Australasian Agribusiness Review
2020, Volume 28, Paper 5
ISSN: 1883-5675

A Diagrammatic Framework for Accounting for Externalities in Agriculture and Food Sector Value Chains[1]

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Abstract

In recent decades both domestic and global agricultural and food value chains have become more private, powerful, self-regulated, closely-coordinated or fully vertically-integrated, and experience-based. Consumers are now wealthier and have expectations that go beyond the traditional provision of goods. They now seek a food "experience" and meeting this demand requires a well-coordinated value chain. However, the provision of a wider range of attributes increases the probability of unpriced spillovers into these chains or into the broader community. How then should all the chain participants be aligned to deliver these food experiences efficiently, to maximise consumers' willingness to pay, and to account for any externalities that may be present? A diagrammatic procedure is used to develop, outline and explain a framework based on value chain failure due to value chain externalities, and how the provision of value chain goods can internalise these externalities.

Key words: value chain; chain goods; chain failure; externalities.

Introduction

Agricultural markets worldwide have become increasingly global, private and powerful, closely-coordinated or fully vertically-integrated, self-regulated, and experienced-based (see for example Burch and Lawrence, 2007; Burch, Dixon and Lawrence, 2013; OECD, 2007; and various publications from the FAO, the World Bank and the European Commission). The strong implication is that the agricultural and food sector is no longer selling/marketing a commodity or even a product but rather a consumer food (beverage and fibre) "experience". The consumer seeking a food experience demands the bundle of attributes they have selected, delivered precisely when, where and in the form required, guaranteed to be the same every time. Delivering this consumer food experience requires a very well-coordinated value chain with closed information sharing. Agricultural and food markets therefore are no longer populated by large numbers of small players who are predominantly price takers and so do not have sufficient incentive to invest themselves as individuals in more efficient outcomes; they are populated by networks of private, consumer-driven

[1] This is a substantially revised version of a chapter in Griffith et al. (2014). We thank Meat and Livestock Australia for funding that project.

value chains. Thus value chains are the new unit of enquiry when analysing and evaluating agricultural and food sectors (Baker et al., 2016; Griffith et al., 2015).

Coordination and cooperation among chain partners involved in these agricultural and food networks are mandatory if they are to be profitable and sustainable (Carter and Easton, 2011). This coordination demands a certain standard of relationship amongst the partners due to the inevitable trade-offs of benefits between them (Mueller et al., 2007). The economic issue, then, is how do we align all the chain partners to deliver that food experience that maximises consumer willingness to pay, and also be efficient?

In this paper we outline and explain diagrammatically a theoretical framework relating to value chain externalities, value chain failure, and value chain goods (Malcolm et al., 2017; Griffith et al., 2017; and Fleming et al., 2018). The development of the chain failure, chain externalities and chain good framework rests on the premise that the ability of food producers to benefit from value creation is constrained by the potential for misalignment between the financial incentives for individual firms and their collective incentives when they are part of a value chain. Value chain participants maximise their private net benefits, and this could lead to suboptimal performance of the whole chain because of underinvestment in "chain goods" and the presence of "chain externalities".

Chain Failure, Chain Goods and Bads, and Chain Externalities

First, let us recap the concepts already elaborated in Malcolm et al. (2017), Griffith et al. (2017), Fleming et al. (2018) and Mounter et al. (2019).

Chain failure

The concept of chain failure is analogous to the concept of market failure that is used widely in the microeconomics literature. Bannock et al. (1984) defined market failure as a "situation in which economic efficiency has not been achieved through imperfections in the market mechanism" (p. 262), and economic efficiency as the "state of the economy in which no one can be made better off without someone being made worse off" (p. 125), commonly known as Pareto efficiency. These concepts are normally applied to a national economy but can be adapted to smaller economic networks such as value chains or larger ones such as the global economy.[2]

Chain failure is defined as a situation in which a value chain fails to maximise chain surplus because it supplies a suboptimal level of throughput and value (Griffith et al., 2015). Using the Pareto efficient criterion in the context of value chains, an economically efficient value chain is one in which no one chain participant can be made better off without another participant being made potentially worse off. It can be determined by ascertaining where chain economic surplus (the sum of consumer surplus and producer surplus) is at a maximum.[3] The degree to which chain economic surplus is less than its potential maximum value shows the extent of chain failure. Chain failure can occur as a result of the presence in the value chain of chain goods and bads (including merit goods and

[2] It is usual to distinguish between an actual and potential Pareto improvement by applying Hicks' criterion, that gainers could compensate losers by bribing them to accept a change so that no one could be potentially made worse off (Hicks, 1939). Meeting Pareto efficiency criteria in one part of an economy, such as a value chain, may not necessarily improve Pareto welfare in an economy more broadly and may result in a "second best" solution in general equilibrium. The authors thank an anonymous reviewer for highlighting this point.

[3] In this context Marshallian rather than Hicksian measures of economic surplus are employed.

"sumptuary"[4] goods), positive and negative chain externalities, and asymmetric information leading to adverse selection, moral hazard and the principal-agent problem. In terms of strategic fit (Mounter et al., 2016), this could be because the value chain is not on the production possibilities frontier, or not on the optimal production point on that frontier. It can also arise from the many forms of market failure originating from outside the chain.

Chain goods

The concept of a chain good is analogous to a club good (McNutt, 1999) where the club comprises all members of a value chain. A club good is a sub-type of a public good, and populates the space between a pure public good and a pure private good. A public good has three possible attributes: non-excludability; non-rivalry in consumption and (often) non-rejectability in consumption (Bannock et al. (1984, p. 335). Non-excludability means if one person consumes a good, other people cannot be excluded also from consuming it. Non-rivalry in consumption means that one person's use of a good does not diminish its availability to other consumers. Non-rejectability means that no individual can abstain from consuming the good.

The criteria of non-excludability and non-rivalry in consumption are the ones usually applied in assessing whether a good can be described as a public good. A private good is one that is excludable and rival. A quasi-public good is non-rival and excludable and a common resource is rival and non-excludable. A typology of these goods is provided in Table 1. The other five categories in Table 1 are all impure public goods – some combination of being at least selectively excludable *or* at least partly rivalrous. McNutt (1999) observed that club goods (and therefore, from our viewpoint, chain goods) are essentially public goods without the condition of non-excludability.

Table 1. Nine Types of Private and Public Goods

	Excludable	Selectively Excludable	Non-Excludable
Rivalrous	Pure private good	Impure public good/club good	Common resource
Partly Rivalrous	Impure public good/club good	Impure public good/club good	Impure public good
Non-Rivalrous	Quasi-public good	Impure public good	Pure public good

Source: Adapted from Hubbard et al. (2017, Figure 15.7)

Thus, chain goods are those types of goods and services that allow effective coordination across value chain partners. They resemble what used to be called the facilitating functions of agricultural

[4] Originally a reference to luxury goods, the term "sumptuary" is now more commonly used in relation to products (or, usually, their excessive consumption) that are considered vices, notably "fast foods" and alcohol and tobacco products.

markets (Kohls and Uhl, 1980, Chapter 2, 25): "The facilitating functions are those that make possible the smooth performance of the exchange and physical functions. These activities are not directly involved in either the exchange of title or the physical handling of products. However, without them the modern marketing network would not be possible. They might aptly be called the grease that makes the wheels of the marketing machine go around." The four key groupings of facilitating functions were stated to be standardisation, financing, risk-bearing and market intelligence.

Some other types of goods are not explicitly included in Table 1. For example, a "merit" good is a particular kind of public good that is socially beneficial regardless of consumers' preferences: the social benefit of consumption exceeds the private benefit. Three key questions on merit goods from a food value chain perspective are: what qualifies as a merit good, how should merit goods be paid for, and should they be supplied through the public or private sector? Merit goods abound in food value chains. They are associated with the social benefits from the availability and affordability of foods that most contribute to a good diet, health, a sustainable environment and greater equity (see for example, Barling, 2007).

Examples of foods that are asserted to be merit goods include:

- So-called "brain foods" that are under-consumed (particularly by children) as a consequence of many important minerals and vitamins being removed from food products during processing,
- Organic foods (see Mann, 2003),
- Livestock products produced in a humane manner, and
- Products sourced through "fair trade" value chains.

The literature is sparse on the use of the club goods concept in studying value chains (see Fleming et al. (2018) for a review). McNutt (1999) is one of the few to deal directly with the concept. From McNutt's observation, we can conclude that chain goods resemble club goods in that they are non-rival and selectively excludable, and often also non-rejectable. That is, members of society outside the value chain are excluded from sharing in any benefits derived from joint action[5] within the chain unless scope exists for "free riding" or because certain members of the chain do not cooperate because they feel that they are "forced riders" (McNutt, 1999). The selectively excludable condition depends on the ability of chain participants to prevent free riding by excluding those outside the chain from benefiting from actions taken within the chain.

Chain bads

When a unit of a good is produced or consumed that beneficially (adversely) affects third parties but entails no market transaction, a positive (negative) externality occurs. When this production or consumption beneficially (adversely) affects *everybody* in a given population (in our case, chain participants), the good or service has chain good (bad) characteristics. Hence chain bads may be treated as extreme cases of goods with negative chain externalities.

The use of the concept of chain economic surplus to reveal the extent of chain failure ignores equity issues. Chain bads can be scrutinised at least partially to overcome this neglect, in three dimensions.

[5] We follow Schmitz (1999, p. 469) in mainly using the expression "joint action" rather than collective action or cooperation as an umbrella term. Schmitz makes the points that collective action fails to capture "bilateral ventures" while cooperation has a different meaning in game theory. "Collective action" is used where multilateral ventures are implied.

First, underinvestment in chain goods is likely to be especially damaging to small-scale producers because of their limited ability to capture the benefits created by chain goods (Mounter et al., 2011). On the other hand, major players in food value chains such as large supermarket and food processing corporations can capture some of these benefits. There is thus an inequity dimension to the presence of chain failure that can be represented as a chain bad.

Second, the most important of the various competition issues in food value chains is arguably the so-called "undue" exertion of monopoly power or monopsony power by dominant firms – a highly emotive and subjective concept. These firms have the potential to create a chain bad, which could be a problem for small firms that have limited or no market power. Its presence points to the key role of chain governance in avoiding or limiting these negative effects.

Third, a sumptuary product can be an example of a chain bad, such as overconsumption of food and the associated social costs of obesity (Lehnert et al., 2013). Most of these products involve the processing of raw materials supplied by agricultural producers. Examples are fatty meat products, tobacco leaf, sugar cane and wine grapes. There is an equity issue again here in that, in Australia, poor people are at greater risk of unhealthy eating habits (Burns, 2004).

Chain externalities

A study of chain externalities rests to some extent on the analytical framework used to study chain goods. Chain goods may be treated as extreme cases of goods with positive chain externalities. Alternatively, chain bads may be treated as extreme cases of goods with negative chain externalities. While these conditions suggest we could simplify discussions by referring just to positive and negative chain externalities that subsume chain goods and bads, respectively, another condition suggests that this approach is unwise. Public goods (bads) do not have a market because it pays nobody to provide (eliminate) them whereas chain externalities typically occur in situations in which markets operate, albeit imperfectly from society's viewpoint. Hence, the economic analysis of these concepts will differ.

The existence of negative or positive externalities amongst participants of a value chain too can be explained in terms of the size of the transaction costs of individuals acting to reduce negative externalities or to supply more of something which has positive externalities. It may be that only by acting jointly can the transaction costs per individual be reduced sufficiently relative to the individual's share of benefits that it warrants something that causes a negative externality being reduced or a positive externality being supplied. The absence of uniform grading or classification schemes in food value chains is often considered to be a case of a chain failure, even though in recent times powerful individual participants have introduced their own grading systems.

Hence, a positive chain externality refers to a benefit received by a third party who is not directly engaged in producing, trading in or consuming the good providing the benefit, through the actions of a participant in this particular value chain who does not receive compensation from the third party. Conversely, a negative chain externality refers to a cost incurred by a third party who is not directly engaged in producing, trading in or consuming the good causing the cost, through the actions of a participant in this particular value chain who does not compensate the third party.

A Diagrammatic Framework for Analysing Chain Externalities

In this section we present a theoretical framework where positive and negative chain externalities, generated from both production and consumption, are analysed graphically in the context of a food

market. Using this framework, welfare benefits and losses to chain participants, to market participants outside the value chain and to national welfare are able to be defined.

The concept of externalities, based on the principles of welfare economics, is usually described using two levels of interest: private and social (Hubbard et al., 2017). We use three levels of aggregation in this analysis[6]. We add the value chain (broadly defined) as an intermediate level between private welfare and social welfare considerations. Germane to this approach is recognition that different groups of people have different welfare concerns, and spillovers typically occur between these groups. Our analysis here is particularly concerned with spillovers from actions within the food value chain under study to society at the national level.

Four types of externalities can exist: positive and negative production and consumption externalities. Examples of each in food value chains are:

- RD&E within a food value chain - widely regarded as an positive production externality.
- Pollution and the abuse of market power - typical examples of a negative production externality in a food value chain.
- Improved dietary habits from consumption of better-quality foods - an example of a positive consumption externality.
- Any adverse effects of food consumption on people's nutritional status - a negative consumption externality.

With the possible exception of market power, all of the above examples are unlikely to be confined to the value chain; they can be expected to have spillover effects in society at large.

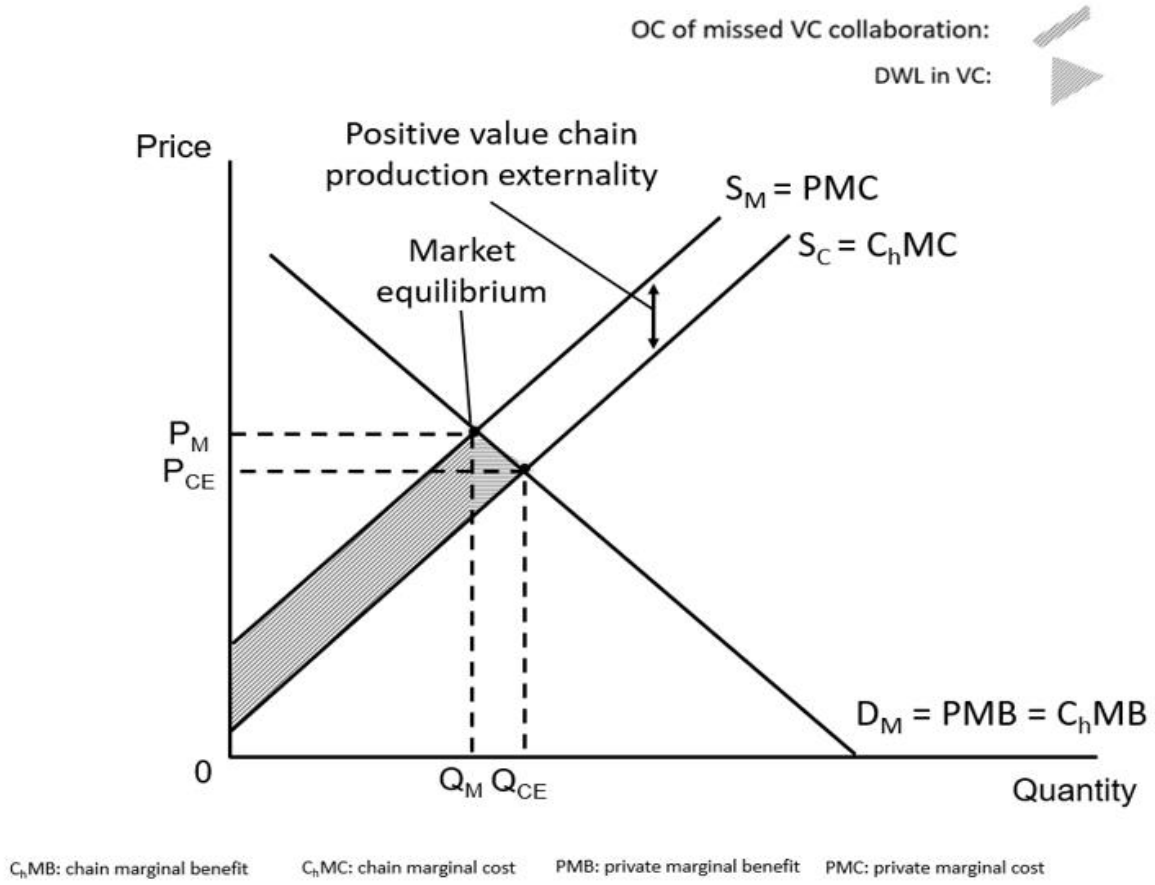
We use standard welfare economics principles including Marshallian surplus measures as detailed in texts such as Hubbard et al. (2017). Welfare changes are represented in the diagrams as changes in consumer and producer surplus assuming parallel shifts of linear demand and supply curves. Consumer surplus is the benefit to consumers and is the difference between "willingness to pay" as indicated by the demand curve, and the market price. Producer surplus is the area above the supply curve and below the price line and is the difference between the price received and the marginal cost of production. Any changes in these areas depict changes in consumer or producer welfare. The use of economic surplus as a means of measuring welfare can be traced back to Dupuit (1844) and Marshall (1930).

The following exposition of externalities and their internalisation begins with a situation where activities within the value chain result in no spillovers beyond the chain border and all trade takes place in the domestic economy. We focus on apple value chains as they seem to have all the possible combinations of characteristics that we wish to analyse (Rohr et al., 2020). Using these examples, apples beyond the fresh domestic market – those imported and exported – are not included as the volume is relatively insignificant compared to the domestic fresh value chain quantities.

The impact of a positive production externality within an apple value chain without any spillovers is llustrated in Figure 1. At market equilibrium, the price of apples is P_M and the quantity consumed is Q_M. The market supply curve (S_M) represents the private marginal cost (PMC) of supplying apples within the value chain. The market demand curve (D_M) represents the willingness to pay for the apples, which determines the value of the marginal benefit to consumers (PMB) of consuming an

[6] We could also add a fourth level by distinguishing between social welfare at the national and global levels. This would be particularly useful when analysing markets with large export or import components. That extension is the subject of ongoing analysis.

Figure 1. Positive production externality in an apple value chain



additional unit of apples. Without considering externalities, market equilibrium is where PMC and PMB intersect.

An example of a positive production externality in the fresh apple value chain is research and development in post-harvest treatment methods for sustained quality in storage and distribution. One area of research is hot water treatment (HWT) which has proven to be effective in reducing pathogen-induced postharvest decay (Wassermann et al., 2019). Postharvest losses for fresh produce is approximately 6 per cent in the handling, storage, processing and packing stages of the value chain (Gustavsson et al., 2011). The typical losses at this stage are damaged or spoiled fruit driven by improper storage methods, handling, surplus supply and poor handling techniques. These losses can be costly to value chain members, and in Australia these losses reduce the number of apples available to the domestic fresh market.

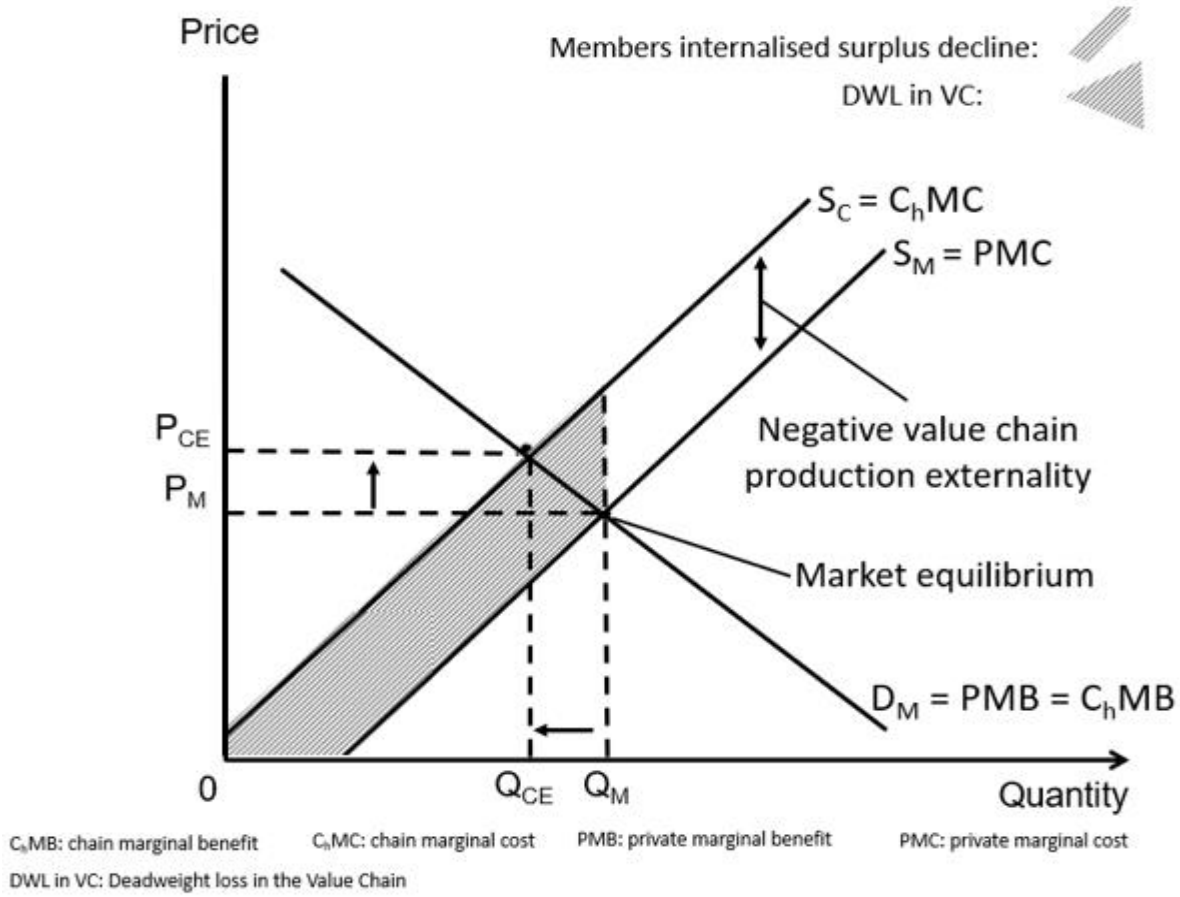
Existing methods to manage pathogens which contribute to apple rot are predominantly physical and chemical treatments and demand for effective alternatives has increased in recent years (Droby et al. as cited in Wassermann et al., 2019). HWT involves submerging the recently harvested apples in a 53°C water bath for three minutes, followed by storage in a controlled atmosphere environment. The HWT apples exhibit no evidence of decay or postharvest disease. Development and uptake of this methodology among chain actors may reduce loss in the stages following harvest thereby increasing the supply of fruit available to market.

Assume there is profitable but unfunded RD&E available. The chain failure is the high level of loss due to poor handling and storage. The current equilibrium is sub-optimal from the viewpoint of

participants in the apple value chain for whom individual investment in RD&E does not pay. The value chain perspective is the perspective of interest in this market, as opposed to private marginal benefits and costs. If participants were to collaborate in order to conduct the RD&E, it would be possible to shift the supply function from S_M to S_C, reducing the cost of an additional unit of product passing through the value chain to P_{CE} and increasing the quantity consumed to Q_{CE}.[7] The deadweight loss (DWL) in the market at current equilibrium is represented by the light grey-shaded triangle. This deadweight loss is eliminated if the supply function shifts from S_M to S_C. The dark-shaded trapezoid represents the opportunity cost (OC) of missed value chain collaboration. OC and DWL together represent the gain in value chain surplus from internalising the positive externality through the joint provision of better handling and storage technology.

The impact of a negative value chain production externality is illustrated in Figure 2.

Figure 2. Negative production externality in an apple value chain



Again, the price of apples is P_M and the quantity consumed is Q_M at the market equilibrium. Using pollution created by value chain activities as an example this time, the market solution is sub-optimal from the viewpoint of participants in the apple value chain who it does not pay individually to do something about reducing the amount of pollution. The presence of pollution is indicated by the plain grey-shaded triangle which represents the DWL. If value chain participants were to collaborate, it would be possible to internalise the negative externality created by pollution by

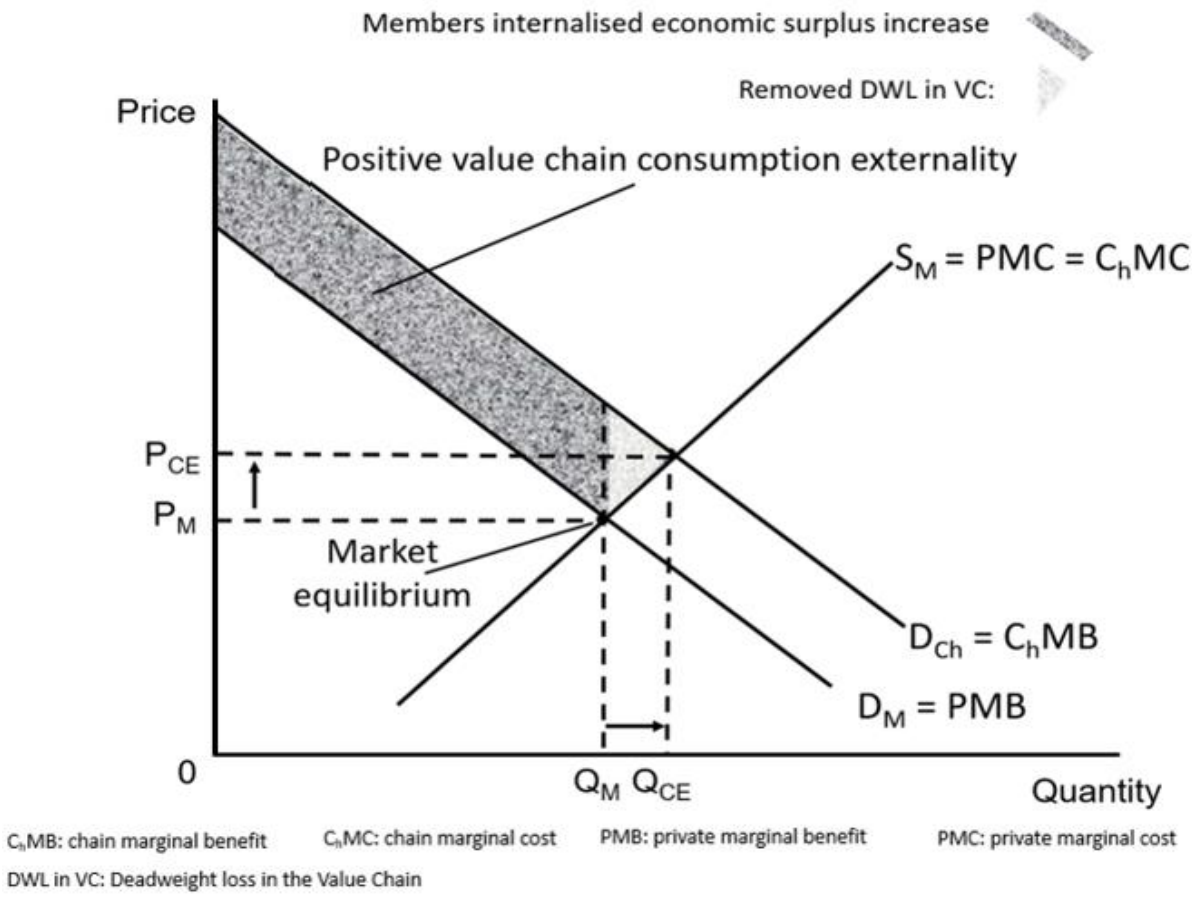
[7] The new supply function, $S_C=C_hMC$, represents the net cost of the introduction of HWT, and does not account for the RD&E costs incurred.

shifting the supply function to the left from S_M to S_C. Quantity consumed would fall to Q_{CE} and the price of an additional unit of product passing through the chain would be increased to P_{CE} to reflect its true value to chain members after accounting for the external cost of the pollution. The dark-shaded trapezoid represents the chain-members internalised surplus decline in correcting for the externality.

Pollution results from almost all stages of the value chain which employ energy in harvesting, processing, storage and distribution of apples in the Australian market. The most frequently mentioned type of pollution is greenhouse gas (GHG) emissions which result not only from the production of apples but also from the treatment of apple loss and waste, the fruit that is removed from the value chain and not consumed (Buzby et al., 2014). Both carbon dioxide and methane are GHG emissions that contribute to climate change; however methane which, in the case of apples, is produced when unconsumed produce ends up in landfill, is 25 times more significant in contributing to global warming than carbon dioxide (Buzby and Hyman, 2012). GHG emissions impose social and environmental costs to those outside the apple value chain. Internalising a negative externality such as this may be done via intervention such as the previously imposed Australian carbon tax scheme (Meng, 2015). A carbon tax shifts the supply function to the left and the quantity decreases, equating to a decrease in the externality that is proportion to production.

A positive consumption externality, of improved dietary habits by apple consumers, is represented in Figure 3.

Figure 3. Positive consumption externality in an apple value chain



In the apple value chain, consumption of apples has been associated with better nutrient intake (Nicklas et al., 2015) and wellbeing (White et al., 2013). Nicklas et al. (2015) focused on the relationship between consumption of apples and overall nutrition of children and concluded that apple consumption provided a range of valuable nutrients to children's diets. Apple consumption was associated with lower intakes of saturated fatty acids, mono-unsaturated fatty acids and sodium in addition to greater intakes of fibre, magnesium and potassium. Nicklas et al. demonstrate that the benefits of apple consumption are not limited to the direct nutrients of apples but also relate to preferable dietary habits. White et al. examined well-being experiences associated with consumption habits and reported positive effects such as higher energy levels, happiness and feeling more calm both on the day and the day following consumption of fruits and vegetables. They concluded that "…many apples a day is part of a balanced approach to keep the blues away" (p. 793).

Internalising this form of externality at the value chain level requires a shift of the demand function from D_M to D_{Ch}. The total increase in chain surplus is equal to the removal of the DWL as shown by the light-shaded triangle and the additional chain surplus increase as indicated by the dark-shaded trapezoid. This may be achieved by chain participants collaborating to exploit the externality, engaging Australian apple consumers in the quest to improve their nutritional status.[8]

Finally, a negative consumption externality in an apple value chain is shown in Figure 4. This form of externality is rare although food wastage is emerging as a major environmental issue. In Australia, Foodwise (2013) estimated that the average Australian household annually discards $1036 worth of food, representing up to 20 per cent of total food purchased. More recently, in 2016/2017 it was reported that Australian households wasted a gross amount of 2.5 million tonnes of food (Australian Government, 2017, as cited by ARCADIS, 2019, pp. 56). Gustavsson et al. (2011) reported that approximately 28 per cent of fresh produce purchased by consumers is wasted and not consumed, with drivers of the waste including spoilage, improper preparation or incorrect storage that leads to deterioration of the fruit. Internalising it at the value chain level requires a shift of the demand function from D_M to D_{Ch}, where the aim is to reduce its extent. The removal of the DWL associated with the externality is shown by the light-shaded triangle and the dark-shaded trapezoid represents the decrease in chain economic surplus.

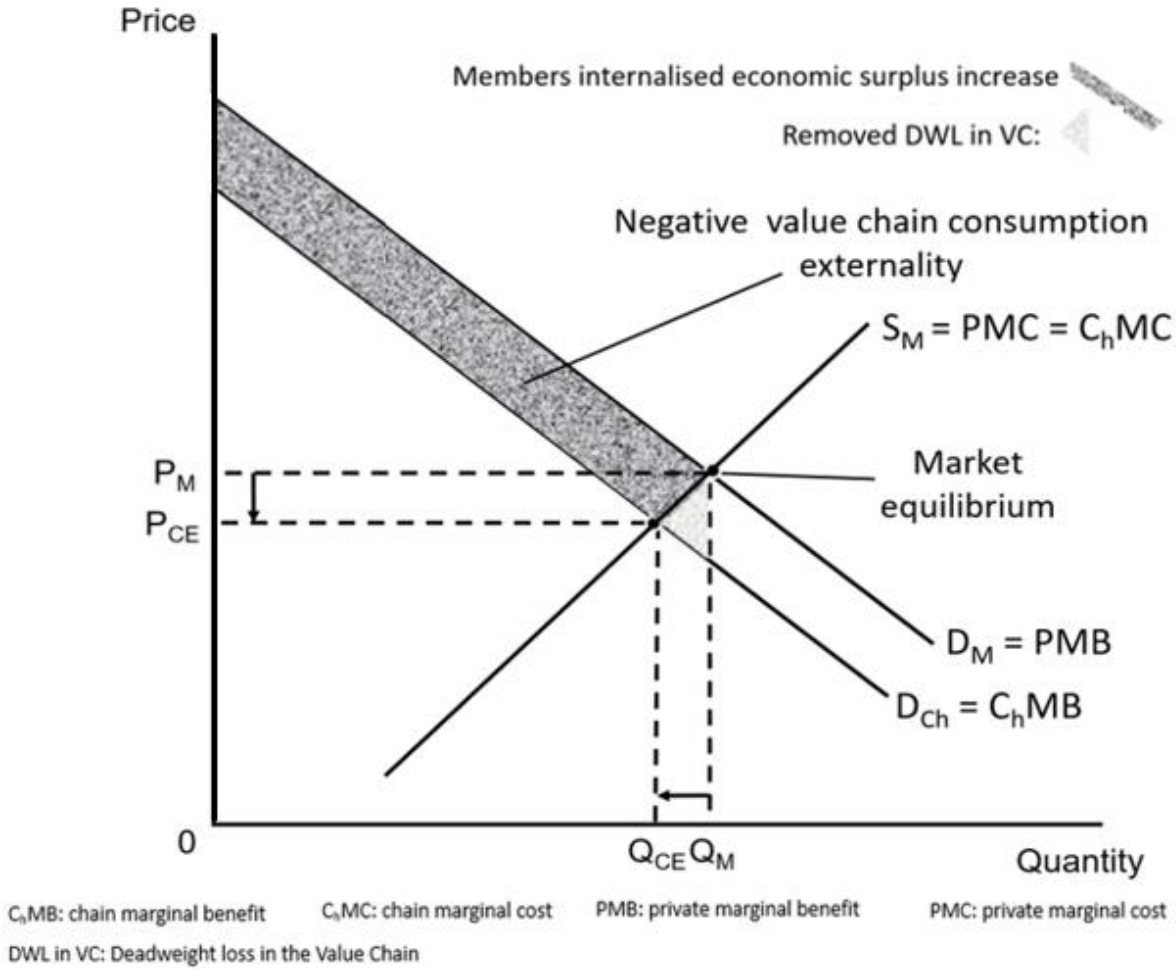
The negative societal consumption externality which results from this waste are the social and environmental costs that are not accounted for by the value chain but are borne by those outside the chain (not shown in Figure 4). Households are the greatest contributors of carbon dioxide emissions resulting from food waste (Beretta et al., 2017).

Achieving Economically Efficient Levels of Negative and Positive Externalities in Agriculture and Food Sector Value Chains

The economically efficient level of a negative externality in a value chain is not zero; neither is this usually possible. The optimal decision is to continue an activity to the point where the marginal benefit from reducing the negative externality from that activity is equal to its cost. As the externality is further reduced, the additional benefits become smaller and the additional costs of reducing it become greater.

[8] The broader health benefits that go beyond the direct nutrition of apples consumed are a positive externality that is not captured within the market yet is beneficial to those outside the chain. Conceptually, in terms of Figure 3, a societal marginal benefit curve lies above the chain marginal benefit curve and would reflect a positive societal consumption externality.

Figure 4. Negative consumption externality in an apple value chain

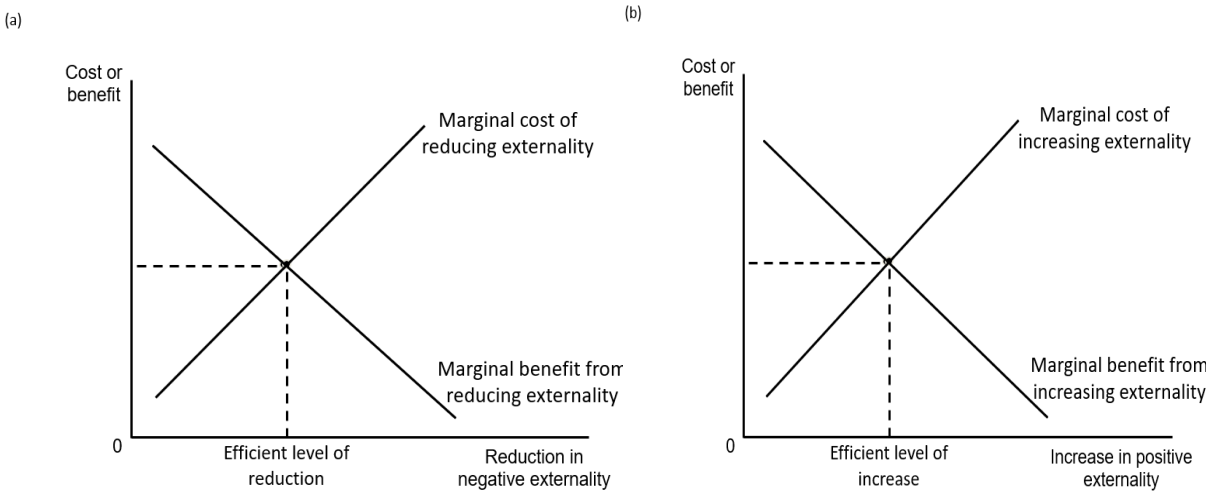


This concept also applies to the provision of a positive externality, which will have its benefits and costs. The imposition of taxes and subsidies can bring about an efficient level of throughput in a value chain in the presence of externalities. Taxes are typically used to reduce a negative externality while subsidies are used to internalise a positive externality. A tax that is equal to an external cost can be placed on chain throughput to internalise the negative externality. In principle, at least, it does not matter at which level in the chain the tax is imposed because how much of the tax is borne by participants at each stage is a function of the price elasticities of demand and supply, which dictate the pass-through ratio of the tax from one stage in the chain to the next. However, this incidence may have no bearing on how the benefits from internalisation are distributed across the chain.

A subsidy to producers, consumers or other participants in the chain that is equal to the value of the positive externality can be provided to encourage the provision of goods reflecting that externality. In parallel to a tax, the benefits of a subsidy are distributed across stages in the chain according to the price elasticities of demand and supply. Again, this incidence may have no bearing on how the benefits from internalisation are distributed across the chain.

For a negative externality, setting the marginal cost of reducing it to equal the marginal benefit from its internalisation is shown in Figure 5(a). For a positive externality, setting the marginal cost of producing it equal to the marginal benefit from its internalisation is shown in Figure 5(b).

Figure 5. Costs and benefits of internalising chain externalities



Examples of internalising a chain externality are:

- Imposing a carbon tax that internalises the environmental and social costs of GHG emissions,
- Managing disease problems at a stage in an apple value chain by introducing disease control regulations,
- Investing in RD&E processes to internalise a positive externality where quality advances at one stage provide benefits to others in the chain.

We expect the governing agency in a value chain or network (such as the dominant firm or an industry body) to have a potential role to play in counteracting many different types of chain failure. The more tightly circumscribed are such externalities, the more likely it is that a solution can be found without the need for government intervention. Applying the Coase theorem (Coase, 1960), private solutions to the problem of externalities can be found in some circumstances through joint action within the value chain. Solutions obtained from applying the Coase theorem are likely to be more feasible within value chains than in society at large because of the shared interest of members in making the chain work better. There needs to be an economically efficient level of adjustment of an activity causing an externality that members of the value chain can agree to.

Concluding Comments

Suboptimal performance of a chain or network can occur due to underinvestment in “chain goods” and the presence of “chain externalities”. An example of this is the Australian fresh apple value chain and the positive and negative externalities that result from activities within the value chain. Two key questions regarding chain goods are whether perceived inadequacies of information flows through the value chain have the characteristics of being a chain good and, if so, whether the benefits of fixing this failure exceed the costs? Assessment of the Australian fresh apple value chain and the potential for collaboration between actors demonstrate value chain opportunities to rectify inefficiencies in the market. Improvements in value chain operations ideally move towards an economically optimal equilibrium. Collaborative RD&E, promotion of the positive externalities associated with consumption, and internalisation of negative externalities can improve suboptimal performance such as the example of the Australian apple value chain.

One of the commonly used modelling frameworks for evaluation of the net economic benefits from new technology adoption at an industry level is a comparative static approach, often referred to as

"Equilibrium Displacement Modelling" (EDM). A number of EDMs have been developed in relation to Australian agricultural industries (Zhao et al., 2001; Hill et al., 2001; Mounter et al., 2005, 2008). These applications, however, have been primarily concerned with the private costs and benefits from RD&E, generic promotion and government policies, and their distribution among industry sectors. Continuing work in this area is the extension of existing EDMs to account for externalities in a manner that is consistent with the diagrammatic analyses above.

References

ARCADIS Design & Consultancy (2019), National Food Waste Baseline: Final assessment report. Viewed October 11, 2019. Accessed at: https://www.environment.gov.au/protection/waste-resource-recovery/food-waste

Baker, D., Hamza, K., Parker, W., Scrimgeour, F. and Griffith, G. (2016), "Primary industry chains and networks: analysis of public and private interests", *Systems Research and Behavioural Science.* Available at: http://onlinelibrary.wiley.com/doi/10.1002/sres.2400/pdf.

Bannock, G., Baxter, R.F. and Davis, E. (1984), *Dictionary of Economics*, 3rd edn, Hutchinson, London.

Barling, D. (2007), "Food supply chain governance and public health externalities: upstream policy interventions and the UK state", *Journal of Agricultural and Environmental Ethics*, 20(2), 285-300.

Beretta, C., Stucki, M. and Hellweg, S. (2017), "Environmental Impacts and Hotspots of Food Losses: Value Chain Analysis of Swiss Food Consumption", *Environmental Science and Technology,* 55, 11165-11173.

Burch, D., Dixon, J. and Lawrence, G. (eds) (2013), "From Seedlings to Supermarket: Agrifood Supply Chains in Transition", *Special Edition of Agriculture and Human Values,* 30(2), 215-309.

Burch, D. and Lawrence, G. (eds) (2007), *Supermarkets and Agri-food Supply Chains: Transformations in the production and consumption of foods*, Edward Elgar, Cheltenham.

Burns, C. (2004), A review of the literature describing the link between poverty, food insecurity and obesity with specific reference to Australia, Food Insecurity Program, Victorian Health Promotion Foundation, Melbourne. Downloaded 30 October 2013 from: http://secondbite.org/sites/default/files/A_review_of_the_literature_describing_the_link_between_poverty_food_insecurity_and_obesity_w.pdf

Buzby J. C. and Hyman, J. (2012), "Total and per capita value of food loss in the United States", *Food Policy,* 37, 561–570.

Buzby J.C., Wells H.F. and Hyman, J. (2014), *The Estimated Amount, Value, and Calories of Postharvest Food Losses at the Retail and Consumer Levels in the United States,* U.S. Department of Agriculture, Economic Research Service, Economic Information Bulletin, Number 121, Washington, DC.

Carter, C. and Easton, P.L. (2011), "Sustainable supply chain management: evolution and future directions", *International Journal of Physical Distribution & Logistics Management*, 46-62.

Coase, R.H. (1960), "The Problem of Social Cost", *Journal of Law and Economics,* 3 (1), 1-44. doi:10.1086/466560

Dupuit, J. (1844), "On the Measurement of the Utility of Public Works", *Annals des Ponts et Chaussees*, Second series, Vol. 8; translation reprinted in Kenneth Arrow and Tibor Scitovsky, eds. (1969), *Reading in Welfare Economics*, Homewood.

Fleming, E., Griffith, G., Mounter, S. and Baker, D. (2018), "Consciously pursued joint action: Agricultural and food value chains as clubs", *International Journal on Food Systems Dynamics* 9(2), 166-177. DOI: https://doi.org/10.18461/ijfsd.v9i2.925

Griffith, G., Fleming, E., Mounter, S. and Malcolm, B. (2014), *Accounting for Externalities in Agriculture and Food Sector Value Chains and Networks: Chain Failure, Chain Goods and Chain Bads*, Final Report to Meat and Livestock Australia on Project B.COM.1086, UNE Business School, The University of New England, Armidale, July.

Griffith, G., Gow, H., Umberger, W., Fleming, E., Mounter, S., Malcolm, B. and Baker, D. (2015), "Refocussing on the value chain perspective to analyse food, beverage and fibre markets", *Australasian Agribusiness Perspectives* Paper 104. Available at: https://www.agrifood.info/perspectives/2015/Griffith_et_al.pdf

Griffith, G., Fleming, E., Mounter, S., Malcolm, B., Umberger, W. and Baker, D. (2017), "Chain failure and chain goods: re-thinking value chain upgrading in developing countries", *International Journal on Food Systems Dynamics* 8(2), 146-154.

Gustavsson, J., Cederberg, C. and Sonesson, U. (2011), *Global Food Losses and Food Waste*, Food and Agricultural Organisation of the United Nations, Rome.

Hicks, J.R. (1939), "The foundation of welfare economics", *Economic Journal,* 49, 696-712.

Hill, D., Piggott, R.R. and Griffith, G.R. (2001), "Profitability of incremental generic promotion expenditure of Australian dairy products", *Agricultural Economics,* 26(3), 249-262.

Hubbard, R.G., Garnett, A.M., Lewis, P. and O'Brien, A.P. (2017), *Microeconomics*, 4th edition, Pearson, Sydney.

Kohls, R. and Uhl, J.N. (1980), *Marketing of Agricultural Products*, 5th Edition, Macmillan Publishing Co., New York.

Lehnert, T., Sonntag, D., Konnopka, A., Riedel - Heller, S., Konig, H. (2013) "Economic costs of overweight and obesity", *Best Practice & Research Clinical Endocrinology & Metabolism*, Vol. 27 (2), 105-116

McNutt, P. (1999), "Public goods and club goods", in B. Bouckaert and G. de Geest, (eds), *Encyclopedia of Law and Economics*. Cheltenham, Edward Elgar. Downloaded on 30 May 2011 from: http://www.scribd.com/doc/239217/0750-Public-Goods-and-Club-Goods

Malcolm, B., Griffith, G., Fleming, E. and Mounter, S. (2017), "Chain failure theory as a framework for evaluating horizontal and vertical strategic alliances among food value chain participants: A red meat industry perspective", *Australian Farm and Business Management Journal,* Volume 14, Paper 4, 47-62.

Mann, S. (2003), "Why organic food in Germany is a merit good", *Food Policy,* 28, 459-469.

Marshall, A. (1930), *Principles of Economics*, London, MacMillan.

Meng, S. (2014), "Is the agricultural industry spared from the influence of the Australian carbon tax?", *Agricultural Economics,* 46 (1), 125-137.

Mounter, S., Fleming, E. and Griffith, G. (2019), "Financing agricultural value chain R&D: a framework with examples from the red meat industry", *Australasian Agribusiness Review,* Volume 27, Paper 3, 45-64.

Mounter, S.W., Griffith, G.R. and Piggott, R.R. (2005), "The payoff from generic advertising by the Australian pig industry, in the presence of trade", *Australasian Agribusiness Review,* Volume 13, Paper 4 (listed February 22, 2005). Available at: http://www.agrifood.info/Publications_Review/Mounter_Griffith_Piggott.htm

Mounter, S.W., Griffith, G.R., Piggott, R.R., Fleming, E.M. and Zhao, X. (2008), *An Equilibrium Displacement Model of the Australian Sheep and Wool Industries*, Economic Research Report No. 38, NSW Department of Primary Industries, Armidale, April.

Mounter, S., Griffith, G. and Fleming, E. (2016), "Achieving better strategic fits and higher surpluses for Australian beef value chains by recognising and countering chain failure", *Animal Production Science.* Available at: http://dx.doi.org/10.1071/AN15460.

Mounter, S., Grant, B., Fleming, E. and Griffith, G. (2011), "Latecomers: Charting a course for the New England Australia wine region", *Australasian Journal of Regional Studies,* 17(3), 298-327.

Mueller, R.A., Buergelt, D. and Seidel-Lass, L. (2007), "Supply Chains And Social Network Analysis", paper presented at the 1st International European Forum on Innovation and Network Dynamics in Food Networks, Innsbruck-Igls, Austria, February.

Nicklas, T.A., O'Neil, C.E., and Fulgoni, V.L.III. (2015), "Consumption of various forms of apples is associated with a better nutrient intake and improved nutrient adequacy in diets of children: National Health and Nutrition Examination Survey 2003-2010", *Food & Nutrition Research,* 59.

Organisation for Economic Cooperation and Development (OECD) (2007), *Moving Up the Value Chain: Staying Competitive in the Global Economy. A Synthesis Report on Global Value Chains*, OECD, Paris.

Piggott, R.R. (1992), "Some old truths revisited", Presidential Address, Annual Conference of the Australian Agricultural Economics Society, Canberra, February.

Rohr, S., Mounter, S., Fleming, E. and Griffith, G. (2020), "Loss and waste in the Australian fresh apple value chain", *Proceedings of the 14th Food Systems Dynamics Forum*, Garmisch, Germany, February 11-14 (in press).

Schmitz, H. (1999), "Collective efficiency and increasing returns", *Cambridge Journal of Economics,* 23, 465-483.

Smith, T.G., Chouinard, H.H. and Wandschneider, P.R. (2011), "Waiting for the invisible hand: novel products and the role of information in the modern market for food", *Food Policy,* 36, 239-249.

Swann, G.S.P. (2003), "Funding basic research: when is public finance preferable to attainable 'club goods' solutions?", in A. Geuna, A.J. Salter and W.E. Steinmuller (eds), *Science and Innovation: Rethinking the Rationales for Funding and Governance*, Edward Elgar, Cheltenham.

Wassermand, B., Kusstatcher, P. and Berg, G. (2019), "Microbiome Response to Hot Water Treatment and Potential Synergy With Biological Control on Stored Apples", *Front. Microbiol.,* 10, 2502.

White, B.A., Horwath, C.C. and Conner, T.S. (2013), "Many apples a day keep the blues away – Daily experiences of negative and positive affect and food consumption in young adults", *British Journal of Health Psychology,* Vol 18, Issue 4.

Zhao, X., Mullen, J.D., Griffith, G.R., Griffiths, W.E. and R.R Piggott (2001), *An Equilibrium Displacement Model of the Australian Beef Industry*, Economics Research Report No. 4, NSW Agriculture, Orange, January.