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Abstract

This paper examines the potential impact of interconnectivity of supply chain partnerships through electronic means (e-business practices) on the governance and management of Public Sector Agriculture R&D in Australia.

We review the global forces driving the move towards supply chain involvement in Public Sector Agriculture R&D in the first section of this paper. We show that this movement is largely a mechanism (consistent with fifth generation R&D) to spread risk and minimize market failure. Public sector R&D organizations are having to reassess who their customers are and in the case of Agriculture R&D, extend the arena past the farm gate to include all constituents along the supply chain.

In the second section, we examine the communication and administrative processes that are theoretically consistent with the move towards supply chain involvement and the increase in active constituents in Public Sector Agriculture R&D. We then examine the potential of emerging e-business models to change the patterns of inter-connectivity, speed and omnipresence of partners in the supply chain that are on one hand eliminating these barriers and on the other creating new ones. Amongst the emerging new barriers is the increased instability of these supply chains because of the decrease in switching costs that the e-connectivity brings with it. Value net business models can potentially capture these fluctuations in alliances and may provide a useful tool for guiding public sector Agriculture R&D management. Implications of these e-business practices for R&D corporate governance and project management are discussed.

Introduction

Most businesses need to examine how to survive in a knowledge-based economy. Public Research and Development agencies are no exception. This paper examines the movement towards supply chain partnerships and the potential impact of interconnectivity of these partnerships through electronic means (e-business practices) on the governance and management of Public Sector Agriculture R&D in Australia.

One of the oldest and enduring Australian government R&D involvements has been in Agriculture. From OECD figures, half of all the productivity gains in Australian agriculture in the 20 years to 1998 were directly attributable to R&D. Funds for this R&D are provided by the commonwealth government and state governments and augmented by funds provided through voluntary levies administrated through commodity based Research and Development Corporations. The major research funded through these sources is done through State Departments of Agriculture, Universities and the Commonwealth Science and Industry Research Organisation (CSIRO). The Commonwealth Government contributed $150.5 million to rural R&D corporations in 1998-9. Recognising the importance of R&D, the industry financial contributions for the same period were $135.5 million" (Minister Warren Truss, Minister for Agriculture, Fisheries and Forestry. Revitalising Rural Australia through Revitalising Rural Industries, Outlook 2000 Conference March 2000). However, while still a substantial amount of moneys, in reality the proportion of Government funds for Agricultural Research has significantly decreased (Whittemore, 1998) and programs that are funded are shifting in focus. These trends are not limited to Australia (Alston, Pardey and Smith, 1998).

Historically, much of this involvement had been in research and development aimed at improved farming methods, implementing crop protection and regulatory standards. Prior to 1980's, most Agricultural R&D projects in the public sector were done without much formal involvement with

persons other than those within the research unit. This researcher driven focus has been looked upon as one reason for poor rates of uptake of the outputs of these research efforts (Scoones & Thompson, 1993). Combined with the political reality that significantly smaller proportion of the electorate are involved in farming, Governments are raising serious questions about their involvement as funders of research and as doers of research. In order to spread risk of failure to a wider audience and to adopt potentially better procedures for extension, public sector research organisations are seeking commercial partners and joint funding alliances. These partnerships are encouraging the adoption of marketing and end-users involvement strategies to minimise market failure (Papageorgiou, 1993; Eisenberg, 1996; Massaro, 1996). Many of these R&D practices are consistent with the third, fourth and fifth generation R&D models that have been developed in the private sector (Liyanage, Greenwood & Don, 1997; MacLeod & Shulman, 1997). One result of involving more stakeholders in the R&D process has been an increase in the identification of supply chain factors beyond the paddock where potentially greater returns on R&D investment can be secured. For the public sector R&D enterprise as a business, at least from a Resource -Based Theory of the Firm, the entrance into new supply chain strategic alliances is likely to be facilitated by the factors listed in table 1 (adapted from Barney and Hesterly, 1996: 138) and as argued in this paper, the unique market niches that are made possible because of engaging in time sensitive R&D practices associated with adoption of e-business practices.

In this paper we first examine developments in Agricultural R&D management as it moves to incorporate supply chain alliances. [1] We then examine how the entrance of e-commerce business models are overtaking the supply chain approaches and presenting new challenges for Government Agricultural R&D Agencies both in their role as Funder and as Provider of R&D. We investigate e-business solutions where the interconnectivity and speed are comparative advantage. We find that increased competition and lowering of switching costs are leading to adjustments through amalgamation, with mergers and alliances in value chains. We suggest that the current supply chain R&D focus is likely to be modified as the advantages of value nets are realised. R&D management will need to recognise the possibilities and threats associated with the changing information technology infrastructure on R&D process and governance.

Developments in R&D Management

Models of R&D management have evolved from linear models to process models of managing an arena of players, and moving from closed systems to open systems approaches; from R&D simple linear transfer of technology approaches where specialists operated independently of each other and often independently of outside clients, to increased dialogic practices with market pull and science push. These models of R&D are summarised in Table 2.

Insert Table 2 here

Each of these normative models has progressively built on the failures of the previous one to guide improved outcomes. The current fifth generation model acknowledges that R&D exists within a multi-layered network of relationships, where the value adding performance of R&D depends to a large extent on the performance of other actors to which it is directly and indirectly connected. The arena model highlights that projects are not isolated occurrences, but are part of a larger context of action. An arena is comprised of those entities (persons, organisations etc) actually engaged in an activity. The composition of an arena effects decision making in various ways, through (1) the range of views on a problem and ways of proceeding (2) the dynamics of the ways in which people relate (3) the availability of human and capital resources and (4) the distribution of responsibilities for outcomes (MacLeod & Shulman, 1997).

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Historically, much of the Agricultural R&D carried out was related to concerns of production of a commodity such as increased yield or developing products and farming systems that would be resistant to pests or more suited to particular climatic conditions. The primary focus has been on "before the farm gate". However, in part due to opportunities to develop new markets within the global economy, the focus has been shifting to issues beyond the farm gate. These include supply chain issues such as improving storage systems, distribution systems and packaging for serving new markets. The view that there is only marginal value to be gained in the efficiency of production compared to the value that can be gained by developing new markets and improving supply chains is reflected in recent changes in the research priorities of the industry/ commodity funded research and development corporations in Australia (Unpublished Report, "The Alignment of DPI's R&D Effort with Government Priorities", December, 1999). Under conditions of decreasing financial resources, this shift presents major challenges to the established Australian Government Research Agencies in their role as a provider of Agricultural research. Among these challenges is divesting their investments in physical capital, (i.e. experimental plot field stations), human capital (i.e. scientific staff mainly trained in pre-farm gate science) and social/ organisational capital (ie much of their political support has come from the disproportionately powerful rural lobby and the overlapping directorships of the Commodity funding bodies and the research providers), whist shifting to investment intensive challenges in biotechnology and post harvest supply chain opportunities where their comparative advantage is yet to be established.

Implications of moving to Supply Chain R&D Management and the emergence of e-businesses

Interest in the supply chain is a natural progression from market failure. New and more players are involved in developing solutions past the farm gate and include suppliers, transport, processors and consumers, each of which may have different agendas. Because of reduction in trade barriers, much of the post harvest production is oriented to increasing transaction efficiencies and product differentiation for domestic consumption and developing new products that have comparative advantage for international markets.

The development of niche markets, speed to market and quality of product within windows of seasonal variation are current supply chain issues that augment the need to ensure continuity of supply to these markets. The ways of managing the R&D processes that can deliver changing market specific products and processes are getting more complex. Private sector Agricultural organizations such as Chiquita, are creating larger vertical supply chain trading groups through amalgamation of existing organisations. In many ways R&D Agencies are finding that they must form new alliances with these new players to provide the necessary skills to address the increased range of issues arising within the expanded arena. From an R&D perspective, more players need to be included and involved earlier in the research process. Managing more stakeholders stretches the expertise of the management. This itself gives rise the need for new dispute resolution and coordination mechanisms that allow for dynamic adjustments in speed of discovery and implementation of research.

As in other industries, information technology has reduced the coordination costs and has also changed the nature of R&D alliances that government R&D agencies are part of. Global R&D through consortia provide different opportunities, which lead to different ways of research. Alliances in R&D are not new, but what is new is how they operate and the rather fluid nature of their relationships. The advantage of new alliances is that they "are more strategic than traditional joint ventures, create value in many different ways and their ultimate consequences cannot be measured with precision"(Doz & Hamel, 1998: 11). These new alliances being formed have a strategic approach. For example, The Australian Commonwealth Scientific Industry and Research Organisation (CSIRO) has developed a strategic alliance in food science with Singapore based F& N foods (the largest food research organization in the Asia Pacific region) and is building alliances with major international firms operating in strategically important markets. The initial focus is on dairy products and juices and will be extended into functional foods such as those with special

health benefits. The alliance establishes a framework for co-operation between the two organizations in research, training and the exchange of personnel (CSIRO 2000 Media Release) "Our growing involvement in international markets should enable us to develop more relevant and competitive research programs and the overseas collaborations that follow from them enhance our ability to deliver world-class results" (CSIRO 2000 Media release.) Much of their work is performed by scientists at different locations. Such distributed collaborations are not viable without the internet.

Scientists and Researchers were amongst the first group to develop and utilise the internet for enhancing the exchange of information. However with the increased connectivity and ubiquities of e-business links amongst most members of the supply chain, new R&D approaches to fulfilling supply chain opportunities are emerging. These e-business models eliminate problems related to time and distance and increase the possibility of collaboration among partners. However, e-business models are much more than technology. They are the application of communication and information-sharing tools among trading partners in the pursuit of their business objectives. E business practices can coordinate markets, coordinate research players within researchers and input from constituents access to laboratories for better information and distribution.

E business has introduced two effects into Agricultural R&D. First on the supply chain, it has acted as a conduit by collecting, coordinating and disseminating information about markets and the supply chain. Secondly, the nature of alliances and the style of alliances is itself threatening reduced switching costs. To date much of the return on investment in utilizing e business process in R&D has been mainly in business to business (B2B) relationships, and the benefits are the reduced development cycles, and the possibility of "Just in Time" procedures. But it offers opportunities to speed up novel approaches to adaptable products through the application of knowledge and information technologies. The emerging picture is of a value net, which reflects the multiple roles that an R&D firm plays as complementor, supplier, substitutor, competitor, and customer. These multiple roles require the rethinking the relationships of those roles For Public Sector R&D organizations.

Embracing change and Flexible R&D

With increased competition and changes in information technology, many research organisations are moving from a long term R&D product approach to R&D product planning and implementation with radically faster real-time strategies for response variation. The changes in R&D management are parallelling the changes in mass customisation. "Rather than competing by forecasting customer's needs and then planning the year's production using inventories to match supply and demand, firms are relying on real-time sensors to continuously discover what each customer needs sometimes even anticipating unspecified needs, and then quickly fulfilling those needs with customised products and services delivered with hitherto unavailable capabilities and speed. The result is an almost immediate responses to customer's demand through dynamic resource allocation and execution" (Bradley & Nolan, 1998: 4).

That is, these changes in mass customisation are reflected in models of flexible development emerging in R&D. Traditional models of R&D tend to emphasise the need to avoid unnecessary change and uncertainty during development. There is a clear concept development phase, producing a stable product concept that leads into a distinct development phase. In this traditional model, extensive efforts are first made to identify customer needs and assess the feasibility of new technologies. In contrast, recent research in fast-moving technology driven industries shows that "leading firms embrace change rather than fight it and the new approach is characterised by its emphasis on flexibility" (Iansiti & MacCormack, 1998; Inasiti 1995, 97; Thomke, 1996). In this flexibility research model the concept development stage continues as long as the specification is evolving. Systemic changes in a project's definition and basic direction are managed proactively in a process without a precise idea of how the effort will end. "The key to the new approach is the ability to gather and rapidly respond to new knowledge about a technology and its application

context on an ongoing basis even after implementation has begun" (Iansiti & MacCormack, 1998:178). This approach moves the concept freeze as close to the market introduction of a product as possible. That is, concept development and implementation became tightly linked rather than separated. Project managers move back and forth between fundamental, architectural choices and the detailed design and work on the project is integrated and tested at regular intervals and feedback from those tests is integrated into the design. This "design-build-test" sequence repeats continuously as long as the concept development and implementation phases overlap. The need to respond rapidly to unpredictable changes in technology or market conditions makes iteration essential (Iansiti & MacCormack, 1998: 178).

Agricultural R&D can learn from the flexibility initiatives developed in other industries, as R&D the auto industries, that has developed different research processes of "research at the last minute". Within this industry, co-development research teams have enabled more speed of development for new models, and better ways to work with more sharing of ideas. Co-development is similar to parallel development with a multiple focus on problems but it is based on ongoing bilateral flows on complete information with negotiation about risks and costs. Technical and economic objectives are negotiated early in the development process and interactive work methods focused on joint problem solving. Co-development has contractual forms that take into account specific problems caused by shared innovation (economic and legal treatment of confidentiality, patent rights and royalties, risk and benefit sharing, exclusive rights to market a product). Through a process of co-development, "Suppliers have acquired full responsibility over the design and engineering of components, suppliers tend to apply simultaneous engineering of product and process suppliers manage the technical interfaces between components and suppliers create prototype testing, modeling, simulation and design data bases" (Laigle, 1998: 211). These high connectivity processes have been used n in distributive systems where members of the teams are working in different locations on similar or dissimilar processes.

The flexible model has major implications for how agricultural R&D is conducted. These are summarised in Figure 1. First, as new varieties are developed it may be possible to simultaneously explore potential markets and delivery channels before the product is fully developed. Production researchers can work with market researchers to find opportunities to sell projected products where the processes affecting the possibility of building changes in production and marketing in agricultural products offers a range of opportunities for existing products in terms of new markets or new channels. One example is the marketing of Australian apples to the lucrative Hong Kong market at a time when markets in the northern hemisphere are not supplying. What Australian enterprises were able to do was to package large red apples for the Chinese New Year complete with greetings for this new niche market.

Secondly, flexible production requires quick responses and developing models or funds to research new ways of working and new technology to enable quick response to changed markets and changed conditions or alternative distribution systems. The need for speed leads to new systems ordering and delivery for products. Following the emerging intermediary role that small to medium size organizations are creating for themselves in the supply chain, the Government sponsored or operated research infrastructures needed by industry to deliver information and to coordinate the information and lessons may become much smaller than the large infrastructures that now exit. An example of this can be seen in the effective downsizing of the Department of Agriculture in New Zealand and their creation of the much smaller and agile Crown Research Institutes.

Thirdly, flexible production has implications for research on the nature of the product itself. Variation of agricultural product has been used in the selection and breeding of market specific products (including animals and germplasm) and recently effort has been directed at developing new markets for these existing products. However, the notion of flexible production in agricultural products suggests that selection or enhancement of characteristics or traits that can be modified by changed environmental treatments or conditions closer to the market. In this way a number of

variations in the products themselves can be extended and enhanced at the development rather than the concept phase with last minute changes. For example variations in colour, in texture, or in resistance may be introduced closer to the market with multiple possible outcomes from a basic product. R&D previously directed at enhanced production could be refocused to speed up or to slow down biological processes such as ripening, or faster growth. 'Flexible' or changing products creates possibilities of an increased variety of end products for a variety of niches and ensures further customisation. In addition to this, potential market failure of agricultural products requires active participation of an R&D unit in different ways, including ways of stabilising acceptance of agricultural output. These new ways include forward selling, or developing with supply chain partners, ways of increasing the durability of the product (storage, temperature control etc), or with e-commerce strategies, developing new channels and markets and administrative structures and research structures and flexible alliances for switching channels to develop or meet markets. Initiatives such as developing new products (and research protocols) that can be transformed at the last possible moment to serve opportunistic markets, again as part of research collaborative enterprises and as part of value chains, where as an intermediary in the supply chain, the R&D firms alliances are also governed by decreases in switching costs.

From a research management point of view, e-business processes may provide a strategic advantage to companies. R&D organisations have the potential to speed up research access with multiple sources of information, with improvements in accessing information as well as remotely running experiments (CSIRO), or to run parallel projects at the same time. Other possibilities include sharing infrastructure or scheduling infrastructure innovation serving. Sharing information and participating in joint ways of working through establishing sets of partnerships, vertical integration , such as Chiquita, and alliance management CISCO Agriculture: group of partners supply needs.

Implications for Public Sector Agricultural R&D Management

Much of the research in the area of e-business in general is of a prescriptive nature and not guided by systematic data. This paper continues and suffers from this trend, as many of our observations of the effects of supply chain changes to R&D are anecdotal. However the emerging pattern raises questions for the future role of Australian agricultural R&D management. The need for and the desirability of Australian Public sector R&D to engage in strategic alliances is clear. From the resource based theory of the firm, developing the capacity to meet the demands of serving the supply chain from end to end, with existing structures and staff is likely to be impossible. R&D administrators recognise this.

The Public sector has traditionally played important roles in situations of market failure and in developing capacity in important industries. In Australia it has been both a funder and provider of research. However, the reduction in government funding for R&D and the increased demands of multiple constituents involved in supply chain alliances are likely to change the role and activities of public sector R&D.

We assume that the public sector will continue to play a major role in industry development with new R&D practices. The need for a 'speed to market' response to attain competitive advantage and an immediate increase in competitiveness through mass customisation creates the possibility for the variety of products which can be altered at the last minute, a variety of niche markets and variety of distribution are new elements in agricultural R&D. However, the responsibility for R&D lies with both public and private sector bodies and differentiating between who carries out the work and who takes the risk.

Some of the questions of future roles for public sector R&D in agriculture include the development of research infrastructures. We suggest that the public sector may take initial roles of seeding or coordinating while other intermediaries provide information in conjunction with industry. At least

in Australian agriculture, the public sector is likely to continue to collaborate with R&D corporations and will play a subsidiary or facilitative role with industry bodies.

Public sector R&D is increasing collaborative relationships and partnerships with the private sector. In the area of "flexible products", public sector R&D is likely to continue to take a lead role to develop capacity in the variability of products for different markets, through partnership with the private sector to develop new solutions. For example new packaging for fresh fruits for extended shelf life but marketed as "fresh".

E business practices are already influencing project management in public sector R&D at the project implementation level and at project monitoring. On the one hand, project leaders have increased potential for international collaboration with opportunities for real time collaboration, parallel projects and sharing the use of existing facilities in other parts of the world. The speed with which experiments can be undertaken can be improved and well as the required frequency of communication. Time has become a commodity and speed to market a driving force.

However, on the other, external stakeholders can expect to have more influence with increased involvement of more players and improved flow of information. The changed outcomes of R&D comes from more people, and a dynamic situation which create new markets, new partners and new information. How the goals dealing with shifting outcomes are negotiated is determined by partnership and the way they are structured by government. Traditionally the influence of funding bodies on RD&E projects had been in relation to the concept proposal and accountability for meeting milestones. However in practice milestone reports are submitted and reviewed long after the project has ended its next phase. E-business brings with it the potential of real time accounting, and R&D corporations and other funders have possibilities of more and regular information at more relevant points. Systems can be established to provide early warning signs that projects are going off the rails or not meeting the required progress.

The challenges of e-business and supply chain raise questions for public sector agriculture R&D in a context of reduced funding. Public sector agriculture R&D is likely to continue with industry development roles and with partnerships with private sector to minimize risks, and hence increase the flexibility and speed of response to emerging and dynamic markets. However, the paradox that remains is how to manage the risk sharing required for longer-term R&D projects and how to manage the transition in human and social capital to maximize the viability of the industry.

Conclusion

Models of R&D and R&D management will continue to evolve influenced by e- business processes and multiple value nets. The flexible development processes developed in R&D in other industry sectors have application in agricultural R&D and increased development of time to market and entering at the last minute provides new directions. The combination of moving from supply chain to demand chain together with the processes of e- Researchers previously had power and could control the agenda, this power has decreased. E-business opens the possibility for flexibility of production and marketing in niches that may be open for short time periods, as well as flexibility in R&D product development and new research infrastructures that enable and support such initiatives.

References

Allen, T.J. (1977) *Managing the Flow of Technology: Technology Transfer and the Dissemination of Technological Information within the R&D Organization.* Massachsetts Institute of Technology.

Alston, J., M., Pardey, Philip, G., Roseboom, Johannes (1998) Financing Agricultural Research: International Investment Patterns and Policy Perspectives. *World Development* **26**(6): 1057-1071.

Baker, J. (1999) "The Alignment of DPI's R&D Effort with Government Priorities", Unpublished Report, December.Barney J.B. & Hesterley, W. (1996) Organizational Economics: Understanding the Relationship between Organizations and Economic analysis. In Clegg, S.R. Hardy, C. & Nord, W.R. *Handbook of Organizational Studies*. London. Sage.

Bradley, S.P. & Nolan, R.L. (1998) Capturing Value in the Network Era. In Bradley, S.P. & Nolan, R.L. *Sense and Respond: Capturing Value in the Network Era*, Boston, Massachusetts: Harvard Business School.

Brown, J. S. (1997) *Seeing Differently*. Boston, Mass: Harvard Business School.

Coombs, R. and Hull, R. (1998) Knowledge management practices and path-dependency in innovation. *Research Policy*, **27**, 237-253.

CSIRO web page: http://www.csiro.au

Doz, Y.L. and Hamel, G. (1998*) Alliance Advantage: The Art of Creating Value through Partnering*. .Boston, Mass: Harvard Business School Press**.**

Eisenberg, R. S. (1996) Public research and private development: patents and technology transfer in government-sponsored research. *Virginia Law Review*, **82**: 1663 - 1735.

Iansiti, M. & MacCormack, A. (1998) Product development on the Internet. In Bradley, S.P. & Nolan, R.L. *Sense and Respond: Capturing Value in the Network Era*, Boston, Massachusetts: Harvard Business School.

Laigle, L. (1998) Co-operative Buyer-Supplier Relationships in Development Projects in the Car Industry. In Lundin, R. A &

Midler, C. (1998) *Projects as Arenas for Renewal and Learning* Processes. Boston: Kluwer Academic Publishers**.**

Massaro, T. (1996) Innovation, technology transfer, and patent policy: the University contribution - Commentary. *Virginia Law Review*, **82**: 1729 -1737.

OECD (1996) The Knowledge-Based Economy. Excerpted from *OECD Science, Technology and Industry Outlook*. Paris:

Papageorgiou, J. C. (1993) Issues on the future of R&D and Innovation in the USA. *International Journal of Technology Management*, 8[6/7/8]: 500 - 512.

Ross, J. and Staw, B. M., (1993) Organisational escalation and exit: Lessons from the Shoreham nuclear power plant, *Academy of Management Review*, **36**, 4, 701-32.

Rothwell, R. (1994) Towards the Fifth-Generation Innovation Process, *International Marketing Review*, **11**, 1:7-31.

Scoones, I. and Thompson, J. (1993) Challenging the populist perspective: rural people's knowledge, agricultural research and extension practice. Discussion Paper 332, Institute of Development Studies, University of Sussex, Brighton.

Thomke, S. Von Hippel. E.A. & Franke, R.R. (1997) Modes of experimentation: An Innovation Process Variable. Working Paper, Boston Harvard Business School. (97-052).

Unpublished Report, "The Alignment of DPI's R&D Effort with Government Priorities", December, 1999.

Minister Warren Truss, Minister for Agriculture. Fisheries and Forestry. Revitalising Rural Australia through Revitalising Rural Industries Outlook 2000 conference March 2000.

Wilkinson, J. (1998) The R&D Priorities of leading food firms and long-term innovation in the agrofood system. *International Journal of Technology Management*, **16**. 7. 711-720.

Whittemore, C. T. (1998) Structures and processes required for research, higher education and technology transfer in the agricultural sciences: a policy appraisal. *Agricultural Economics* **19**: 269-282.

Table 1 Motivations for entering strategic alliances

1	Exploit economies of scale
2	Low-cost entry into new markets
3	Low cost entry into new industry segments and new industries
4	Learning form competition
5	Managing strategic uncertainty
6	Managing costs and sharing risks
7	To facilitate tacit collusion
8	Time sensitive entry into new markets
9	Time sensitive development of new products

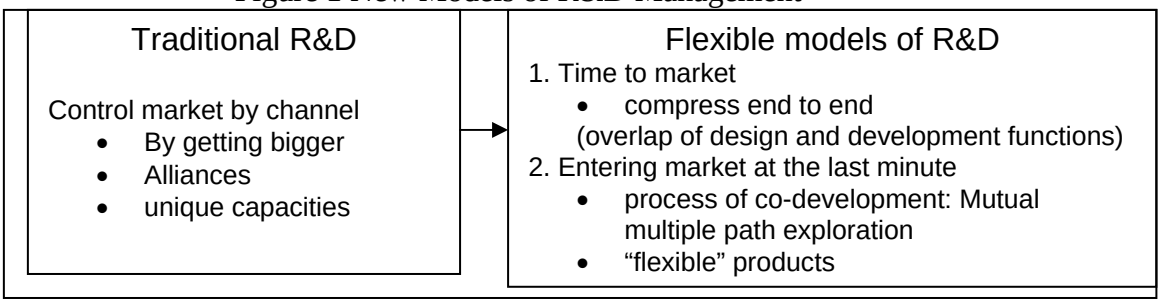
Source: Modified from Barney & Hesterley (1996)

Table 2 R & D Project and portfolio communication management models

MODELS OF R&D	DISTINGUISHING FEATURES
First Generation	Linear Transfer of Technology (TOT), where R&D specialists operate independently of other extension & marketing staff and from potential clients from outside agencies. Followers of these practices have had limited success in improving outcome performance
Second Generation	Increased dialogue at the formulation stage concerning aims of specific R&D projects, both science-push & market-pull; seek interactive dialogue between R&D providers & clients. Limited success.
Third Generation	Recognised need for partnerships between public R&D providers and clients & commercial businesses. 3 key features: portfolios of projects are used to spread risk, unnecessary tight coupling is to be avoided particularly in the research phase, and the need for mutual trust between parties and acceptance of unique contribution to RD& E process is recognised. This has emerged as the dominant 1990's model.
Fourth Generation	Recognition of the political nature of R&D. RD&C is a dynamic process with resolution of conflicting interests changing alliances and competing world views. Major understanding of the rules for managing appropriate expectations within the partnerships and alliances.
Fifth Generation	Arena theory: composition, predisposition and relative power of different stakeholders will shape the range of possible inputs, outputs and outcomes. The knowledge generation capacity and the political nature of constituents are to be conjointly managed. Hence, choice and timing of involvement of stakeholders is critical for optimising innovation and delivering on its potential.

Source: Adapted from MacLeod & Shulman (1998)

Figure 1 New Models of R&D Management



Source: developed for this paper