Author/s:
Baker, D;Dizyee, K;Parker, W;Scrimgeour, F;Griffith, G

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1. Introduction

Primary industry's role in wealth creation is commonly associated with a perceived early stage of economic development. A taxonomy of industry designating primary, secondary and tertiary industries associated with natural resource extraction, manufacturing and services respectively has long been in use (see Wolfe, 1955 for an early synthesis). Much macroeconomic and development thinking has employed this nomenclature in a linear sequence from agriculture toward service sector emergence and dominance, and this largely mirrored an implicit assessment of nations' degrees of economic development or sophistication. This paper presents an alternative view of primary industry, recognising its changing form and emphasis, and the new mechanisms by which it adds value. Its contribution is to rationalise the needs of today's dynamic and networked primary industry in terms of policy, skills, information flows and analytical approaches.

Primary industry features backward and forward linkages between economic actors (Sauvee, 2014; Harland, 1996), and emergent manufacturing and service functions (de Janvry, 2009) that add value throughout the chain (Gereffi and Fernandez-Stark, 2011). In this setting, primary industry serves to add value to raw, unrefined or un-extracted material rather than purvey it to firms in other industries (Carter and Easton, 2011). Primary industry associated with production, processing, distribution and marketing of agricultural products – agroindustry – provides an example in the economies of both developed and developing nations: it has emphasised value addition, and challenges ideas of boundaries between primary, secondary and tertiary industries (Henson and Cranfield, 2009; Reardon and Barrett, 2000).

A driver of this transformation has been the nature of markets served. Because primary industry's technologies tend to dictate a scale of production above requirements for local utilisation or consumption, the value to be added is often presented to a distant final consumer. Referring again to agroindustry, an array of branded and high margin products are produced that enables price discrimination across categories of consumers (Grunert *et al.*, 2005). This shift away from raw material supply, to consumer orientation, also necessitates leadership in product design and development, and in marketing: this has led to a degree of control by a small numbers of firms (Gereffi and Fernandez-Stark, 2011). In turn, chain governance mechanisms have emerged that counter complexity in transactions, and support codified information (Gereffi *et al.*, 2005) that facilitate innovation (Revoredo-Giha *et al.*, 2012) in pursuit of competitive advantage at various chain stages (Burgess, 2008; Soosay *et al.*, 2012). Primary industry might also be characterised by linkages to land and localities. Land owners' multiple roles as ecosystem managers, producers, residents, local leaders, and guardians of various forms of legacy typically distance them from commercial value chains. These expectations, projected at new industry structures and functions, need to be accommodated in policy regimes, which remain more geared to markets and individual firms than to vertically-co-ordinated chains. This paper presents the case for re-orientation of policies to combat market failure, toward vertically-oriented policies that address failures in the chain.

Demands on primary industry that extend beyond profitability and into social and biophysical sustainability require coordination and cooperation among actors involved in the extraction of raw material and its transformation and transmission to consumers (Mueller *et al.*, 2007; Narasimhan *et al.*, 2013), investment in technology and relationships, and responses to market power such as that held by retailers (Revoredo-Giha *et al.*, 2012; Kraemer *et al.*, 2011). Globalisation, in which primary industries are well represented due to their history of raw materials' exports, has extended governance across national boundaries through business networks (Gereffi *et al.*, 2005, Belussi and Sammara, 2009). This paper examines these network considerations in terms of the dynamics of relationships and the viability of financing mechanisms to overcome chain-oriented market failure, or "chain failure".

Market, within-chain and regulatory aspects of primary industry resource allocation for future development are addressed by an application to New Zealand's forest products industry. Critical industry needs are identified in terms of avenues of approach in value addition. Specific aspects of redirection within the production process, and management of feedbacks, are then discussed in a System Dynamics (SD) framework well-suited to chain-oriented analysis and the complexities of primary industry.

2. New Zealand's forestry and wood products primary industry

The foundation of the New Zealand forestry, and associated wood products, industry is 1.73 million ha of plantation forests, primarily the exotic species *Radiata* pine and Douglas Fir. The majority (91%) of forests are privately owned, with the balance owned by the national and local governments, state owned enterprises, and public companies. Some 45,000 hectares of replanting and 11,500 hectares of new planting occurred in 2012. Current log flows are illustrated in Figure 1. The industry's overarching goal is to increase exports of wood based products and logs to $NZ 12 billion (from a $NZ 4.8 billion baseline in 2011). This entails changing the proportion of logs processed onshore from 50% to over 70%, in the context of the value of related forest technologies' being expected to grow by at least $2 billion annually by 2022 (New Zealand Forest and Wood Products Industry Strategic Action Plan, 2012).

Figure 1. New Zealand Forest Industry's Log Flows.

Source: NZ Wood Council Strategic Action Plan (2012).

A selection of improvement scenarios for achieving the $12 billion export target have been assembled[1] (see table 1). In addition to product and processing innovation, improved supply chain coordination is required in the supply chain to redirect residues into new higher-priced and higher-

[1] Full details and economic modelling assumptions are presented in Kantz (2012).

margin technologies. The GDP contributions of combinations of traditional and emerging wood processing technologies were examined by Jack (2013) by looking at alternative new industrial structures. In broad terms, that study identifies points in the industry's value chain where new capital investment and product development could be focussed to achieve the stated export goal. It also highlights the need for wood flows to be improved both vertically and horizontally in order to realise the full economic value of each log.

Table 1: Potential sources of incremental gain in NZ forest products export earnings

Improvement of flows within the industry would address general supply network design, but would also extend to the material feedback loops which increase the wood volumes available for high value products. This requires co-ordination of functions, both between and within firms, enabled by technology and information flows.

3. *Chain analysis in the primary industry context*

The analytical challenges to management of change in a chain-oriented primary industry include the interaction between feedbacks of material and information, and the market linkages within and beyond the chain that provide the incentive structure. These feedbacks are particularly of interest in terms of sensitivity to exogenous shifts in supply and demand due to the international market connections, development of demand for new and advanced products, climatic and other supply risks, and the diverse motivations of landowners that characterise modern primary industry. Further, social considerations must align costs and benefits in a market failure setting within the value chain.

Policy interventions in primary industry networks that are based on pure public good arguments are increasingly difficult to justify (Griffith *et al.*, 2011), especially where the manufacturing-based elements of supply chain management break down due to less reliable and riskier production and consumption, lack of oligopsonistic/oligopolistic markets (notably, except at retail stages) and the abovementioned geographic dispersal both between (Gereffi and Fernandez-Stark, 2011) and within (McIntyre-Mills *et al.*, 2008) countries. Primary industry networks increasingly feature private ownership, are closely coordinated (or fully vertically integrated) around enduring commercial partnerships, are self-regulated, and are more global (e.g. Burch and Lawrence, 2007; OECD, 2007) than previously. The effect is that the classical maximisation of value chain surplus aligns poorly with value chains in primary industries due to the presence of chain and network "goods" and associated chain externalities (Fleming *et al.*, 2013). These are the chain analogues of global externalities and public goods, derived from the concept of club goods.

Here we define a chain externality as a benefit or a cost that affects a chain actor not directly engaged in producing, trading in or purchasing the good or service in question. The actor causing the cost or providing the benefit avoids paying or receiving compensation, although persons or firms outside the value chain or network can be excluded from benefitting or suffering from its consumption. Chain failure occurs when such an externality is not internalised within the chain. Such internalisation delivers a "chain good" (Griffith *et al.*, 2014), and can take the form of inclusion of value adding actors into the chain or network in question, and/or the inclusion of actors offering support processes such as research and training. Feedbacks and re-routed flows of product and information as presented in the wood products case are obvious applications. An overarching government role in defining and implementing policy is apparent both within the network in terms of public-private partnership and in more conventional regulatory roles.

Product proliferation can be considered a horizontally-defined chain good. Amongst fully engaged transacting parties, new sources of revenue (and hence value) are being captured by firms with traditional roots in raw material supply or manufacturing whose products are now accompanied by services (Neely *et al*., 2011). An example in primary industry is the utilisation of customers' wastes in recovery, recycling and remanufacture (Anderson and Narus, 1995), considered further below as a reconfiguration of product flows. Such self-interested reconfigurations of production and marketing chains and networks are increasingly a part of primary industry strategic planning, although they have been widely discussed in other complex economic systems such as financial markets (Chen, 2013).

Empirical tools to inform and aid such industry-wide development in terms of specification and measurement of chain performance remain in their infancy. Indeed, most purported analyses of value chains focus on descriptive diagrams, extending at most to unidirectional product flow and margins. Primary industry examples include Global Commodity Chains (GCC), International Production Networks (IPN) (Belussi and Sammara, 2009), Sustainable Value Chain Analysis (SVCA) (Soosay *et al.*, 2012), Global Value Chains (GVC), and Global Production Networks (GPB) and Global Innovation Networks (GIN) (Parrilli *et al.* 2013). Increased computing capacity, data inter-operability and improved modelling packages have facilitated the development of holistic models to represent chain- and network-oriented flows, feedbacks, interactions between actors, and the interaction of separate systems. Systems approaches have been widely advocated for management in value chains (Xu, 2013), and System Dynamics[2] (SD) has been applied to primary industry value chain management (Olsen and Swenseth, 2014; Rich *et al.*, 2011). The analysis of such dynamics to improve strategy and policy requires multidimensional thinking that integrates the views of actors within networks where linkages between actors can be either contextually active or inactive, and change may occur between actors and across networks (Abdirahman *et al.*, 2014).

[2] The System Dynamics Society, the professional association of system dynamics practitioners, defines SD as follows (see http://www.systemdynamics.org): *[SD is] a computer-aided approach to policy analysis and design. It applies to dynamic problems arising in complex social, managerial, economic, or ecological systems — literally any dynamic systems characterized by interdependence, mutual interaction, information feedback, and circular causality.*

These approaches are of particular interest to analysts of primary industry, and SD is here applied to the challenges facing the New Zealand forestry industry as described above. Although SD modelers usually employ quantitative SD models, qualitative applications of SD portray the structure of problems within a system to identify changed flows and associated policy leverage points. Vennix (1996) provided examples of the applicability of qualitative models through the use of Nominal Group Techniques (NGT) and a Delphi-type approach to the Dutch shipping fleet and health system, respectively. Moving further into public goods considerations, Olabisi (2010) delivered insights from a qualitative model of forest cover in the developing world. A quantitative SD model of the forest and sawmill industry in the northeastern United States was used by Jones *et al.* (2002), and we here apply it in qualitative form to present a stock and flow SD model of the New Zealand forest industry.

Our model also draws on Sterman's (2000) market SD specification to include endogenous price mechanisms arising from resource and product flows. Our focus on the stocks and flows of the system as presented by Jones *et al.* (2002), emphasizes its measurable elements which provide for later extension to a quantitative model. The model was developed and refined following presentation to an audience specialised in New Zealand forest and timber industry research.[3] The model was tested in terms of structure verification and boundary adequacy (Forrester and Senge, 1980). The structure verification is based on the absence of components lacking real life interpretation, and its construction in consultation with appropriate expert opinion. The boundary of the model is judged to be adequate for the purpose of our paper as we focused on bottlenecks and policy leverage points.

On the upper-left side of figure 2, the stock of *forest resources* represents the total volume of trees available in forest plantations. *Forest resources* increase through the inflow of *planting* and decrease through the outflow of *harvesting*. Harvested trees are processed to *sawlogs* through the flow of *sawlog production* which flows into the stock of *harvested sawlogs*. A portion of *harvested sawlogs* is sold to export markets, and another portion to the domestic market for further processing. We assume all sawlogs traded in the domestic market proceeds to lumber through the flow of *sawlog processing onshore* which flows into the stock of *lumber stock*. Processed lumber is sold to customers through the outflow of *sales rate* to satisfy customer demand. The set of co-flows and stocks structures on the upper side of figure 2 facilitate transforming forest trees to sawlogs and lumber. At the bottom of figure 2, the stock of *mill capacity* represents the processing capacity for sawlogs to lumber. The stock of *mill capacity* increases through the inflow of *investing* and declines through the outflow of *capacity depreciation*.

Figure 2. A System Dynamics Model of the New Zealand forest industry.

[3] Details are available from the authors.

In figure 2 production, marketing, and mill capacity stocks of resources are governed by multiple feedback loops, including:

Balancing feedback loop 1 (or B1) provides market signals about lumber supply and demand conditions. When there is lumber surplus (i.e. high *lumber stock*), *inventory ratio* is higher than what it would normally be which leads to a lower *lumber price*. This in turn augments *lumber demand* which in turn increases the outflow *sales rate*. Sales deplete *lumber stock* which in turn lowers *inventory ratio* and leads to higher *lumber price*. This is a balancing feedback loop because the system self-corrects itself.

Reinforcing feedback loop 1 (R1) governs investment in mill capacity. An increase in *mill profit* encourages investment in *mill capacity* which in turn increases *mill production*. Higher *mill production* further increases *mill profit* which leads to more investment in *mill capacity*. This is a positive feedback loop because the system reinforces itself.

B2 represents mill capacity that provides for processing sawlogs onshore. Higher *mill capacity* allows more sawlogs to be processed onshore which leads to more lumber supply on domestic markets. However, higher lumber supply leads to lower *lumber price* which in turn lowers *mill profit* and discourages investment and, in the long-run, leads to lower *mill capacity*.

B3 regulates investment in mill processing efficiency. Higher *mill profit* motivates mill owners to invest in new technology. Higher mill efficiency increases lumber supply which in turn lowers *lumber price,* which reduces *mill profit*.

B4 balances the growth of *mill capacity*. An increase in *mill profit* leads to more investment in *mill capacity* which in turn leads to more *mill production* and *sawlog demand*. Higher *sawlog demand* increases *sawlog price* which in turn lowers *mill profit* and hence lowers investment in *mill capacity*.

B5 governs producers' (forest owners') willingness to harvest their forest. Higher *sawlog price* motivates producers to harvest more trees which leads to higher *sawlog* and *lumber* supply. Higher *saw log* and *lumber* supply lowers prices of both *sawlog* and *lumber* which in turn discourages producers from harvesting.

B6 is the same as B1 but for *sawlog* supply and demand signals.

B7 governs the effect of *sawlog* price movement on decisions to expand or contract forest lantation areas, by connections to the *forest resources* stock.

The symbol "//" denotes delays in the system. These vary depending on characteristics of the system. For example, consumers are quick to react to changes in lumber and sawlog price, while mill and forest owners are much slower to react to movements in price to invest or divest in mill capacity and forest plantation area.

4. *Chain failure and policy responses*

Interactions among the main feedback loops, including inherent delays, are a major determinant of the extent to which policy interventions can influence industry structures and the generation of benefits to value chain stakeholders. The imperative to reduce exports of sawlogs in favour of more value addition onshore, for example, requires the availability of mill capacity to avoid processing backlogs. Similarly, an increase in the supply of more processed products to domestic markets can lead to lower prices if not coupled with policies at the national level to increase demand for more processed forest products and avoid accumulation of surplus product which would in turn depress prices. The elimination of such bottlenecks calls for enhanced horizontal and vertical co-ordination, improved information flows in terms of infrastructure and enhanced standardisation of data, and standardised quality descriptions and handling procedures. In turn, this requires enhanced knowledge and skills that are developed and shared amongst actors.

Delivery of such a package across an entire industry engaging diverse stakeholders, however, encounters chain failure. Papadopoulos (2012) addressed health service delivery in this setting, but there are few examples from primary industry. Public-private partnership in the Australian beef industry provides a notable exception, by way of the Australian Government's Cooperative Research Centre (CRC) program. CRCs are collaborations amongst researchers, private firms of various sizes, industry representative groups, communities and governments (at several levels). CRCs address major challenges facing Australia, many of which are global in nature centred on sustainable international competitiveness. Some 49 of the 196 CRCs implemented since 1991 have been in the primary industries of Agriculture, Forestry and Fishing sectors, and several more have been in mining (Australian Government, 2014).

A CRC addressing the beef industry was implemented over 21 years to 2012, featuring over 20 domestic and foreign partner institutions who contributed some $A 90 million in addition to a government contribution of $A 30 million. Australia's beef industry produces around 2.5 million tonnes of beef and veal per year, from a national herd of about 13 million cows farmed on some 77,000 farms, largely using natural grazing systems. Around 70% of the industry's production is exported, earning around $A 7.5 billion. Quality-oriented domestic markets generate over $A 6 billion in earnings. The production, processing, retail and export sector employs 200,000 people (Meat and Livestock Australia, 2015). The target impact of Beef CRC was an additional A$ 1.9 billion in gross revenue for the Australian beef industry over the 25 years to 2030 (Griffith, 2009). This was to be achieved by developing and disseminating new genetic and genomic technologies and non-genetic "products" (practices, processes, tools and technologies) to improve profitability, productivity, animal welfare and responsible resource use. Impact projections through to the year 2030 showed that the Beef CRC was still expected to generate a total benefit to the industry of $A 1,004 million, or a return on investment of more than $A 8 for every $A 1 invested (Griffith *et al.*, 2013).[4] The CRC's delivery of chain goods centres on government's role in cohesion and catalysis, rather than a conventional role associated with correction of market failure.

5. Discussion and conclusions

This paper interprets primary industry as an information-enabled, co-ordinated, global producer of customer value and not as a laggard economic sector. Primary industry's chain-oriented and networked structure, scale of operation, systems orientation and linkage to land and natural resources offer both challenges and opportunities. These are however demanding of new analytic frameworks and policy environments, which this paper identifies and discusses. New approaches to analysis are advocated, and dynamic and networked models are advocated. New policy approaches are described, primarily targeting chain failure. Public-private partnership is discussed in a primary industry setting as one that generates chain goods.

Suitable methods for analysis of scenarios which take systems' flows and feedbacks into proper account, have been slow to emerge. The primary industry example presented here, the New Zealand forestry and timber industry, is familiar to many policy advocates by virtue of its call for increased export earnings. Pursuant to the changed nature of primary industry, however, value addition is emphasised in favour of production increase. A reconfiguration of product flows is identified as a means of adding such value, and cited analytical work supports such options. The model employed applies systems dynamics analysis to identify key vertical and horizontal relationships in the chain that, together with the delays inherent in adjustment and investment decisions, can reduce or reverse the impact of selected changes on export volumes, and the destination of the associated benefits. Further research will populate this model to enable a quantitative analysis.

The opportunities offered by modern primary industry centre on co-ordination of chain or network actors so as to transfer wealth generated in advanced consumer markets to selected stakeholders or resources bases: typical targets are rural and remote resource owners, but environmental quality and other public goods, as well as sustainability, are also desirable products. That co-ordination is an enabling feature of innovation for cost reduction, and for service addition to products and product ranges. Challenges feature the imperfect transmission of incentives by way of chain failure: not necessarily as a barrier to co-ordination but rather as the incapacity of chain actors to capture the benefits of investment within firms, and to generate investments in the chain or network as a whole. A further challenge, presented in the paper's qualitative model in some detail, is the interacting effects of delays due to differences between actors and contexts, and in decision time frames. Government roles in eliminating chain failure are discussed, with some prominence given to government-led research and training partnerships, for which the Australian beef industry offers a rare example in a

[4] Further details are available from the authors.

primary industry (Australian beef). Of substantial interest to industry and policy stakeholders is the return on investment of around 8:1.

The first call to emerge from this paper is for concerted effort on research, targeting the roles of public and private actors of various types in primary industry value chains facing rapidly growing demand. Identification of chain failures represents a new policy challenge: delivery of primary industries' products and services, investment incentives, information and skills development requires co-ordinated action along the value chain but occurs subject to constraints. The research initiative should examine new roles for actors within and beyond existing networks, particularly in relation to emerging commercial behaviours or environments such as new forms, sources and combinations of data. This is likely to be best provided by an internationally connected and recognized programme of work.[5]

For such an approach to be successful, commercial industry must be engaged, and motivated by access to information on value chain management from the best possible global sources. This would include case studies on how world-leading companies in a range of industries are innovating around value chain management. Companies will be able to recruit graduates for defined projects on a demand-driven and sustained basis, but would also be able to partner with research bodies and engage research staff as needed. Graduates from a variety of universities would ideally be available to firms, with unique skills but a common platform of concept and vocabulary concerning primary industry and its associated chains and networks.

The next action advocated here is the development of co-ordination mechanisms, both within firms and in government agencies, to assist primary industry to expand networks and value adding linkages. This directly addresses chain failures by internalising them. Distant, dynamic and chain-dominating retail markets require cost-saving innovations by primary industries at least as much as higher-margin new products (Abdirahman *et al.*, 2014). Such cost savings will arise from elements shared within and beyond primary industries (e.g. grading and packaging norms, data handling, infrastructure) as well as from the internal workings of firms. This is to say, chain goods are unlikely to be provided efficiently without co-ordinating mechanisms from beyond the network. This in turn requires a newly-defined set of government roles in primary industry development. The value proposition for universities and research institutes, academic staff and students includes access to large and small companies operating in dynamic primary industries and featuring world-class value chain management and innovation.

A third call emerging from this paper is for enhanced empirical capacities. An immediate application is the calibration and testing of the system dynamics model presented in this paper. Despite advances in systems thinking in other industrial sectors (Xu, 2013), no empirical whole-chain methods have to date been employed over management-relevant time frames for costs and returns on primary industry development pathways. Conventional cost-benefit analysis addresses most new technology questions

[5] An example is the Centre of Excellence in Primary Industry Value Chain Management or an adaptation of the Australian Bureau of Agricultural and Resource Economics and Sciences (ABARES)

concerning individual firms, but not those requiring horizontal and vertical sharing of costs and benefits, nor risk exposure. Further, re-engineered value chains for such tasks as recovery of energy or waste products are a system-specific change for which costs and benefits are dispersed amongst value chain actors and themselves generate demand for chain goods. These elements of primary industry feature an overlay of dynamics often associated with seasonal supply and demand, long cycles of physical growth and renewal, and long term consequences of changes in investment. These arguments support a concerted effort in systems dynamics modelling for primary industry development.

Finally, there is a need for innovation in government's primary industry roles. In addition to funding and partnership-building, its attractive elements include long term engagement, regular evaluation and continual interplay between government and industry, all built on goals agreed by actors in the value chain. This paper has discussed export and producer income goals, but many others are relevant including environmental and regional economic impacts. Innovation will initially entail identifying the chain failures, and associated chain goods for delivery.

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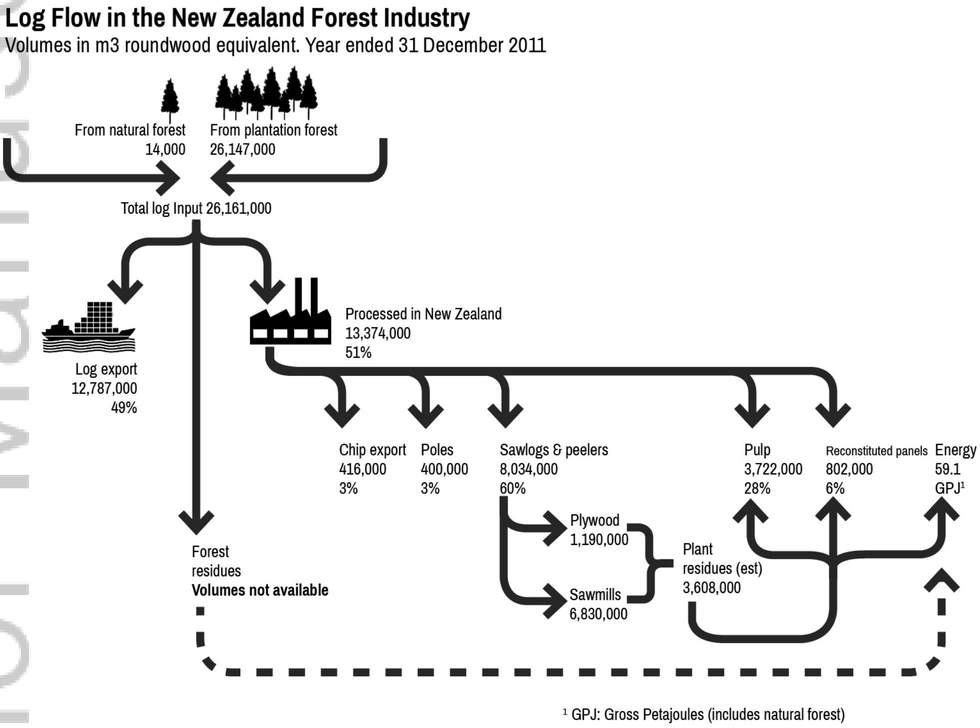

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