Howard PARTNERS
Howard Partners Pty Ltd ACN 090 817 369

Research Report 1

PERFORMANCE REVIEW OF THE RURAL INNOVATION SYSTEM

RESEARCH REPORT 1: RURAL INNOVATION OUTCOMES AND GLOBAL VALUE CHAINS

The attached report has been prepared by Dr Mark Matthews, of SDG Economic Development (now re-branded as Steer Economic Development), to inform the Performance Review of the Rural Innovation System. SDG Economic Development was engaged by Howard Partners under a subcontracting arrangement to assist in undertaking the Review. Section 3 of this report, on value chains and distributed ledger technologies and, was added by Dr Matthews subsequent to the submission of the SDG Economic Development report and at the request of Howard Partners.

Contents

Figures

Executive Summary

This Discussion Paper has been prepared to inform the Review of the Australian Rural Innovation System being conducted by Howard Partners Pty Ltd under a contract with the Council of Rural Research and Development Corporations. It reports on exploratory technical work assessing the potential to use data on the nature and extent of rural economy participation in Global Value Chains as a measure of innovation outcomes. As such, the paper is a resource document to be drawn upon in the Review report prepared by Howard Partners.

Overview

The study of innovation, and public policy aiming to enhance innovation performance, has faced long-standing challenges in effective *measurement*. It is far easier to measure inputs to innovation (funding, person-hours etc.) and certain innovation related outputs (patents etc.) than innovation *outcomes*. Whilst these outcomes are, at a general level, widely acknowledged to appear in differential rates of economic growth and productivity between countries and regions, and in historical variations in these rates of economic growth, there is a relative weakness in measuring the factors that intermediate between economic growth and innovation. This limitation is of concern to policymakers because new initiatives, programmes and projects are strongest (and most likely to be funded) if they can define how their success can be measured. In particular, how their success has helped to generate useful outcomes that would not otherwise have taken place.

The aim of this paper is to explore the extent to which the recently available data able to map the structure and performance of Global Value Chains (GVCs) might contribute to addressing this public policy challenge. It builds on a previous SDG Economic Development Discussion (SDG ED) Paper on 'Innovation strategy and global value chains' prepared as part of the development of Australia's new national innovation strategy.[1] This Discussion Paper also draws upon innovation strategy insights developed in an SDG ED paper on PERFORMANCE REVIEW OF THE RURAL INNOVATION SYSTEM

The three core principles underpinning this Discussion Document are that:

- Innovation effectiveness is maximised by 'braiding' together science and innovation capability with a rage of complementary business capabilities (strategic marketing, knowledge and systems integration, supply chain management etc.);
- This 'braiding' is what determines the nature and extent of participation in GVCs – this participation is key to economic growth and prosperity because it both determines levels of domestic value added *and* the ability to leverage other nations' capabilities and markets in generating that value added; and
- These policy objectives are best met by transitioning from a focus on innovation strategy and towards a broader Industrial Strategy, in which innovation plays an integral role.[2]

Given that the Review of the Rural Innovation System commissioned by the Council of Rural Research and Development Corporations (CRRDC) has been informed by the prior work on Australia's national innovation strategy, an opportunity existed to explore the empirical implementation of the above 'connected innovation' ideas.

[1] Matthews and Lacy (2017) Innovation strategy and global value chains. Discussion Paper commissioned by Innovation Science Australia: Manchester.

[2] SDG Economic Development (2018) *Building the Evidence-Base to Inform 'connected innovation' Strategies for Local Enterprise Partnerships: A prototype methodology*. Report for the Smart Specialisation Hub: Manchester, UK.

To this end, this paper reports on exploratory empirical work that maps and characterises Australian rural industry participation in GVCs. This empirical work is now possible only because new global input-output data have been placed into the public domain. The new input-output datasets track both economic transactions between different industries in each economy and between national economies. These are large and complex datasets that treat the entire global economy as a single economic system. The major advantage of the new data is that it is now far easier to create profiles of the composition of output and value added in specific industries that:

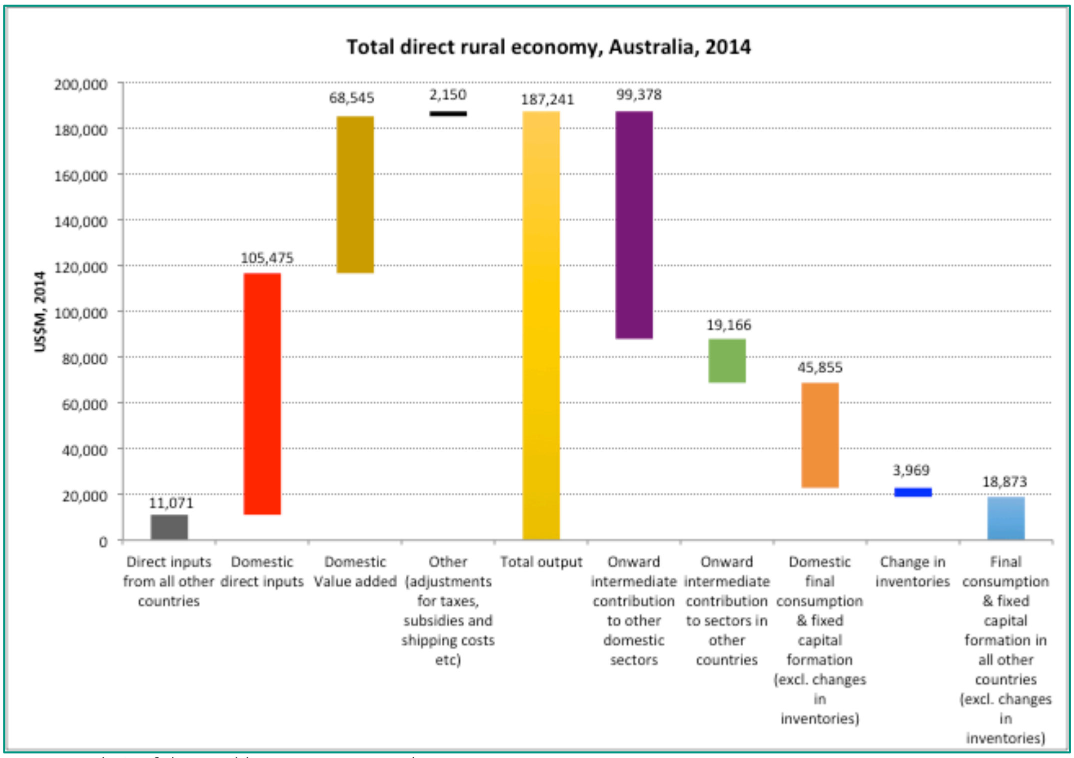
- Identify the commodity classes and the specific countries from which imported production imports come from;
- Allow these imported inputs to be compared to domestically produced inputs;
- Measure the gross value added to these production inputs;
- Track the onward flows of the resulting industry outputs to other domestic industries, overseas industries, and to final consumption – both domestically and internationally.

The result is a far richer picture of the structure of production that explicitly maps GVC participation. One example is provided below – a profile of the key rural economy sectors combined. This highlights the ways in which domestic value added relies on 'upstream' domestic and imported inputs (tangible and intangible) to deliver total output that is driven by a mix of domestic and international 'downstream' demand channels: forward linkages to other domestic and international industries together with domestic and international final demand. GVC participation is reflected in the relative reliance on imported intermediate production inputs (the first, grey, bar) and also exported intermediate production outputs (the green bar).

In general, 'globalisation' means that the level of value added and hence (in general terms) productivity and employment, is driven by these upstream and downstream linkages. This implies that innovations that facilitate stronger GVC participation will help to lift value added and, in so doing, generate useful knock-on economic benefits. From this perspective, Australia's rural industries are not strongly engaged with GVCs. Consequently, the potential to increase the economic contribution of the sector rests, in part, upon finding ways to increase GVC participation – there is a limit to domestic final and intermediate demand relative to global demand.

Indeed, the Australian economy as a whole, when compared to a similar economy like Canada, has stronger correlations between value added and both domestic intermediate inputs and domestic outputs across different industries. Again, this points to Australia's relative lack of engagement in GVCs. Thus, Canada is able to benefit more easily and directly from economic growth on the global economy.

Illustration of a value chain profile



Source: Analysis of the World Input Output Database.

Results of this type derived from Computable General Equilibrium (CGE) analyses of trade and production in the global economy are familiar to policymakers. However, the simple descriptive use of industry-specific GVC profiles in this paper provides an easily-grasped visual representation of the significance of these international economic inter-dependencies. Furthermore, this is achieved without the need for a range of technical assumptions that can bias the results of more complex calculations. Thus, policymakers can, for the first time, gain ready access to descriptive data that maps each industry's participation in GVCs. The basic principle is that relative industrial competitiveness between nations is reflected in differential participation in GVCs – participation that can now be measured far more easily than in the past.

The rural industries provide a particularly useful domain for further developing this line of investigation because they play a distinctive and high-profile role in Australia that is linked to *natural capital*. Indeed, Australia stands out in the breadth and depth of official data on its stocks of natural capital, which are reflected in the National Balance Sheet, and focus attention (via experimental estimates) on the depletion and degradation of natural capital as a consequence of economic growth (a measurement issue that Australia plays a leading role in). This link between economic activity and natural capital adds an especially interesting dimension to a review of rural innovation. It points to opportunities for not only framing rural innovation objectives in a pragmatic manner in terms of lifting participation in GVCs, but also factoring-in the *measurable* impact of this innovation on economic and environmental sustainability. As such, the potential exists to define a vision for rural innovation in Australia that aligns explicitly with 'circular economy' principles, *a vision whose implementation can, in principle, be demonstrated empirically*.

Main Findings

The following findings emerged from the exploratory analysis set out in this Discussion Paper are as follows:

1. In methodological terms, the approach to profiling value chain participation as a partial indicator of innovation outcomes is viable, and is able to generate useful and easily grasped evidence for policymakers to draw-upon.
2. The value chain profiles for different rural industries in countries with similar economic structures are comparable. This means that industry-driven characteristics shape value chain participation more than country-specific factors.
3. However, the Australian rural economy's participation in GVCs is (as would be expected from studies of international trade) is sensitive to the 'tyranny of distance' and, as a result, unusually dependent on domestic upstream and downstream value chain linkages and on domestic final consumption over international final consumption.
4. This structural consideration highlights the importance, to the Australian rural economy, of innovations that mitigate distance from market. This, in turn, suggests that the return-on-investment from innovations that focus on ways of lifting GVC participation are likely to exceed the return-on-investment from rural production per se – the latter is a dominating aspect of current rural innovation efforts.
5. This conclusion is aligned with the basic, and well-known, innovation strategy principle that primary production activities, such as occurs in the rural economy, are the lowest value-added stage in value chains. Hence, value added (and associated productivity gains) can be increased by innovations that will allow Australia to benefit from participation in both upstream and downstream value chain segments. These tend to be the intangible segments of value chains. For example, developing and exploiting rural innovation intellectual property and know-how as *itself* an export that lifts GVC participation (something that technologically sophisticated nations like Israel have been prioritising).
6. In terms of the mind-sets that shape strategy (whether innovation specific or in broader industrial strategy terms), these findings highlight the importance of using an understanding of the importance of GVC participation i*tself* to set objectives, rather than setting objectives too narrowly around traditional 'farm' and other rural industry domains. However successful production-based innovation is, the payoffs will be limited by geographical challenges in translating what is grown on land and in water into downstream GVC participation.
7. In terms of the evidence-base, the potential therefore exists to build on this approach by generating an updated profile of the rural economy's GVC participation, and using this profile to both define opportunities for pursuing a Rural Economy Industrial Strategy for Australia, and for tracking progress achieved by this strategy over future years.

Conclusions

There are major advantages to 'braiding' together science and innovation capability with a rage of complementary business capabilities (strategic marketing, knowledge and systems integration, supply chain management etc). The dividend to public and private investment in innovation is maximised when this braiding is effective but is constrained when this braiding is not effective. The combined innovation and industrial strategy outcomes that result are reflected in increased participation in Global Value Chains.

Consequently, there are strong empirical and conceptual grounds for re-framing Australia's approach to maximising the effectiveness of the rural innovation system as a broader *Industrial Strategy* challenge. Innovation is a necessary but not a sufficient component of an Industrial Strategy. An Industrial Strategy brings together a range of complementary public policy concerns in a way that has a greater likelihood of success than persisting with long-standing support for innovation in a more stand-alone manner.

A major policy implication is that Australia should re-imagine ‘innovation systems’ (and associated ‘innovation strategies’ intended to lift the effectiveness of these systems) as *Industrial Strategy objectives*. Strategies for a rural innovation system (per se) are not required, rather a more focused and forthright Industrial Strategy for Australia’s rural economy is.

This strategy would be most effective if it started by considering how Australia’s participation in Global Value Chains could be improved (the ‘ends’) and then moved on to consider how best to deliver on these strategic aspirations (the ‘means’). Other important dimensions of this strategic approach would be to avoid making risky trade-offs when lifting participation in Global Value Chains: these Industrial Strategy pathways should be environmentally sustainable (crucially not running down our stocks of natural capital in the process).

This paper demonstrates that it is now possible to provide empirical evidence on rural industries’ participation in GVCs and, also, to start to link that analysis to the value of the natural assets that drive and facilitate that participation.

1 Introduction

This Discussion Paper is organised as follows. It commences by re-iterating the key measurement challenges faced in innovation policy and draws attention to the potential for analysing GVC participation as a contribution to addressing these measurement challenges. It then considers the conceptual model of value added used to frame thinking on GVCs and highlights the importance of integrating specific concerns with 'innovation' within a broader industrial strategy approach (as is currently being articulated in the United Kingdom). This integrated approach avoids the problems of 'balkanising' innovation strategy by de-coupling it from the commercial realities that determine whether or not that innovation effort will actually generate economic and social benefits.

The discussion then moves on to pilot an analysis of the recently available World Input Output Data in order to start to develop industry-by-industry GVC participation profiles. As this work was carried out to inform the Review of Australia's Rural Innovation System it is merely exploratory and intended to act as a 'proof-of-principle' for further research that could be carried out in the future as part of a possible CRRDC initiative to develop an innovation rich Industrial Strategy for the rural economy. The paper concludes by considering the policy implications to emerge from this study.

Additional material in Appendix B considers some results obtained from using related data on GVCs generated by the OECD to profile the 'biologically derived contributions to value added. Appendix C contains a brief discussion of rural and biologically related assets on the National Balance Sheet and Appendix D provides comparative data on Canadian value chain profiles.

1.1 The Challenge

The study of innovation, and public policy aiming to enhance innovation performance, has faced long-standing challenges in effective measurement. It is far easier to measure inputs to innovation (funding, person-hours etc) and certain innovation related outputs (patents etc) than innovation outcomes per se.

Whilst these outcomes are, at a general level, widely acknowledged to appear in differential rates of economic growth and productivity between countries and regions, and in historical variations in these rates of economic growth – there is a relative weakness in measuring the factors that intermediate between economic growth and innovation.

This limitation is of concern to policymakers because new initiatives, programmes and projects are strongest (and most likely to be funded) if they can define how their success can be measured. In particular, how their success has helped to generate useful outcomes that would not otherwise have taken place. Or, more pragmatically, outcomes that were *less likely* to have taken place (it is usually very had to be definitive over the 'additionality' of public sector interventions).

Whilst results of this type derived from Computable General Equilibrium (CGE) analyses of trade in the global economy are familiar to policymakers, the simple descriptive use of industry-specific GVC profiles in this paper provides an easily grasped visual representation of the significance of these international economic inter-dependencies (and without the need for a range of technical assumptions that can bias the results of more complex calculations). Thus, policymakers can, for the first time, gain ready access to descriptive data that maps each industry's participation in GVCs.

The descriptive aspect is especially important because it avoids using data that embody a number of, often 'heroic', assumptions involved in more complex analyses like CGE modelling. Recognition of the limitations to these assumptions is now leading to recommendations by some national statistical agencies (including the Australian Bureau of Statistics) to avoid using the resulting input-output multipliers because they greatly exaggerate the scale of indirect impacts on output and gross value added. In contrast, this paper simply reports simple descriptive profiles of GVC participation designed to inform how we think about innovation and industrial performance. The basic principle is that relative industrial competitiveness between nations is reflected in differential participation in GVCs – participation that can now be measured far more easily than in the past.

1.2 Global Value Chain Approach – the New Datasets

As the global economy has become more inter-dependent, trade flows have become extremely complex - and in a manner, that means that traditional trade statistics provide a misleading picture of trade and national value-added performance. A country's exports will more likely than not feed into other countries' domestic value-adding chains, in turn, feeding into several more countries' value-adding chains on the pathway to final demand. This fragmentation of production means that traditional trade statistics that record cross-border flows of goods and services give a misleading picture of trade and production because intermediate goods and services repeatedly cross-national borders before reaching their final destinations as consumed products and services or capital assets.

The response to this problem has been a joint OECD-WTO initiative to develop a large and analytically sophisticated database that allows the global economy to be analysed as trade in value-added rather than simply trade per se. This is known as the Trade in Value Added (TiVA) database. It measures the network of inter-country flows of value-added of goods and services. As such, it seeks to eliminate the double counting associated with a reliance on trade statistics alone. A comprehensive discussion of these issues can be found in OECD (2013).

Rectifying this measurement error is important for public policy both in specific regard to trade-related decisions and more generally in relation to industry strategy and policy, including science and innovation policy. In regard to trade-related issues, the use of TiVA data results in different estimates of bilateral trade balances, Koopman et al (2011). The TiVA data were first released in January 2013, and with a substantial update in 2015.

In addition, there is also a complementary dataset produced using EU Framework 7 programme funding that provides global input-output tables for each year from 2000 onwards (currently up to 2014). This very useful dataset is freely available and can be used to create simpler descriptive profiles of GVCs. Whilst both datasets have been drawn upon in this Discussion Paper, the bulk of the results reported are based on analysing WIOD data simply because this minimises the potential biases created by the technical assumptions required to create the OECD TiVA estimates.

The response to this problem has been a joint OECD-WTO initiative to develop a large and analytically sophisticated database that allows the global economy to be analysed as trade in value-added rather than simply trade per se. This is known as the Trade in Value Added (TiVA) database. It measures the network of inter-country flows of value-added of goods and services. As such, it seeks to eliminate the double counting associated with a reliance on trade statistics alone. A comprehensive discussion of these issues can be found in OECD (2013).

Rectifying this measurement error is important for public policy both in specific regard to trade-related decisions and more generally in relation to industry strategy and policy, including science and innovation policy. In regard to trade-related issues, the use of TiVA data results in different estimates of bilateral trade balances, Koopman et al (2011). The TiVA data were first released in January 2013, and with a substantial update in 2015.

In addition, there is also a complementary dataset produced using EU Framework 7 programme funding that provides global input-output tables for each year from 2000 onwards (currently up to 2014). This very useful dataset is freely available and can be used to create simpler descriptive profiles of GVCs. Whilst both datasets have been drawn upon in this Discussion Paper, the bulk of the results reported are based on analysing WIOD data simply because this minimises the potential biases created by the technical assumptions required to create the OECD TiVA estimates.

2 Global Value Chains and Innovation

In conceptual terms, the GVC approach recognises that the success of individual national economies rests on competing over the shares of value-added in this global system – a competitive process in which onward 'downstream' economic success tends to be linked to adding value to imported 'upstream' inputs (what countries export is influenced by what they import, especially when high-tech inputs and capital equipment are required).

After reviewing the relevant literature on the innovation–GVC relationship, Matthews and Lacy concluded that a focus on GVCs impacts on innovation by providing a new and realistic imperative for competitive strategy:

'When national innovation strategies shift their main focus from nationally focused to internationally engaged performance, considerations for the frame of reference evolve to take into account international leverage opportunities i.e. how can we maximise the benefits we obtain from global engagement in value-adding? A GVC-focus encourages innovation strategy to consider not just how exports will be achieved and the associated domestic value added increased (or protected), but how imports embodying technology and know-how will be leveraged to achieve this enhanced export performance. In other words, recognition of the importance of GVCs encourages a more systemic approach to the global economy that considers the indirect/embodied drivers of competitiveness – not just the drivers that exist within a national boundary.' [3]

This leverage-based approach has been further developed to consider the implications for sub-national innovation strategies specifically geared to exploit the potential for 'connected innovation'.[4] Namely a perspective in which:

- The effectiveness of a *national* innovation strategy can be amplified by treating it as a means of enhancing *international* participation in both Global Value Chains (GVCs) and Global Innovation Networks (GINs) – a recently introduced concept reflecting international collaborative arrangements in science and research;
- This amplification effect stems from the ways in which both GVC and GIN participation acts as pathways for exploiting a range of useful knowledge spill-overs via which broader global capabilities and substantial international investments are leveraged; and
- Consequently, national investments in innovation that allow contributions to GVCs and GINs can yield amplified returns via the substantial international knowledge spill-overs thus enabled. These global leverage opportunities are restricted by national strategies that fail to recognise the long-term significance for innovation strategy of this international connectivity.[5]

This innovation connectivity-based focus shifts the main emphasis in innovation support away from a 'go it alone' ethos in which the domestic 'means' are treated as the primary way of meeting domestic objectives ('ends') and towards an amplification/leverage-based strategy that develops solutions to domestic objectives through internationally engaged approaches.

A 'connected innovation' approach linked to GVC participation facilitates an approach to innovation that recognises the varied ways in which innovation both influences relative prices and is, in turn, stimulated by changes in relative prices. For instance, anticipated rises in the price of production inputs (e.g. water) encourage innovations with the potential to economise on the use of that input

---

[3] Matthews and Lacy (2017) page ii-iii.
[4] SDG Economic Development (2018) Building the Evidence-Base to Inform 'connected innovation' Strategies for Local Enterprise Partnerships: A prototype methodology. Report commissioned by the UK Smart Specialisation Hub. Manchester, UK.
[5] Matthews and Lacy (2017) page i.

and/or create opportunities to substitute new, more cost-effective inputs (e.g. fertilisers that require less energy to produce them).

Similarly, imported inputs to production will become most costly to purchase if the Australian dollar becomes weaker relative to the currencies of the countries from whom these inputs are being imported. This will tend to stimulate efforts to substitute domestic inputs, a process that may require new types of innovation.

These aspects mean that the impacts of rural innovation are best understood from the perspective of the inter-twinning of scientific and technological factors and relative prices and associated risks to commercial success. Using data that are able to profile changes in the structure of value chain over time, therefore, provides a coherent and comprehensive context for understanding rural innovation.

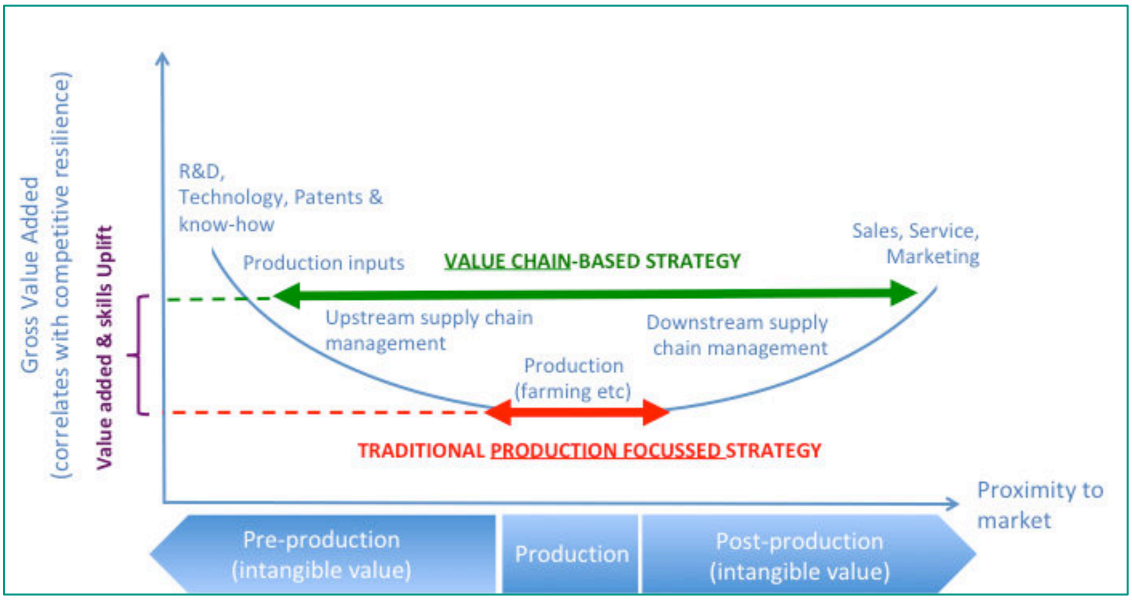
From this perspective, success in innovation in a national context is reflected in defending, and enhancing, these shares of global value added in production chains. Whilst there are multiple pathways via which innovation impacts upon shares of global value chains, some direct and some indirect, the over-arching principle is that innovation effectiveness correlates with changes in GVC participation. Consequently, many of the metrics used to try to capture innovation outputs and outcomes (patenting etc) are, in effect, intermediate and enabling measures.

In a global economy, the litmus test of innovation effectiveness both in particular sectors and for national economies as a whole is whether or not shares of the value added in GVCs is increasing or decreasing – and which countries and sectors are either gaining shares at our expense or, more positively, losing shares to us. Whilst complementarity between different sectoral and national shares of GVCs is inherent in the concept, the sectors and national economies that best exploit this complementarity are those that prevail in global competition.[6]

The following diagrams summarise the main pathways via which innovation performance drives participation in global value chains. The first, Figure 1 is a version of the well-known 'smiling curve' relationship between position/span in value chains and the level of value added. It highlights the higher value-added associated with activities remove from production per se. The second, Figure 2 highlights the inverse relationship between the value-added curve and ease of measurement.

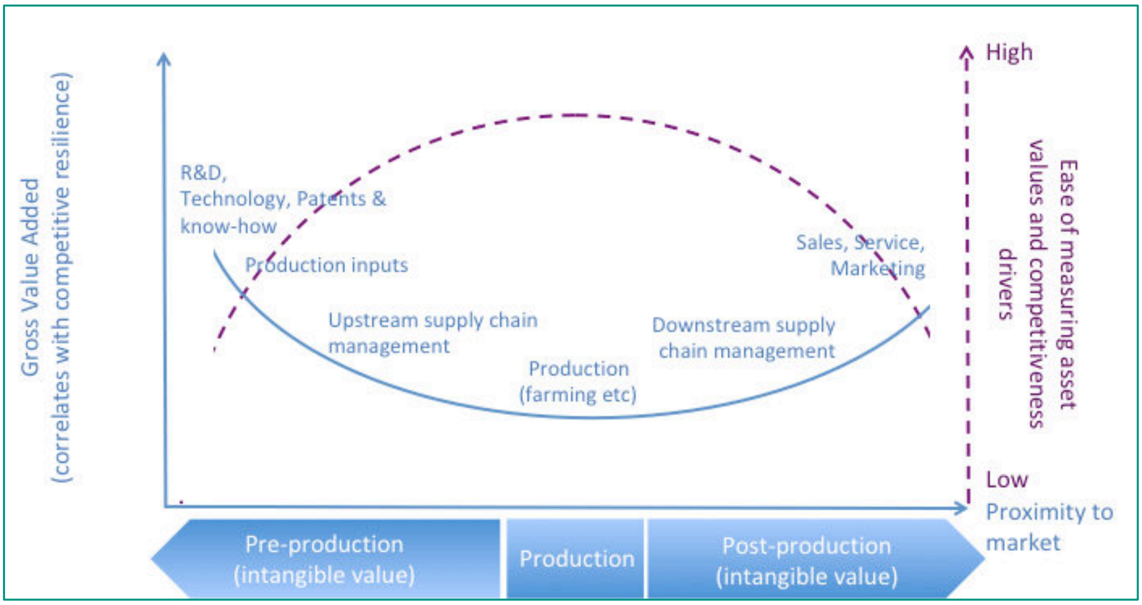
[6] Howard Partners, via their partnership with SDG Economic Development in the UK, have helped to draw attention to this link between innovation strategies and GVCs – as reflected in the Discussion Paper on 'Innovation Strategies and Global Value Chains' commissioned as part of the process of developing Australia's National Innovation Strategy, see Matthews and Lacy (2018). This work is only possible because of the pioneering efforts of the OECD and other international bodies to produce readily accessible data on the structure and performance of global value chains.

Figure 1: Production versus Value Chain Approaches to Innovation



Source: Based on Shih (1996), and taken from SDG-ED (2018)

Figure 2: Measurement Challenges for Value Chains



Source: SDG-ED (2018)

The implication is that unless progress is made with measuring and demonstrating how global value chains and configured, and are evolving, innovation strategies risk being too focused on the lower value-added production segments of value chains whilst neglecting the important higher value-added, but harder to measure segments.

The logical solution is to seek to use data on value added in global value chains – a focus that starts by considering how value added is created via links between activities in different sectors and national economies. Innovation is then treated as one of the drivers for changes in the structure and performance of these global value chains.

The literature on global value chains highlights the way in which upgrading can be achieved by strategies focused on lifting value-added contributions to GVCs that use innovation as part of a broader competitive agenda. Four strategies are identified, as summarised in OECD (2013a) these are:

- *Process upgrading* is achieved when firms can undertake tasks with significantly greater efficiency and lower defect rates, and process more complex orders than their rivals. This tends to rely on firm-specific management skills and flexible organisational structures;
- *Product upgrading* is achieved when firms can supply higher value-added products than their rivals owing to their superior technological sophistication and quality and also introduce novel products faster than rivals. This tends to rely on introducing advanced production technology, effective quality management and good designs;
- *Functional upgrading* is achieved when firms can provide competitive products or services in new segments or activities of a GVC which are associated with higher value added. For firms previously specialised in production, this means becoming competitive in upstream or downstream activities such as design or marketing. This requires sophisticated technologies and design capabilities together with strong marketing, brand visibility and extensions in retail and collaboration networks; and
- *Chain upgrading* is achieved when firms are able to participate in new GVCs that produce higher value-added products or services, often leveraging the knowledge and skill acquired in the current chain.

One example of a GVC-focused innovation tactic is the deliberate targeting of 'choke point' technologies, McKinsey & Co (2010). This approach is associated, in particular, with technologically sophisticated Japanese corporations who identify opportunities take positions in GVCs that allow them to dominate the market key technology-intensive components widely used in GVCs. For example, the highly specialised substrates and bonding chemicals used in microprocessor fabrication. The economic value of this strategic approach stems from understanding and then positioning within GVCs in a manner intended to limit the ability of new competitors to enter these 'choke point' markets.

These 'connected innovation' strategies also apply to a rural innovation context, but crucially only if innovation is treated as an integral part of a broader GVC upgrading strategy rather than in a more stand-alone framing (an issue to which we return when considering the policy implications of this approach to innovation strategy). GVC upgrading strategies tends to focus on the intangible segments of value chains. For example, developing and exploiting rural innovation intellectual property and know-how as *itself* an export that lifts GVC participation (something that technologically sophisticated nations like Israel have been prioritising).

Interestingly, (and despite the ready availability of the data discussed in this paper) the UK Industrial Strategy White Paper does not emphasise the relevance of GVC participation to the UK's future export potential, or indeed the inter-connects between GVC participation and innovation performance. From the perspective advocated here, this is a missed opportunity to fully exploit the advantages of developing and implementing an industrial strategy.

3 Value Chains and Distributed Ledger Technologies

In any value chain, global or domestic, as with all production processes, productivity is strongly influenced by the likelihoods that materials and sub-assemblies with be in the *right place*, at the *right time* and in the *right state* (i.e. processed and quality certified as agreed). Productivity declines as these 'place-time-state' likelihoods diminish because error-tracing, troubleshooting, re-work etc are required, and sometimes, production inputs must be scrapped. Not surprisingly, maximising these place-time-state' likelihoods are a major emphasis in advanced manufacturing techniques and a familiar feature, in particular, of Japanese high-reliability 'lean production' methods.

As production systems become more complex, the productivity consequences of low place-time-state' likelihoods can become very serious. This is mainly because this complexity in production systems can amplify problems. So too can limitations to the accuracy of the information available on these 'place-time-state' likelihoods. Indeed, limitations in the ability for production inputs to achieve high place-time-state' likelihoods are compounded by errors, inconsistencies and uncertainties in the information available on the 'place-time-state' status. This can be thought of as a multiplicative relationship: a bad situation regarding the status of production inputs is made worse by information imperfections on 'place-time-state' status.

For instance, there may be 'false positive' cases in which information systems say a production input or in-process product is at state X on a particular day in a specific facility when it is at not. There may also be 'false negative' cases in which information systems say a production input or in-process product is not at state X on a particular day in a specific facility when it actually *is* in that state. Anyone who has worked in a factory will be familiar with such problems in the inter-play between what is actually happening and what information systems say is happening. The closer the correlation between information and reality the better the production system. The symptoms of a poor correlation are readily observed on the shop floor via excessive unplanned inventory build-up, scrapped materials and sub-assemblies and production scheduling problems caused by unexpected 're-work' as non-compliant components and sub-systems are corrected prior to use.

A GVC system represents an especially complex challenge in this context due to the large number of participating firms and the profusion of cross-border transactions. Production inputs can be delayed because the import paperwork is missing or not correctly completed, uncertainties over where these production inputs actually are when in transit and other challenges can all be highly disruptive to industry.

Indeed, when we consider this inter-play of what is actually happening and what information systems say is happening that we can quickly grasp the importance of adopting systems thinking for GVCs. As the correlations between information and reality in a GVC system weaken, the damaging consequences of this mismatch tend to be amplified and cascade throughout that system. An ideal GVC has both perfect place-time-state likelihoods and perfectly accurate information on actual place-time-state status.[7] A real GVC faces a myriad of challenges that stem from imperfections in both real flows of inputs and the information in the current status of these inputs.

These systemic coordination challenges are addressed in the research literature on GVCs via work on value chain *governance* (Gereffi et al., 2005). This work emphasises the importance of the *complexity of transactions*, the how these transactions and *codified* and the differential *competence of suppliers* in GVCs. Different modes of GVC governance are associated with specific combinations of transaction complexity, their modes of codification and levels of supplier competence. Governance, framed in this manner, is critically important to GVC performance for the obvious reason that a complex system prone to generating 'nasty surprises' needs governing. For some GVCs a large multinational

[7] The severe challenges that are emerging as the UK attempts to leave the European Union and new 'boundary crossing' arrangements are required that were previously unnecessary are a pertinent reminder of the importance of these issues.

corporation (MNC) provides this governance function (setting standards for quality assurance, technical communication etc). But, there are many types of GVCs, and their governance can pose a severe collective challenge especially when there is no single MNC GVC 'architect' and 'controller' – distributed authority requires distributed governance.

The severity of this distributed governance challenge in GVCs is driving a growth in interest in the use of what are known as 'distributed ledger' technologies, of which blockchain applications are currently the most well-known. These distributed ledger technologies seek to provide a computational solution for verifying the accuracy of information on complex systems with distributed governance. They can also be used in MNC controlled GVCs. The aim is to eliminate mis-information via widely distributed and large-scale information validation. In a blockchain, all participants must validate (via complex calculations) new information added to the system. This can reduce fraud by using a form of 'voting' based consensus to validate and permanently record transactions.

For example, IBM and Maersk are developing a blockchain solution for tracking shipping containers. Such systems have the potential to significantly increase the accuracy of real time information on the status of shipments and may result in large reductions in the transaction costs associated with managing the shipping aspect of GVCs.

However, because current systems rely in a 51% validation 'vote' it is possible to validate incorrect information by drawing on overwhelming computational power of the sort currently mainly available to major state actors or malicious actors taking control of millions of personal computers and servers.

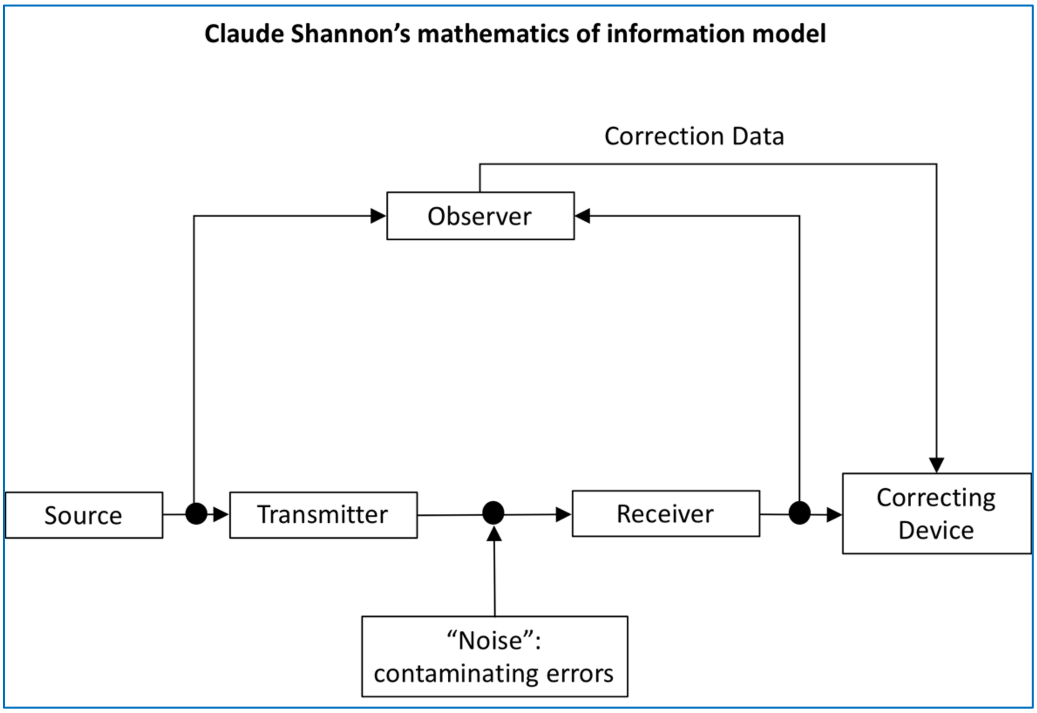
There are already significant applications of blockchain methods in agricultural value chains, for instance in 'provenance' certification – providing assurance that food products come from where they purport to come and have been checked as they were supposed to be checked.

As part of this Review we carried out an analysis of the potential importance of distributed ledger technologies to the rural industries by tracing the developmental trajectory of distributed ledger technologies back to the seminal work of Claude Shannon on the 'mathematics of information', Shannon (1948)[8] – the conceptual foundation for the information age. Shannon's model, which as summarised in the following diagram, focused on the way in which a well-designed communication/computational system can deal with various errors by comparing what has been sent with what was received, identifying mathematical patterns in these errors and then using these mathematical patterns to correct errors in the future.

This is the mathematical foundation for many of the technologies with which we are now so familiar and reliant on, Wi-Fi for example. In Wif-Fi, technology, a version of this model is able to use the noise introduced in a simple test 'calibration' signal to perform near-instant mathematical adjustments to the signals containing real information. This means that we can walk across a room using a Wi-Fi device, thus introducing complex distortion to the radio signals transmitting our data, but the error correction system can (most of the time) handle this interference, repeating transmissions where necessary to assure accuracy.

[8] Shannon, C. E. (1948) A mathematical theory of communication. *The Bell System Technical Journal*. Vol XXVII. July. pages 379-423

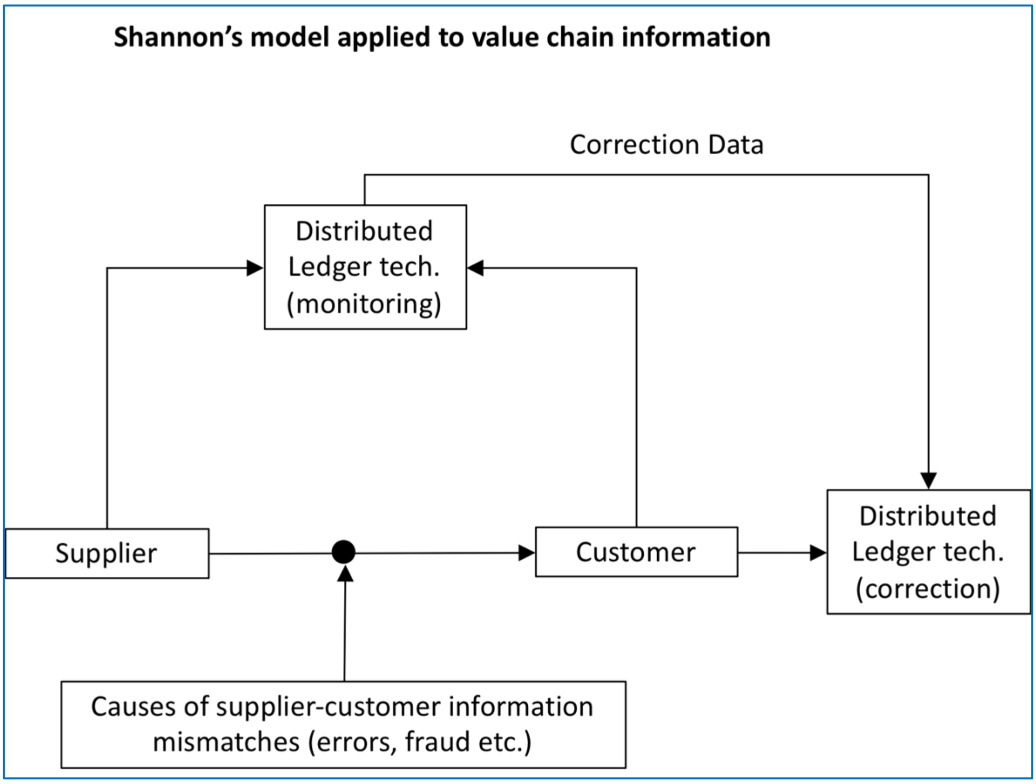
Figure 3: Error identification and correction in information systems



Source: Howard Partners based on Shannon (1948)

The following diagram translates the Shannon information error correction model into a value chain context. In this version the supplier and customer are made explicit, but the same error identification and correction feedback loops are retained.

Figure 4: Error identification and correction in value chains



Source: Howard Partners based on Shannon (1948)

Relating distributed ledger technologies back to their basis in mathematics of information in this way provides an important insight into GVC governance: *current distributed ledger technologies such as blockchains focus primarily on* ***monitoring*** *(i.e. validation of information) not on* ***correction****.* This is understandable because blockchain validation technology was originally developed in a cryptocurrency context, but has subsequently started to develop 'with a life of its own' independently from cryptocurrency concerns per se.

If we consider the wide range of information accuracy problems faced in a GVC context, together with related national jurisdiction problems such as Goods and Services Tax (GST) collection in Australia, then the main challenge is less about identifying *unvalidated data* (e.g. GST on sales not matching GST upstream and downstream in value chains) than in working out what to do about these 'matching errors' (deliberate or inadvertent).

In the strategic framework of McKinsey & Co, information monitoring and validation is Horizon 1, but *information correction is Horizon 2*. From this longer-term developmental perspective, the rural industries (for whom provenance validation is especially important) could usefully explore innovative ways of developing automated (perhaps AI-based) *information error correction* technologies. Specifically, when distributed ledger monitoring identifies information that *cannot be validated* then the system, and the relevant organisations (governmental and non-governmental) must start forensic work on *why* this information cannot be validated and *what should be done in response*.

In some cases, a validation failure can be attributed to genuine errors, in others the cause will be fraud and other challenges. Automated follow-up systems using Big data can help to eliminate spurious unnecessary follow-ups (there will be false positive and false negatives in the error monitoring system that will be revealed and resolved by further AI-driven analysis). This allows skilled people to focus on the correction actions that matter most – especially as regards criminal behaviour.

> *The adoption of distributed ledger technologies in the rural industries opens up potentially important innovation pathways beyond provenance and quality assurance per se. It creates opportunities to drive the evolution of rural industry GVCs as a system by fixing system performance limitations using robust information on "what does not add up".*

In summary therefore, distributed ledger technologies are poised to play a major role in lifting the efficiency and the effectiveness of GVC governance in general, and will also play an increasingly important role in the future evolution of GVCs involving biologically-derived inputs (especially for food and pharmacological products). Consequently, national participation in the developments and use of distributed ledger technologies should be a key feature of an Industrial Strategy for Australia's rural industries.

4 The significance of biologically-derived economic activity

An additional feature of this Review, also facilitated by the emergence of better data on global value chains, is that it draws attention to the benefits of considering the overall nature and extent of biologically derived economic activity. Many industries make use of production inputs of a biological nature. Examples are wooden formwork used in concrete pouring through to fish oils in food supplements, and even animal fats in some 'plastic' banknotes.

This pervasive impact of biological materials (and processes) means that rural innovation plays a current and potential future role in a myriad of ways, often very indirectly and via the ways in which downstream industries use a mix of biologically derived and non-biologically derived inputs. From this perspective, biologically derived inputs provide the 'feedstock' for a very wide range of biologically derived value-added downstream in value chains. This covers food production, textiles and a range of forest and wood products. There is also a growing appreciation of the interconnecting between food and nutrition, rural production and the environment.

This feedstock is a national strategic resource. It sets the biologically oriented rural industries apart from other industry sectors that make up the Australian industrial system. In particular, the link between biologically derived economic activity and the 'circular economy' concept is gaining ground in industry policy discussions and initiatives. Biologically derived economic activity aligns especially well with the circular economy ethos because these processes involve naturally generated and re-cycled bio-chemical pathways that can be further enhanced by innovation and capital investment. This is clearest when it comes to re-cycling and re-purposing biologically derived goods and physical assets.

This approach has the advantage that it combines a familiar focus on the key industry sectors that act as this biological input 'feedstock' (agriculture, forestry, fishing and aquaculture) and also a systemic appreciation of how this primary production then contributes through multiple pathways in modern economies. Rural innovation plays a key role in driving the productivity of these biological feedstock processes, however, innovation in biological systems also plays an important role throughout modern economies. Indeed, the cutting-edge of technologies with biological applications now has the potential to create radical transformations both in specific industries and the economy as a whole.

It is becoming possible to use genetic manipulation to change both how familiar products grow (e.g. artificial animal meat) and also to create entirely new types of grown products, potentially replacing products that have not been 'grown' in this biological sense. Possibilities here are wood-type cellular structures that can be self-healing and more easily decomposed than non-biological materials. We are already witnessing a step change in the use of wood and wood products in buildings, hence these more disruptive and transformational technologies could further strengthen this use of biologically derived new materials.

In this context, it is also useful to note that the distinction between biological and non-biological materials and processes is itself a potential emerging area for innovation with non-biological materials adopting some biological characteristics such as self-organisation and replication and biological materials potentially adopting aspects of additive manufacturing/3D printing.

In short, therefore, it is useful that a review of rural innovation carried out in an era of such scientific and technological promise not overlook this potential. Innovation in this context covers existing familiar sectors ('Horizon 1') but also more pervasive biologically derived aspects of extended value chains ('Horizon 2') and, more radical transformational impacts over the longer-term ('Horizon 3').

Given the relatively small scale of the Australian innovation effort (both overall and in more specifically rural aspects) and the potential for a wide range of cutting-edge science and technology to impact on biological material and processes, it is important to consider how we can play a key role in this larger global innovation context.

Restricting how we think about rural innovation to existing industries, and overlooking the potential of international cooperation in innovation (with the associated step change in the scale and scope of work this enables), will in combination risk Australia missing out on some major opportunities.

The following fleshes out this comprehensive and 'future proofed' perspective on the rural economy and the broader biologically-derived economy for which the rural economy acts as a 'feedstock'.

5 General Overview of Rural Value Chain Profiles

5.1 Evidence on Rural Value Chain Structures

Rural production makes direct and indirect contributions to the Australian economy, and (as outlined above) innovation contributes to these contributions via several pathways. One way of grasping the key features of each sector's direct contribution is to use value chain profiles that summarise where inputs come from and outputs go to, namely:

- The relative contribution of production inputs that are imported compared to provided domestically;
- The proportion of total output comprising value added;
- The proportion of total output that contributes intermediate to other domestic sectors compared to sectors overseas; and
- The proportion of total output that goes straight to domestic final consumption and fixed capital formation.

The data to construct these useful profiles can be found in the World Input Output Database (WIOD) – freely available for the years 2000 to 2014, see Timmer et al (2015).[9]

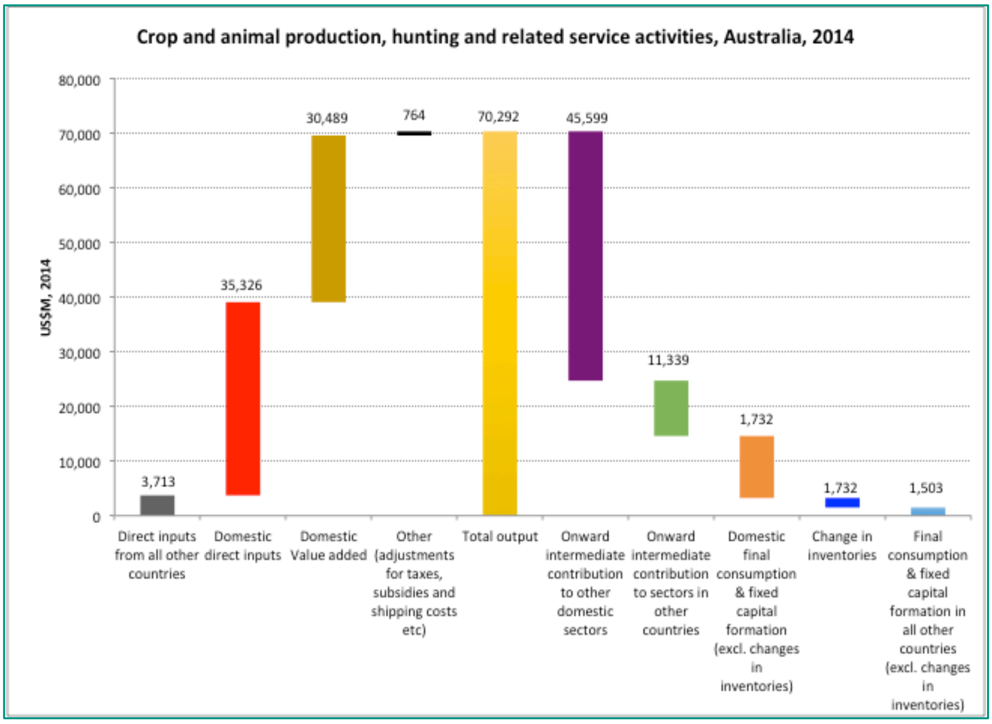
For technical reasons it is necessary to also profile changes in inventories because if these changes are not made explicit they can distort the conclusions drawn (e.g. the potential for final consumption to be negative in a particular year if there is a very large drop in the value of inventories in 'upstream' industries with relatively low levels of final consumption relative to total output. Figure 5, below, contains the summary value chain profile of Australian crop, animal production hunting and related activities in 2014 (the last year for which World Input Output Database data is available.[10] This graphical representation has been based on a format used by Stojanovic and Rutter (2017) to profile the value-added structure of the UK automobile industry.

We can see that in 2014 the rural industries (crop and animal production, hunting, forestry and fishing) directly contributed $US70.3 billion (4.8 per cent) to the Australia economy (GDP, $US 1.46 trillion). One half of that output relied on domestically supplied purchased inputs (hence excluding the asset value of un-purchased land, soil and water inputs) and contributed $US45.6 billion to other sectors in Australia and $US 11.4 billion to sectors in other countries. Only 2.5 per cent of output was consumed directly by Australian consumers and 2.1 percent by international consumers. In other words, the bulk of total output makes a further indirect input to value added in other Australian sectors but relatively little indirect input to value added in other countries.

[9] See: http://www.wiod.org/home

[10] In all following value chain profiles values are expressed in US dollars at the current prices in each year considered (the measure of value used in the World Input Output Tables). Hence, monetary values cannot be compared directly, only the relative proportions in each year being considered – and changes in these relative proportions over time.

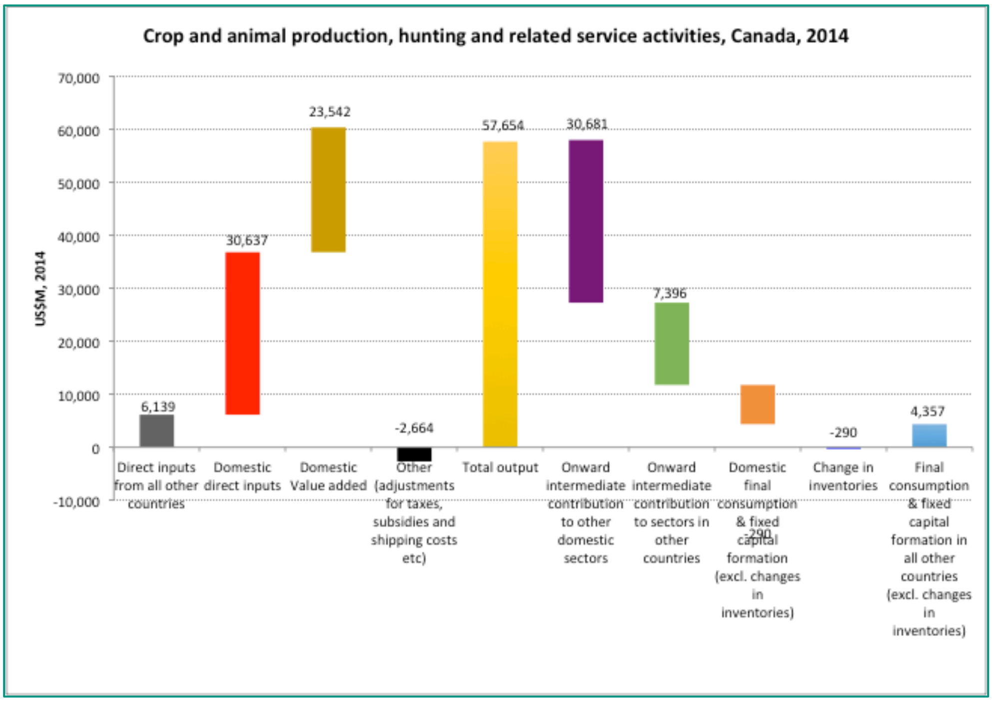
Figure 5: Australian crop, animal production hunting and related activities in 2014



Source: Analysis of the World Input Output Database

Evidence that this value chain structure is not unusual is provided by comparing this profile to that of the same sector in similar economies such as Canada, see Figure 6. The Appendix provides additional evidence on Canada in order to provide a comparative perspective on Australia's rural industry value chain structures.

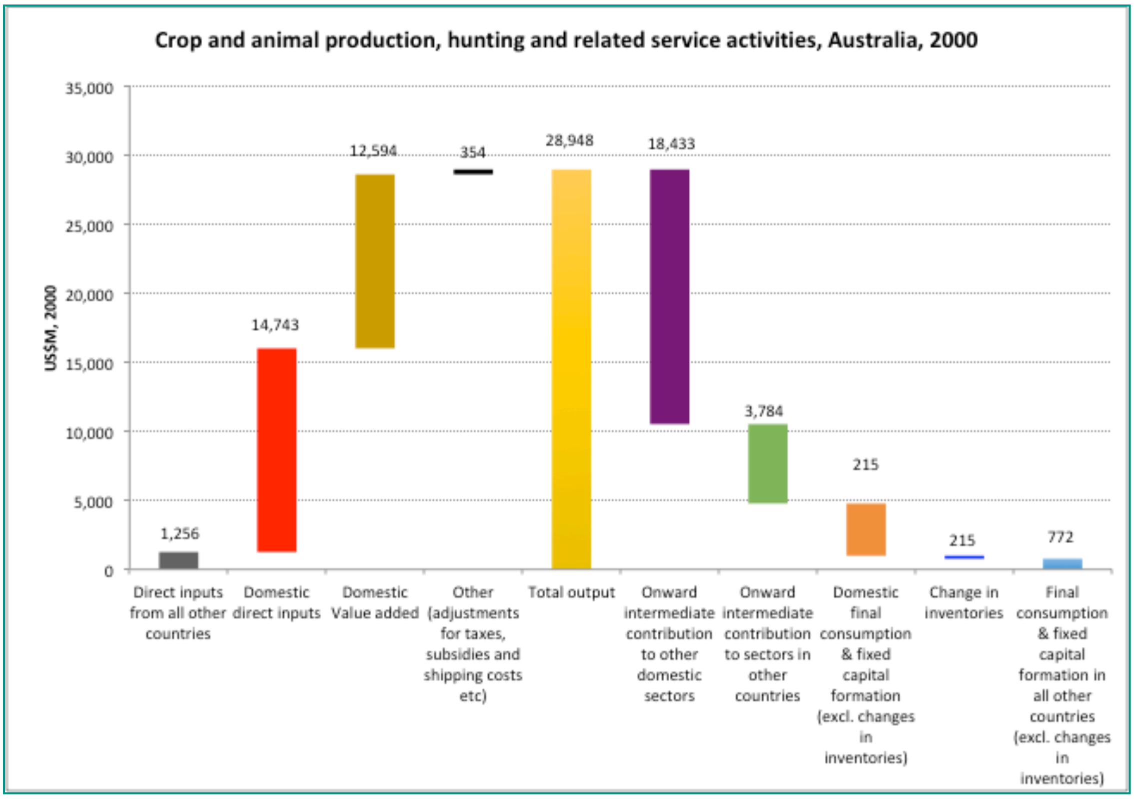
Figure 6: Canadian crop, animal production hunting and related activities in 2014



Source: Analysis of the World Input Output Database.

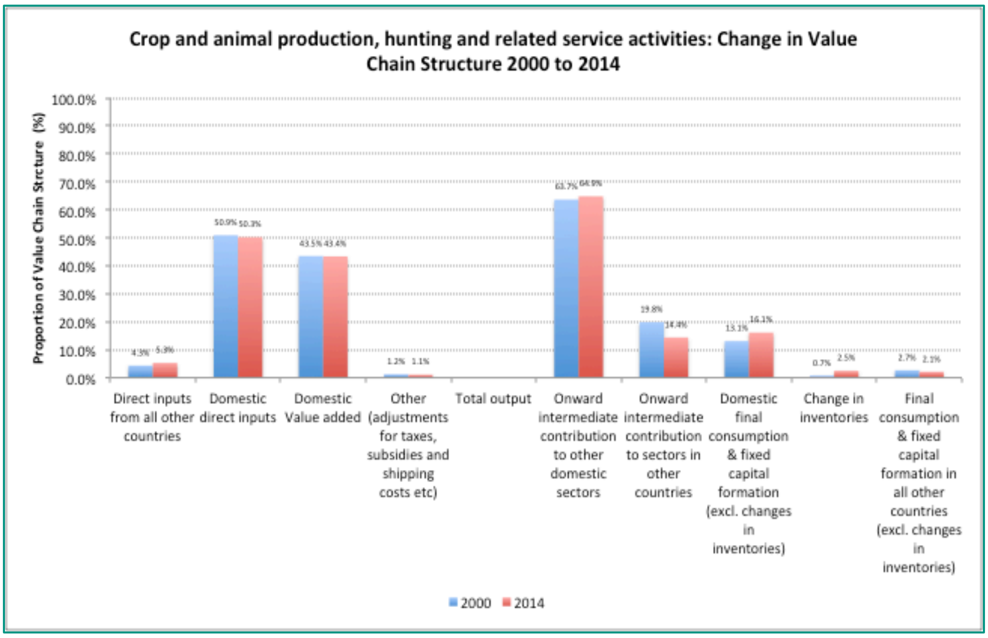
If these value chain profiles are considered over time then this structure is relatively stable, as indicated in Figure 7 and Figure 8 (which contains measurements of change in this structure between 2000 and 2014).

Figure 7: Australian crop, animal production hunting and related activities in 2000



Source: Analysis of the World Input Output Database.

Figure 8: Crop and animal production, hunting and related services: change in value chain structure 2000-2014



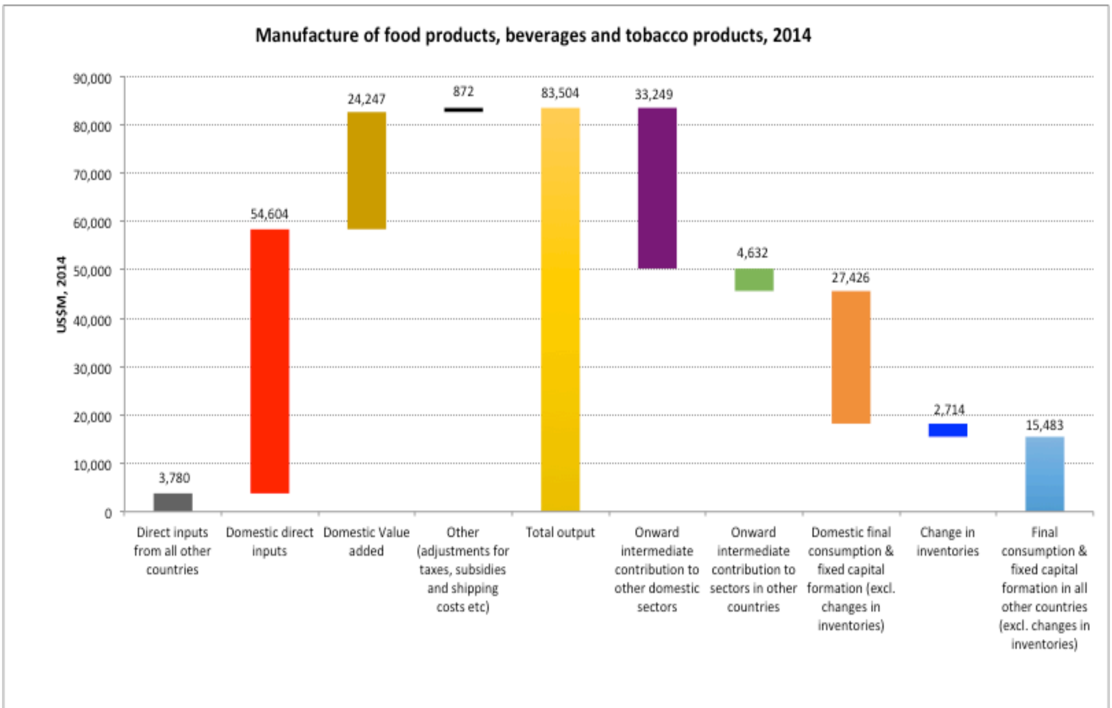
Source: Analysis of the World Input Output Database.

The next stage in the edible (and inhaled) strand of the value chain is food, beverages and tobacco. This is profiled in Figure 9 and Source: Analysis of the World Input Output Database.

Figure 11 for 2014 and 2000 respectively. This is also a relatively stable value chain structure, with little change in the proportion of total output feeding-in inputs to value-added overseas.

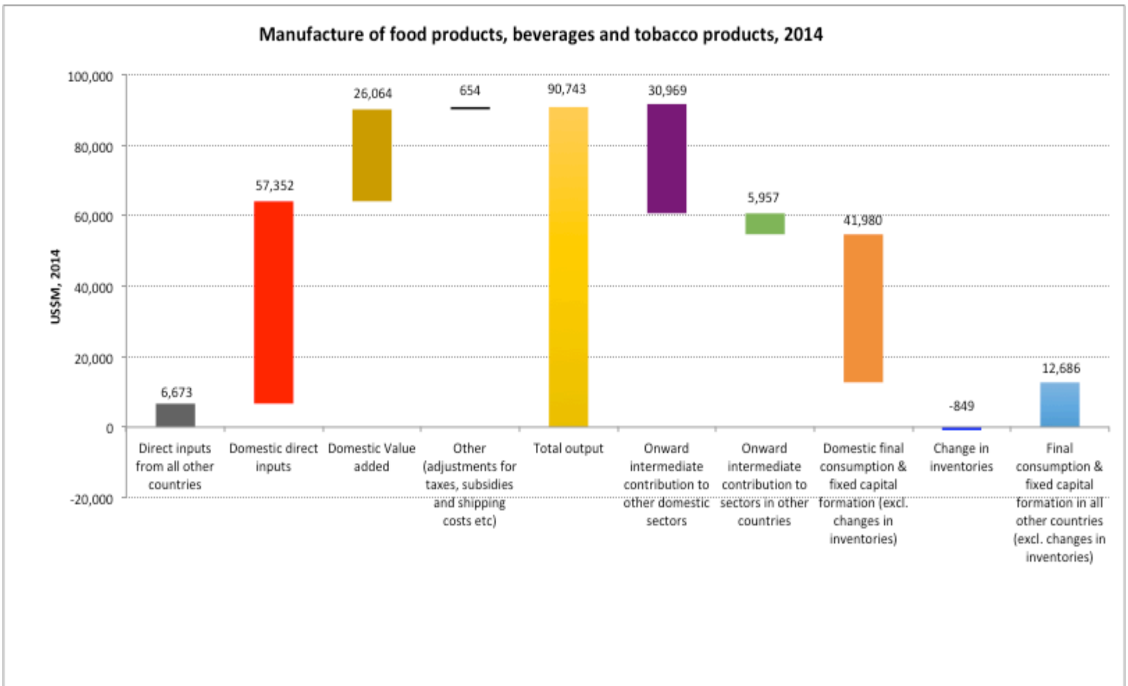
The Australian and Canadian value chain profiles are similar, with both making much stronger downstream value chain inputs domestically than internationally.

Figure 9: Australian manufacture of food products, beverages and tobacco in 2014



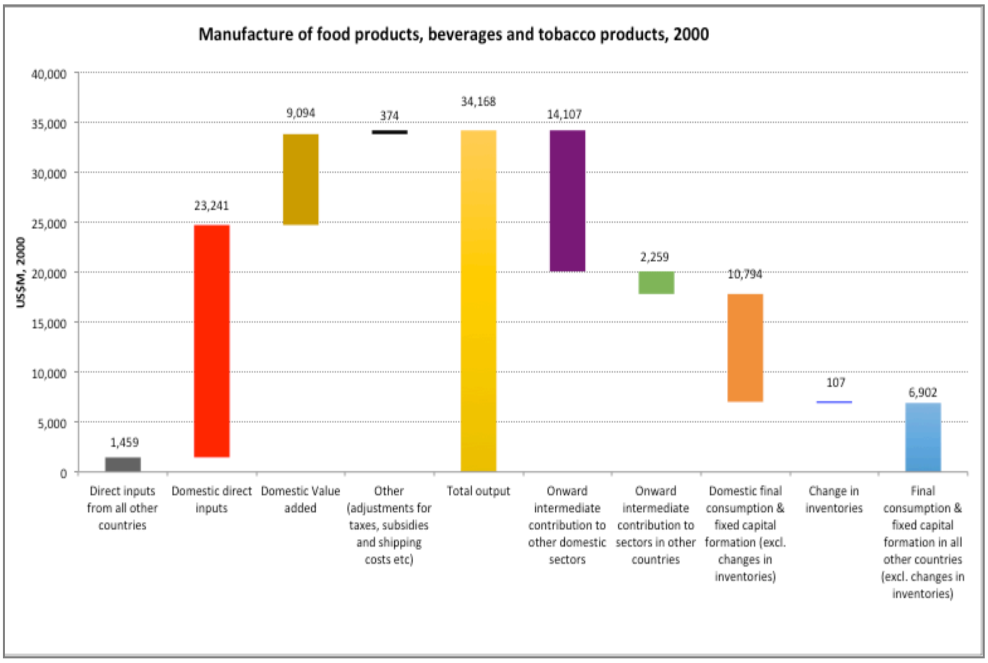
Source: Analysis of the World Input Output Database.

Figure 10: Canadian manufacture of food products, beverages and tobacco in 2014



Source: Analysis of the World Input Output Database.

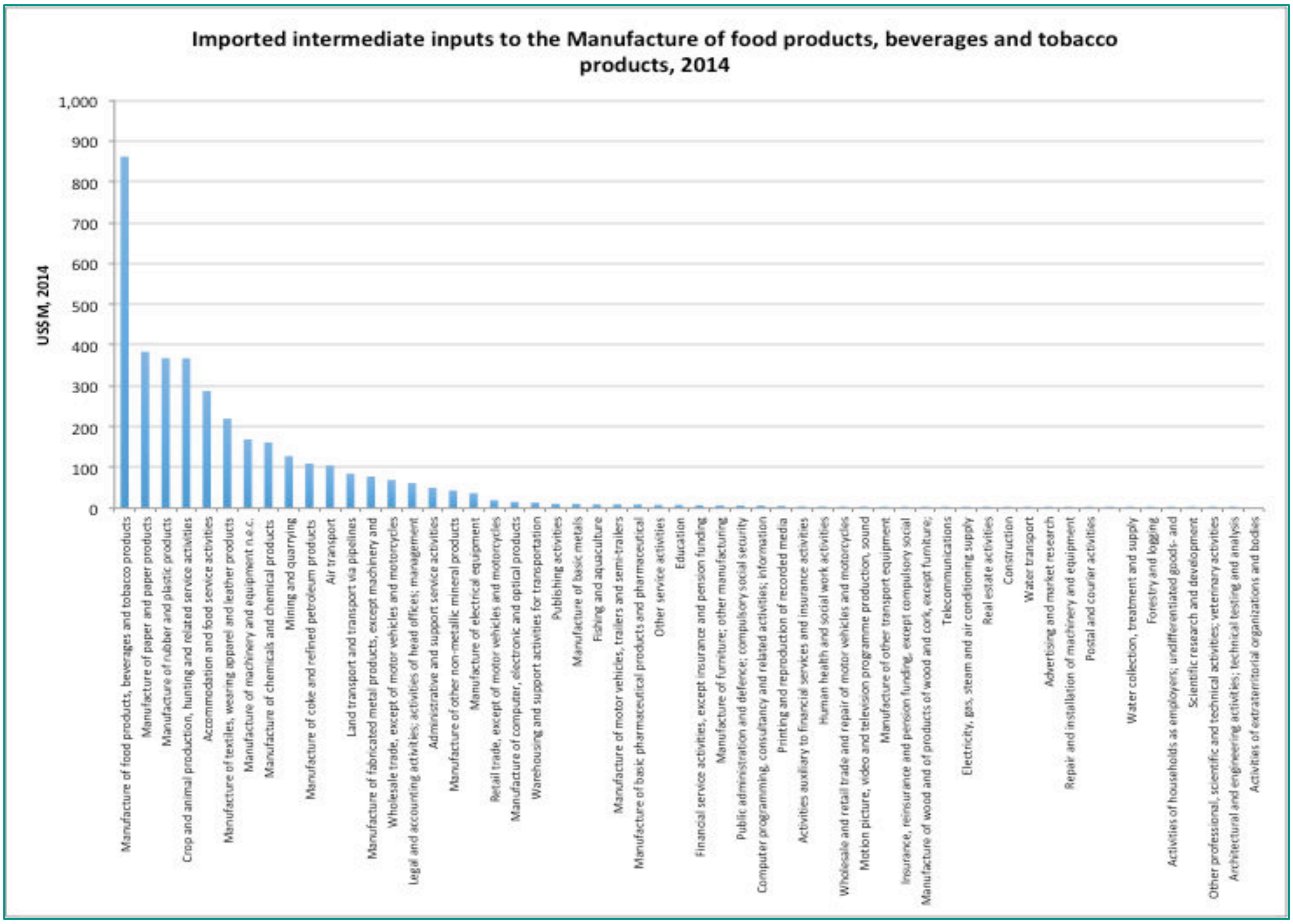
Figure 11: Australian manufacture of food products, beverages and tobacco in 2000



Source: Analysis of the World Input Output Database.

Figure 12 provides a breakdown of imported intermediate inputs to Australian production of food, beverages and tobacco. It shows that the largest category of these inputs are in the same category as the sector itself (greater than the direct upstream sector of animal and crop production).

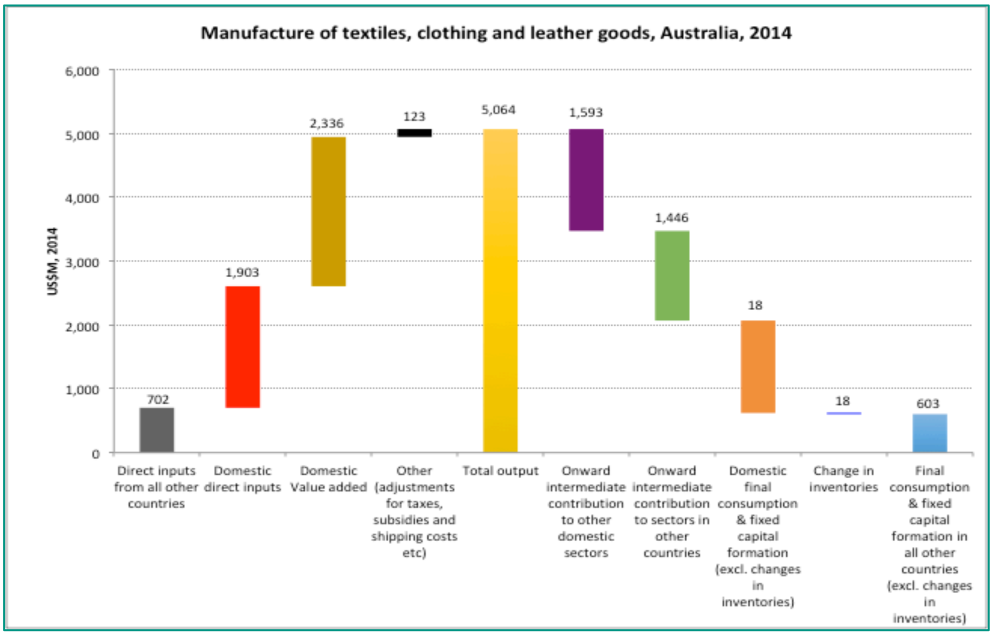
Figure 12: Profile of imported intermediate inputs to Australian production of food, beverages and tobacco, 2014



Source: Analysis of the World Input Output Database

Rural production is also an important raw material for the textiles, clothing and leather goods industry, as seen in Figure 13.

Figure 13: Australian manufacture of textiles, clothing and leather goods in 2014



Source: Analysis of the World Input Output Database.

The Australian furniture industry is of a similar size to textiles, clothing and leather, but makes a greater contribution to other domestic sectors, as demonstrated in Figure 14.

Figure 14: Australian manufacture of furniture and other products in 2014

Source: Analysis of the World Input Output Database.

6 Implications

The picture that emerges from these value chain profiles is that rural and 'rural related' economic activity is not strongly engaged in exports of the intermediate inputs that feed into additional value chains overseas. This can be easily grasped in Figure 15, which provides the combined value chain profile for the following rural and rural related sectors:

- Crop, animal production hunting and related activities;
- Forestry and logging;
- Fishing and aquaculture;
- Manufacture of wood and of products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials
- Manufacture of food products, beverages and tobacco products
- Manufacture of furniture; other manufacturing;
- Manufacture of textiles, wearing apparel and leather products; and
- Manufacture of paper and paper products.

The proportion of total output feeding into overseas value chains is relatively small and may represent an opportunity for exploring innovation objectives that would enhance this component of Australian exports. On the inputs side, analyses of global value chains on a general level have highlighted the ways in which imported intermediate inputs embodying technology and know-how can lift domestic value added by, in turn, increasing exports (both exports into value chains and to final consumption and fixed capital formation) – 'what you import impacts usefully on what you export'.

From this perspective, a rural innovation strategy should consider the nature and extent of opportunities make better use of technology embodied in imported production inputs (benefitted from R&D and innovation in the rest of the world). This attention to innovation-intensive inputs can then be translated into higher value-added via export growth.

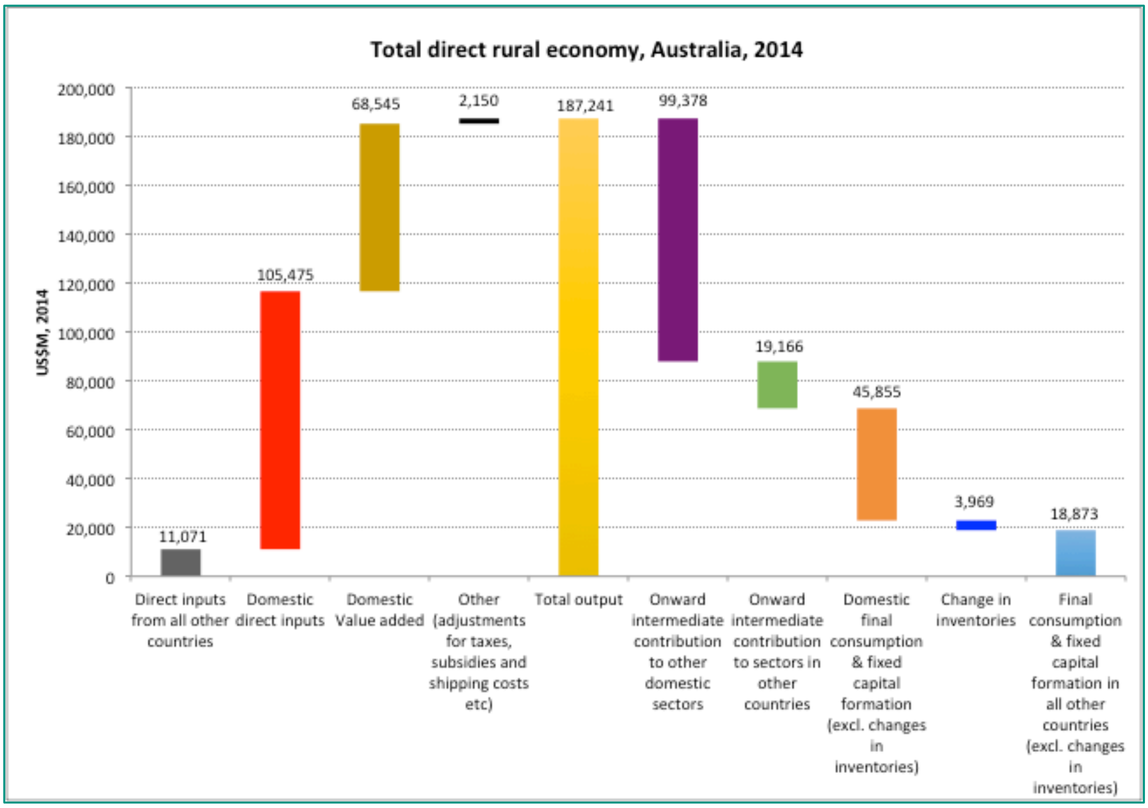
In short, a rural innovation strategy can usefully be framed in terms of ways of increasing participation in global value chains, hence the importance of providing the sort of evidence considered in this Review.

6.1 The value created by rural production for the Australian economy

Our estimates of the total value created by the Australian rural economy in 2014 is $US187.2 billion, or 14 per cent of total national value added (i.e. GDP) in that year.[11] Of this, almost $US60 billion was consumed in Australia, and $US100 billion delivered as intermediate inputs to other sectors in Australia. Only a relatively small amount, 10 per cent, was delivered as final consumption in other countries. These data are reflected in Figure 15.

[11] Total value Australian added in 2014 was US$1,1357,150.

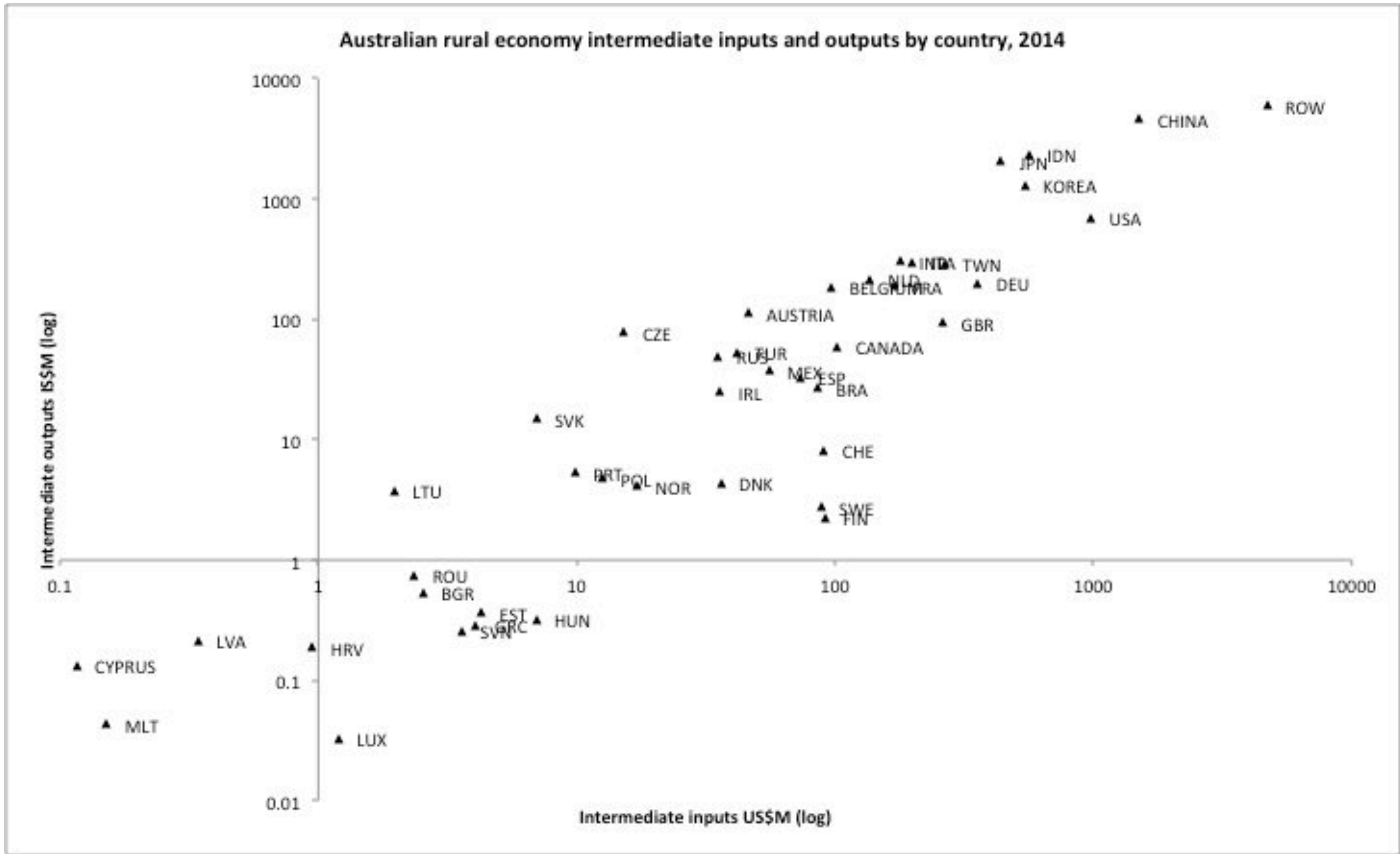
Figure 15: The Australian rural economy in total in 2014



Source: Analysis of the World Input Output Database.

As Figure 16 demonstrates, there is a fairly close correlation between the countries that provide intermediate 'upstream' inputs to Australia's rural economy and the countries that are 'downstream' destinations for intermediate outputs.

Figure 16: Australian rural economy intermediate inputs and outputs by country, 2014



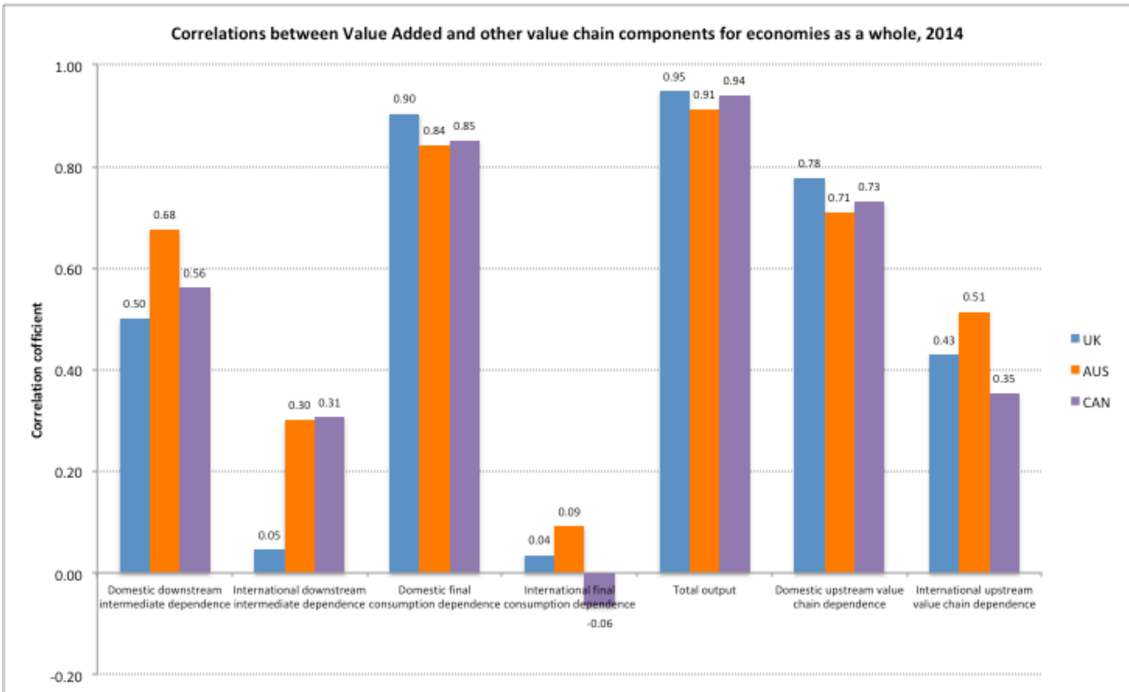
Source: Analysis of the World Input Output Database.

A more comprehensive picture of the full national and international value-added contribution of rural 'feedstock' activities can be obtained using more sophisticated analyses of the direct and indirect (i.e. embodied) contribution of biologically-based inputs. This is considered in the following section.

Figure 17 plots the correlation coefficients between value added and the other value chain components for all Australian industries, allowing Australia to be compared to the UK and to Canada. It shows that Australia's reliance on both upstream and downstream domestic value flows is higher than for these two comparator economies. This is most likely a consequence of the 'tyranny of distance' – shipping costs to and from other economies are higher.

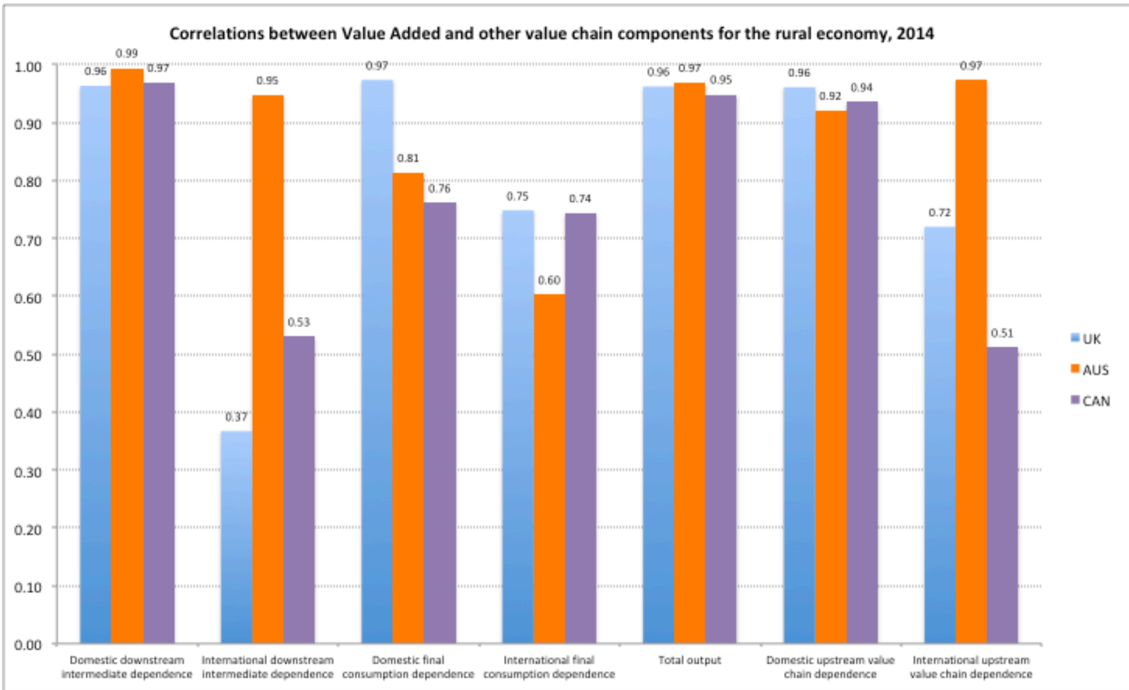
Figure 18 provides the same calculations for the rural economy. In this case, Australia's dependence on international upstream and downstream value flows is far greater than for the UK and Canada. The indicative results here suggest that it would be worthwhile investigating these patterns by extending the analysis to a wider list of comparator economies.

Figure 17: Correlations between value added and other value chain profile components for the economy as a whole, Australia, UK and Canada



Source: Analysis of the World Input Output Database

Figure 18: Correlations between value added and other value chain profile components for the rural economy, Australia, UK and Canada



Source: Analysis of the World Input Output Database

7 Conclusions

Australia, along with many other nations, has a long history of public support for innovation predicated on the assumption that more innovation translates into higher economic growth (albeit via multiple pathways). Economic growth, in turn generates benefits in terms of social inclusion and wellbeing – mainly via higher levels of workforce participation than would otherwise be the case.

This paper has stressed the importance of 'braiding' together science and innovation capability with a rage of complementary business capabilities (strategic marketing, knowledge and systems integration, supply chain management etc). The dividend to public and private investment in innovation is maximised when this braiding is effective but is constrained when this braiding is not effective. It has highlighted the ways in which innovation outcomes (or the lack of them) are reflected in participation in Global Value Chains. It has also highlighted the importance of braiding together science and innovation capability with a rage of complementary business capabilities rather than treating innovation itself as a driver of economic growth.

There are strong empirical and conceptual grounds for re-framing Australia's approach to maximising the effectiveness of the rural innovation system as a broader Industrial Strategy challenge. Innovation is a necessary but not a sufficient component of an Industrial Strategy. An Industrial Strategy brings together a range of complementary public policy concerns in a way that has a greater likelihood of success than persisting with long-standing support for innovation in a more stand-alone manner. Given that the UK's recently released Industrial Strategy does not articulate a clear stance on ways of lifting GVC participation an opportunity exists for Australia to enhance its thought leadership role in this regard – starting with the rural industries.

Consequently, a major policy implication from this Review is that Australia should re-imagine 'innovation systems' (and associated 'innovation strategies' intended to lift the effectiveness of these systems) as Industrial Strategy objectives. We don't require strategies for a rural innovation system (per se), rather a more focused and forthright Industrial Strategy for Australia's rural economy.

This strategy would be most effective if it started by considering how our participation in Global Value Chains could be improved (the 'ends') and then moved on to consider how best to deliver on these strategic aspirations (the 'means'). Other very important dimensions of this strategic approach would be to avoid making risky trade-offs when lifting participation in Global Value Chains: these Industrial Strategy pathways should be environmentally sustainable (crucially not running down our stocks of natural capital in the process).

The easiest way of doing this is to transition from the currently dominating 'flow' paradigm (focused on flows of GDP etc) and towards a 'stock' paradigm – the contribution of the rural industries to Australia's national Net Worth. Indeed, Australia is fortunate in playing a world-leading role in producing comprehensive National Balance Sheets as part of the System of National Accounts. Australia is also playing a leading international role in efforts to factor natural resource degradation and depletion into the National Balance Sheet.

This focus on measuring natural capital greatly assists with the complementary emphasis on moving to a 'circular economy'. A circular economy maintains (and even enhances), rather than runs down, stocks of natural capital.

Thus, as a nation, Australia is particularly well placed to develop an Industrial Strategy for the rural economy because there are the necessary data to draw on than other nations. An Industrial Strategy for the rural economy should, and can, focus attention on innovations that both lift participation in Global Value Chains and that do this in an economically and environmentally sustainable manner.

It is especially important to introduce a National Balance Sheet dimension into any Industrial Strategy aimed at lifting GVC participation because, if potential impacts on national net worth are not considered, there is a risk that GVC participation will allow, in effect, other countries to run down Australia's national balance sheet. These other countries' value added will be extracted, in part, by depleting and degrading Australia's natural capital. Indeed, some time ago now the French Government sought to convince the EU to apply trade restrictions to Australian agricultural imports to the EU on the basis that environmentally unsustainable farming was depleting and degrading natural capital, thus constituting a form of unfair subsidy. Such considerations will always constitute a risk to free trade – and especially as data on stocks of natural capital and its economic exploitation improve over time.

This aspect provides an important focus for our innovation priorities – innovation that reduces the risks of natural capital depletion and degradation. The rural economy is, for obvious reasons, the logical starting point for initiating this transition to an 'National Net Worth aware' industrial strategy in Australia. Such an approach has the potential to excite and stimulate both academic researchers and rural businesses by creating a shared focus on objectives of national importance. This would constitute a world-leading example of public policy.

Appendix A: References

Australian Bureau of Statistics (2003) Accounting for the Environment in the National Accounts in Environment by Numbers: Selected Articles on Australia's Environment. Catalogue no. 4617.0 2003. Canberra: Australian Bureau of Statistics.

Harkness, J. and Bain, D. (2007). Fisheries accounts, a summary of current work in New Zealand and Australia. Issue Paper prepared for the London Group on Environmental Accounting Meeting, Rome 17-19 December. Australian Bureau of Statistics and Statistics New Zealand.

Koopman, R., Powers, W., Wang, Z., and Wei. S. 2010. Give Credit where Credit is Due: Tracing Value-added in Global Production Chains. *NBER Working Paper.* No. 16426, Cambridge, MA.

Matthews, M. and Lacy, C (2017) *Innovation strategy and global value chains*. Discussion Paper prepared for the Australian Government as part of a consortium led by Howard Partners. SDG-ED: Manchester

McKinsey & Co (2010) Global Grid. *McKinsey Quarterly*. June.

SDG Economic Development (2018) *Building the Evidence-Base to Inform 'connected innovation' Strategies for Local Enterprise Partnerships: A prototype methodology*. Report for the Smart Specialisation Hub: Manchester, UK.

Shih, S (1996) *Me-Too is not my style.* ACER Foundation, 136. Chinese Taipei.

Stojanovic, A. and Rutter, J. (2017) *Frictionless Trade: What Brexit means for cross-border trade in goods*. Institute for Government, 17 August 2017.

Timmer, M. P., Dietzenbacher, E., Los, B., Stehrer, R. and de Vries, G. J. (2015), An Illustrated User Guide to the World Input–Output Database: the Case of Global Automotive Production, *Review of International Economics*, 23: 575–605

Appendix B: Rural innovation and the 'biologically derived' components of the Australian economy

Overview

Biologically derived sectors cover the cultivation of animals, plants, fish, fibre, and the environments in which this takes place – land, soils, rivers, and oceans. The rural industries are the 'feedstock' (in Input-Output table terms) for a range of biologically derived value added. Biologically derived value-added is particularly important as the feedstock for creating value in several industry sectors –

- Manufacture of food products and beverages;
- Manufacture of textiles, wearing apparel, and leather goods;
- Manufacture of wood products and products of wood;
- Manufacture of paper and paper products;
- Construction;
- Wholesale trade;
- Retail trade;
- Accommodation and food service activities;
- Education; and
- Human health.

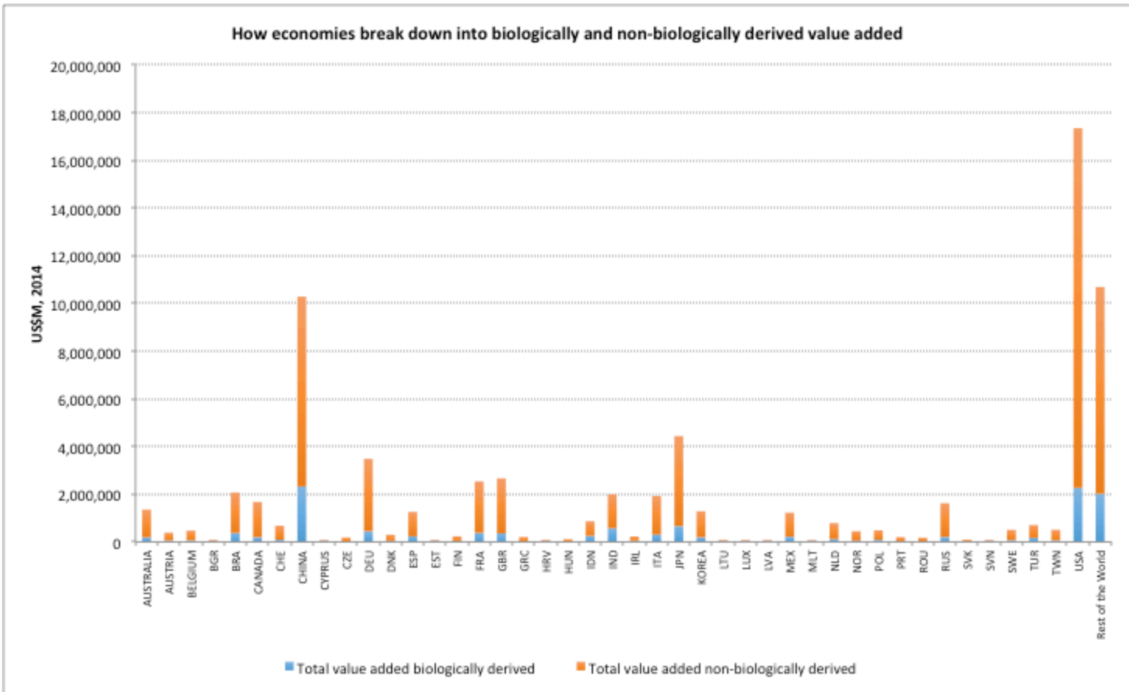
There is potential for the greater application of Australian biologically derived output and reuse to create additional value in these sectors - and potentially others. Also, as noted above, there is a clear affinity and potential at the nexus between biologically derived economic activity and the circular economy.

Australia's current share of globally biologically derived value added

Given the importance of biologically derived economic activity, especially in regard to strengthening the 'circular economy' in Australia, this Review has piloted new experimental estimates of the proportion of the national and global economy that can be classed as biologically derived. In order to do this, we analysed the new OECD Trade in Value Added (TiVA) datasets that capture the proportion of value added directly and indirectly in global final demand (i.e., 'flowed through' the entire global input-output structure). The initial impetus for carrying out this investigation was the following initial estimate in Figure 19.

This chart plots rough initial estimates of the biologically derived and non-biologically derived components of value added for all countries covered by the World Input Output Database. The calculations assume that the main downstream user sectors for biological inputs split value added contributions between biological and non-biological value flows on a 50:50 basis. The indicative results indicate that the biologically derived component of global value added is significant but much smaller than the non-biologically derived component. An additional analysis, not reported here, shows that (as would be expected) developing economies have a higher biologically derived value added share. However, as noted earlier, future innovation is likely to raise the biologically derived share of value added in advanced economies hence this pattern will evolve over time.

Figure 19: Initial estimates of the biologically-derived and non-biologically derived breakdown of value added, 2014



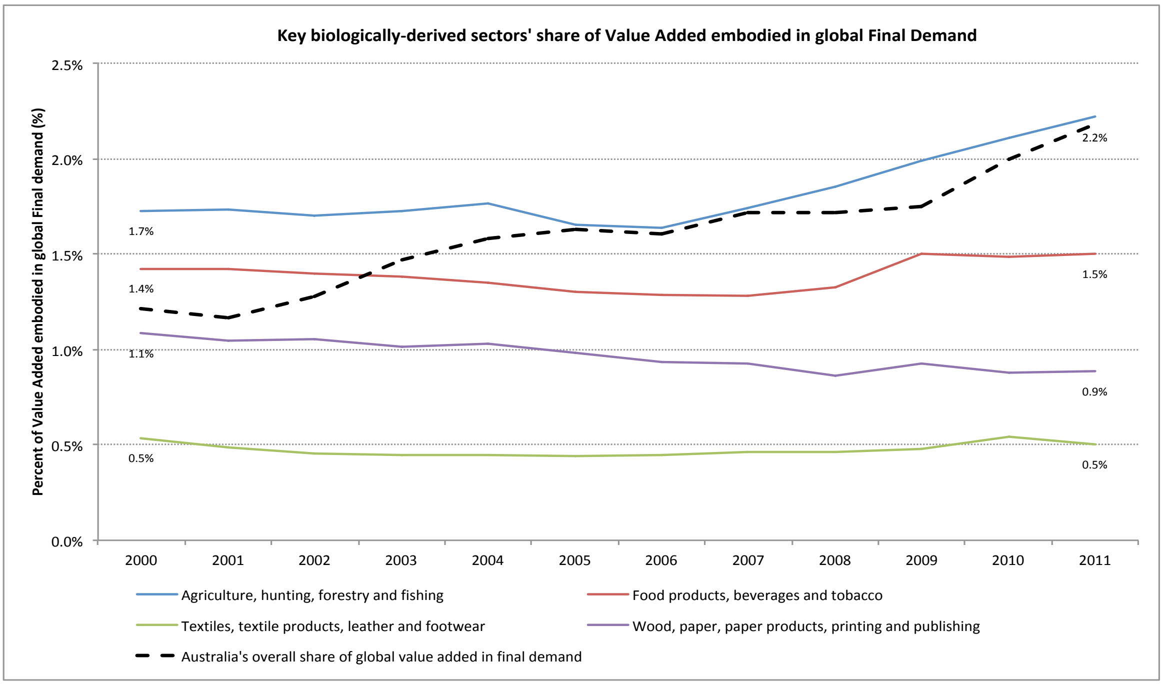
Source: Analysis of the World Input Output Database.

Given that these initial rough estimates indicated it may be useful to analyse value added in this way, OECD Trade in Value Added (TiVA) data were analysed in order to produce more robust estimates. Use of the TiVA data means that shares of biologically and non-biologically derived value added have been calculated by the OECD using sophisticated methods that flow-through each sector in each country's full contribution to global final demand.[12] This is the same calculation used in country-specific Input-Output analyses but on a much larger and harder to compute scale. The results tell us what each country's industry sectors contribute to global value chains – encompassing *all* production and *all* trade in the global economy. This means that all biologically derived value added is, in principle, being captured irrespective of particular details of exports, imports and production in each national economy.

Figure 20 contains a graph of Australia's (increasing) overall share of the value added in global final demand, together with the world total shares for four key biologically derived sectors (i.e., overall multi-country shares of biologically derived value-added contributions by feedstock sector). This shows us that Australia's overall national value-added contribution is broadly the same as the overall agricultural contribution made by all economies.

[12] The OECD TiVA results on have been adjusted by Howard Partners to reflect the proportion of each sector's inputs that are biologically derived (details are provided in the Appendix).

Figure 20: The biologically derived share of global final demand, 2000 to 2011



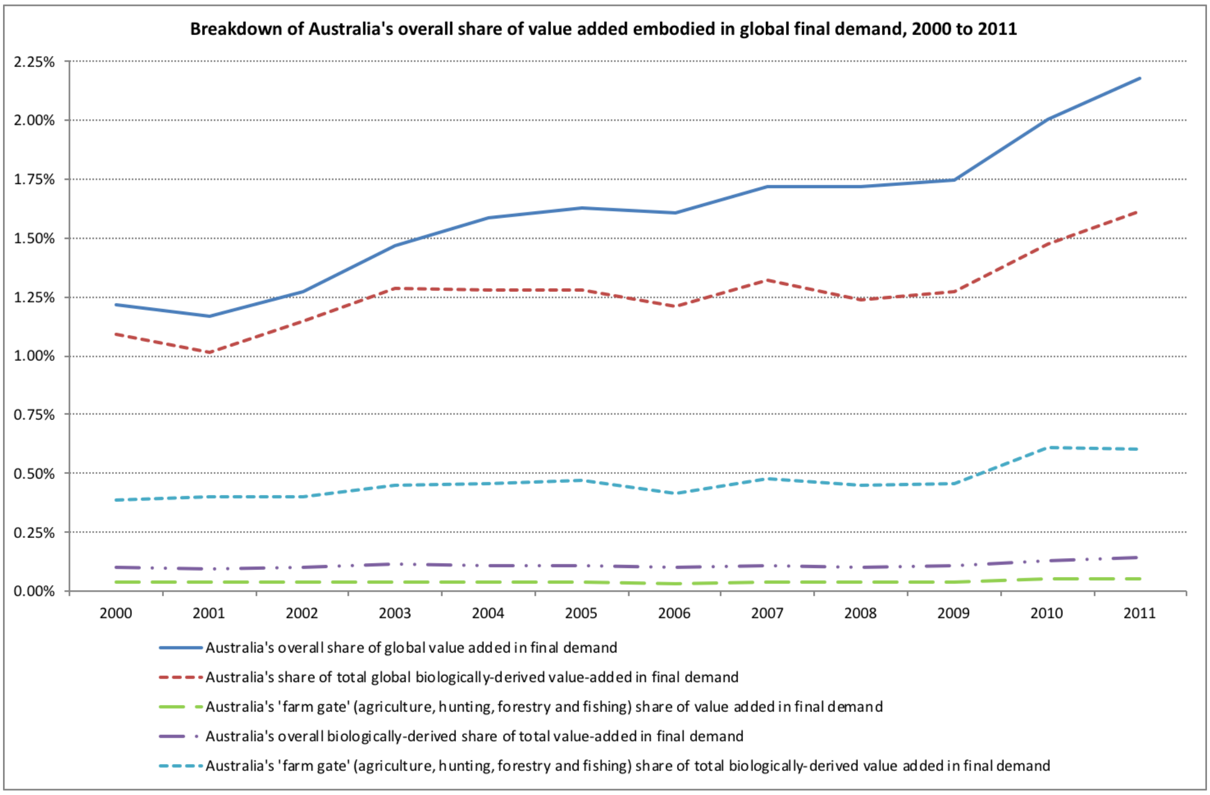
Source: Analysis of OECD TiVA data

Figure 21 provides a summary of how Australia's overall share of value-added embodied in global final demand relates to the total biologically-derived component created by all countries. This graph also plots the 'farm gate' contribution as both a share of all value-added embodied in global final demand and also the share of the biologically-derived component of global final demand. These are only broadly indicative estimates based on calculating the relative shares of the sectors in the OECD TiVA dataset identified in Figure 20 (though they do capture the full direct and indirect 'embodied' value-added contributions to global final demand). A more sophisticated analysis using raw global input-output datasets would produce more accurate (and up to date) estimates.

These results tell us that whilst our share of all value-added embodied in global final demand and our share of the biologically-derived component of this aggregate are both increasing, the increase in the share of global biologically-derived value added is not matching that of the overall total share of value added in final demand over this time period. This divergence is partly caused by the 'mining boom' era, which resulted in a strong non-biologically-derived (metallic) 'flow through' input from Australia into the rest of global production. As stressed in this Review, looking to the future it is likely that the biologically-derived share of global value added in final demand will increase in prominence - hence providing important export opportunities for Australia.

Crucially however, as this graph makes clear, the 'farm gate' component of the value-added embodied in global final demand is not *in itself* strong – rather it is the (crucial) 'feedstock' stage in a broader system of global value-added. Consequently, to limit innovation/industrial strategy support to the farm gate stage is likely to result in missed opportunities for Australia.

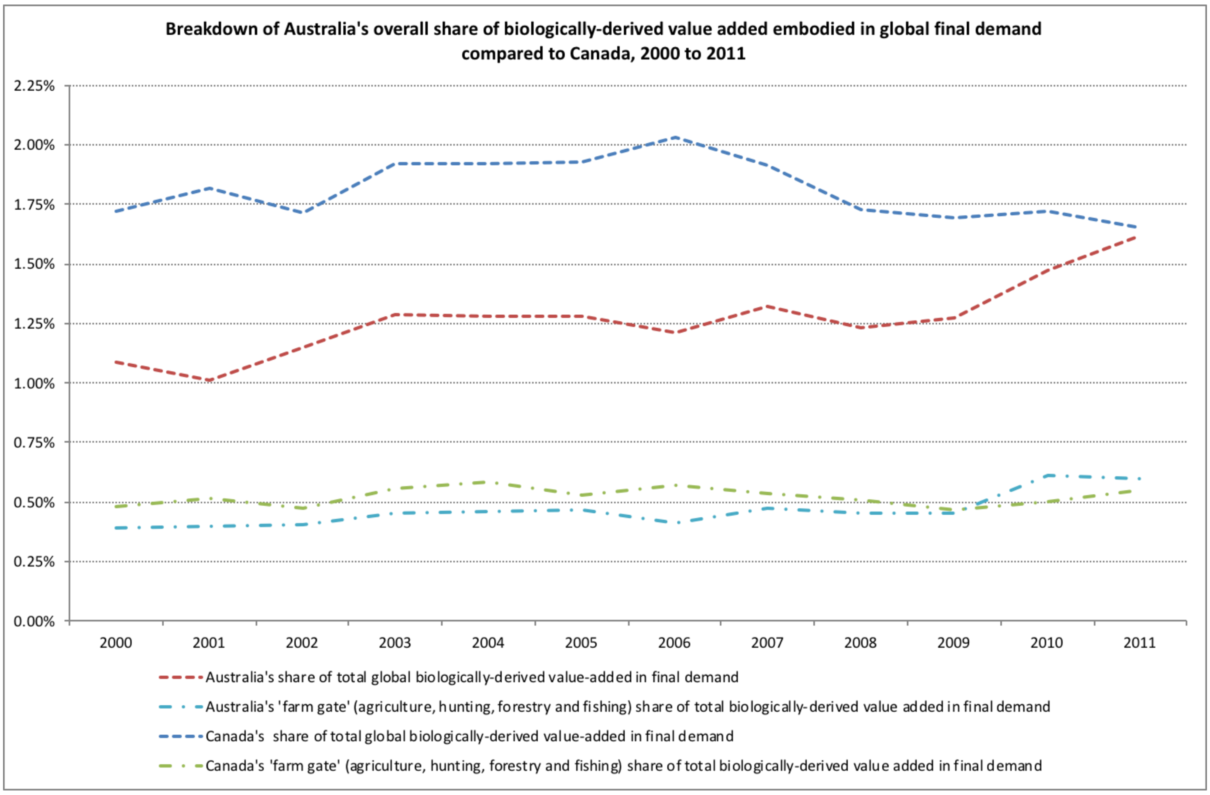
Figure 21: Australia's share of value-added embodied in global final demand and its biologically-derived component



Source: Analysis of OECD TiVA data

Figure 22 provides a comparison between Australia and Canada's performance in these terms. It tells us that Australia's share of overall biologically-derived value added embodied in global final demand has been increasing relative to Canada, and given the OECD TiVA data only extends to 2011, has probably now risen above Canada's share. The smaller 'farm gate' component increased above Canada's share in 2009. Since 2009, the increase in Australia's share of overall biologically-derived value added embodied in global final demand is associated with what happens 'after the farm gate' not up to the farm gate.

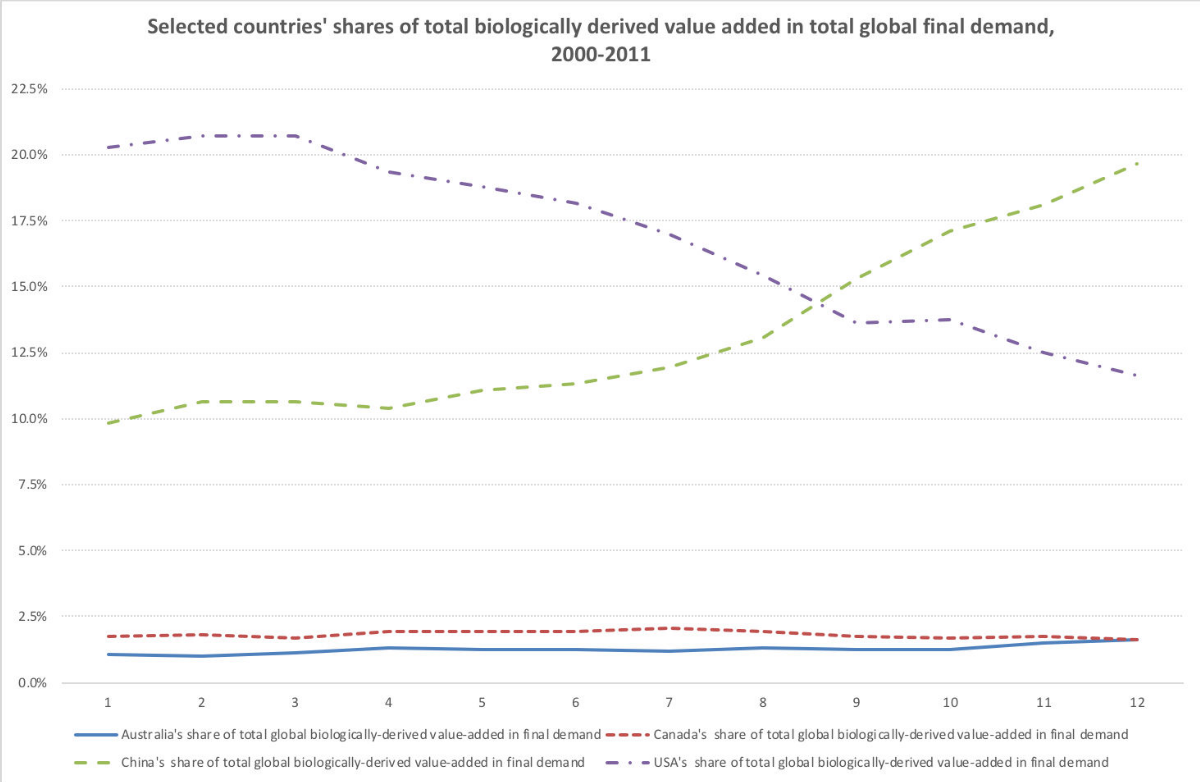
Figure 22: A Comparison of Australian and Canadian performance in shares of biologically-derived value added in final demand



Source: Analysis of OECD TiVA data

Figure 23 profiles the more general global trends in shares of biologically-derived value added in global final demand by picking out the performance of some key countries. What stands out is the way in which the USA and China have effectively 'swapped' their shares over the 2000 to 2011 time period.

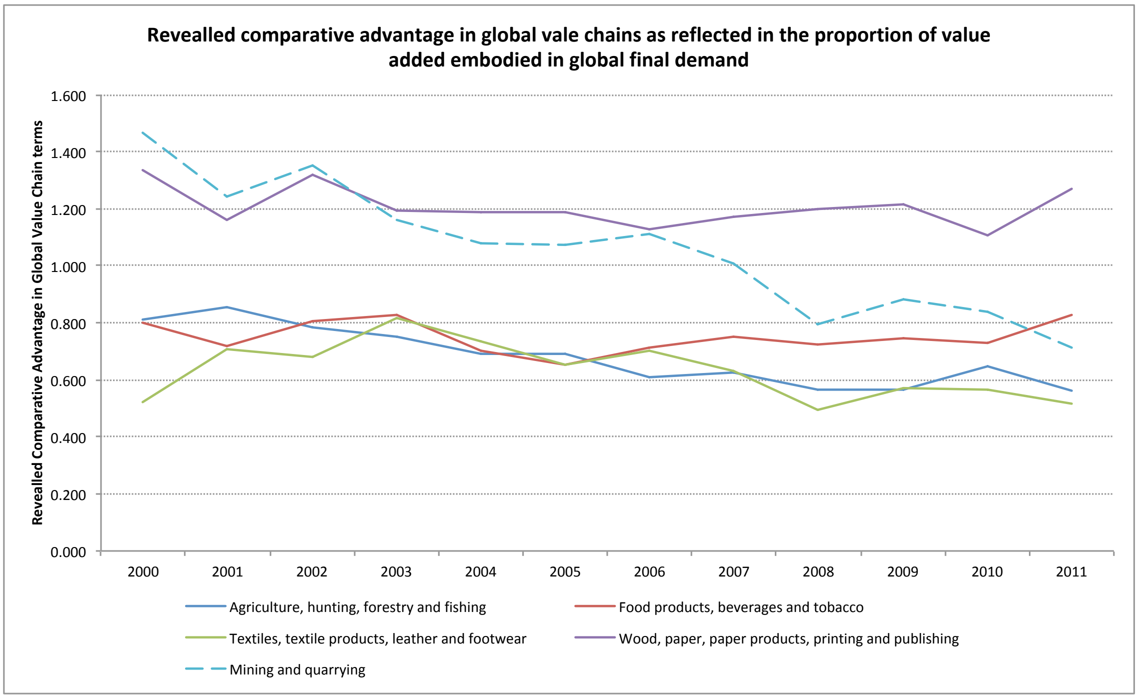
Figure 23: Changes in selected countries' shares of total biologically-derived value added in global final demand



Source: Analysis of OECD TiVA data

Figure 24 provides the results of calculations of the ratio of Australia's share of the value added embodied in global final demand for key rural sectors compared to our overall share of value-added embodied in global final demand. A ratio above 1.0 tells us that the sector concerned has a higher share than Australia as a whole and below one a lower share. Mining and quarrying have been added to this chart as a comparator. The results tell us that these rural sectors are broadly stable but that mining and quarrying have been declining (other 'downstream' economies are adding value to Australian minerals and metals exports).

Figure 24: Revealed comparative advantage for Australia in sector shares of value-added embodied in global final demand



Source: Analysis of OECD TiVA data

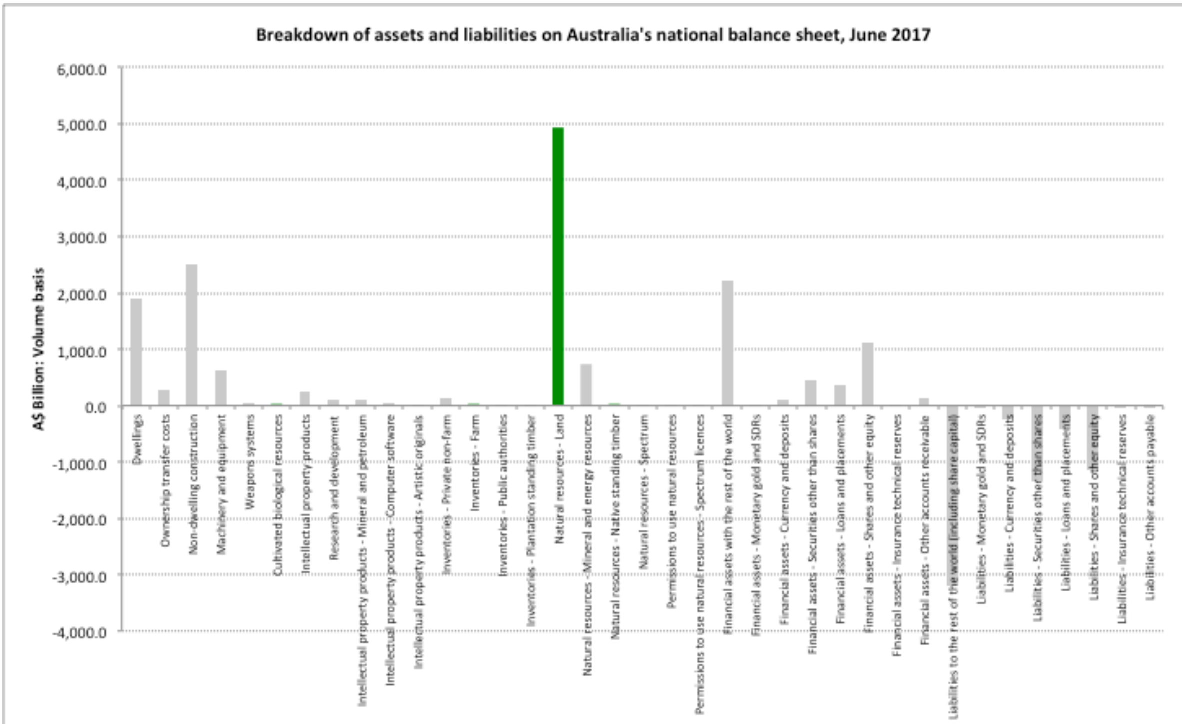
As stressed above, these are only crude indicative estimates carried out mainly in order to determine whether or not it is worthwhile using results from global input-output datasets to inform Australia's rural innovation/industrial strategies. As such, the results do suggest that it would be useful to build-up a more accurate and comprehensive picture of Australia's evolving role in the biologically-derived dimension of the global economy.

Appendix C: The potential to integrate analyses of global value chain participation with National Balance Sheet considerations

The Rural Economy and the National Balance Sheet

Figure 25 details the major assets and liabilities on the Australian National Balance Sheet in 2017. The major asset value contribution of land stands out (far greater than mineral resource asset values). However, this is driven my urban land values rather than rural values. It would, therefore, by useful for future analysis of the rural economy's contribution to the National Balance Sheet to separate urban from rural land values in the National Balance Sheet context.

Figure 25: Profile assets and liabilities on the Australian National Balance Sheet

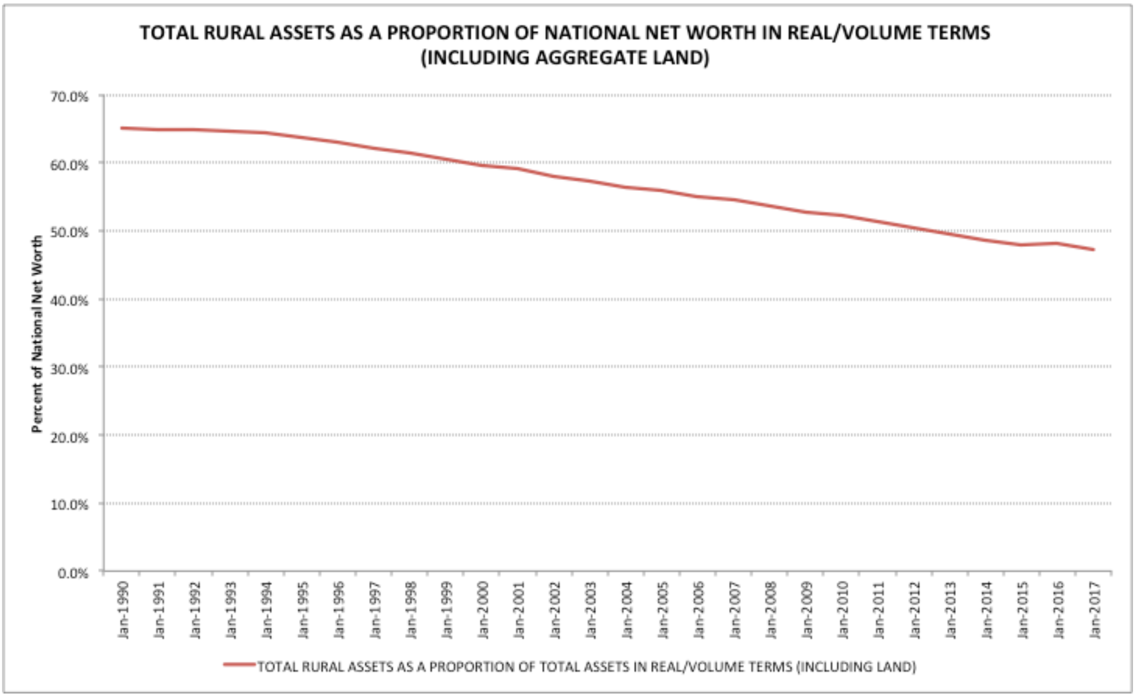


Source: Analysis of Australian System of National Accounts (ABS 5204010)

Figure 26 plots total rural assets as a per cent of Australian net worth and Figure 27 contains the same plot but excludes land values. It is worth noting that, at present, fish stocks are not captured in the national balance sheet – although concepts and methods for doing this have been proposed.[13]

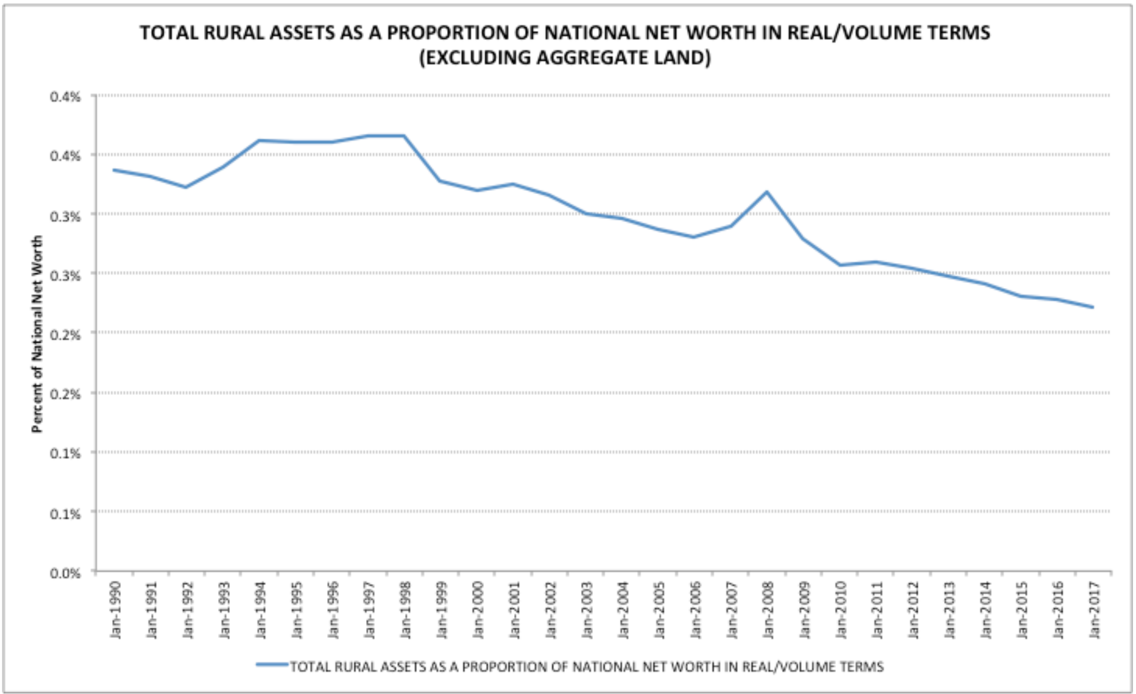
[13] See Harkness and Bain (2007).

Figure 26: Total rural assets as a percentage of Australian national Net Worth, 1990 to 2017



Source: Analysis of Australian System of National Accounts (ABS 5204010)

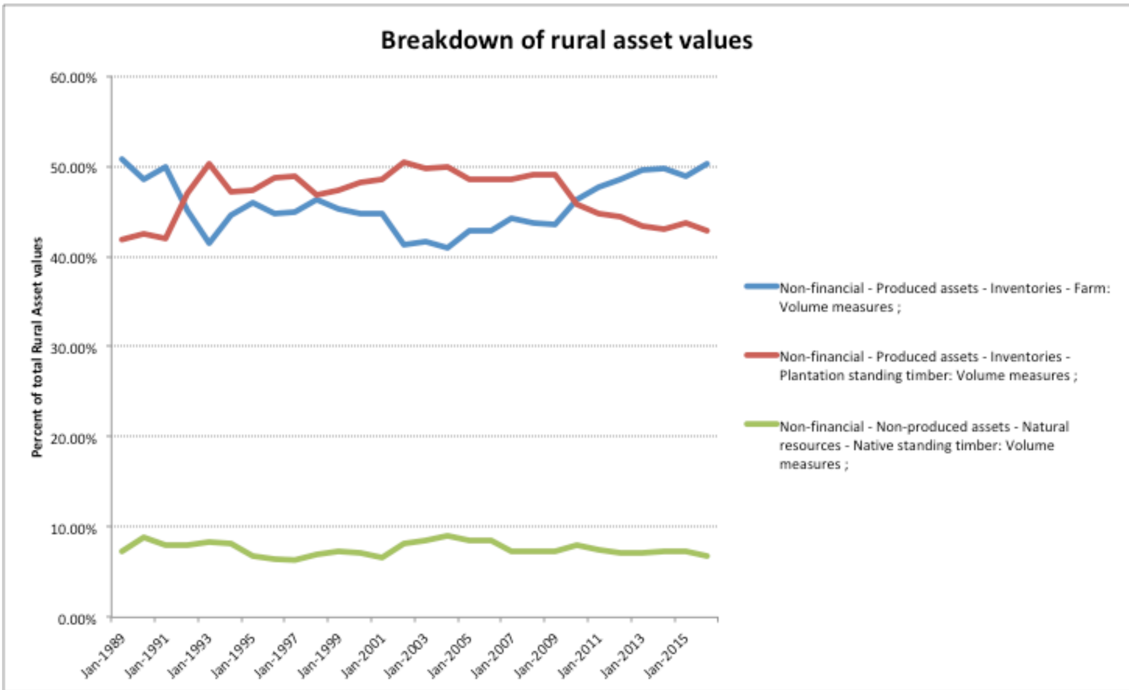
Figure 27: Total rural assets as a percentage of Australian national Net Worth (excluding land values), 1990 to 2017



Source: Analysis of Australian System of National Accounts (ABS 5204010)

Figure 28 allows a comparison to be made of the relative importance of plantation and native timber asset values. It demonstrates the relatively low asset value (at present) of native standing timber.

Figure 28: Australian plantation and native timber as a share of total rural economy asset values



Source: Analysis of Australian System of National Accounts (ABS 5204010)

Factoring the depletion and degradation of natural capital into the picture

Australia has helped to pioneer estimates of Net Domestic Product (i.e. Gross Domestic Product less capital depreciation) that factor in the depletion and degradation of natural capital, see Australian Bureau of Statistics (2003). Net Domestic Product (NDP) is accepted to be a more accurate measure of economic growth because it adjusts for capital depreciation, but is more rarely reported in official data because it is harder to calculate.

Given the importance of agricultural land assets in the Australian economy, the potential exists to produce an integrated picture of both economic stocks (the National Balance Sheet) and economic flows (NDP) that factor in the depletion and degradation of natural capital. If also linked to an analysis of GVC participation, this would provide a powerful evidence-base for tracking and understanding the role of biologically derived assets and their economic exploitation from a ‘circular economy’ perspective.

Australia is uniquely positioned to do this because the Australian Bureau of Statistics plays a leading global role in: (a) publishing comprehensive National Balance Sheet data, and (b) being willing and able to experiment with producing estimates of depletion and degradation adjusted Net Domestic Product.

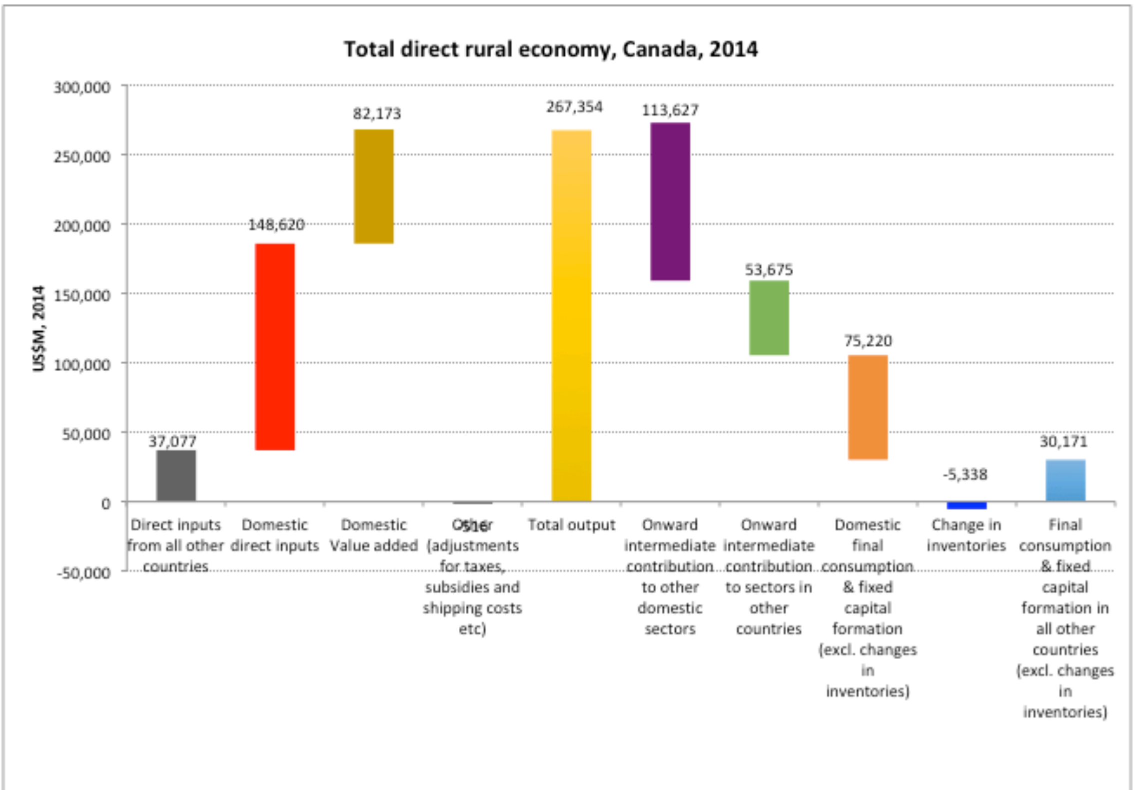
As such, Australia is at the frontier of implementing internationally agreed standards for environmentally aware national accounting (covered by the evolving UN System of National Accounts framework).[14] Use of these data have the potential to position the CRRDC as a world-leading source of concepts and evidence for informing innovation and industrial strategy in the biologically derived economy. This is, therefore, one possible avenue for future analysis of the rural economy very pertinent to innovation. It would provide an especially useful picture of the extent to which

[14] Covered by the System of National Accounts (SNA) and the System of Environmental-Economic Accounting (SEEA).

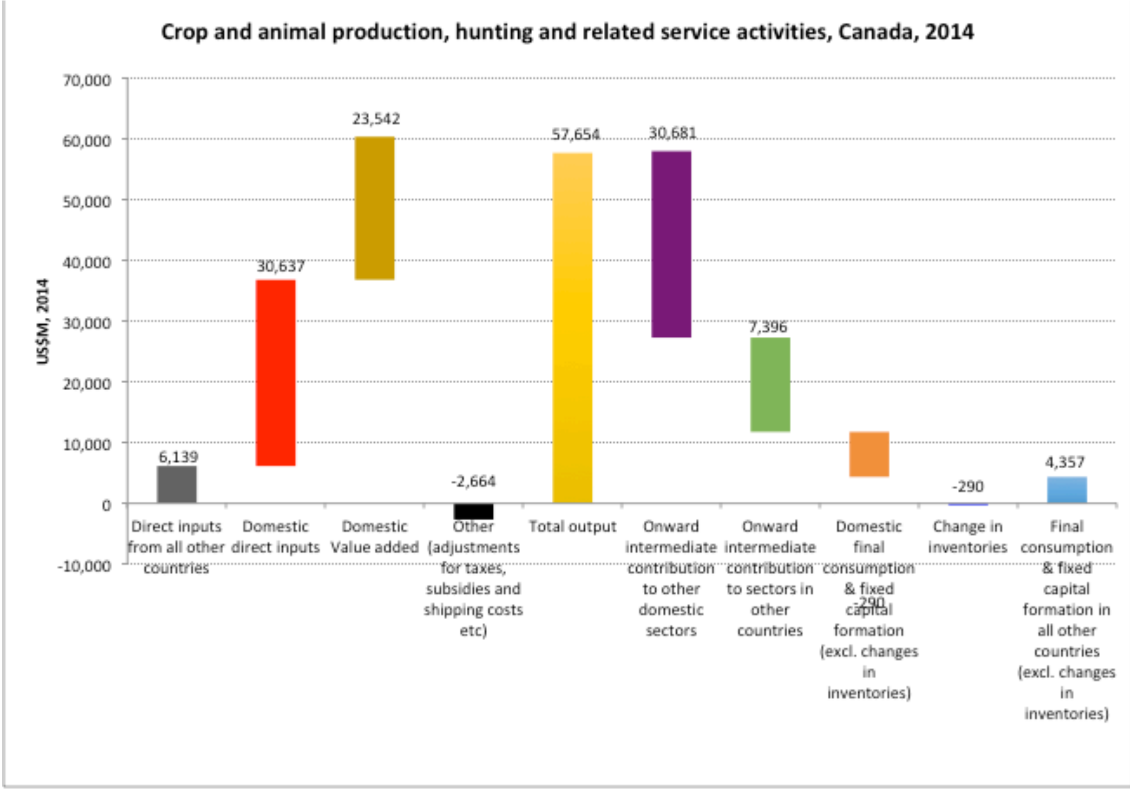
innovation is able to offset the depletion and degradation of Australia's natural capital – innovation outcomes measured as lower rates of depletion and degradation of natural capital than would otherwise be the case.

Appendix D: Profile of Canadian GVC participation for rural industries

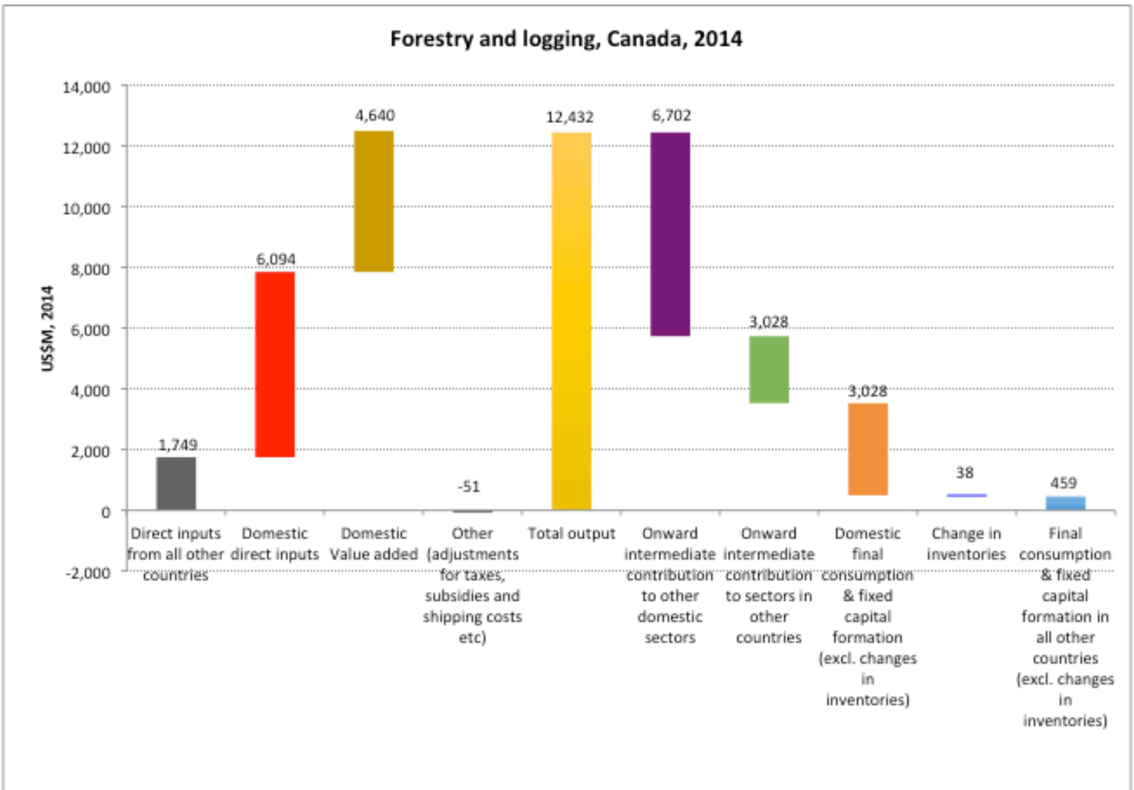
The following value chain profiles for Canada have been provided in order to allow comparisons to be made for each of the Australian rural industries profiled in the main body of the report.



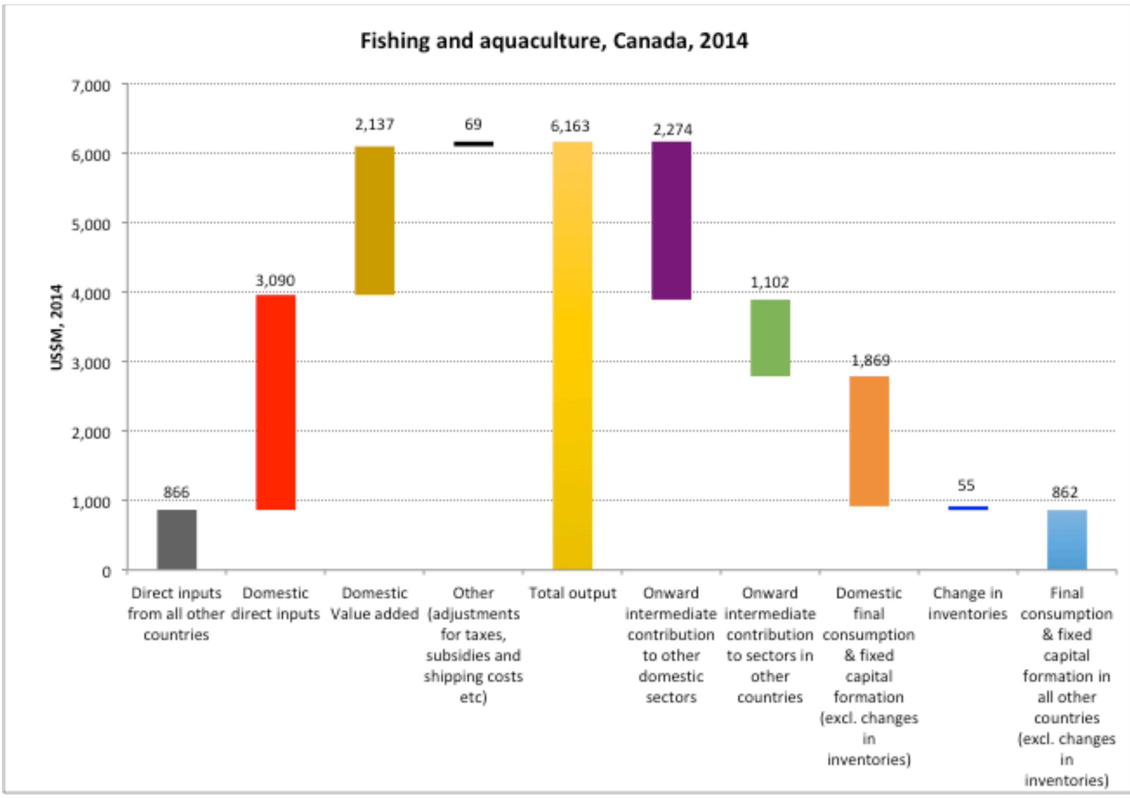
Source: Analysis of the World Input Output Database



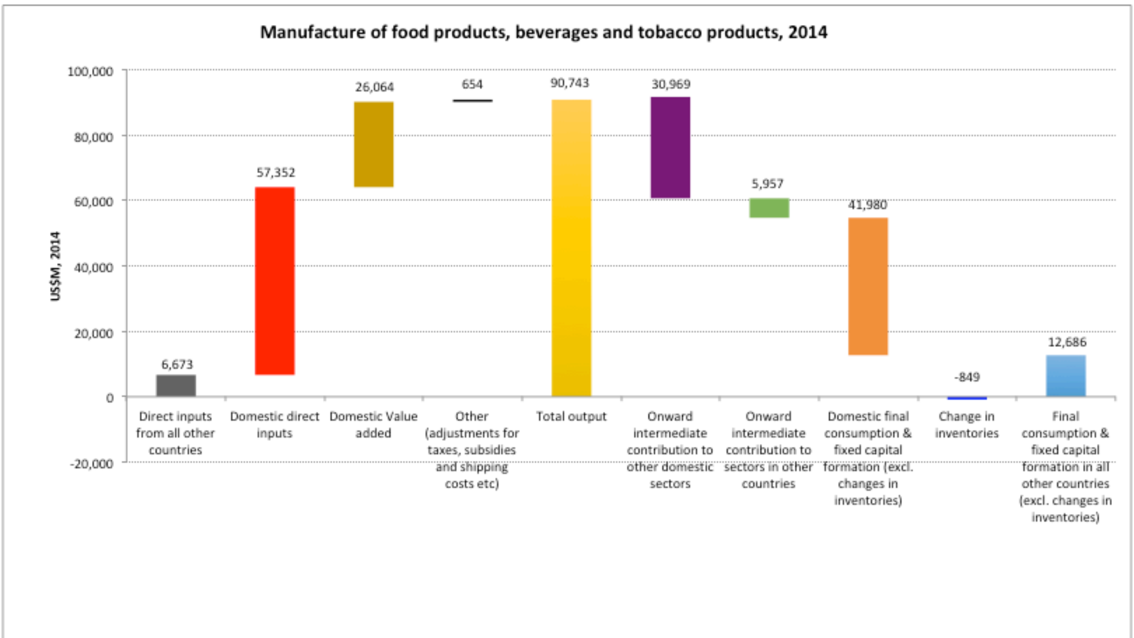
Source: Analysis of the World Input Output Database



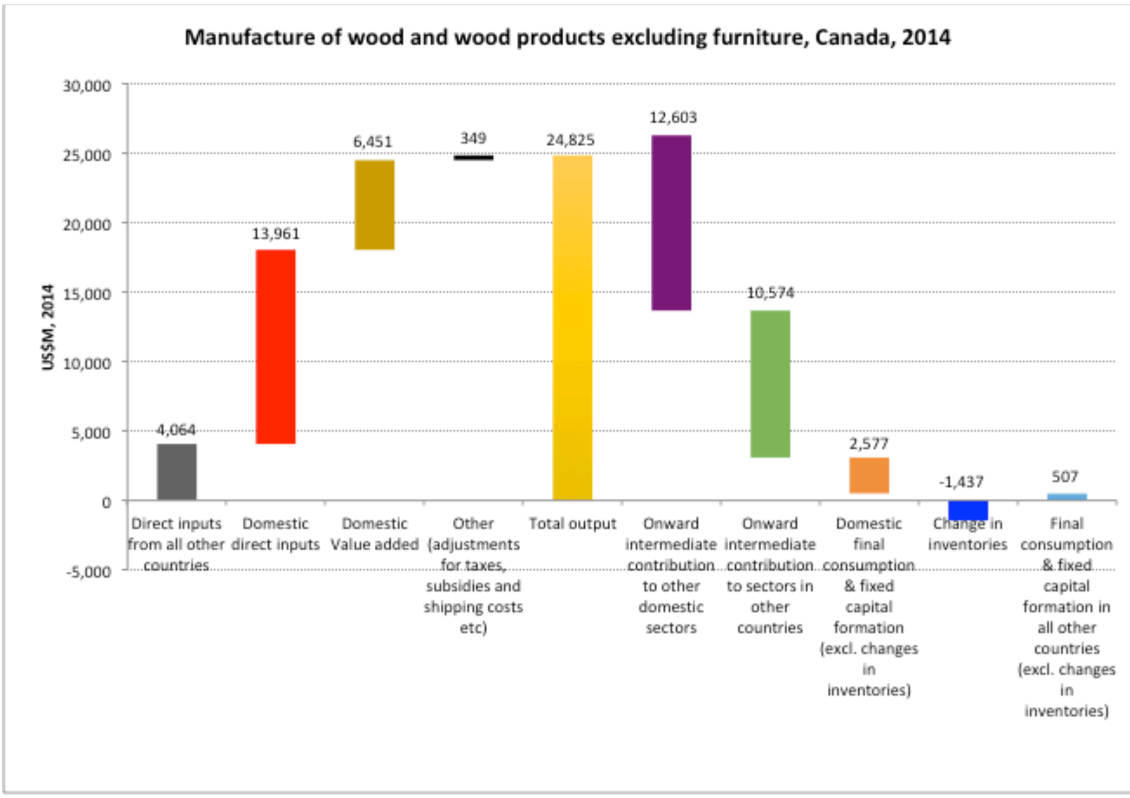
Source: Analysis of the World Input Output Database



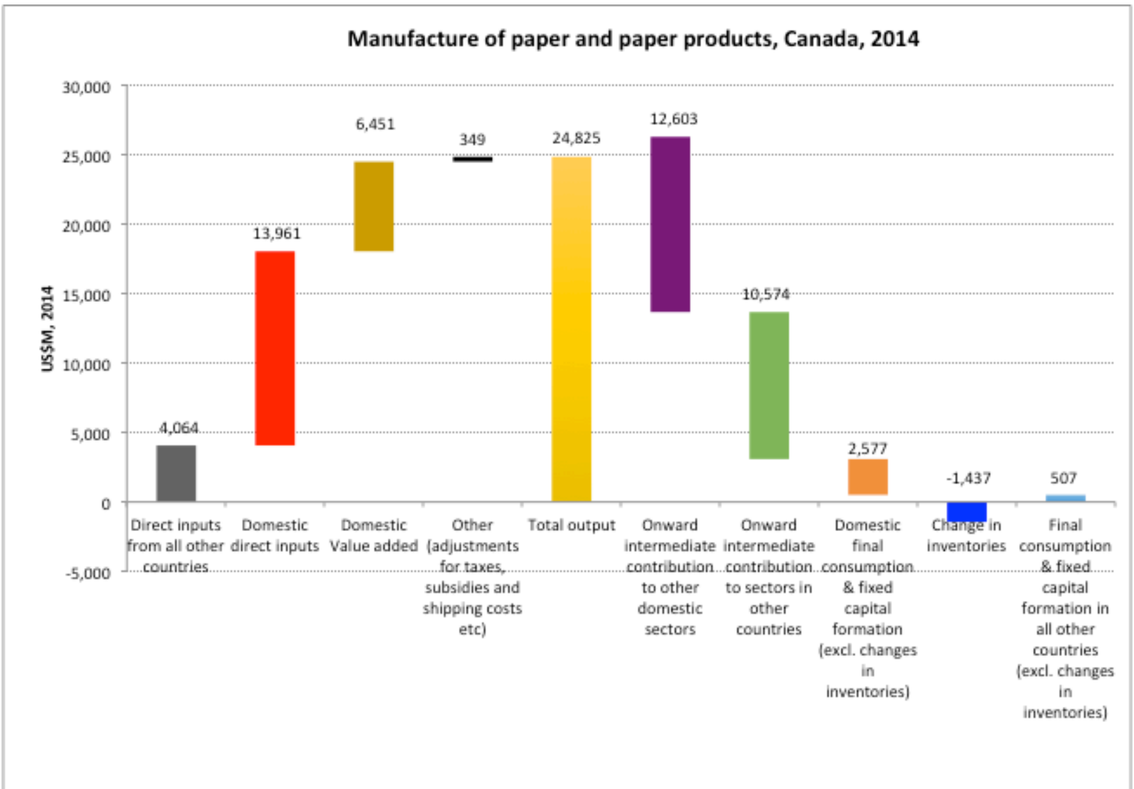
Source: Analysis of the World Input Output Database



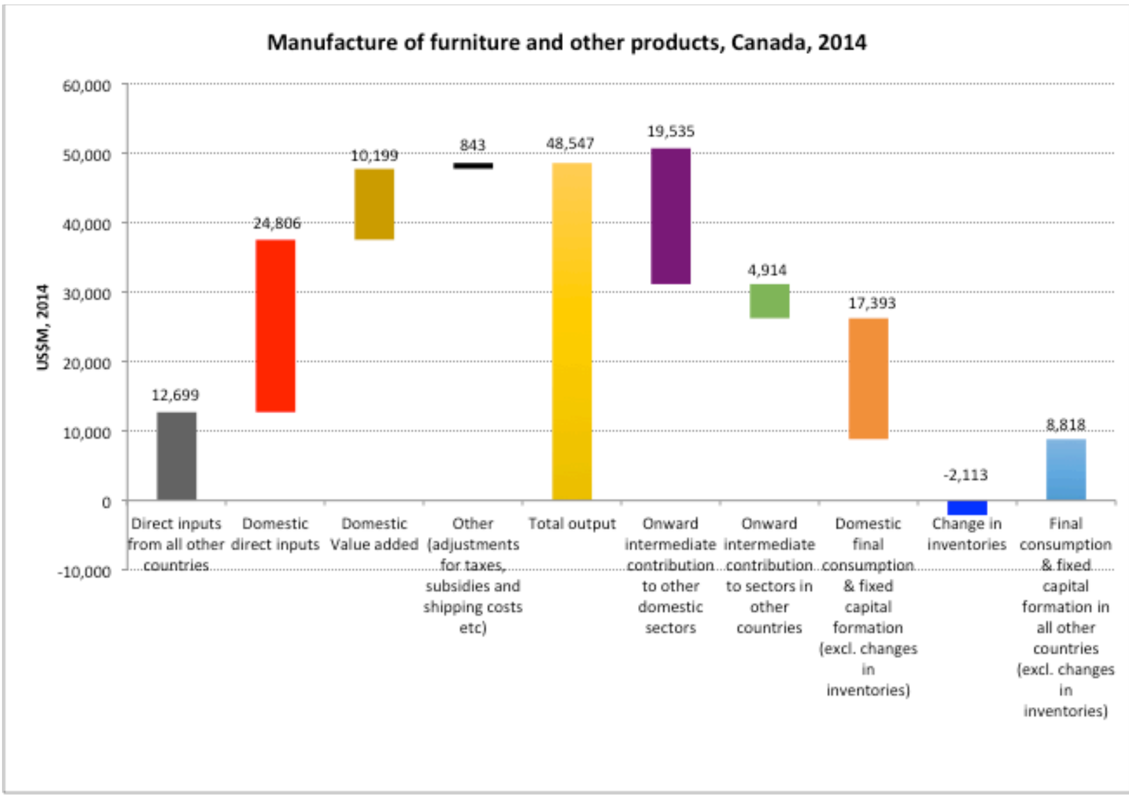
Source: Analysis of the World Input Output Database



Source: Analysis of the World Input Output Database



Source: Analysis of the World Input Output Database



Source: Analysis of the World Input Output Database

Gereffi, G., Humphrey, J., & Sturgeon, T. (2005). The Governance of Global Value Chains. *Review of International Political Economy, 12*(1), 78-104.