Binenbaum, Pardey & Wright 2002).

Catalysis and Coordination. The Centres' uniquely connective position in the global agricultural R&D system enables them to initiate arrangements, even ones in which they themselves are not directly involved. They may strengthen or even help emerge a local private sector. The Papalotla arrangement helps Papalotla grow, and it has begun engaging in R&D itself, in collaboration with CIAT. The International Institute for Tropical Agriculture (IITA), another Centre, has also assumed a catalytic role. It helped to get the private seed sector started in West and Central Africa (Binenbaum & 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.[16]

[16] For example, CIMMYT IP policy IV.4 states: "On occasion, CIMMYT may enter into contracts that provide for the acquisition and management of confidential materials. CIMMYT may also seek to protect the products of its research by obtaining intellectual property protection through patents, plant breeders' rights, copyrights, trademarks, statutory invention registrations or their equivalent, and/or trade secrets to serve the resource poor in the following kinds of situations:" This IP policy document,

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, especially the land-grant colleges and 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 & Liebeskind 1998).

In practice, 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 intellectual property claims, which in turn may be justifiable on a number of grounds. Second, the disclosed information might be used by third parties in ways inimical to the disclosing organization's mission. Third, liability concerns could play a role. 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, results and outputs generated throughout the course of its research and development… 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… The remaining small amount of work that is not in the public domain relates to a highly sophisticated formulation, that has not been as extensively tested… The OF formulation could not

dated August 2001, was in force as of, and downloaded, January 8, 2003. The point is that this quote puts confidentiality and IP together in consecutive sentences.

be produced by an artisanal approach because its manufacture requires the use of costly specialist machinery. 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). For more on the LUBILOSA project, see Binenbaum & Pardey (2003b).

The Centres' reliance on reputation in securing the cooperation of many players 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 strategic value for a prospective partnership, but low value for the Centres' clients. The situation for information transferred or generated within a collaboration with a private-sector partner 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.

However, this does not imply that it is optimal for the Centres to unconditionally share their information in most cases. In fact, it would be misleading to entirely reduce disclosure strategy to a simple secrecy/openness dichotomy. 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 has not yet been fully tapped. The CG System does traditionally have a system whereby recipients of breeding products oblige themselves contractually to supply technical data relating to the use of the products, e.g. in their own breeding programs (Binenbaum, Pardey & Wright 2001; Binenbaum & Pardey 2003b).

The publication of information can serve as a tool to keep third parties from claiming IP related to the information. Publication may create "prior art", thus destroying the potential novelty of an invention and rendering it non-patentable. But if you decide to publish 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 & 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 (which are automatically subject to worldwide copyrights), plant varieties, animal vaccines, pest control methods, enabling technologies that are useful in laboratories and genebanks, genomic information, software, all sorts of field data that Centres collect, data on organisations and inter-organisational partnerships, and Centre names and logos. Each of these categories can be matched with one or more types of IPR.[17]

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' uniquely centrality in worldwide inter-organisational interactions 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 Centers' missions, but needs to be made subject to conditions. And IP protection could make a big difference in enforcing such conditions. Thus, IP

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

protection can actually be employed in the service of maintaining and furthering the open exchange of knowledge (Longhorn, Henson-Apollonion & White 2002).

IP protection must be considered in conjunction with alternative and complementary tactics, such as publishing (in the case of defensive purposes) and the use of contractual arrangements that may help protect other elements of technology bundles. Confidentiality agreements may be used to protect human knowledge; information transfer agreements, to protect codified information; and material transfer agreements (MTAs), to protect materials, in particular genetic resources. However, such contractual arrangements may be relatively weak forms of protection, as only the signatories to contracts are bound by them.

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: "Clearly, not all research findings need to be protected; indeed, as a practical matter, very few of them do."

Costs or risks involved in IP protection include: (1) an often substantial direct IP protection cost; (2) "… a concern that the capability to obtain intellectual property rights 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 rare as an independent motive, but may play a role in conjunction with any of the other motives.

The Defensive Motive. The public sector might on occasion 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.[18]

The Revenue Motive. Given widespread misgivings among stakeholders, direct revenues are unlikely to be a major motive for Centre patenting in the near future. The controversial nature of the revenue motive was reflected in disagreement among members of an advisory panel on IP: "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. Only a few developments generate income—and it is not easy to predict which—but all cost money to protect. This does not mean that if money is offered, it must be refused.

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 (there are many possibilities, including paying farmers who preserve biodiversity, royalties to communities of origin, supporting research into *in situ* conservation benefiting the poor, etc.). Not to protect such developments is to waste useful resources" (CGIAR 1998, p.8).

The United States' experience after the Bayh-Dole Act of 1980 has been that royalties from most university inventions are modest, with a few notable exceptions; for a few universities, royalty income constitutes a significant, though not major, contribution to research budgets. The International Centre for International Centre for Genetic Engineering and Biotechnology (ICGEB) is an interesting contrast to the CG System. It is somewhat comparable to the CGIAR as an international R&D organisation, but has no qualms about licensing revenues, of which it receives more than $1 million annually.

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

[18] The name of this Centre cannot be disclosed due to confidentiality.

financial and germplasm contributions (Binenbaum, Pardey & Sanint 2002). IP can be an important partnership asset in agreements that also involve financial contributions. For example, the International Wheat and Maize 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. Hybrid varieties that reproduce sexually lose their vigour in successive generations; their seeds must therefore be re-purchased. If apomixis is engineered into hybrid varieties, successive generations will be genetically identical and seeds may only need to be purchased once. The firms' interest in this partnership may have been motivated by the desire to partly control a technology that has could potentially transform their business strategy.

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 agreement mentioned above.

According to a related argument 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 the for-profit sector, they might obtain, in return for licenses and other forms of use rights to the IP: (1) use rights to others' IP and materials ("cross-licensing"); (2) other desirable assets; (3) these and/or other favorable conditions in R&D partnerships; or (4) desirable behaviors, for example in for-profits' dealings with developing countries. In fact, the term "bargaining chip", though widely used, is a bit awkward: Bargaining occurs often, but not always, in the relevant relationships. A better term would be "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 nonprofit research.

Sentiments among the CGIAR System's stakeholders appear to be largely favorable towards this motive. For example, in an electronic conference on the CGIAR System'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 Signaling Motive. By obtaining a patent, a Centre may demonstrate its innovative capability and enhance its reputation. This alone 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 & 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 & Sanint 2002).

3.6 The Extent of Standardisation of IP policy at the Centre and System Levels

Many aspects of IP policy lend themselves well for standardisation across interactions of a single Centre or even among all Centres. For example, Centres employ standard MTAs, including a System-wide standard MTA for in-trust materials. Although the Centres are independent organisations, they largely have the same missions and face the same pressures. They study each other's IP policy statements, MTAs, etc., so that a time-ordered sequence of IP policies statements from different Centres may reflect a series of adaptations and improvements (Aart van Schoonhoven, pers. com.) as well as strategic differences.

Standardisation is also often appropriate for IP-related rules involving access to the databases of the Centres and System-wide units.

However, partnership choices and specific institutional IP arrangements do not lend themselves for standardisation.

3.7 The Proper Level of Investment in IP Expertise, Strategy Formulation and Supporting Information Systems

The benefits of investment in IP expertise, strategy formulation, specific IP choices, and supporting information systems, are extremely difficult to quantify. This is especially due to the relational nature of IP matters. The impacts of an improvement in IP strategy resources on the totality of relevant game-like interactions, and via these the impacts on mission-related indicators, would have to be anticipated – a close-to-impossible task. However, managers may improve their intuitive sense of the prospective value of such investments by familiarising themselves with the principles put forth in this paper.

Most Centres have by now invested in IP management. Some have created IP management positions, others have allocated significant 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's experiences. In practice, it is difficult for one person plus some administrative support – the current size of CAS-IP – to do all this.

The quality and impact of IP strategy depends in a large measure 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 extensive technological information systems (including, to some extent, patent databases and the like) 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?" There is a wide variety of institutional arrangements and scope for improvements in them. The problems, risks, and opportunities inherent in partnerships are manifold, and managers should be able to learn from accumulated worldwide experiences. They should have ready access to track records of prospective partners in their prior partnerships. They should have available data that allow estimation of the value of their organisations' assets to prospective partners. This requires both readily available market analyses (even though the managers themselves may not be commercial players) and internal laboratory notes and invention disclosure systems. Information on competitive relationships Large and rich information systems should be extremely user-friendly – in this way a small number of managers and advisors can effectively access astronomical amounts of data through rapid filtering procedures. User-friendliness of information systems requires relatively large investments.

Portfolio thinking implies that managers should have access to pooled information from the System and beyond. This would enable them, for example, to rapidly identify another Centre that could contribute an invention or other assets to a prospective public-private partnership.

Some game-theoretic awareness goes a long way towards appreciating the value of fine-tuned incentive provision in institutional arrangements and the value of possessing information indicative of partners' valuations of one's assets.

Two further connections between IP strategy and information systems are worthy of mention. First, 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 that may initially be intended to avoid trouble with proprietary inputs, may simultaneously serve to alert managers to technological opportunities to further the Centres' missions. The discipline and organisational routines required to conduct a minimally responsible and defensive IP policy might simultaneously enable more proactive and entrepreneurially-minded IP approaches. Second, IP managers/advisors and ICT managers/advisors should spend time to coordinate their strategies/advice. This working time should be taken into account in budget allocations.

To a certain extent, the proper design of information-sharing mechanisms can substitute for explicitly budgeted investments in information systems. In-kind support from Centres can be elicited for system-wide information systems if the Centres anticipate, in return, a commensurate improvement in information provision. Nonetheless, in light of the foregoing considerations, the expected allocation of only US$300,000 annually to the System-wide Chief Information Officer's unit seems positively paltry in relation to the CGIAR combined annual budget – on the order of one-tenth of a percent. Two effects of investment in information provision (as well as CAS-IP) can be distinguished: the impact on the productivity of a given budget, and the expected boost to the budget. If all other CGIAR activities were to sacrifice another one-tenth of a percent to double the CIO's budget, that would likely boost the effectiveness of those activities (in terms of indicators of mission fulfilment and managers' valuations of those indicators) by a multiple of that percentage. In addition, the improved information provision would probably allow Centres to increase their budgets – again, by a multiple (in terms of net present value) of the investment. Remember that funds can be raised in the context of partnerships.

In summary, it is likely that a budget increase for both CAS-IP and the CIO would make sense from a mission optimisation perspective. Unfortunately, such intuitions are practically impossible to back up with numbers – what is really required is a proper understanding of what is at stake among managers and donors of the CG System.

3.8 Overall Strategy and Higher-level Initiatives

Policymakers at any level (donor, other stakeholder, System, Centre) can initiate institutional innovations that may help the System's IP strategies. There may be some unexploited scope for IP clearinghouse mechanisms (Graff et al. 2001; Graff & Zilberman 2001). Many institutions and persons (including some employed in multinationals) share the values embodied in the Centres' missions. Combined with the System's network connectivity and its reputation for scientific excellence, this might enable the continuation of an innovation system - that of the CG System and its nonprofit partner institutions – that is, to date, for the most part non-proprietary. The viability, efficiency, and scope of such an innovation system are illustrated by Open Source approaches in software development, such as Linux (Lerner & Tirole 2000, 2002). Critical to such a system is the existence of a small set of leaders that are respected in the R&D community (Tuomi 2003). This is the sociological status that Centres need to have in order to be or become foci of information flows.

The Centres may overcome their limitations as small players in biotech and enhance their freedom to operate by finding allies in the public and private nonprofit sectors. To do so, a rich and user-friendly supply of relevant information on these players is indispensable. Consider one (sub)type of solution to the proprietary-input problem. Manager M at Centre C needs input I from private player P. P is unwilling to share I. M searches her information system and finds an advanced research institute (A) that might be able to invent around I. After some initial contacts it is apparent that A is indeed capable of developing the alternative I' to I, but the funding isn't available. M again searches her information system, this time concerning the prospective commercial value of I. After all, if I is an important enabling technology, then would I' not be able to capture some of the value of I? The information search reveals the potential of I' to do so its applicability for additional purposes not served by I. C's sponsors as well as venture capitalists who might be interested in a commercial spinoff from A are approached for funding. Some respond positively. Meanwhile, some information concerning these activities is transmitted to P. Now, P is willing to share I with C, while joining a partnership with A to develop I' that will give it some control of I'.

This example is just one among an endless amount of permutations in patterns that may be followed to operate successfully in the era of advanced ICT, advanced biotech, and widespread IPR. It illustrates relational thinking (including game-like features) as well as the critical role of information systems in finding institutional solutions to IP problems.

The example of FLAR and a few similar commodity-based consortia shows that there is potential to find private-sector funding from developing countries in the type of crops that dominate the CG's research agenda, namely crops with large domestic markets but without large exports to rich countries. Thus, someone in or around the CG System should examine the relevant markets to see if consortia can be arranged that tap into this source of funding.

Some Centres have developed a culture conducive to such initiatives. Other Centres appear to be more cautious. While Centre missions and sponsors are similar, these differences and differences in mandates guarantee that a large diversity of institutional experiments are undertaken. Some of these experiments are more defensive and less risky, aimed at avoiding IP trouble; others involve substantial risk, for example exclusivity in licensing. The diversity in Centre policies may lead to differences in Centre growth, as sponsors and other funders will observe success or failure.

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. Countries – that is, their NARS – could be made to be 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.

5. Concluding Comments

I hope to have persuaded the reader that the CG System, as other nonprofit and for-profit organisations active in the life sciences, needs to undergo a management revolution in response to the biotech, ICT, and IP revolutions. This management revolution 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 de 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.

For economists, the message is complex yet in essence simple: Systemic thinking is worthwhile for understanding innovation strategy. Theoretical modelling (e.g. to contribute to institutional solutions to incentive problems) 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 complexity. Embracing parsimony as the only valid methodology would destroy our understanding of this situation.

If they pay sufficient attention to both systemic features – e.g. relation types – and insights from the other social sciences – such as the sociology of Open Source –

economists have much to contribute. They can provide subtle rationales for public and nonprofit action, for example by pointing at the existence of multiple equilibria in repeated games. They can apply econometric testing to many relations between variables. They can help design innovative incentive mechanisms and institutional structures. They may find in the present paper plenty of ideas to do these things. In addition, the present paper is only one step in the direction of systemic analysis of the CG System – much more remains to be done here.

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