Turning Research into Innovation: A Systems Approach to Innovation in Food Safety

Ian Jenson[1, 2*]

[1]School of Land and Food, University of Tasmania, Hobart, Tasmania 7005, Australia

[2]Meat & Livestock Australia, P.O. Box 1961, North Sydney, NSW 2059, Australia

SUMMARY

Consumers expect food to be safe, and whether this expectation is fulfilled influences the success of a business and/or industry sector. However, economic and social factors do not support willingness to adopt food safety practices. Therefore, even though food safety management needs to be improved and research is funded, research alone is insufficient to ensure change in food safety activities (innovation). Innovation is a complex process, and reasons in addition to economics may prevent innovation from occurring. The concept of innovation systems can be used to analyze innovation processes and identify the elements that need to be managed. A number of factors, other than the quality of the research, have been shown to be essential to ensuring that research projects lead to innovation and improved food safety results. Furthermore, an innovation system intermediary is required to ensure that the innovation system is operating effectively and that research outputs are implemented so as to improve food safety.

OVERVIEW

Innovation, defined most simply, is the implementation of something new, or a significant improvement, in business practices, workplace organization, or external relations *(1)*. Innovation is of great interest to both governments, seeking to develop national economies, and business, seeking higher return on investment *(46)*. Innovation should also be of great interest to food safety research agencies, researchers, regulators, and others wishing to see improvement in food safety performance and public health. Food safety research must leave the laboratory and be applied in the food supply chain and associated institutions (for example, public health agencies) before it can be considered innovation. Many researchers find sufficient reward in the process of discovery, but greater recognition and public benefit arise from the application of those discoveries by producers, suppliers, industry, consumers, and public health officials. For funding agencies, the headline of an opinion piece in *The Times* holds too true: 'Don't expect public science to lay golden eggs' *(38)*, as funds are gambled on research in the hope that an investment will lead to a new approach to the control of foodborne illness and to improvements in public health.

This article explains a systems approach to understanding innovation, which has been shown to be applicable to food safety research conducted in the Australian red meat industry. The article proceeds by describing the economic and social context of food safety and innovation, systemic approaches to understanding innovation, studies conducted on food safety innovation in the Australian red meat industry and, lastly, the implications for food safety research policy and innovation practice.

THE SOCIAL CONTEXT OF FOOD SAFETY INNOVATION

Consumers' desire for safe food, and the failure of markets to respond appropriately, has resulted in food safety being subject to government intervention. Because of weak market signals, strong institutional arrangements, expressed as laws, regulations, and standards, are necessary. Market signals are said to be weak because attributes such as food safety are often not valued in markets since it is difficult for consumers to measure and because poor quality can be difficult to judge, even after consumption *(7)*. It is not easy for the supplier to provide information to consumers that will allow them to evaluate the food safety of the product because of the inherent uncertainty and complexity of determining food safety attributes such as the presence of pathogens and of anticipating the conditions of storage and transport that may exist in the supply chain. Market signals are thus generally considered too weak to induce action to improve food safety *(37)*, and gaining a poor reputation for food safety may be necessary before a business takes action to improve its performance. Scientists and technologists often complain that this lack of signalling results in industry being unwilling to invest in processes and new plant because these will not provide a rapid return on investment *(14)*. Significant actions to improve food safety have often occurred only as the result of government intervention or strengthening of private quality assurance standards in the face of significant foodborne illness and demonstrably inadequate voluntary food safety management

*Author for correspondence: Phone: +61.2.9463.9264; email: ijenson@mla.com.au

systems. Governments can intervene in a number of ways, including through regulation, that cause those in the food supply chain to make changes to their business practices in an attempt to improve food safety outcomes. Changes made to regulation, or the way business is conducted, may result in innovation in food safety (rather than increased attention to already established practice).

Innovation in food safety is always required in the event of newly recognized hazards or newly recognized foods as sources of illness. Food safety is a relative, rather than absolute, concept; there is always a chance that a serving of food will cause an adverse reaction, or illness. The relative nature of food safety risk is reflected in regular reports of the incidence of foodborne disease from well-known pathogens as well as from emerging hazards *(41, 42)*. Disease is attributed to foods that have a long historic record of association with illness, as well as to unexpected foods, as demonstrated by occasional outbreaks caused by foods that would usually be considered safe *(15)*.

Consumers and their representatives, such as customers or businesses purchasing food, may also demand food safety *(47, 48)*. Governments respond to such demands to protect citizens by encouraging industry development and by making policies that they expect to gain or retain public confidence in the food supply. Laws and regulations define acceptable practices and systems in the hope that implementation will meet consumer expectations. For over one hundred years, governments have been sufficiently concerned about the quality and safety of food supplied to citizens to enact broad legislation that has placed responsibilities on food businesses and has set requirements on their activities *(47)*.

Improvements to food safety through innovation is a knowledge-based activity. Knowledge about products, processes, safe sources of supply, and systems of production need to be possessed, implemented effectively by the business, and capable of being demonstrated to customers and/or regulatory authorities. Knowledge, understanding, and practice are essential ingredients of a safe food supply. Practice is heavily dependent on understanding the hazards and the food supply chain, which in turn is dependent upon scientific knowledge, from the creation of knowledge through to its adoption. Many scientists are employed in the area of food safety, funded by both government and industry. Most research is in the public domain because the research is not easily valued (and therefore, not subject to intellectual property protection) and because it potentially benefits all stakeholders when actions are taken to improve food safety.

Responsible participants in the industry invest heavily in knowledgeable staff, product development, packaging design, storage and distribution infrastructure, quality control systems, certification, and licenses before they commence a business operation. Staying in business requires attention to product safety and, among other things, maintaining a good reputation and having a favorable status with regulators.

Joseph Schumpeter defined five types of innovation over 100 years ago *(45)*, and these are still being used for analysis by the OECD *(1)*. While food safety professionals think about their work as leading to changes in product formulation, processes, or procedures, it is useful to consider how the changes are perceived by businesses and consumers, because this leads to an understanding of how change needs to be implemented. The types can all be applied to food safety:

- New products and product qualities; the product may be new because the product has been reformulated *(33)*. For example, a preservative maybe added to the product, either a completely new ingredient or one that has been used previously only in other products or that has been used only at a lower (ineffective) concentration.
- New production methods; a new process may be used to produce an existing product *(14)*. For example, pasteurization may have been used but with a different combination of time and temperature, or newer technology may be used, such as the application of high pressure or electromagnetic fields.
- New sources of supply; the food producing businesses may find a new, safer source of supply for a significant ingredient *(33)*. For example, supply chain relationships may change and private quality assurance standards may be implemented *(19)*.
- Exploitation of new markets; the business may choose to sell their product only to certain customers for certain uses to ensure that it is rendered safe for consumers *(49)*.
- New ways to organize business; the business may be organized in a different way, such as empowering staff to consistently take actions that result in subtle process changes that make food safer (*53)*.

HOW CAN INNOVATION PROCESSES BE UNDERSTOOD?

A number of models have been employed in an attempt to explain the innovation process *(2)*. A popular model in the scientific community and in product development has been the linear model *(Fig. 1)*, with stages emphasizing the significance of basic research as the prerequisite for later applied research and then development *(3, 16)*. The linear model has received much criticism, including the stinging rebuke that it "is well suited to defend the interests of researchers and scientists and the organizations in which they work" *(13)*. Models that are more sophisticated have been developed that attempt to encompass the complexity of the innovation process. In particular, systems approaches to innovation have been developed to "describe, understand, explain — and perhaps influence — processes of innovation" *(11)* over the past 25 years. The systems approach has been defined in general terms as including "all important economic, social, political, organisation, institutional, and other factors that influence the development, diffusion, and use of innovations" *(11)*.

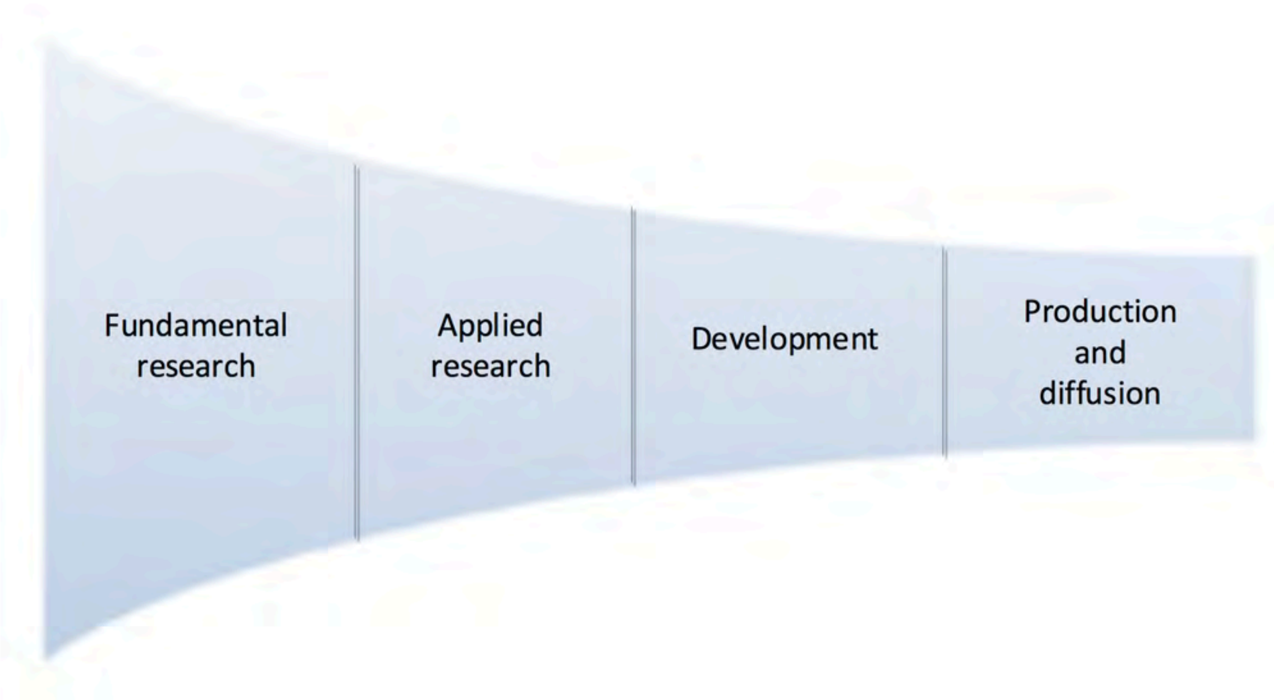

FIGURE 1. The linear model of innovation *(17)* is often characterized as a funnel in which research and development progresses sequentially through stages and a decreasing number of opportunities are pursued to the point of innovation.

Innovation system models supplement the process of discovery and development found in the linear model with elements that include the social and economic market drivers for innovation (as illustrated in the previous section) and the resources (financial, infrastructure and people) required for innovation. Actors and institutions are significant elements in innovation system models *(12)*. Actors are people or bodies that make decisions and take actions within the innovation system; they may be government, independent government bodies, research organizations, universities, individual firms, entrepreneurs, researchers, consultants, or civil society groups. Institutions influence the way that the system operates by facilitating the activities of the system. Institutions may be divided into hard institutions such as laws, financial systems, intellectual property protection systems, and soft institutions such as the prevailing attitudes and the conventions of doing business within a country or industry sector (degree of trust, orientation toward action, risk aversion, long term orientation, etc.). By identifying the elements of an innovation system, and how that system works, the proponents of innovation systems approaches hope to make the innovation process more certain and therefore more valuable to society. There are, however, few if any examples of an innovation system approach being used to manage an innovation process; rather, they have been used as retrospective analytical tools.

Four major systems approaches to innovation have been described: the national, regional, sectoral, and technological. Governments and similar bodies have used national and regional innovation system approaches for economic and social development. Sectoral and technological innovation system approaches have been used to understand and suggest policy approaches for encouraging the development of industry sectors and technologies, and thus are potentially applicable to food safety innovation. Both sectoral and technological innovation systems may cross the boundaries defined by national and/or regional systems *(34)*. Sectoral innovation systems seek to understand how innovation occurs within and between firms within a sector of the economy and are acknowledged as a flexible, holistic, and interdisciplinary approach to understanding innovation of products and services within an environment influenced by multiple actors and institutions *(12)*. Technological innovation systems consider the development of a technology itself, without being unduly encumbered with the constraints of national, regional, or sectoral system elements. They are considered to contain all the components necessary to influence the innovation process for a particular technology *(4)*.

Thus, multiple factor models, or frameworks, have been developed to explain innovation system performance within sectoral *(29)*, and technological innovation systems *(4)*, and these frameworks therefore have the potential to be used for diagnosis, and rectification, of any failure or weakness that may occur in the sectoral or technological innovation system. The elements of these innovation system failure frameworks (listed and defined in *Table 1*) can be assessed and have been used in the study of the success or failure of technological innovation in industry sectors *(17, 25, 51)*. The system elements may be thought of as prerequisite conditions and essential processes that occur in innovative industry sectors, and in successfully introduced technologies.

An example of how innovation system elements can operate within food safety innovation is provided here, based on the author's experience and reflection. Around 2004, it became apparent to some senior managers in the Australian beef export industry that the demands of regulators and customers in the USA for assurances of the safety of manufacturing beef was likely to increase. Manufacturing beef (beef trim) is used as a component of ground beef that is used in the production of hamburger patties, and efforts were under way in the U.S. to reduce the likelihood of contamination of the product with *E. coli* O157:H7. Meat & Livestock Australia (MLA) was asked to convene a committee, comprised of industry representatives, their industry association, the export regulator, scientists, and industry consultants, to prepare a response to future requirements from international customers and regulators. The committee held a number of meetings over a period of years, discussed and commissioned various research projects, and developed response plans. When the Food Safety and Inspection Service (FSIS) of the U.S. Department of Agriculture (USDA) announced in October 2007 that they would commence testing of manufacturing beef in commerce, the Australian industry was prepared to respond with sampling and testing protocols, as well as a considered industry position, and the export regulator was prepared to negotiate with the USDA-FSIS. As a result, trade was not impacted, U.S. customers were assured of the safety of Australian product, and the USDA-FSIS chose to test Australian product at a very low rate. The innovation was judged by those with knowledge of the work to be a market (supply chain) and a business model innovation. All of the innovation system elements were judged to have been strong *(Table 1)*.

Innovation systems are not simply theories or analytical constructs; they are comprised of real actors, shaped by institutions, including government policy, that can be considered to produce critically important food safety innovation outcomes that have consequences for organizational, sectoral, and national economic competitiveness.

APPLICATION OF INNOVATION SYSTEMS TO FOOD SAFETY INNOVATION

Sectoral and technological innovation systems failure frameworks have been applied to food safety research projects in the Australian red meat industry that were expected to result in innovation in food safety management *(21–24)*; a description of the application of these frameworks to the retrospective analysis of projects follows.

A case study design, with cases being defined as food safety projects concerned with the safety of mostly exported raw beef and sheep meat managed by MLA, was conducted *(21, 22, 24)*. MLA, an industry organization funded by the Australian red meat industry and the Australian Government, and works cooperatively with industry to define research needs, contract research to universities and other providers, and exploit the results for the benefit of the industry. Innovation is the desired outcome, but is not always the result. An on-line survey of project participants was used to determine whether innovation occurred and to estimate the strength of the elements that the two innovation system theories identified. Fuzzy set Qualitative Comparative Analysis (fsQCA) methods were applied *(39, 43)* which utilized set theoretic methods to determine the relationship between the condition sets (innovation system elements) and the outcome (innovation).

Types of Food Safety Innovation

Food safety innovations were classified according to the Schumpeter/OECD typology *(1, 45)*. In this study, 27 cases of successful innovation were identified. Business model innovation was most frequently evident (14 cases), usually in combination with another type of innovation. Two or more types of innovation were evident in 16 of the cases of successful innovation *(Fig. 2)*. The distribution of predominant innovation types is a function of the projects conducted by the research organization. However, the occurrence of multiple types of innovation identified in individual projects is significant. Understanding the type of innovation that is implemented by businesses or supply chain provides an insight into how food safety research will affect the business and supply chains and therefore indicates how change needs to be implemented. The combination of different innovation types reflects the complexity of innovation affecting safety of a product in a heavily regulated environment; an innovation in industry practice likely results in several changes to the operation of the business. For example, the introduction of an innovative product to existing customers may require changes to the production process, or to business process as well as new regulations or approval. The occurrence of multiple innovation types in a single innovation has been noted and promoted in the popular business literature *(26)*.

Validation of innovation system theory

Innovation system frameworks have generally been applied qualitatively and thus have not been subjected to rigorous testing. In this case study of red meat food safety projects, frameworks based on sectoral *(29)* and technological *(4)* innovation systems have been subjected to testing *(24)*.

TABLE 1. Elements identified in sectoral and technological innovation systems *(4, 5, 18, 28, 29)*. Definitions are supplemented with an example of the implementation of testing innovations for *E. coli* O157:H7 in beef trim (context of the example is provided in the text)

Innovation system	System element	Definition/Indication of an effective system element	Example
Sectoral	Actors	Groups involved in the project have the competence to participate and capacity (resources) to do so.	All of the participants in the committee had an interest in the outcomes and were experienced in their respective areas. Researchers and consultants had paid contracts and industry members had their expenses reimbursed.
	Infrastructure	Items such as information and communication technology, power, scientific and applied knowledge and skills, facilities, patents, training, and education are sufficient.	The level of knowledge and experience of research scientists, and the level of expertise of testing laboratories resulted in test methods being applied and compared in Australian laboratories.
	Institutions	Availability of laws, finance, systems, culture, 'rules of the game' facilitate the innovation process.	A policy of funding research in the industry ensured that funds, systems and ways of working together already existed. A cooperative environment existed between industry and the export regulator with the joint aim of ensuring that customer (country) requirements were satisfied efficiently and effectively.
	Interaction	Good connections between actors — enough to bring the skills and views required, but not so close that no new approaches or ideas can be considered.	The committee enabled views to be exchanged, and additional views were obtained when needed. The committee made decisions about preferred methods.
	Market	The potential users can see the value in what is being proposed and can understand how implementing change will benefit them.	The U.S. market was clearly a very important market. Maintaining the confidence of the market was an industry imperative.
Technological	Knowledge development	R&D and knowledge development; 'learning by searching' and 'learning by doing'; new knowledge of production, design, and markets.	Specific sampling and testing methods were evaluated and a watch was kept on international developments. Only minor modifications to the agreed position were required to meet, and exceed, the USDA-FSIS expectation.
	Knowledge diffusion	Exchange of information, especially between R&D providers, government, competitors, and market that may be mediated through networks, supply chains, and standards.	Every exporter and testing laboratory needed to be able to implement the required method. A series of newsletters, meetings and a telephone consultation service, provided everyone with the knowledge of what to do.

Continued on next page.

TABLE 1. Elements identified in sectoral and technological innovation systems *(4, 5, 18, 28, 29)*. Definitions are supplemented with an example of the implementation of testing innovations for *E. coli* O157:H7 in beef trim (context of the example is provided in the text) (cont.)

Innovation system	System element	Definition/Indication of an effective system element	Example
	Guidance of the search	Choices are made from various technological options for further investment, involving industry, government, and markets. Guiding actors to select options for investment through articulating visions, expectations, regulations, policy, or taking action.	The joint committee considered options, and prepared to respond to USDA-FSIS requirement. Discussions were held with customers in the USA to ensure that their views were considered.
	Entrepreneurial activities	Turning the potential of new knowledge, networks, and markets into concrete actions to generate, and take advantage of, new business opportunities. Investigation of new technologies and applications in an attempt to overcome the uncertainties that exist; social learning.	Sampling and testing was arranged at (anonymous) export establishments and the results analysed and shared with the industry. An industry endorsed plan was negotiated by the Australian Government with USDA-FSIS within a few weeks, and was implemented by the industry within a few additional weeks.
	Market formation	Regulation and formation of markets that will allow new, or developing, technologies to continue to be created and develop spaces through policies, standards or regulations that nurture demand for innovations; development of a market through capability to, and actual articulation of demand, price/performance requirements, or required reduction of uncertainties.	The action taken by USDA-FSIS in October 2007 'created' the market for the research and preparation work. The Australian industry wanted to provide the most acceptable product by testing prior to shipment.
	Acceptance/counteract resistance to change	Becoming part of an accepted paradigm or overthrowing it; development of advocacy groups for processes of change; social acceptance by relevant actors. Entry of new firms that resolve uncertainties about technologies, and markets, and thus make the technology legitimate.	The industry members of the committee worked with their industry organization to provide information to their exporter members. A number of newsletters provided practical advice in response to compliance questions. Meetings were held with customer groups.
	Resources mobilization	Supply of resources, both financial and human capital, for innovation. The ability of the system to provide competence/human capital, financial capital and complementary products, service and network infrastructure.	Committee activities, pilot testing, publications, industry meetings, and meetings with major customers were funded through industry levies and sometimes through government funding. These were part of ongoing activities in food safety and market access. Test suppliers were involved in evaluations.

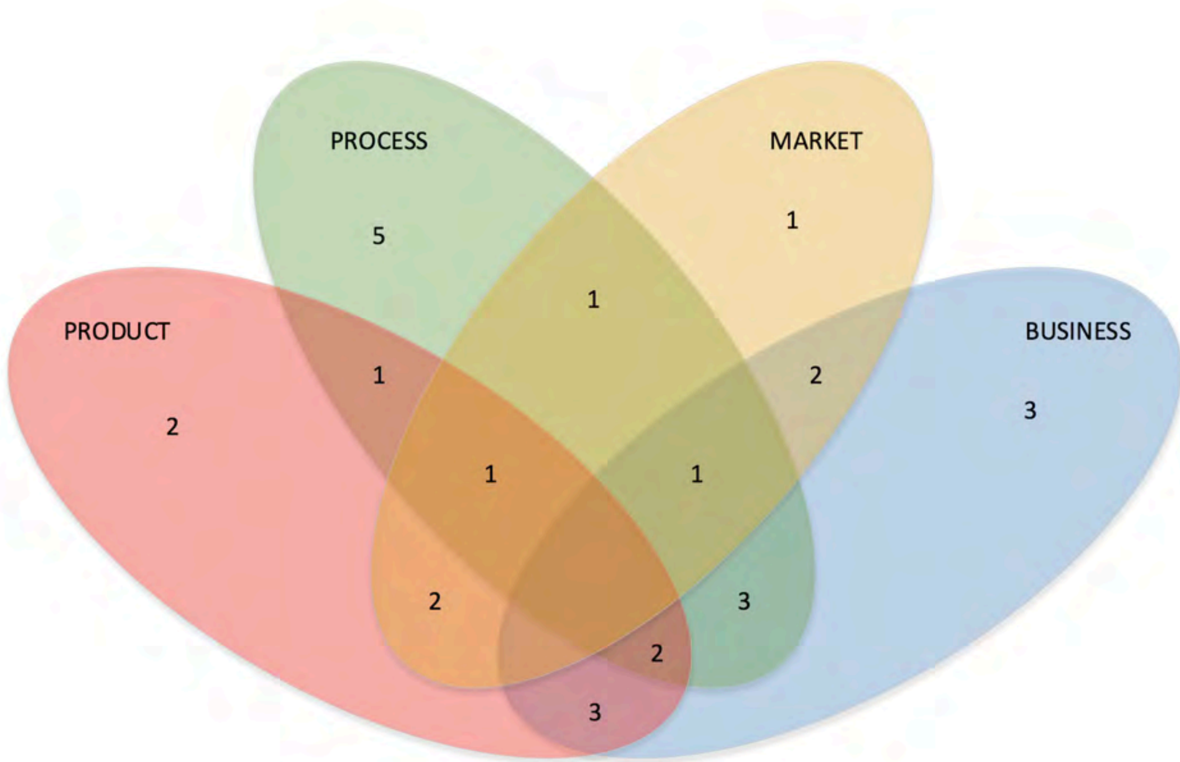

FIGURE 2. Food safety innovation can be of several types, and many innovations consist of more than one type of innovation. The distribution of innovation outcome types noted in 27 successful food safety projects in the Australian red meat industry according to the Schumpter/OECD typology (new sources of supply and exploitation of new markets have been combined as market innovation).

Survey respondents retrospectively indicated that all innovation systems elements were present in cases where they also judged innovation to have occurred. Analysis of the data indicated that weakness in one element of either innovation system failure framework was sufficient to result in a consensus that innovation did not occur. Within the limitations of the available dataset (the 41 cases available for analysis), the innovation system failure frameworks were supported; all elements defined by each innovation system failure framework needed to be sufficiently strong in order to ensure certainty of innovation *(Fig. 3)*.

The implications of this finding is that proponents of any innovation (change in a system), cannot work with a narrow understanding of the required actions for innovation but also must pay attention to all the other elements of the innovation system. Some of these elements are well defined in law or practice. For example, the need for regulatory approval of a new ingredient in a food, or the validation of a diagnostic test to a particular standard, are well-defined and perhaps obvious, but other elements, such as the competence of actors, existence of sufficient infrastructure, or the acceptance of the innovative idea may not be so obvious. The relevance of the other innovation system elements may not be obvious to the proponent or manager of the innovation project, but the results of this research suggest that they must not be overlooked.

Failures in the food safety innovation system

Failure to succeed in an innovation project is often thought of as a chance event (bad luck). For example, it is well known that only a small percentage of new food products will survive in the marketplace, and tactical approaches are taken to ensuring that the rate of successful launches is improved *(44)*. An alternative, in the innovation system paradigm, is to ask whether there are weaknesses in the system that predispose the system to failure. Food safety innovation in the Australian red meat industry, conducted by MLA, operates as a system, with projects failing to lead to innovation often having the same innovation system weaknesses *(22)*. For example, market value was frequently not established, or the development of knowledge was considered insufficient by those relying on the outputs of the system. These recurring weaknesses suggest that, rather than the projects failing by chance, at least some failure is predictable; prediction of failure may be based on the recognition of system weaknesses.

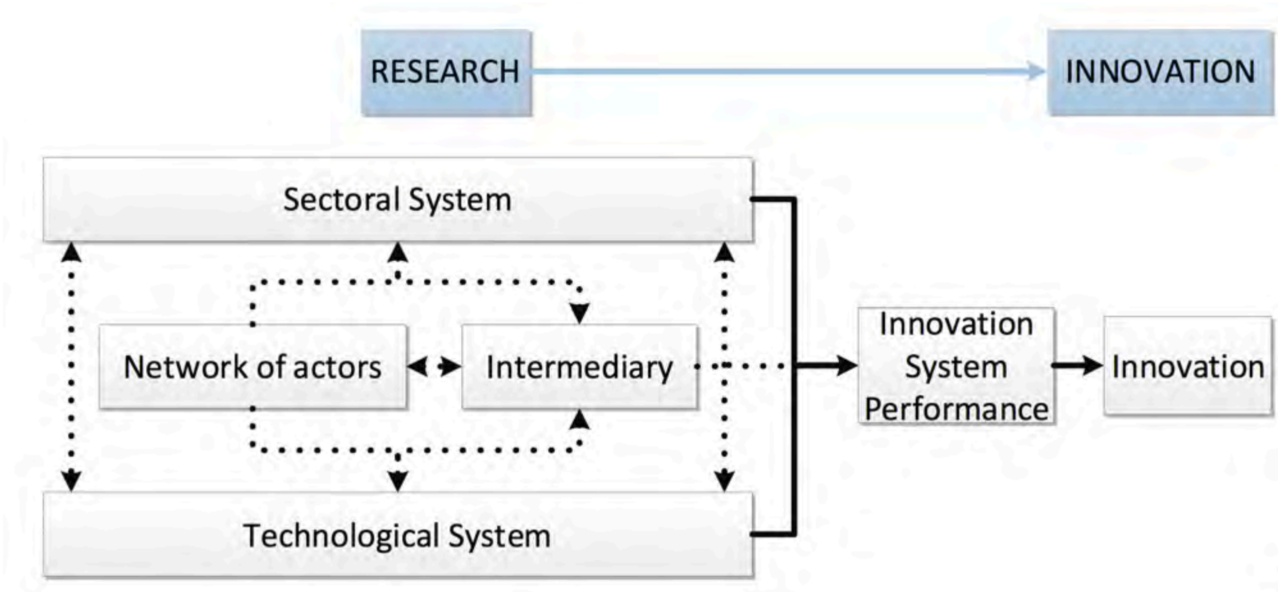

FIGURE 3. A system approach to innovation attempts to understand the complexity of the environment and factors that mediate the process that results in research resulting in innovation.

If the system is found to be weak, then it follows that improvements to that aspect of the system through policy and practice interventions are desirable.

'Systemic instruments' *(50, 52)*, policies, practices and tools can be applied to overcome system weaknesses and improve innovation performance. This retrospective study suggests that if changes were made to the operation of the system, greater innovation would occur. The use of innovation system failure frameworks to diagnose system weaknesses at the project level during the conduct of the project and to guide the use of interventions to correct system weaknesses are yet to be fully developed in practice but seem worthwhile as attempts to improve innovation outcomes.

INNOVATION SYSTEM INTERMEDIARIES IN FOOD SAFETY

The task of analyzing a project through use of an innovation system framework and by modifying the weaknesses of the system to ensure greater innovation performance must fall to one (or more) actors in the system. The actor in the system taking this role is likely to be, by either design or default, the innovation system intermediary.

Innovation system intermediary actors have been identified as individuals, organizations, or institutions such as technology brokers, university extension services, government technology transfer programs, and research organizations. Frequently, researchers function within technology platforms, or regional or sector-based ecosystems, and these probably have a "lead organization" that sets the rules, coordinates the networked ecosystem *(9, 40)*, and is responsible for creation of value. For example, Apple or Microsoft are firms that lead a sector based around their unique technology platforms *(35, 36)*.

The role of intermediaries was identified in the early innovation systems literature *(6)*, and the critical nature of their role has been identified by a number of scholars *(10, 20, 27, 30–32)*. Innovation system intermediaries link sources of technology with those who can develop, commercialize, or apply it, derive value from its commercialization or application, and compensate for any weaknesses in the system. Innovation system intermediaries have six basic functions *(27)*: (1) the understanding, articulation and stimulation of demand for the innovation; (2) network brokering; (3) serving as knowledge brokers; (4) managing the innovation process within and between the system actors; (5) capacity building, and (6) creating the institutional framework that facilitates commercialization of the innovation.

In this case study, MLA has the intermediary role in the Australian red meat food safety innovation system. When its role in ensuring innovation system performance by linking the innovation system actors with each other was investigated *(21)*, MLA was seen to be highly involved and effective in a high proportion of projects and significantly more involved and effective in projects with an innovation outcome. The intermediary's role was necessary to ensure that several innovation system elements were strong. Researchers were also seen as involved and effective by almost every survey respondent, reflecting the highly knowledge-intensive nature of food safety *(8)*.

Actors are effective in the innovation system because they contribute to the strength of innovation system elements, either through their own effort in effectively applying resources to the innovation system or through acting as a conduit for the contributions of others, thus ensuring innovation system performance.

This study suggests that intermediaries and the networks they build are critically important to innovation system performance *(Fig. 3)*. Managers need to understand and function as intermediaries within the innovation system to facilitate innovation outcomes.

APPLYING INNOVATION SYSTEMS TO FOOD SAFETY

Innovation systems approaches have had a significant impact on the development of innovation policy (particularly national and regional innovation policy), but little attention has been given to how innovation system approaches can be applied at the level of projects. Innovation policy needs to be focused not only on systems-level outcomes, but also on the project-level outcomes that are critically important to system-level success. Policy needs explicitly to take into account the important role of researchers and intermediaries in innovation success.

The case study presented here suggests that effective use of funds occurs when they are applied to develop all of the elements of the innovation system and when an intermediary ensures that the system is operating effectively. Arguably, funds need to be applied flexibly, so that, when innovation system elements are found to be weak, funds can be applied to strengthen the weak elements of the innovation system.

Many of the elements of the sectoral innovation system are amenable to policy intervention. The competence of actors, effectiveness of hard institutions, and adequacy of infrastructure may all be addressed by policy. It is likely that other elements, such as the presence of sufficient actors *(21)*, cannot be directly addressed by policy. However, if sufficient actors cannot be induced to be involved in an innovation project, then it may indicate that other elements, such as markets, are not sufficiently strong to attract actors to the project *(23)*.

The elements of the technological innovation system may be addressed within the system, that is, by project management. Funds must, however, be applied beyond the usual areas of knowledge development and dissemination. It is tempting for the intermediary and the researchers to believe that funding and producing research, embodied in a scientific paper or industry-oriented report, is sufficient. This research presents a clear challenge to this belief and contends that all elements of the innovation system are required if investment is to be effective in leading to innovation.

Given the importance of the intermediary demonstrated by this study *(21)*, policy-makers should ask whether other areas of technological development would benefit from a designated intermediary organization.

Project managers should ensure that all of the elements of both the sectoral and technological innovation systems are operating sufficiently well such that they do not limit the ability of their project to result in innovation. That is, project managers must consider their role as an innovation system intermediary. This research has not investigated how project managers can gauge the strength of elements pre-emptively or the strength of elements required. The interaction of competent actors is probably the most important aspect of the sectoral innovation system that can be managed within the project; the other elements may be largely outside the research aspect of the project. Many elements of the technological innovation system may be best addressed at a project level, by the actors involved in the system. Direction of the search, knowledge development and dissemination, acceptance, and entrepreneurial experimentation may all be addressed by the decision of innovation system actors, providing that sufficient actors have been involved.

ACKNOWLEDGMENT

I thank Dr. Richard Doyle, Professor Morgan P. Miles, and Dr. Peat Leith for their guidance through the work described in this article. Meat & Livestock Australia provided access to internal records, study leave, and funds to allow this research to be conducted. Dr. Kylie Hewson is thanked for her careful reading of the manuscript and advice.

REFERENCES

1. Anonymous. 2005. Oslo Manual: Guidelines for collecting and interpreting innovation data. OECD Publishing.
2. Bagno, R. B., M. S. Salerno, and D. O. da Silva. 2016. Models with graphical representation for innovation management: a literature review. *Res. Dev. Mgt.* 47: 637–653.
3. Balconi, M., S. Brusoni, and L. Orsenigo. 2010. In defence of the linear model: An essay. *Res. Policy* 39:1–13.
4. Bergek, A., S. Jacobsson, B. Carlsson, S. Lindmark, and A. Rickne. 2008. Analyzing the functional dynamics of technological innovation systems: A scheme of analysis. *Res. Policy* 37:407–429.
5. Cagnin, C., E. Amanatidou, and M. Keenan. 2012. Orienting European innovation systems towards grand challenges and the roles that FTA can play. *Sci. Publ. Policy* 39:140–152.
6. Carlsson, B., and R. Stankiewicz. 1991. On the nature, function and composition of technological systems. *J. Evol. Econ.* 1:93–118.
7. Caswell, J. A. 1998. Valuing the benefits and costs of improved food safety and nutrition. *Aust. J. Agric. Resour. Econ.* 42:409–424.
8. Desmarchelier, P. M., and E. A. Szabo. 2008. Innovation, food safety and regulation. *Innovation* 10:121–131.
9. Dhanaraj, C., and A. Parkhe. 2006. Orchestrating innovation networks. *Acad. Mgt. Rev.* 31:659–669.
10. Edler, J., and J. Yeow. 2016. Connecting demand and supply: The role of intermediation in public procurement of innovation. *Res. Pol.* 45:414–426.
11. Edquist, C. 1997. Systems of innovation approaches — their emergence and characteristics, p. 1–35. *In* C. Edquist (ed.), Systems of Innovation: technologies, institutions and organizations. Pinter Publishers, London.

12. Edquist, C. 2005. Systems of innovation: perspectives and challenges, p. 181–208. *In* J. Fagerberg, D.C. Mowery, and R.R. Nelson (eds.), The Oxford Handbook of Innovation. Oxford University Press, Oxford.

13. Fagerberg, J. 2005. Innovation: a guide to the literature, p. 1–26. *In* J. Fagerberg, D.C. Mowery, and R. R. Nelson (eds.), The Oxford Handbook of Innovation. Oxford University Press, Oxford.

14. Fryer, P. J., and C. Versteeg. 2008. Processing technology innovation in the food industry. *Innovation* 10:74–90.

15. Garner, D., and S. Kathariou. 2016. Fresh produce-associated listeriosis outbreaks, sources of concern, teachable moments, and insights. *J. Food Prot.* 79:337–344.

16. Godin, B. 2006. The Linear Model of Innovation: The historical construction of an analytical framework. *Sci. Technol. Hum. Values* 31:639–667.

17. Haddad, C. R., and M. U. Maldonado. 2016. A functions approach to improve sectoral technology roadmaps. *Technol. Forecast. Soc. Change* 115:251–260.

18. Hekkert, M. P., R. A. A. Suurs, S. O. Negro, S. Kuhlmann, and R. E. H. M. Smits. 2007. Functions of innovation systems: A new approach for analysing technological change. *Technol. Forecast. Soc. Change* 74:413–432.

19. Henson, S., and J. Caswell. 1999. Food safety regulation: An overview of contemporary issues. *Food Policy* 24:589–603.

20. Howells, J. 2006. Intermediation and the role of intermediaries in innovation. *Res. Policy* 35:715–728.

21. Jenson, I. 2016. Systems for successful innovation: The case of food safety in the Australian red meat industry. Ph.D. thesis. University of Tasmania, Hobart.

22. Jenson, I., R. Doyle, P. Leith, J. West, and M. P. Miles. 2016. Innovation system problems: causal configurations of innovation failure. *J. Bus. Res.* 69:5408–5412.

23. Jenson, I., P. Leith, R. Doyle, J. West, and M. P. Miles. 2016. The root cause of innovation system problems: formative measures and causal configurations. *J. Bus. Res.* 69:5292–5298.

24. Jenson, I., P. Leith, R. Doyle, J. West, and M. P. Miles. 2016. Testing innovation systems theory using qualitative comparative analysis. *J. Bus. Res.* 69:1283–1287.

25. Kebebe, E., A. J. Duncan, L. Klerkx, I. J. M. de Boer, and S. J. Oosting. 2015. Understanding socio-economic and policy constraints to dairy development in Ethiopia: A coupled functional-structural innovation systems analysis. *Agric. Syst.* 141:69–78.

26. Keeley, L., R. Pikkel, B. Quinn, and H. Walters. 2013. Ten types of innovation: The discipline of building breakthroughs. Wiley, Hoboken, NJ.

27. Kilelu, C. W., L. Klerkx, C. Leeuwis, and A. Hall. 2011. Beyond knowledge brokerage: An exploratory study of innovation intermediaries in an evolving smallholder agricultural system in Kenya. *In* UNU-MERIT Working Papers Maastricht Economic and Social Research Institute on Innovation and Technology, Maastricht. https://www.merit.unu.edu/publications/working-papers /abstract/?id=4374. Accessed 27 December 2018.

28. Klein Woolthuis, R. 2010. Sustainable entrepreneurship in the Dutch construction industry. *Sustainability* 2:505–523.

29. Klein Woolthuis, R., M. Lankhuizen, and V. Gilsing. 2005. A system failure framework for innovation policy design. *Technovation* 25:609–619.

30. Klerkx, L., N. Aarts, and C. Leeuwis. 2010. Adaptive management in agricultural innovation systems: The interactions between innovation networks and their environment. *Agric. Syst.* 103:390–400.

31. Klerkx, L., and C. Leeuwis. 2008. Balancing multiple interests: Embedding innovation intermediation in the agricultural knowledge infrastructure. *Technovation* 28:364–378.

32. Klerkx, L., and C. Leeuwis. 2008. Institutionalizing end-user demand steering in agricultural R&D: Farmer levy funding of R&D in The Netherlands. *Res. Policy* 37:460–472.

33. Loader, R., and J. E. Hobbs. 1999. Strategic responses to food safety legislation. *Food Policy* 24:685–706.

34. Markard, J., and B. Truffer. 2008. Technological innovation systems and the multi-level perspective: Towards an integrated framework. *Res. Policy* 37:596–615.

35. Moore, J. F. 1993. Predators and Prey: a new ecology of competition. *Harv. Bus. Rev.* 71:75–86.

36. Nambisan, S., and R. A. Baron. 2013. Entrepreneurship in innovation ecosystems: entrepreneurs' self-regulatory processes and their implications for new venture success. *Entrepreneurship Theory and Pract.* 37:1071–1097.

37. Rama, I., and S. Harvey. 2009. Market failure and the role of government in the food supply chain: an economic framework. Victorian Department of Primary Industries, Melbourne.

38. Ridley, M. 2014. Don't expect public science to lay golden eggs. *In* The Times, 28 April. London.

39. Rihoux, B., and C. Ragin. 2009. Configurational comparative methods: qualitative comparative analysis (QCA) and related techniques. Sage, Los Angeles.

40. Ritala, P., L. Armila, and K. Blomqvist. 2009. Innovation orchestration capability — defining the organizational and individual level determinants. *Int. J. Innov. Mgt.* 13:569–591.

41. Scallan, E., P. M. Griffin, F. J. Angulo, R. V. Tauxe, and R. M. Hoekstra. 2011. Foodborne illness acquired in the United States—unspecified agents. *Emerg. Infect. Dis.* 17:16–22.

42. Scallan, E., R. M. Hoekstra, F. J. Angulo, R. V. Tauxe, M. A. Widdowson, S. L. Roy, J. L. Jones, and P. M. Griffin. 2011. Foodborne illness acquired in the United States—major pathogens. *Emerg. Infect. Dis.* 17:7–15.

43. Schneider, C. Q., and C. Wagemann. 2012. Set-theoretic methods for the social sciences: a guide to qualitative comparative analysis. Cambridge University Press, Cambridge.

44. Schneider, J., and J. Hall. 2011, Why most product launches fail. Harvard Business Review. https://hbr.org/2011/04/why-mostproduct-launches-fail. https://hbr.org/2011/04/why-most-product-launches-fail. Accessed 27 December 2018.

45. Schumpeter, J. A. 1934. The theory of economic development: an inquiry into profits, capital, credit, interest, and the business cycle. Transaction Publishers, New Brunswick, NJ.

46. Stiglitz, J. E., and B. C. Greenwald. 2014. Creating a learning society: A new paradigm for development and social progress. Columbia University Press, New York.

47. Swanson, K. W. 2011. Food and drug law as intellectual property law: Historical reflections. *Wis. Law Rev.* 2011:331–397.

48. Unnevehr, L. J. 2007. Food safety as a global public good. *Agric. Econ.* 37:149–158.

49. U.S. Department of Agriculture, Food Safety and Inspection Service. 2016. Ground beef and food safety. Available at: https://www.fsis.usda.gov/wps/portal/fsis/topics/food-safety-education/get-answers/food-safety-fact-sheets/meat-preparation/ground-beef-and-food-safety/CT_Index. Accessed 24 February 2017

50. van Mierlo, B., M. Arkesteijn, and C. Leeuwis. 2010. Enhancing the reflexivity of system innovation projects with system analyses. *Am. J. Eval.* 31:143–161.

51. Walrave, B., and R. Raven. 2016. Modelling the dynamics of technological innovation systems. *Res. Policy* 45:1833–1844.

52. Wieczorek, A. J., and M. P. Hekkert. 2012. Systemic instruments for systemic innovation problems: A framework for policy makers and innovation scholars. *Sci. Public Policy* 39:74–87.

53. Yiannas, F. 2009. Food Safety Culture: Creating a behaviour-based food safety management system. Springer, New York.