KELLOGG
RURAL LEADERSHIP
PROGRAMME

ECONOMIC COMPLEXITY AND THE NEW ZEALAND WINE INDUSTRY

Implications for Government Policy in the Primary Sector

ABSTRACT

New Zealand's primary sector is facing uncertainty from all angles, but GDP figures indicate the country's economy is performing well. Herein lies a gap between traditional measures of economic performance and the country's economic resilience. An alternative measure based on Economic Complexity (EC) principles is applied to New Zealand and its implications for the primary sector are discussed. EC can uncover causal links between economic performance and resilience where traditional methods appear to fail. Five key recommendations are made in relation to New Zealand's primary sector and wine industry: Adopt complexity analysis in policy making; Make industry network gaps transparent; Establish knowledge networks; Structure industry knowledge and Invest in R&D early.

Heath Stafford
Kellogg Rural Leaders Program 40

I wish to thank the Kellogg Programme Investing Partners for their continued support:

Strategic partners

Programme partners

Media and supplier partners

Disclaimer

In submitting this report, the Kellogg Scholar has agreed to the publication of this material in its submitted form.

This report is a product of the learning journey taken by participants during the Kellogg Rural Leadership Programme, with the purpose of incorporating and developing tools and skills around research, critical analysis, network generation, synthesis and applying recommendations to a topic of their choice. The report also provides the background for a presentation made to colleagues and industry on the topic in the final phase of the Programme.

Scholars are encouraged to present their report findings in a style and structure that ensures accessibility and uptake by their target audience. It is not intended as a formal academic report as only some scholars have had the required background and learning to meet this standard.

This publication has been produced by the scholar in good faith on the basis of information available at the date of publication, without any independent verification. On occasions, data, information, and sources may be hidden or protected to ensure confidentially and that individuals and organisations cannot be identified.

Readers are responsible for assessing the relevance and accuracy of the content of this publication & the Programme or the scholar cannot be liable for any costs incurred or arising by reason of any person using or relying solely on the information in this publication.

Scholar contact details may be obtained through the New Zealand Rural Leadership Trust for media, speaking and research purposes.

Thank You to:

"The Band" Catherine, Elke and Claudia

Joel Stafford

Indevin Group Ltd., and the Team

The Kellogg Team – Pat, Scott, Lisa and Anne

Kellogg Team 40 "Manatee"

Contents

Introduction

New Zealand's (NZ) primary sector is facing uncertainty from all angles. Brexit and the USA/China trade war has thrown our primary sector exports in the air and we don't know where they'll land. Climate change, sustainability and natural resource management ask serious questions of the sector's performance and its adaptability. Changing consumer preferences along with a rise of low carbon impact lifestyles also put pressure on the sector. Global export dynamics are in flux as emerging economies such as India and China build momentum. On top of this, a myriad of government regulatory changes in the form of the Zero Carbon Bill, Three Waters Review, and the movement for a living wage, to name a few, will continue to affect the primary industry sector.

New Zealand has the 51st largest global economy measured by nominal Gross National Product (GPD), 21st largest measured by nominal GDP-per capita at $41,555 (USD)). New Zealand's GDP-per capita is comparable to Japan, which has a population of 127 million people and is ranked 3rd in GDP but 24th in GDP-per capita at $39,306 (USD). New Zealand's forecast overall growth for 2019 is 2.5% which surpasses Japan (0.9%), Australia (1.7%), the United States (2.4%) and the EU (1.2%) (IMF, 2019). Based on these measures, New Zealand is performing well.

But there appears to be misalignment between the situation experienced by the primary sector, New Zealand's largest earner ahead tourism and services, and measures of the nation's economic health. Is this due simply to the monotony of the media's crisis narrative as they report on the economy? Are economists right to suggest everything is ok or are there deeper problems for primary production in New Zealand?

There are well known limitations to GDP as a measure of economic success. For example, GDP doesn't account for the contribution made to the economy of people and natural resources. The NZ wine industry's (NZWI) performance is rolled up into a single measure of export value by economists and other monetary observers. The dairy industry answers to only one measure which is the milk solids price. Some argue GDP is a reductionist and reactive measure, a lagging aggregate measure of growth that doesn't predict how we will fare as circumstances or assumptions change. It is also not very good at illustrating the need to simultaneously grow and be resilient. Considering current primary sector uncertainty, these are important limitations.

To understand the economic environment of the NZWI is to understand the complex interactions of the value chain that are required to make and sell wine. The emergence of methods to measure economic complexity (EC) has proved to be of interest to contemporary economic researchers and practitioners in this regard (Simoes and Hidalgo, 2011; Tacchella, *et al*., 2012; Battiston, *et al*., 2012; Cristeli, *et al*., 2013; Bahar *et al*., 2014; Hausmann and Hidalgo, 2014; Cristeli, *et al*., 2015; Morrison *et al*., 2017; Ortiz-Ospina and Beltekian, 2018). This is because these methods are like using a microscope compared to the magnifying glass of GDP in its ability to measure complex interactions and explain their value. By uncovering the actors and their connections within a value chain, complexity analysis can tell us more about uncertainty and, more importantly, what to do about it. This isn't to say that GDP as a measure of the economy is useless, merely that it should be used in conjunction with measures like EC.

Economic complexity also has the capacity to account for the productive contribution of human and natural resources to the economy in ways that GDP can't. But, most importantly, EC offers measures for the economy that account for knowledge.

The counter to economic vulnerability and uncertainty is resilience (Briguglio, 2006). Increasing the economy's complexity increases its resilience which in turn reduces its vulnerability and the uncertainty held by the industries within it. Economic complexity analysis provides insights into how to understand, measure and build a resilient economy.

Wine Industry Focus

The NZWI operates in the horticulture sub-sector of the primary industry sector. It tends to be reported in government and other publications separately from horticulture because of its high revenue and contribution to promote "brand New Zealand". Although these unique characteristics separate it from primary sector hierarchy to some degree, in an economic sense it is no different. In this paper the wine industry is used as a case study to understand methods of economic analysis at a more granular level and to take advantage of real-world examples. This paper will also describe how alternative methods of economic measurement might support change in the industry.

Aims

The aims of this paper are to investigate:

1. How measures of economic complexity can assist the primary sector to better understand economic performance
2. How to select tools that build resilience, reduce uncertainty and improve policy making.

The conclusions of the paper are described in the form of recommendations:

- application to current sector policy and strategy development
- application to industry decision making methods, and
- areas and topics for further investigation.

Methodology

A systematic desktop review was conducted to support the writing of this paper including using industry examples in the application of economic performance measurement. This methodology is commonly used in the production of briefing reports to executive teams and boards of directors, and by public servants to brief senior management and ministers.

Background

What is Economic Complexity?

It is widely held that business capability depends on the generation of high quality, specialised and complex embodied knowledge (Asheim and Gertler, 2005; Hidalgo and Hausmann, 2009; Balland and Rigby, 2016). Measuring the extent of an organisation or sectors' knowledge is difficult and until recently relied on simple empirical methods and anecdotal evidence, such as counting patents per industry classification.

Economic Complexity (EC) understands a large economy as a complex system, consisting of components such as people and firms, their interactions, the environment in which they function and their spatial distribution. Hidalgo and Hausmann (2009) developed the concept of EC from Adam Smith (1776) who argued that the wealth of nations was related to the division of labour, that is, as people and firms specialise in individual activities, economic 'efficiency' increases (Smith, 1776). The concept

treats an economy holistically, rather than by independent sectors, and seeks to explain the extent to which the economy depends on the accumulation of knowledge in the population.

Origin of the ECI

Hidalgo and Hausmann (2009) showed that it is possible to quantify the complexity of a country's economy by characterising an export basket. A country's export product mix reflects something important about the complexity of the system required to produce those products. Hidalgo and Hausmann (2009) found that the Economic Complexity Index (ECI), a measure they created to operationalise the concept, is correlated with a country's GDP but also supports predictions of future growth.

In June 2009, Ceasar Hidalgo and Ricardo Hausmann published their paper *The Building Blocks of Economic Complexity* (2009) and went on to develop the Economic Complexity Index. In 2010 Alexander Simoes published his thesis *The Observatory: Designing Data-Driven Decision Making Tools* (2010) under Hidalgo's supervision. Subsequent to this, in 2011, they developed the Observatory of Economic Complexity website (Simoes and Hildago, 2011) and with Hausmann and others published *The Atlas of Economic Complexity* (2012). Further research and refinement of the ECI continues to expand with new publications and industry uptake.

How is Economic Complexity Measured?

The eigenvector centrality measure

Hidalgo and Hausmann (2009) developed the Economic Complexity Index using a 'centrality algorithm'. The eigenvector algorithm measures the influence of a node (capability or product) within a system (a country, region or city's economy) on other nodes around it. Each node receives a score and the relative influence of a node is determined by its number of connections and the value of the nodes connected to it.

In Hildago and Hausmann (2009), the authors use a simple analogy to describe how the concept of the ECI applies to the real world:

> *"We can create indirect measures of the capabilities available in a country by thinking of each capability as a building block or Lego piece. In this analogy, a product is equivalent to a Lego model, and a country is equivalent to a bucket of Legos. Countries will be able to make products for which they have all of the necessary capabilities, just like a child is able to produce a Lego model if the child's bucket contains all of the necessary Lego pieces. […]*
>
> *Using this analogy, the question of economic complexity is equivalent to asking whether we can infer properties such as the diversity and exclusivity of the Lego pieces inside a child's bucket by looking only at the models that a group of children, each with a different bucket of Legos, can make […], connecting countries to the capabilities they have and products to the capabilities they require. Hence, connections between countries and products signal the availability of capabilities in a country just like the creation of a model by a child signals the availability of a specific set of Lego pieces."*

Arguably, this offers a clearer explanation of economic performance than traditional methods such as GDP which typically describe simple measures of quantities produced and prices paid.

Developments in Research on the ECI

More recently, academics studying centrality methods of economic analysis have refined and improved centrality algorithms (Tacchella, *et al*., 2012; Cristeli, *et al*., 2013; Cristeli, *et al*., 2015; Morrison *et al*., 2017). Testing centrality methods on a greater diversity of data sets and real-world applications has resulted in improved robustness of the methods and a wider field of application (Battiston, *et al*., 2012; Morrison *et al* 2017). In Morrisons *et al*., (2017) the authors put recent algorithm developments to the test and found that research on countries' competitive fitness

compared to complexity is only just beginning. The original ECI algorithm remains valid (Hausmann and Hidalgo, 2014; Hausmann, *et al*., 2007) and has been strengthened by the work of Bahar *et al*., (2014).

Is the ECI Related to GDP?

GDP is also an economic measure of productivity. It is a measure of the final value of selected goods and services produced annually. It is used to simplify and standardise the approach of calculating and comparing different countries' economic performance, and future development. The OECD define GDP as the standard measure of the value added through the production of goods and services in a country during a certain period, typically 12 months. As such, it also measures the income earned from that production, or the total amount spent on final goods and services (less imports). These factors are reduced to an aggregate measure of a country's economic performance comparable with other countries' economies. The primary measurement is relative economic growth commonly expressed as 'percentage growth in GDP' and ranked relative to other countries.

The main limitation of GDP is that it hasn't been able to explain variations in performance, and while the ECI and GDP measures correlate well together (Fig. 1), ECI scores are generally accepted to be a strong predictor of the level and growth rate of GDP, and a better way to understand variations in growth rates and predictions of countries' economic performance (Hidalgo and Hausmann, 2009).

Figure 1. Show the correlation of GDP per capita and EC controlled for each country's natural resource exports. EC and natural resources explain 73% of the variance in per capita income across countries (Hausmann and Hidalgo, 2014)

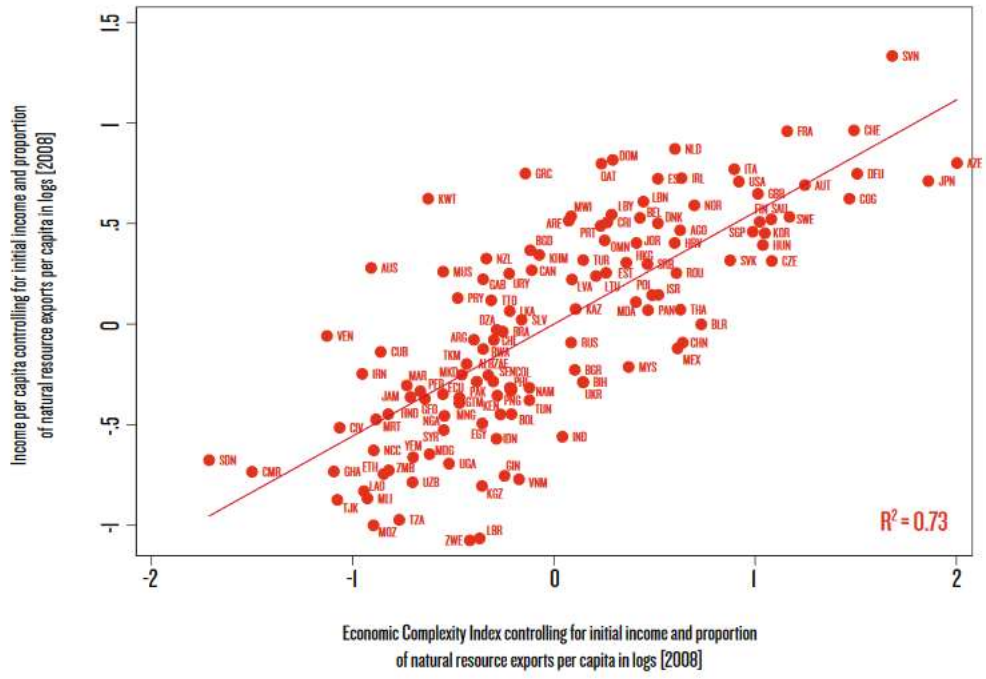

Figure 1 reproduced from Hausmann, R. & Hidalgo, C. (2014)

These factors illustrate an important difference between GDP and the ECI. Aggregate measures of economic output, of which GDP is one example, limit exploration of why an economy performs in the way it does, while the natural expression of the ECI in the form of 'graph networks' (Lesne, 2006) prompts us to think about mechanisms and systems that to some extent make up an economy.

What is the Benefit of Using the ECI?

Not an either/or proposition.

The ECI has been shown to uncover and explain links to economic performance. For example, it has been used to show why many small and large countries produce relatively high levels of GDP but remain vulnerable to economic variability and display low levels of resilience (Briguglio *et al*., 2006; Hildago and Hausmann, 2009). Conversely, ECI can also explain why some small countries possess very high resilience with only moderate GDP performance.

A country exporting a simple and common product mix, such as Australia (ECI -0.6, 93rd/133) (The Growth Lab), has a low ECI because many other countries either do produce or have the capability to produce the same products. In this sense, capability doesn't necessarily mean merely that a country is in possession of natural resources. It also means they have the intellectual and industrial know-how to transform those resources into a product. The ECI recognises unique natural resources but generally countries dominated by less complex industries such as mining and primary industry are only ranked higher when they also have complex industries such as car or computer manufacturing. Equally, a diverse, but simple product mix is not indicative of complexity.

Japan is presently ranked number one on the ECI and its product mix (Fig. 2) is diverse, complex, has a high level of revealed comparative advantage (where its share of global exports is larger than what would be expected from the size of its export economy and from the size of a products global market), and a high level of co-exported products (where two complex products are combined such as, cars with onboard computers). Japan's ECI is made up of individual Product Complexity Indices (PCI) with high levels of complexity (Fig. 3).

Figure 2. Japan's product mix including ICT and services. (The Growth Lab).

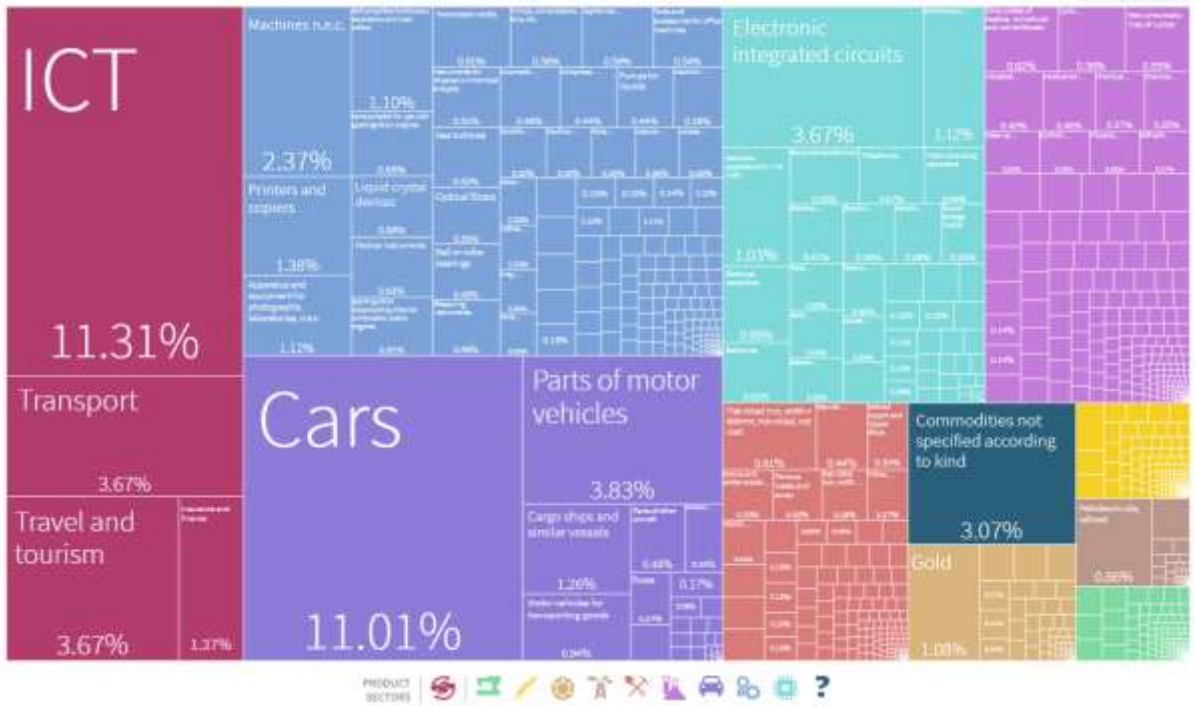

Figure 2. reproduced from The Growth Lab

Figure 3. Japan's ECI made up of individual Product Complexity Indices (PCI). High (positive) ranking are coloured dark green, becoming lighter in colour and switching to light orange and dark orange for low (negative) PCI.

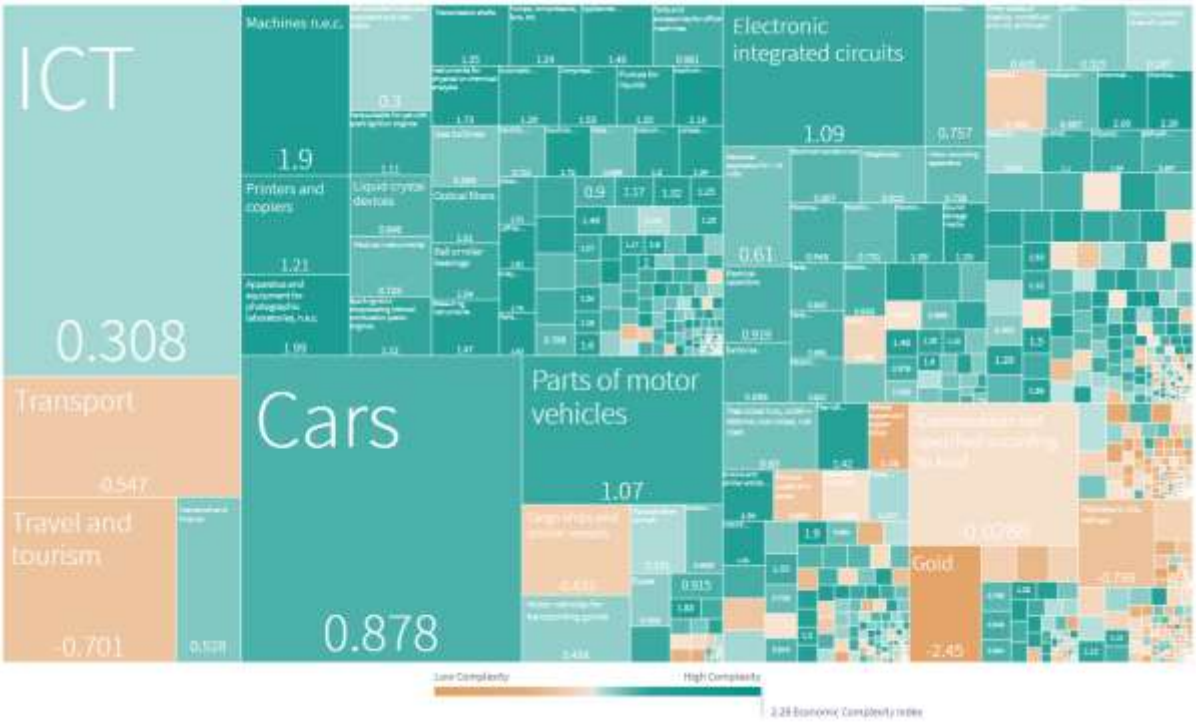

Figure 3. reproduced from The Growth Lab

By comparison, Australia is a rich country with a GPD per capita of $53,825 ranking 14th globally. But, with a simple product mix reliant upon natural resources, it is vulnerable to global swings such that its economy is less able to mitigate peaks and troughs.

The Product Space

The algorithms underlying the ECI measure the size and distance of nodes (representing product categories) from other nodes. The size of the node is, in part, relative to the complexity of that product or industry. Its size reflects the knowledge and capability of people to produce that product. Hildago and Hausmann (2009) found that countries tend to diversify by moving into nearby and related products or into those that require similar know-how, to build on existing capabilities. The 'Product Space' of the ECI represents the relatedness of over 800 goods using real world data and can be visually illustrated in graphical representations of a country's product space (Fig 4).

Figure 4. New Zealand's product space calculated using the ECI. The size and connectedness of primary industry (yellow) are related to the local product mix and to other countries that also produce primary products. These countries are highly likely to be able to produce other primary products but share few links to the know-how required to produce machinery (blue). The Product Space helps to define paths to diversify a country's economy based on the connectedness of its know-how (The Growth Lab).

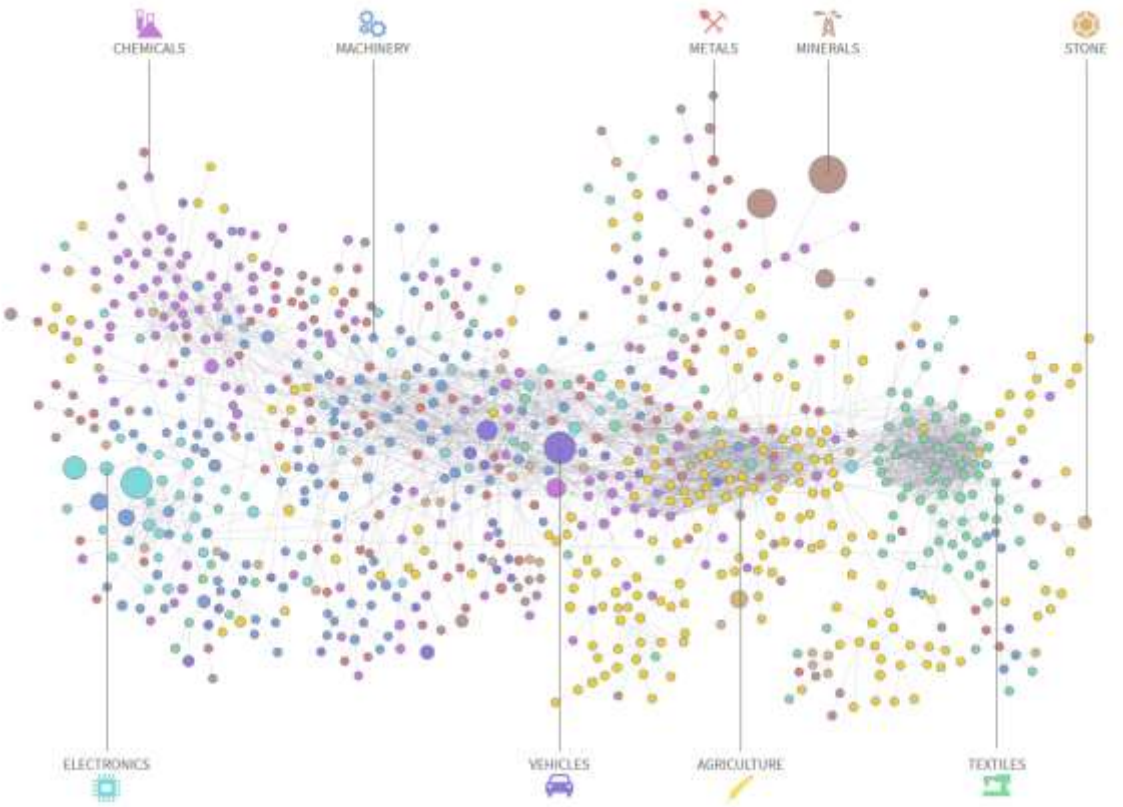

Figure 4. reproduced from The Growth Lab

The ECI contributes two advancements in economic measurement:

1. It identifies the intangible and uncovers hidden contributors to economic growth and development;
2. It provides a structure to develop strategies for economic resilience. The level of sophistication and diversity of a country's production predicts its economic growth.

The ECI provides greater and more granular insights into a country's vulnerability and resilience. Most importantly, the ECI helps to identify a strategic pathway to decrease vulnerability and increase resilience. For example, one does not infer from New Zealand's ECI that it must make its bucket of Lego pieces identical to Japan's bucket of Lego pieces. Rather, one reasons, to increase complexity a sector or country must stabilise and increase the depth of connectedness in its current industries, while at the same time developing new distinct but strategically aligned industries.

Complexity, Fragility and Risk

In economic terms vulnerability is generally defined as the exposure of an economy to 'exogenous shocks' that can occur due to economic openness. An exogenous shock is an effect on the economy caused by factors not represented in standard economic models. Resilience is defined as the policy-induced ability of an economy to withstand or recover from the effects of such shocks (Briguglio, *et al*. 2008). I agree with these definitions and take them further using the ECI principles which introduce non-monetary and non-income-based measures of economic performance, development and growth such as, knowledge, natural capital and the value of community.

Fragility is the opposite of resilience. Where resilience is the diversity, complexity and density of industries (nodes) and connections, fragility is a state obtained by having too few connections and industries, a lack of density and diversity. This definition does not dictate a minimum quantity or configuration of industries and connections. Rather, it indicates a state where too few are present to maintain an acceptable level of resilience. Fragile economies are open to the effects of shocks which are themselves complex, diverse and unpredictable.

Economies can become more resilient over time and the ECI provides insight into structural changes that occur when countries execute effective strategies to increase their economic complexity. For example, Japan's Total Quality Management (TQM) revolution of manufacturing transformed the quality of its materials and thereby created value by producing goods customers paid more for with a greater profit margin. In effect, this approach reduced fragility in the network by strengthening, shortening and making new connections in the production cycle of a product. Conversely, Australia's economic complexity ranking has slipped over the length of a decade, as it removed large parts of its manufacturing capability.

The potential for the ECI to support causal analysis of market structures seems to undermine one of the main principles of neo-liberal economic policy. This approach to policy provides freedom to enterprises to be self-governed with the "market" deciding where the boundaries lie. However, by letting the market decide, the result can be a reduction in network complexity as the population of consumers becomes more homogeneous. The ECI suggests that the decisions of neo-liberal economic policy are based on growth factors that largely ignore 'reflexive knowledge' and, so too, the density of connections and industries within a given network. Under these conditions, when crises and shocks occur, causality is largely left underdetermined, tempting policy makers to fall back on 'market forces' to explain change (Lave *et al*., 2010; Mirowski and Nik-Khah 2017).

What is important about the ECI is that its output provides greater understanding than standard methods by uncovering the networks and knowledge behind a country's productive capacity and therefore, where and how a country can focus its resources to achieve development, growth and resilience of its economy, environment and people.

Economic complexity tells us that complex economies are more resilient, are higher in value, are less prone to downturns and other challenges than simple ones, and comprise people who are healthier, more educated, experience less frequent and severe conflict and make better decisions (Hildago and Hausmann 2009).

The Economic Complexity of New Zealand

How Complex is New Zealand's Economy?

Stats NZ estimated New Zealand's GDP as at June 2019 to be worth $205.9 billion (USD) and ranked it 51st globally with annual growth in the year ended June 2019 of 2.4% p.a. and the IMF's 2019 growth estimate is 2.5% p.a. However, it is relatively rich with a GDP-per capita of $41,555 (USD< 2019 estimate) placing it 21st globally. Its 2017 ECI was 0.23 placing at 51st (133) compared to Japan's ECI of 2.31 in 1st place (133) (The Growth Lab) and has a GDP of $4.8 trillion (USD) placing it 3rd globally with a 2019 growth estimate of 0.9 p.a. (IMF, 2019).

NZ's export economy is predominantly based on tourism and the primary sector (Fig 5). Both sectors are users of technology, not developers and sellers of technology. Furthermore, the largest employer sector is services which hold ~72% of employees (Stats NZ, 2019). Under EC principles, options to

increase NZ's economic resilience are to: help our greatest earning sectors become more valuable; shift to new sectors, such as information technology, biotechnology or genetics, and reinvigorate our manufacturing sector which has decreased from 27% of GDP until the end of the 20th century to its current 11%. The ECI of New Zealand (Fig. 6) compared to Japan's ECI (Fig. 3) indicates where increased network density is best placed and which complex sectors to consider adding to the overall product mix.

Figure 5. New Zealand's product mix as a percentage contribution of exports. (The Growth Lab).

Figure 5. reproduced from The Growth Lab

Figure 6. New Zealand's export product mix with each sector measured by its ECI. Dark green through light green to light orange becoming dark orange indicates a decrease in complexity from high to low. Overall, NZ's ECI is low illustrated by the predominance of orange particularly in the larger dominant sectors. In contrast, Japan's export product mix where the complex product dominates the mix (Fig. 3).

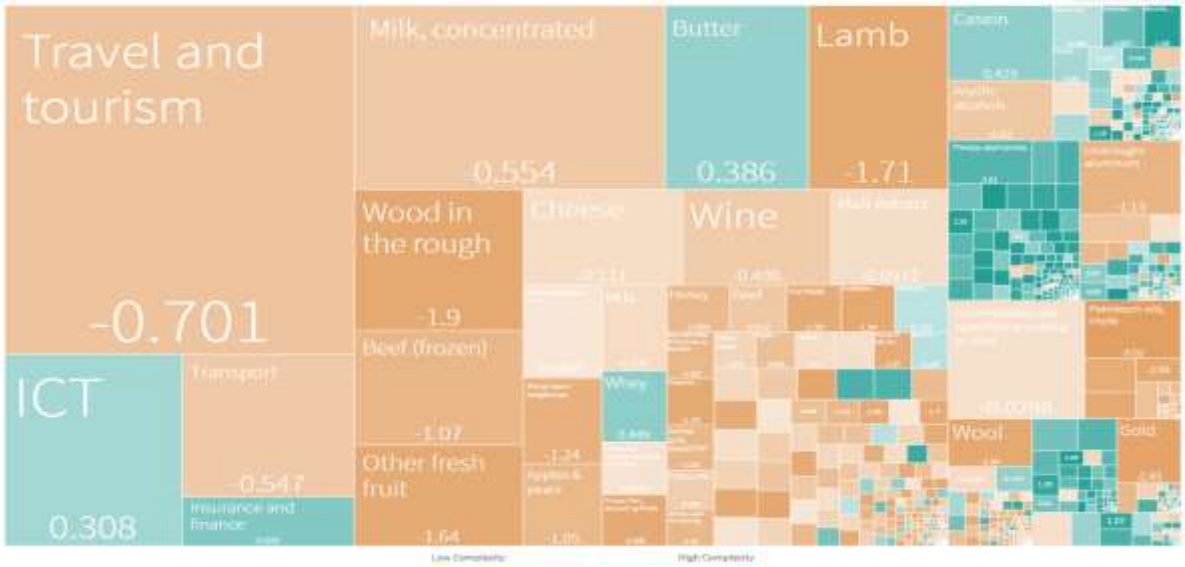

Figure 6. reproduced from The Growth Lab

New Zealand's New Export Growth

Whilst tourism and services are some of the largest sectors of NZ's export product mix, the primary industry sector dominates growth of global market share for NZ (Fig. 7). This is both a positive and a negative. On the positive side, NZ's primary sector continues to grow in market share (not accounting for value) but on the negative side, industries with a high ECI, such as electronics, are in decline.

The Atlas of economic complexity (2013) summarised NZ's new export growth performance as:

> *"Economic growth is driven by diversification into new products that are incrementally more complex. New Zealand has added 17 new products since 2002 and these products contributed $65 in income per capita in 2017 New Zealand has diversified into a sufficient number of new products but at too small a volume to contribute to substantial income growth."*

Figure 7. New Zealand growth in global share of products. The primary sector is dominant followed by services with the remaining sector in decline.

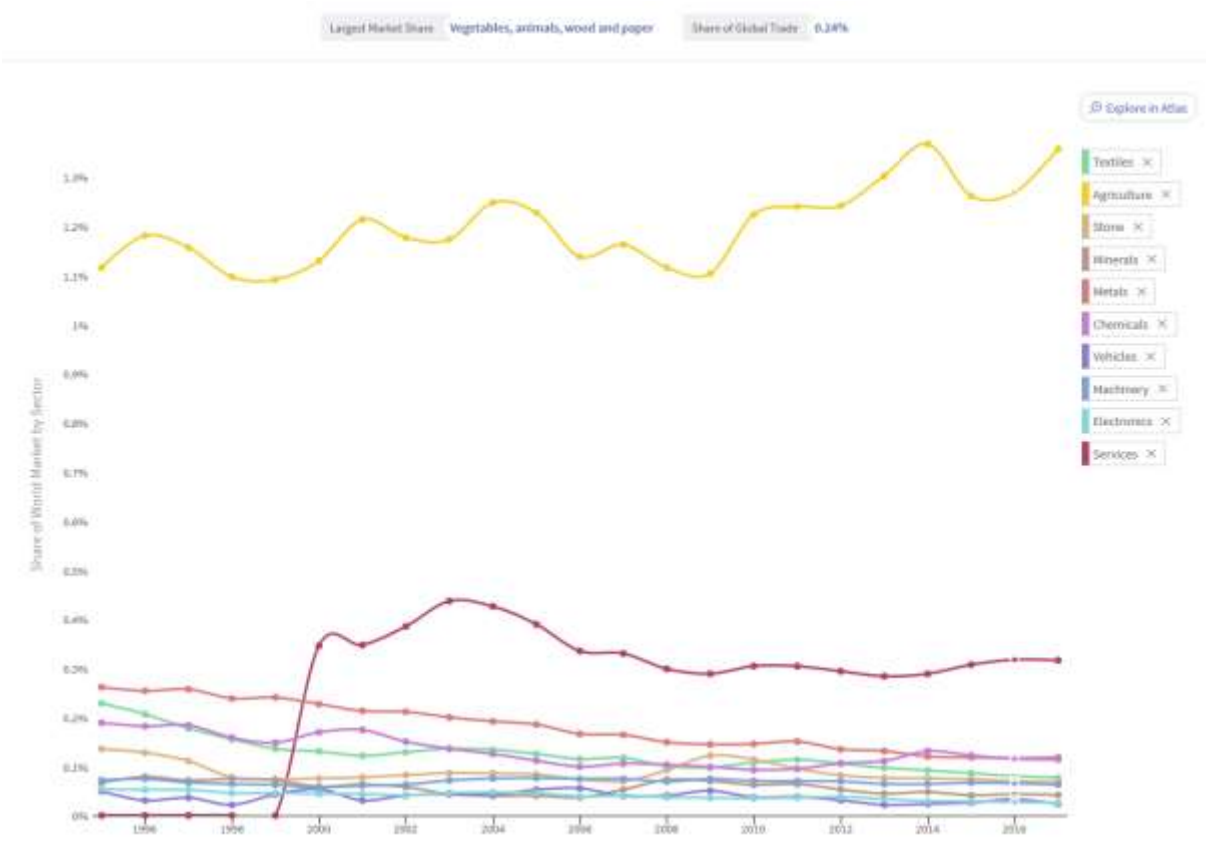

Figure 7. reproduced from The Growth Lab

The economic complexity of New Zealand's economy is moderate (Hausmann *et al*., 2013) driven mainly by a greater reliance on primary sector exports. NZ has too many and too large, low complexity industries with accompanying low growth potential (Fig. 8) which is indicative of its ECI. Japan has a high number of large complex industries accompanied by high growth potential (Fig. 9). Its primary sector is less than 2% of GDP compared to NZ at over 40%.

Figure 8. New Zealand's export growth dynamics and relative ECI by sector is illustrated. Its export growth is reliant upon industries with negative ECI. The largest contributing sectors have growth potential but, under highly competitive conditions. Those industries with positive ECI are ahead of the nation's ECI but, too small to be effective. Figure 9. Compared to NZ, Japan's export growth dynamics has more and larger sectors with positive ECI on the growth side of the graph and more industries in the top right-hand sector (high complexity/high growth potential) of the graph (The Growth Lab).

Figure 8. reproduced from The Growth Lab

Figure 9. reproduced from The Growth Lab

The ECI can determine the type of strategy best suited to growing a country's complexity (Fig. 10). The strategy recommended for New Zealand is the parsimonious approach, which means it should focus on removing bottlenecks and jumping short distances to connect industries. Japan's is the technological frontier approach, in a network that has already exploited major existing industries its focus shifts to developing new products (Fig. 11).

Figure 10 and 11. ECI determines that New Zealand's best economy growth strategy is parsimonious meaning it should focus on strengthening its current industry mix. Compared to Japan whose growth strategy is the technological frontier approach (Fig. 10). The parsimonious approach is reflective of counties that are well connected with low complexity (Fig. 11).

Figure 10. reproduced from The Growth Lab

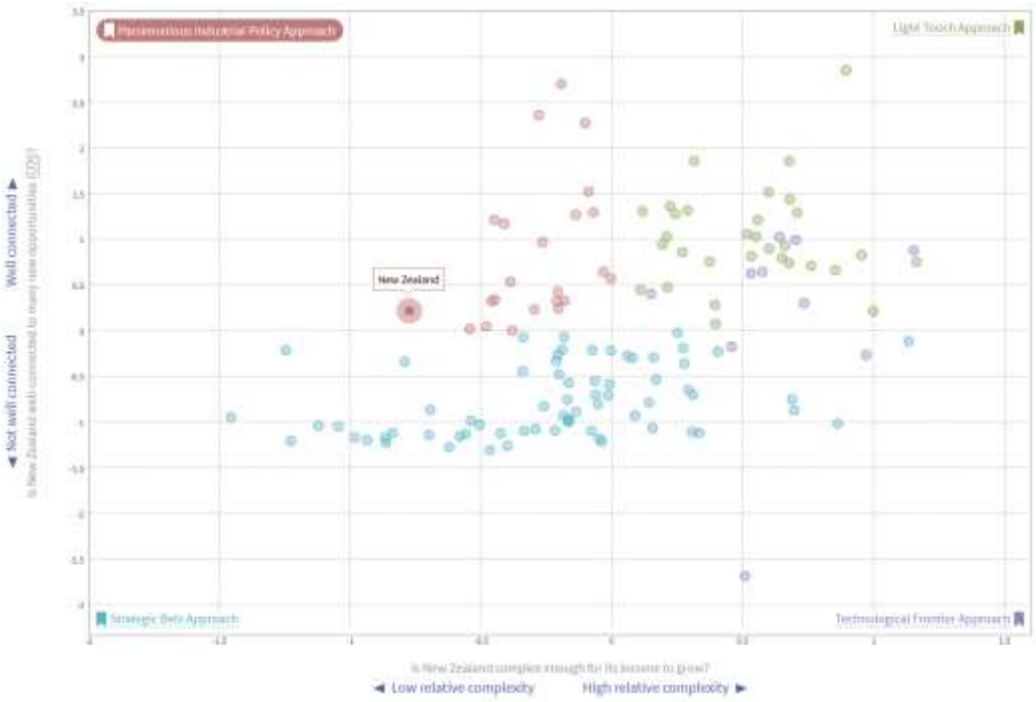

Figure 11. reproduced from The Growth Lab

Research and Development Expenditure

Research and development (R&D) is an effective strategy to grow a country's knowledge. R&D expenditure is therefore indicative of a country's growth potential and most of the top 10 ECI ranked countries are in the top 10 R&D spending countries (Fig. 12). NZ's R&D expenditure is $3.9 billion (USD) or 1.37% of GDP (Fig. 13) and the leading countries are spending over 2% with most aiming to grow to greater than 4% within the next decade.

Figure 12. Global R&D expenditure (2018 figures) by nation expressed as a percentage of GDP. New Zealand's expenditure in 2018 was equivalent to 1.37% of GPD. Six of the top 10 ECI countries Japan, Switzerland, Germany, Finland, Sweden, Republic of Korea, spend greater than 2.5%. The United States ECI rank is 12th with a 2.7% spend on R&D (UNESCO, 2019)

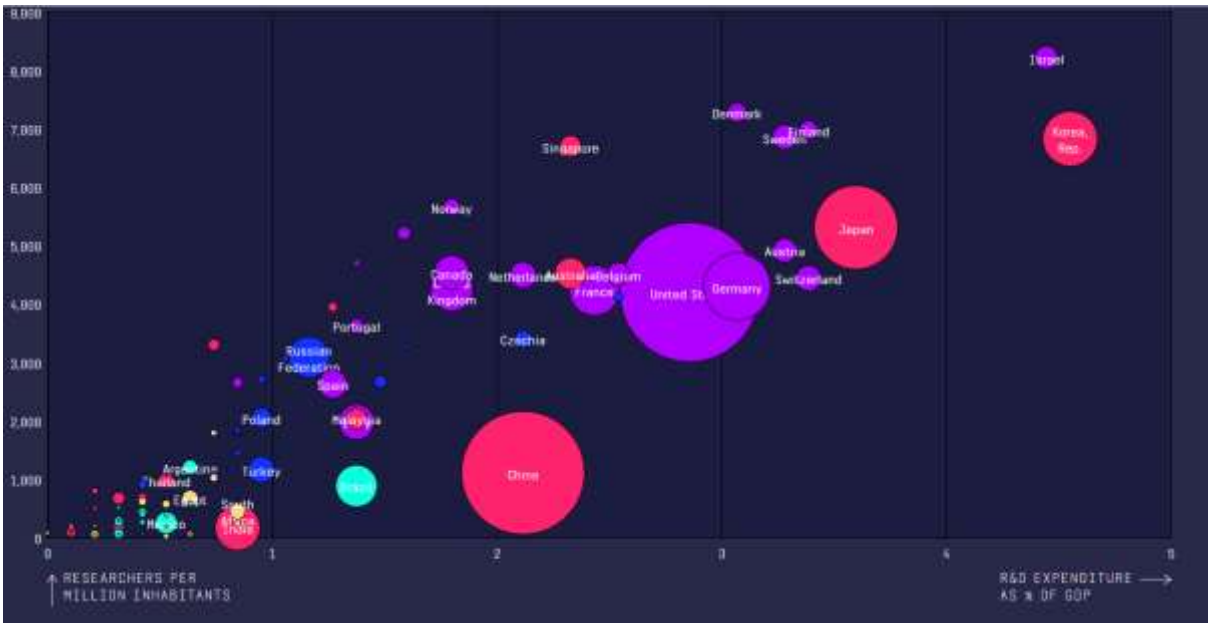

Figure 12. UNESCO

Figure 13. New Zealand's R&D expenditure (NZD) by sector from 2008-2018. Expenditure in 2018 was $3.9 billion (NZD) equivalent to 1.37% of GPD.

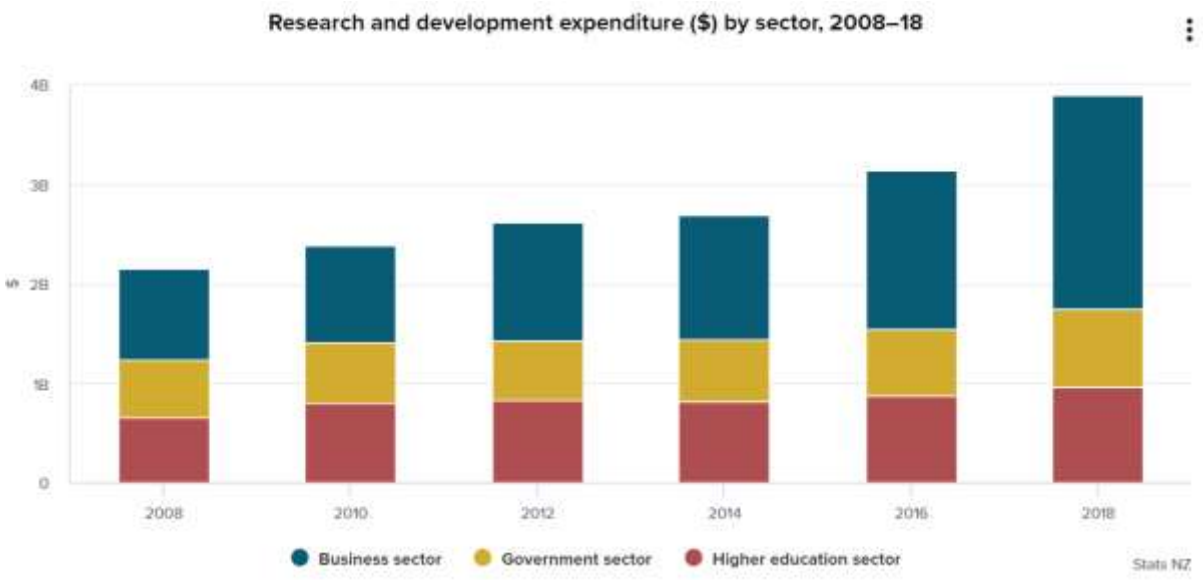

Figure 13. Stats NZ

A good example of increasing complexity in the New Zealand economy is the relatively recent development of New Zealand's space industry, almost single-handedly lead by RocketLab and Peter Beck. Until now New Zealand's contribution to this sector has been through research and monitoring with some development of rocket launching facilities and local manufacturing of space equipment, including rockets. Growth since 2006 has been exceptional and in the last financial year revenue from New Zealand's space industry contributed $1.7 billion (NZD) to the New Zealand economy. The global market is estimated to be over $700 billion (USD). Developments such as this indicate that New Zealand's economic complexity is likely to increase further over time. This growth is fuelled by overseas investment and part of developing NZ's complexity is to understand how such arrangements could return more effective economic and social outcomes.

New Zealand Wine Production and the Complexity of the Horticulture Sector

The New Zealand wine industry (NZWI) is categorised under horticulture in the primary sector grouping. The NZWI accounts for ~4% of total export revenue, worth $1.8 billion (NZD) with a total turnover of ~$2.5 billion (NZD), the difference being domestically earned revenue, to ultimately contribute 2.25% of export revenue and <1% to GDP. Importantly, the NZWI has had a relatively uninterrupted span of growth since 2000 and is one of the country's marketing spearheads, producing consistently high-quality product reflective of New Zealand's marketing image.

Wine is a global commodity, it is the 93rd (1232) most traded product with a correspondingly low PCI at 869th (1232) (Growth Lab). This means it is easily produced by many countries and falls into the

general category of “easy to make but, hard to sell”. There are literally hundreds of thousands of wine labels for sale globally. Consequently, the complexity of the knowledge required to deliver wine to market is relatively low.

For its size, New Zealand is a meaningful contributor to the global wine trade, particularly by value, where it commands the second highest position behind France. Its export destinations reflect the global averages with the USA, UK and Australia filling in its top three of which the USA and UK hold the top two global import positions.

New Zealand is reliant upon wine as one if its top ten exports. Wine isn’t a complex product and nor are any of the other top ten exports, including concentrated milk, sheep and goat meat, butter, frozen bovine meat, rough wood and cheese (Fig. 5). It’s reliance on low product diversity and a simple product mix account for the sector’s low ECI. This feature of the wine sector is contrasted with the space technology sector in Figure 14.

Figure 14. New Zealand’s product-space highlighting the space (left network map) and wine (right network map) industries. The relative complexity of each industry is highlighted by the number of connections with the product-space, length of connections and the size of the nodes involved in the network.

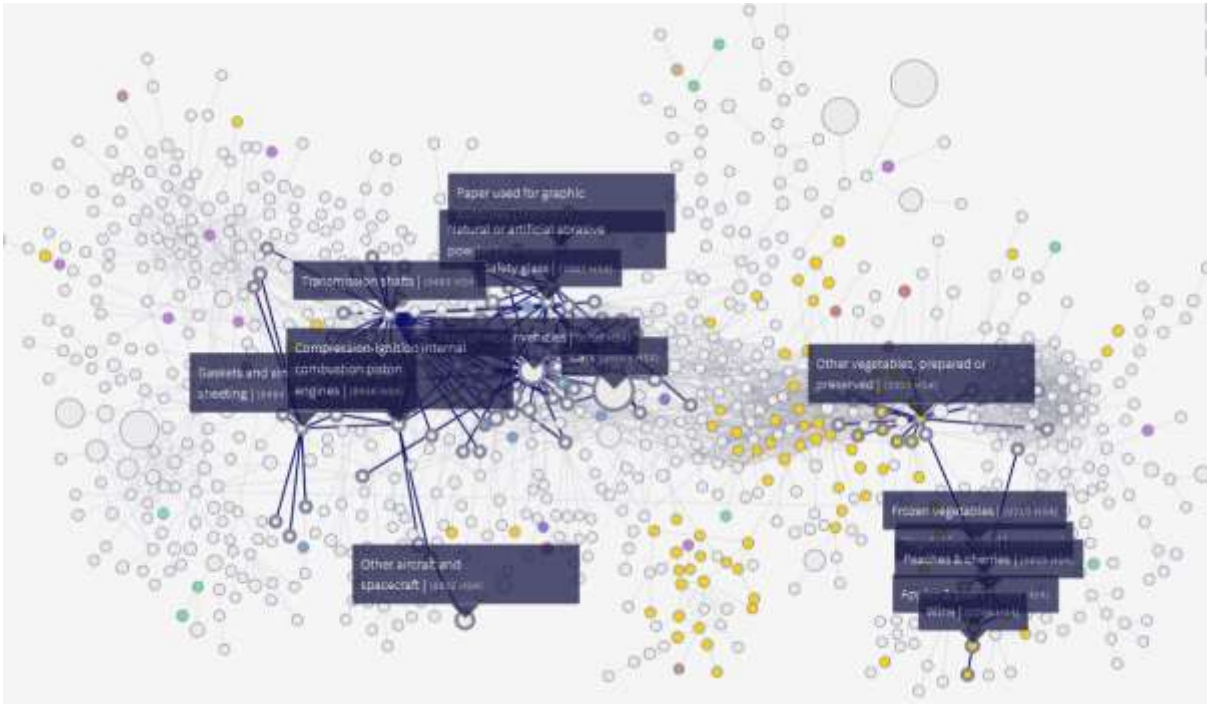

Figure 14. reproduced from The Growth Lab

Although wine is produced simply, the driving factors behind the success of New Zealand wine are the high quality of the production systems and unique and scarce styles, which in turn, continue to drive demand and high value. It is natural to ask under these circumstances what the principles behind economic complexity analysis have to offer New Zealand wine.

Building Complexity in New Zealand's Primary Sector

In this section I consider the ways in which the concepts of economic complexity may affect policy making in the primary production sector in New Zealand.

Economic Complexity as a Measure of Embodied Knowledge

The ECI is designed to treat the productive aspects of a nation's economic activity as a network and to describe the features of this network in a way that reveals important attributes about the interactions between the nation's economic agents. While the ECI does not reference knowledge *per se*, knowledge is an underlying feature of the kinds of attributes Hildago and Hausmann (2009) use the ECI to represent.

Many of the features of economic networks described above appear to have analogues for knowledge. For instance, an advanced industrial manufacturing enterprise operating in a nation that builds, say, nuclear fuel assemblies, does not appear in countries that rank low on the index of economic complexity. Such an enterprise depends on numerous highly coordinated capabilities that reflect a deep knowledge not just of nuclear chemistry, but of practical lessons learnt by people when they attempt to configure a production cycle for such products.

The connection between an index of complexity and depth of knowledge is also related to product or service quality. Looking again at New Zealand's product mix diagram (Fig 5), the value of New Zealand's dairy sector reflects not merely a high level of productivity but also a level of knowledge of dairy production at a given quality standard. This follows because, not only does the production network for dairy reside in New Zealand, by the nature of dairy production, so too does the knowledge.

This inference does not always follow. Consider the operation of a technology company such as Kitty Hawks. This company operates in New Zealand to research, develop and deliver to market a number of high technology products in the aerospace industry. While this operation increases New Zealand's GDP, it doesn't function to increase the knowledge embodied in the New Zealand economy since the work takes place here only to exploit a legal opportunity not available in the company's nation of origin. Consequently, it is possible for economic policy makers to regulate to attract foreign operations in a way that doesn't increase complexity, and consequently, doesn't increase the nation's store of knowledge.

These issues illustrate that more complex economic activity arises from an underlying process of knowledge accretion. The way in which knowledge is produced reflects something about the capability of people in a given set of economic circumstances to engage with one another on common ground. In other words, knowledge depends on social interactions guided by a shared method. In many sectors this method coincides with the scientific method, but it may also reflect methods developed by long periods of trial and error without the benefit of more sophisticated measurements and theories.

Complexity and Happiness

Early in 2019, the New Zealand government indicated its intention to introduce a measure of happiness to augment the general reliance on GDP and related headline indicators as measures of national economic performance.

The so-called 'wellbeing budget' aimed to use an index of happiness as a way to focus government policy-making on the prosperity of local communities. This laudable goal has, for the most part, sought to increase government funding to social services.

The main argument for doing so takes seriously the claim that a central role of government is to ensure its populations' wellbeing and that government interventions into the economy should advance that aim. In New Zealand, this has been articulated as the requirement that all new spending must advance at least one government priority, including transitioning to a low-emission, sustainable economy.

A natural question to ask is how happiness is related to economic complexity. One response is to connect the two by taking happiness to be an indicator of complexity. This would suggest that changes in the prevalence of happiness in the nation would be correlated with changes in economic complexity. But even stronger, it would also suggest that increases in complexity produce or lead to increases in happiness, all other things being equal.

Whether or not it holds for the ECI, it seems obvious that this kind of relationship does not hold for GDP. At various times in the recent history of New Zealand it is clear that GDP figures have fluctuated quite independently of public sentiment and other proxies for happiness. It also seems reasonable to believe that when GDP is correlated with happiness it provides no grounds to explain why. But without adequate data on the latter it is difficult to substantiate this claim.

Stronger ground is available if we accept that at least some of the increases in GDP may be caused by activities in the banking, finance and insurance sectors that increase individual debt and risk, a situation hardly indicative of an increase in national happiness.

A better question to consider is, given the government's acceptance of the need to measure levels of national happiness, are there actions that can be taken to support the government's priority areas, which increase economic complexity?

A deeper analysis of the index of wellbeing might investigate the extent to which actions taken in one or more of the government's five priority areas will improve factors that give rise to or that sustain happiness and wellbeing in communities. This same question can be posed of economic complexity.

An important dimension of the relationship between complexity and happiness is that economic policy makers may make decisions that don't price-in aspects of a sector's operations the sector considers to be of critical importance. One of these in the primary production sector is 'natural capital' – New Zealand's topography and climate, its access to water and soils, and their fecundity. These features also have a direct bearing on New Zealanders' 'lived experience' and so also on their happiness and wellbeing. The inclusion of natural capital in the decision making of the primary sector, but not by government policy makers regulating the primary sector, opens an opportunity for conflict. A sector that is good at learning from other people and from elsewhere is a sector with a happier workforce that is comfortable with change and is better able to manage and value its natural capital.

Complexity, Happiness, and a Theory of Markets

A strong commitment to the concept of marketisation informs much contemporary debate about economic policy in developed countries such as New Zealand. Marketisation, in the sense used by economic liberals influenced by Hayek, is the concept that the introduction of a market to most, if not all, aspects of society is the most efficient way to identify and promote economic value. A market is a place in which goods are exchanged for value, and marketisation is the activity of creating the conditions required for a market to function or removing barriers such that a market may form naturally.

In contemporary economic policy the practice of marketisation is seen as the single best way to gain knowledge about what is valued and how that value can be maintained (Mirowski and Nik-Khah 2017). As a consequence, government policy making today has less to do with the application of orthodox

economic theory governing direct government spending or taxation as a means to increase production and promote economic growth. It is instead more about identifying ways to regulate and de-regulate the economy based on signals that arise from economic transition points or crises, such that economic growth will naturally unfold on average.

This situation has drawn the government policy maker closer to those private sector actors involved in corporate governance, and to 'entrepreneurs' – individuals granted the license to 'translate' what the market wants government to do to overcome an economic impasse.

This theory of markets tends to result in reactive policy making since the government must wait until it can discern from the market a clear signal about likely future direction. Indeed, in some sectors, potential policy options discerned from market signals are opened to further testing in the market of sentiments concerned with how interventions will be perceived when announced. Conversely, for those policy makers who cannot wait patiently for the market signal to become clear, the quick solution is to buy-in the capability needed to fill the gap. Neither of these interventions responds to data on the complexity of knowledge in the economy and may even marginalise it.

A resolution of this tension might arise from reconsidering the concept of marketisation on the basis of a more thorough understanding of the different ways in which a market can and does function. Doing so depends on us having adequate alternative theories of a market. An adequate alternative is a theory that can support explanations of crises and market collapse, an attribute the current orthodoxy does not possess (Mirowski and Nik-Khah 2017).

Some National and International Examples

One area where considerations of economic complexity may change the policy and actions of business operations involves the relationship between residential housing and farming. In many areas where viticulture is practiced in New Zealand, but especially so in the Marlborough region, the cost of housing development and the value of inputs to wine making operations are intertwined. For instance, viable land on which to support grape production within Marlborough, New Zealand's primary growing region, has reached peak planting with a single digit percentage of viable land remaining to be planted. Residential construction decision making has a direct impact on wine production and vice versa. But the question of policy boundaries between real estate development and the farming sectors are in general not coordinated by data representing the network connections between the two sectors.

When the network shows the interdependence of many aspects of each sector, including implications about the flow of finance, the policy questions change, and alternative ways of planning can occur that are better informed by the data in the network. This can maintain or increase complexity rather than diminish it.

Japan is another exemplar of this relationship. Japan makes extensive use of forestry products, the majority of which originate from outside the country. Part of the reason for this is that Japan maintains a series of regulations designed to protect its natural capital. These regulations affect the ways in which Japanese enterprises may build strategies and encourages diversification of business networks.

These examples point to the fact that economic complexity interpreted as 'embodied knowledge' draws a connection between what people and communities are capable of doing under a variety of changing circumstances and the resilience of their economy to stress, as well as the capacity of the economy to grow when new opportunities emerge. It shows that measures of complexity are superior

to traditional economic measures because the former are more proximate to and representative of the capability of actors in the economy than are aggregate measures such as GDP.

Implications for Government policy

This set of issues has several important implications for government policy making in the NZWI.

The public service, notably the agencies engaged with research and support of the horticulture industry in New Zealand, require the support of a theory of markets to inform the ways they engage with the sector. With a suitable theory, policy makers in this sector stand ready to engage in planning processes informed by measures of complexity.

A natural consequence of building measures of complexity into a given sector of the economy is that the sector can no longer compartmentalise its supply of information into sector versus non-sector categories. The opportunity exists instead for policy making to be informed by the actual networks in which the sector is embedded, the thresholds involved in the dynamics the sector displays over time, and how these dynamics might change as key elements of the network fluctuate, are pruned, and when new elements are introduced.

An important implication of this expanded sector view is that the supply of data to the sector must expand. 'Linked data', and the capacity to analyse it in a way that industry can support, become a standard requirement on sector policy makers. In turn, with the support of linked data, research funded by the horticulture sector can be directed at the challenges it faces with the expectation that benefits implemented in the sector will also benefit non-sector entities due to network ties previously not recognised. Similarly, the consequences of policy interventions in sectors other than horticulture can be assessed for their impact.

These factors suggest a need for inter-sectoral collaboration that would benefit improved governance models such as multi-ministerial portfolios rather than single minister portfolios.

There are consequences also for the operation of intra-sectoral policy and research performed or funded by government. Consider, for instance, the opportunity for native species preservation that arises from research in the viticulture sector to reduce reliance on pesticide and herbicide chemical additions. The ecology of the vineyard can be radically reconsidered by introducing a network tie between these two currently unconnected research activities.

Another area of policy that may benefit from considering networks underlying economic complexity is the government's role in settings that affect the acquisition of knowledge by the horticulture sector. Current policy settings have operated to attract to New Zealand high net worth operations. Much of the effort expended in attracting organisations that have extensive knowledge networks, and financial and technical resources, leaves open consideration of the impact such operations have on New Zealand's natural capital and embodied knowledge.

The implication of introducing complexity analysis to this suite of policies is that the economic analysis of buying knowledge in to New Zealand can include the cost of an apparent increase in complexity not accompanied by an increase in embodied knowledge alongside the value created by the operation.

These issues raise an important dimension for policy making informed by economic complexity. Building complexity by increasing the inter-connectedness of the industries in New Zealand may offer benefits to the mobility of labour, because skill sets are more transportable across a connected network and may increase the leveraged value of one part of the economy based on another part. For example, in tying food tourism to wine production, the risk to the former are in part a function of the latter.

This connects two largely distinct sets of knowledge and so would apparently increase New Zealand's economic complexity. But this misses an aspect of complexity that encourages the policy maker to consider opportunities to support the development of resilient networks, ones that may share kinds of skill capabilities, but which optimise the trade-off between connectedness and insulation.

In terms of considering this dimension of economic activity via measures such as GDP, complexity is clearly the more useful. To GDP figures, the activities associated with buying skills in to New Zealand are generally a net benefit even when they don't add to economic complexity. This is another area where the two measures come apart.

Implications for Wine Making in New Zealand

An important implication mentioned above, which also applies to wine making businesses in New Zealand, is how businesses allocate resources to maintain innovation and market competitiveness. The application of economic complexity concepts and analysis at the level of business operations suggest that competition within regions, and perhaps across the nation, requires deeper scrutiny. For example, where a single operation buys-in expertise to create new knowledge about production in their region, considerable effort is expended on ensuring the commercial-in-confidence benefit is not devalued by sharing it with market competitors. This approach may slow the speed with which the sector builds dense knowledge networks.

Implications for the Role of Peak Bodies

One implication for the role of peak bodies in the horticulture sector stemming from the concepts of economic complexity is that their influence on government is a function of shared datasets. That way, the link between respective parts of the horticulture product space are transparent to campaigns to maintain work standards and skills transportability and avoid the degradation or loss of knowledge that has been acquired over long periods of time.

Implications for the Relationship Between Public and Private Agencies

Economic complexity and its relationship with networks of knowledge holds several implications for the operation of public agencies. A significant implication involves the ways in which universities are funded to support industry and the content of courses universities offer to their students. Universities are well placed to support the creation of detailed maps of knowledge in the NZWI and the broader market. Doing this work requires greater continuity and focus to coordinate the funding of research projects as well as a stronger relationship between researchers and industry.

Future Directions and Recommendations

Economic complexity analysis offers the primary industry sector an opportunity to gain a deeper understanding of its operations and the extent to which they are resilient. It also offers the sector the means by which to adopt more sophisticated development strategies than those available from standard sector performance measures.

This paper describes a tension between the capabilities of policy makers and those who operate businesses in the economy whereby the analysis conducted by the latter, being more thoroughly causal in its approach, is made more challenging by the fact that the former remains wedded to aggregate measures of activity and output.

At the base of this tension is an approach to economic measurement that seeks to include the ways in which knowledge is a key driver of sustained economic output. The ECI illustrates the amount of information that can be conveyed about an economy by a small number of annotated visualisations.

The paper indicates that the sector has an opportunity to include complexity analysis to build strategy and to plan the application of resources and to engage with economic policy makers, encouraging them to see more deeply into what makes New Zealand's economy tick.

Recommendation 1: Adopt Complexity Analysis in Policy Making

To improve New Zealand's ECI it must, in tandem with optimisation, create space for complex industries to grow. Policy must provide conditions where these industries can access funds for growth but retain more ownership, revenue, tax, people and knowledge.

New Zealand's industries must optimise to be the most cost effective, innovative, high-quality, and knowledgeable. They must use the country's advantage in innovation to create competitive advantage and migrate into high value market spaces. All these actions will increase the density of connections between products, industries and sectors making the economic network more resilient. But, these advantages, in low EC industries, are short lived and rapidly superseded due to the ubiquity of knowledge and can only be effective alongside high EC industries.

Recommendation 2: Make Industry Network Gaps Transparent

Strategies to increase research and development spending must be developed as one of the country's "must win" battles. Central to achieving this goal is to create the conditions that allow our unique start-up culture to proliferate.

New Zealand must take the time to understand the importance of people's, community's and society's knowledge. It must understand what happiness and well-being mean, how they affect economic performance and how policy can support it. In doing so, it must deal with the challenges brought about by vested interests and develop an alternative culture.

Recommendation 3: Establish Knowledge Networks

The primary sector must focus on establishing high quality connections between its industries and between other sectors, particularly those that have high ECI and other countries who possess highly complex supply chains. EC analysis should be targeted at the sector level focusing on mapping and modelling to compare on a global scale. Analysis should include other country's supply chains in order to understand how complex products are connected.

Recommendation 4: Structure Industry Knowledge

Knowledge is the NZWI's most valuable product. Thought must be given on how to structure and resource strategies to collect, record, communicate and improve on its knowledge base. This could be done by recording the industry's best practice methods in growing and making wine. This information can then be analysed and modelled to extract even greater value to be used by industry.

Wedded to this strategy is recognition by NZWI that a step change to climate restoration is required. By 2050 most wine producing countries will be 'clean and green'. New Zealand wine must promote to consumers that by purchasing its products they are helping restore climate and restore the environment. The concepts of economic complexity can assist the industry to obtain the know-how to make this transition.

Recommendation 5: Invest in R&D Early

Invest in education at technical vocation level and in secondary, tertiary and post-graduate levels and ensure that industry, including peak bodies, are part of the education process. This collaboration can be built through a process that maps the knowledge of the sector and draws stakeholders' attention to previously obscure relationships.

References

AJG Simoes, 2010. Masters Thesis. The Observatory: Designing Data-Driven Decision Making Tools. Northeastern University.

AJG Simoes and CA Hidalgo. 2011. The Economic Complexity Observatory: An Analytical Tool for Understanding the Dynamics of Economic Development. Workshops at the Twenty-Fifth AAAI Conference on Artificial Intelligence.

Asheim, B., and Gertler, M. 2005. The geography of innovation: Regional innovation systems. In The Oxford handbook of innovation, ed. J. Faberberg, D. Mowery, and R. Nelson, 291–317. Oxford: Oxford University Press.

Bahar, D., Hausmann, R. & Hidalgo, C. 2014. Neighbors and the evolution of the comparative advantage of nations: Evidence of international knowledge diffusion? J. Int. Econ. 92, 111 (2014).

Balland, P-A, and Rigby, D. 2017. The Geography of Complex Knowledge, Economic Geography, 93:1, 1-23, DOI: 10.1080/00130095.2016.1205947

Battiston, S, Puliga, M, Kaushik, R, Tasca, P, Caldarelli, G. 2012. DebtRank: Too Central to Fail? Financial Networks, the FED and Systemic Risk. 10.1038/srep00541

Briguglio, L., Cordina, G., Bugeja, S., and Farrugia, N, 2006. Conceptualizing and measuring economic resilience. University of Malta Article.

Briguglio, L., Cordina, G., Bugeja, S., Farrugia, N., and Vella, S. 2008. Economic Vulnerability and Resilience. Research Paper No. 2008/55. Unu-Wider, United Nations Library.

César A. Hidalgo and Ricardo Hausmann, 2009. The Building Blocks of Economic Complexity. Proceedings of the National Academy of Sciences, vol. 106, issue 26, (2009), pp: 10570-10575. Published by National Academy of Sciences

Cristelli, M., Gabrielli, A., Tacchella, A., Caldarelli,G., Pietronero, L. 2013. Measuring the Intangibles: A Metrics for the Economic Complexity of Countries and Products.
https://doi.org/10.1371/journal.pone.0070726

Cristelli, M., Tacchella, A. & Pietronero, L. 2015. The heterogeneous dynamics of economic complexity. PLoS One 10, e0117174 (2015).

Gabrielli, Andrea; Cristelli, Matthieu; Mazzilli, Dario; Tacchella, Andrea; Zaccaria, Andrea; Pietronero, Luciano. 2017. arXiv:1708.01161

Hausmann, R., Hwang, J. & Rodrik, D. 2007. What you export matters. J. Econ. Growth 12, 1 (2007).

Hausmann, R., Hidalgo, C., Bustos, S., Coscia, M., Chung, S., Jimenez, J., Simoes, A., Yildirim, M. (2013). The Atlas of Economic Complexity. Cambridge, MA: MIT Press.

Hausmann, R. & Hidalgo, C. 2014. The atlas of economic complexity: Mapping paths to prosperity (MIT Press, 2014).

Howland, P.J. Social, Cultural and Economic Impacts of Wine in New Zealand. Publisher, Taylor and Francis Group.

IMF.2019.
https://www.imf.org/external/datamapper/NGDP_RPCH@WEO/OEMDC/ADVEC/WEOWORLD

Lave, R, Mirowski, P. and Randalls, S. 2010. STS and Neoliberal Science.
https://doi.org/10.1177/0306312710378549

Lesne, A. 2008. Complex Networks: from Graph Theory to Biology. Lett Math Phys (2006) 78: 235. https://doi.org/10.1007/s11005-006-0123-1.

Lewis, N. 2008. Agri-Food Commodity Chains and Globalising Networks, Ed., Richard Le Heron. Chapter 9, Constructing Economic Objects of Governance: The New Zealand Wine Industry. Publisher, Taylor and Francis Group.

Mirowski, P., and E. Nik-Khah. 2017. The Knowledge We Have Lost in Information: The History of Information in Modern Economics. New York: Oxford University Press.

Morrison, G., Buldyrev, S.V., Imbruno, M. 2017. On Economic Complexity and the Fitness of Nations. Sci Rep ***7,*** *15332 (2017) doi:10.1038/s41598-017-14603-6*

Ortiz-Ospina, E and Beltekian, D. 2018. 'How and why should we study 'economic complexity'? https://ourworldindata.org/how-and-why-econ-complexity

*Sabiou Inoua, 2016. "**A Simple Measure of Economic Complexity**," Papers 1601.05012, arXiv.org, revised Jul 2018*

Smith A *(1776) An Inquiry into the Nature and Causes of the Wealth of Nations (W. Strahan and T. Cadell, London).*

Stats NZ. 2019. https://www.stats.govt.nz.

Tacchella, A., Cristelli, M., Caldarelli, G., Gabrielli, A. & Pietronero, L. 2012. A new metric for countries' fitness and product complexity. Sci. Rep. 2, 723 (2012).

The Growth Lab at Harvard University. The Atlas of Economic Complexity.
http://www.atlas.cid.harvard.edu.

UNESCO. 2019. http://uis.unesco.org/apps/visualisations/research-and-development-spending/. UNESCO Institute of Statistics.

Cover image from: https://www.wine-searcher.com/regions-new+zealand