

The Social Construction of Nanotechnology in the New Zealand Wine Industry

By

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Abstract

This project investigates the social construction of nanotechnology in the context of the New Zealand wine industry by gathering current perceptions on nanotechnology from diverse actors connected to the market-making of wine. Nanotechnology is the use of technological intervention of matter on a near-atomic scale to produce new structures, materials, and devices. It offers an improvement to conventional vineyard inputs. However, its acceptability by potential users and consumers cannot be taken for granted. This project investigates the technical and market acceptability of those solutions by elucidating the downstream attitudes towards wines grown with nanotechnology. It collates perceptions of fifteen New Zealand producers (winemakers, technical directors, viticulturists, and vineyard managers), wine marketers (winery sales and marketing specialists), and intermediaries (wine writers, sommeliers, distributors, and retailers), gathered through in-depth semi-structured interviews. Perceptions and attitudes are understood with respect to stakeholder type, region, and market share while contextualised in an international setting. They are revealed as part of a complex assemblage that makes up 'the wine industry' with diverse needs, expectations, and perceptions of nanotechnology. The study concludes that the present-day reliance on technology combined with an interest in new solutions suggests a high level of technical acceptability. Regulatory approval and safety assurances are evidently expected prior to the adoption of any novel technology. A multitude of attitudes towards nanotechnology were uncovered, ranging from informed parties to those with little understanding of the term. Respondents argue that market acceptability is less clear, and that thought leaders will be critical in shaping public opinion. In particular, the potential negative association of nanotechnology with genetic modification, science-fiction, and vaccine conspiracies requires careful narrative management by producers and industry authorities. Existing narratives of sustainability and provenance—on which New Zealand wine depends—must be reconciled with nanotechnology through discursive strategy as well as scientific and technical evidence. There are potential risks to the reputation and market positioning of New Zealand wine as 'clean and green', 'artisanal', and 'natural'. Nevertheless, New Zealand has the potential to position itself as a fast-mover, and address key challenges through the use of nanotechnology.

Keywords: vineyard nanotechnology, New Zealand wine, social construction of technology, market-making, assemblage

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Chapter 1 Introduction

1.1 The little things in the life of wine

New Zealand wine firms continue to adapt their *modus operandi* in order to remain competitive in domestic and international markets. As the latest in a long line of technological innovations, nanotechnology may well have a role to play. Nanotechnology solutions could enhance current vineyard practises and deliver economic and environmental benefits. Nanotechnology promises to address some of the most pressing problems in New Zealand vineyards, but only if perceptions of New Zealand wine are not damaged. Understanding the market acceptance of nanotechnology use is therefore crucial before nano-solutions can be deployed in the vineyard. This research investigates those perceptions and attitudes in order to understand the acceptance (or not) of nanotechnology in the wine sector.

1.2 Background

1.2.1 A brief introduction to nanotechnology

Nanotechnology can be defined as the technological intervention of materials at the nanoscale, in the range of 1–100 nm (Roco, 2003). Nanotechnology covers a broad spectrum of products and applications, and is regularly termed ‘nano-enabled’ or ‘nano-scale’ technology.

Nanotechnology has been embraced across a variety of industries; pharmaceutical, medical, manufacturing, agriculture, energy, and more. Applications range from zinc nanoparticles in sunscreen to nanomedicines targeting neurological diseases (Lu et al., 2018; Saxena et al., 2020). While nanotechnology can invoke images of self-replicating robots with the potential to take over the earth (Bowman et al., 2007), much of its use is mundane and commonplace. Proponents of nanotechnology point to its potential for enhancing productivity and generating environmental gains by more precisely targeting the application of pesticides, fertilisers, and breeding interventions for enhanced quality in agri-food products (Kah, Tufenkji, & White, 2019). Others emphasise that it is already present in established inputs and practices. For example, in the wine industry many commonly used applications of bentonite and copper sulphate for fining, and diatomaceous earth for filtration, already contain nanometre scale particles (Ezhkova et al., 2015;

Kontoudakis et al., 2019). Critics worry about unknown health impacts, the rise of franken-foods, the loss of connection between people, place and plants/animals, and the concentration of power within agri-scientific and global corporate networks (Scrini & Lyons, 2007; Richards et al., 2011; Lyons et al., 2018).

1.2.2 NZWI facing challenges

The global wine industry, and viticulture in particular, faces growing economic, social, and environmental challenges (Marín et al., 2021). New Zealand Winegrowers (NZWG) is the industry body responsible for collective marketing, advocacy, research, and sustainability funded through industry levies (NZWG, 2021). In their 2021 annual report NZWG list six sustainability goals, centred on people, climate change, pests and diseases, soil, water, and waste. Major challenges for vineyards include labour availability, climate change, pests, and diseases (NZWG, 2021). The production, export, and sale of wine is consequently challenged where the above impacts can lead to lower grape yields such as the comparatively small 2021 harvest (NZWG, 2021). Supporters of nanotechnology would suggest that its use could surmount such challenges. This thesis assesses the social construction and market-making of nanotechnology's promise and possibilities for New Zealand wine.

1.3 Aims and research question

This project asks: "How is acceptability in the use of nanotechnology in New Zealand wine being constructed and what is the current state of understandings of its acceptability?"

The aims of this research are to:

1. Gather perceptions and attitudes of wine producers, wine marketers, and intermediaries (as wine 'market makers') towards nanotechnology use in New Zealand vineyards.
2. Report on these perceptions and attitudes in the context of international perceptions and attitudes as established from desk-based documentary source review.
3. Outline the challenges facing the adoption of nanotechnology in New Zealand vineyards and opportunities for overcoming the barriers.

This research uncovers the assemblage of actors and agential elements that are (or could be) making a market for wines grown with nanotechnology. The research provides an understanding of concerns, opportunities, and the technical acceptability of users of nanotechnology solutions through the analysis of

wine producers' perceptions. The market acceptability of nanotechnology is examined by investigating the views of key market makers, especially intermediaries such as wine buyers, distributors, retailers, and sommeliers. Ultimately, the research contributes to broader discussions surrounding the use of technology in wine production, the construction of 'Brand New Zealand' (BrandNZ), and wine futuring in the face of increasing economic, social, and environmental pressures.

Chapter 2 Contextualising wine and technology

2.1 Introduction

This chapter first examines the assemblage of the New Zealand Wine Industry (NZWI) as discussed in existing literature. Second, it explores the current use of nanotechnology in the wine industry, and the present regulatory framework. Third, it summarises the technical potential of nanotechnology by exploring developments across the agriculture sector. Finally, it reviews existing literature on the perceptions of nanotechnology within international and local research.

2.2 The 'wine industry'

2.2.1 The assemblage of the NZWI

The New Zealand 'wine industry' is commonly narrated as a singular, homogenous, and observable entity. Commentators talk of 'the' industry (Brodie et al., 2006). For social theorists this is both inaccurate and unhelpful (Lewis, 2014; Prince & Lewis, 2013). To tackle the social construction of nanotechnology in wine, here, I focus attention on two features of this complexity.

First, the NZWI is marked by a series of pivotal axes of difference: size, age, ownership structure, and geographical location (Barker et al., 2001; Lewis, 2008; Hayward & Lewis, 2012; Lewis & Le Heron, 2018). When it comes to perceptions about wines, cost-benefits of new technologies, and the impact of nanotechnology on reputations or wine futures, it is crucial to recognise these differences. Perhaps the central difference in this regard is between wines (and the enterprises that make them) relying heavily on the reputation of place and winemaking practice to secure their market position and those centred on fast-moving-consumer-goods business models (Lewis & Le Heron, 2018). Overton and Murray (2021), for example, highlight the diverging interests between large agro-commodity wine producers and small-scale producers whose businesses rely on valued-added and market niches. They point to a 'race-to-the-bottom' in which bulk wine exporting undermines the niche market positioning efforts of fine-wine producers (Overton & Murray, 2021). Nanotechnology will mean different things for those making, selling, and consuming wines,

and will involve different environmental and economic implications. What this means for market perceptions, market impacts, and decision-making at a national level will be highly complex.

Second, more subtly the socio-technical regime that is ‘the industry’ needs to be understood as a complex assemblage of diverse actors as well as parts (Lewis, 2014). Assemblages such as the NZWI are a complex network of social, political, and economic actors and factors. They are political constructions rather than ontological entities and are not created out of thin air. They are governmental as much as they are economic and are created by practice and a host of discursive interventions (Lewis, 2008; Prince & Lewis, 2013; Lewis, 2014). Such assemblages undergo a constant process of becoming through the deliberate actions of producers, consumers, regulators, and others, including non-human actors (Callon, 2007; Lewis, 2014). While in this thesis I take the perspectives of the human actors, I consider these in the context of their articulation with non-human actors of nanotechnology (as a process and thing).¹

2.2.2 Winners and losers

Market-making practices—such as a shift towards nanotechnology—creates winners and losers. While the shared fates and collective efforts of New Zealand wine producers are often emphasised, there is an underlying and obfuscated structural competitiveness to the NZWI (Lewis, 2014). Callon (2016) argues that innovation is at the heart of competition between economic agents and is a driving force of economisation. Nanotechnology use is certainly a form of innovation, and has the potential to increase the competitiveness of the NZWI. Interestingly, Giuliani (2007) found that innovation and knowledge does not spread evenly within geographically clustered firms, so whether the benefits of nanotechnology will be seen industry wide is debatable.

2.3 The current nanotech landscape

2.3.1 Regulation of nanotechnology

Concerns around nanotechnology have led to various responses by regulators and governments. Nanoscale does not make material intrinsically hazardous, however it may pose different risks to larger forms. The British Royal Society and Royal Academy of Engineering (2004) recommended that despite the low evidence of health risk, all nanomaterials should be regulated and treated as if they were harmful. Rashidi and

¹ The theory and epistemology underpinning this assemblage framing are discussed in section 3.2.

Khosravi-Darani (2011) discussed the regulation of nanotechnology in food production, noting there were no special regulations, although governments were starting to consider labelling requirements.

In 2011 the New Zealand government commissioned a review into the adequacy of existing regulatory systems to manage nanomaterials (Moore & Gavaghan, 2011). This report found that nanomaterial will largely fall within existing legislation and regulatory frameworks, however, they noted a number of regulatory gaps and weaknesses. The report did not elicit significant government response or legislation change. Kihara (2021) reviewed the current regulations in Aotearoa.² He summarised that biocidal and industrial chemical products fall under the HSNO (Hazardous Substances and New Organisms Act), and nanomaterials are not subject to special notification, but do require Environmental Protection Authority approval. Food products are managed by the Trans-Tasman Food Standards Australia New Zealand and there is no notification or labelling system in place for nanotechnology.

2.3.2 Nanotechnology use in the winery

Although researched, winemaking applications of novel nanotechnology are not in commercial use. Australian researchers have experimented with using nanotechnology in protein fining. Protein instability can result in the formation of a haze in wine (Lambri et al., 2012). Currently, most wines are protein fined using bentonite, which is a negatively charged clay that absorbs wine proteins (Waters et al., 2005). While protein hazes are harmless, they present a cosmetic concern. Hazes are supposedly off-putting for the consumer, and if wine throws a haze after bottling it can be rejected by trade customers and consumers. Mierczynska-Vasilev et al. (2017) studied magnetic nanoparticles as a protein fining technology. They found these particles were able to remove haze-forming proteins without removing other desirable compounds such as phenolics.³ They suggest this would be an effective alternative to bentonite. One issue with using bentonite is that it fines indiscriminately (Pocock et al., 2011). Dumitriu et al. (2018) found that nanomaterial—by contrast—could prevent haze at lower doses and with less effect on volatile aroma compounds than bentonite, recommending its use where high doses of bentonite would otherwise be needed.

² Te reo Māori terms are not italicised in this thesis, in order to reject their framing in alterity. Māori place names are preferentially used. For clarity, organisations and collectives that include a place in their name are kept in English.

³ Phenolic compounds are responsible for red wine colour, and are a major contributor to mouthfeel, texture, and taste.

2.4 Technical potential of vineyard nanotechnology: making markets and constructing wine futures

Nanotechnology is a developing area with many potential applications in the agricultural industry, particularly in the context of plant nutrition, pest and disease management, and sustainability (Kah, Tufenkji, & White, 2019). These nanotechnology solutions in agriculture are likely to succeed if they target existing and well-defined problems (Kah, Tufenkji, & White, 2019). Versions of the below nano-enabled solutions could be relevant to the viticulture and grape growing sector in Aotearoa.

Kah, Tufenkji, and White (2019) reviewed nanotechnology in crop protection and nutrition. They cited literature dating back to 1999 on the promise of nano-enabled strategies, but note that the justification for these technologies is increasing with growing pressure on agriculture from shifting demographics, climate change, and land use competition. As has been discussed, the NZWI faces these same pressures. Aktar et al. (2009) believe a 20% improvement in any given measure is the minimum at which nanotechnology becomes worthwhile and competitive over conventional analogues. Kah et al. (2018) found that nanopesticides and nanofertilisers are 20–30% more effective than their analogue alternatives, highlighting their viability.

One area with significant discussion—but few published results—is irrigation and water use. Water is an essential albeit limited resource for most vineyards (Gabzdylova et al., 2009). The major use of water in Aotearoa is for agriculture with many key catchments, including Te Tauihu-o-te-waka, nearing the allocation limit of available irrigation water (Herath, 2013). Jägermeyr et al. (2015) found that traditional irrigation systems are only 50% efficient. Koman et al. (2017) constructed a system to measure stomatal closure as an indicator of plant water status, enabling smarter use of irrigation. Parisi et al. (2015) have found nanomaterials can improve soil structure and water holding capacity using zeolites and nanoclays. If these nanotechnology solutions could be adapted to the NZWI, they could reduce the water requirements of irrigation.

Another area of development is pesticides and fungicides. The International Union of Pure and Applied Chemistry (IUPAC) identified nanopesticides as a chemical innovation that will change the world (Gomollón-Bel, 2019). They note the need for field condition trials to build on promising laboratory results. Aktar et al. (2009) note that 10–75% of applied pesticides never reach their target. Cui et al. (2001) developed nanosensors to detect pathogens and stress using proteins and calcium. Chhipa (2017) concluded that

nanopesticides were better at pest protection than their conventional versions. One commonly used vineyard spray is copper, a fungicide to combat downy mildew (Morgan & Taylor, 2004). Kah, Navarro, et al. (2019) tested the rainfastness of copper applied at different formulations. 94% of copper sulfate was washed off, compared with 74% for ionic copper, 22% for Kocide (which is made with silica nano-particles) and <2% for both nano copper oxide and Tribasic blue. They showed that smaller particles experienced less run off. This has great relevance to the NZWI, as vineyard runoff harms waterways, people, and the environment (Gabzdylova et al., 2009).

Nutrition is another vital consideration. Hill et al. (2009) consider nutrition a key viticultural challenge for winegrowers. Verdenal et al. (2021) emphasise the importance of nitrogen nutrition in grapevines and that either an excess or a deficiency can have detrimental effects. New Zealand vineyards can face issues managing nutrition, fertility, and vigour (Wheeler et al., 2005). Chhipa (2017) concluded that nanofertilisers overall had better release and delivery effectiveness. Subramanian et al. (2015) emphasise the slow release of nanofertilisers which make them suitable for balancing crop nutrition. They note that nanofertilisers can be used for both macro and micro nutrients. These products could be used to achieve improved nutrition control, reduced chemical inputs, better balanced vines, and target yield attainment.

2.5 Perceptions of nanotechnology

There is skepticism towards nanotechnology despite no explicit evidence they are inherently dangerous. The notion of self-replicating nanobots converting the world into 'Grey Goo' was first mentioned in *Engines of Creation* (Drexler, 1986), and has stuck in the collective consciousness especially through media and science-fiction portrayals (Bowman et al., 2007). For example, the 2021 James Bond film *No Time To Die* features weaponised, indestructible disease nanobots that kill targeted individuals or groups based on their DNA.

The precautionary principle is one way to deal with developments such as nanotechnology that have significant uncertainties associated with their development and implementation. The precautionary principle places the burden of proof on those trying to implement something new, ensuring that risks and harms are well understood and managed (Sunstein, 2002). While this may be prudent, it also encourages paralysis and inaction which can lead to graver risks and harms than the change itself. Such was the case with Golden Rice, which has failed to gain acceptance despite offering solutions to malnutrition (Dubock, 2014). While GM is a superior method of crop breeding, societal suspicion and onerous enduring regulations hinder

progress at great cost to society (Dubock, 2014). As will be elucidated nanotechnology faces many of the same challenges that genetic modification (GM) faced (see section 2.5.3), and therefore a precautionary principle approach may impede its acceptance.

2.5.1 International perceptions

There has been considerable research on perceptions and acceptability of nanotechnology in non-wine products, particularly in areas like cosmetics where these technologies are already in use. Wright (2016) looked at the public perception of nanotech in sunscreens, where the use of nano-zinc particles can offer superior UV protection. They summarised that Asian markets tended to have a positive perception, with products being marketed there as nano-enabled to fetch a premium price. Australian consumers were more concerned despite the advantages of nano-sunscreens (Wright, 2016). Wright stresses the need for good and clear messaging to the general public on the advantages of nanomaterials. Kookana et al. (2014) similarly emphasise the need for transparency with the public regarding nanopesticide use. They maintain that unexpected behaviours by nanomaterials could lead to graver environment risks so products must be evaluated before release.

Despite its growing importance, there is a lack of understanding of nanotechnology, its uses, and its benefits and risks amongst the general public. Waldron et al. (2006) found that more than 60% of 28+ year olds in the United States had not heard of nanotechnology. They attribute this to the intangibility of the workings of nanotechnology. Kidd et al. (2020) similarly assessed public perception in the United States and found that 90% of respondents had no understanding of nanomaterials or their consumer product uses. Many needed more information before they were satisfied with using nanotechnology products. Chen et al. (2013) likewise found that attitudes depend largely on the perceived risks and benefits. Scheufele et al. (2009) found strong religious beliefs led to lower acceptance of nanotechnology as moral, and clear differences between public attitudes by country. This poses complications for New Zealand wine, which is exported globally and therefore requires near universal acceptability.

2.5.2 New Zealand perceptions

Cook and Fairweather (2006) researched the perceptions of nanotechnology by the general public. While this study is now 15 years old, it serves as a thorough examination of New Zealand attitudes. They found that the general attitude towards nanotechnology was favourable with most showing a fascination for the technology. There was also a high degree of unfamiliarity both with the technologies themselves and their possible effects. They also found that positive attitudes skewed to male, younger, and higher income groups.

In the survey there was a differentiation in acceptance between different applications of nanotechnology. Skin care products and food made using nanotechnology caused concern. Cook and Fairweather attribute this to an aversion towards personal exposure to nanoparticles. More broadly, the consumption of food and drink is a unique internalisation of an external (social, environmental, and economic) world and this has implications on the potential uses of nanotechnology. As Mol (2021) writes, walkers move through their surroundings while eaters move their surroundings through them. Therefore, a distinction should be made between vineyard uses and winery uses of nanotechnology. If nanotechnology is used in a winery setting this implies a higher personal exposure to the nanomaterials. Vineyard uses are (or are perceived to be) less likely to end up in the finished product, and market acceptability is likely to be higher.

2.6 Parallels to biotechnology/genetic modification

The challenges faced by acceptance of GM can provide valuable lessons for the development of nanotechnology. Dubock (2014) explored how despite being a superior methodology in crop breeding, societal suspicion of GM led to a restrictive regulatory framework that hinders development. He argues that legacy regulations which restrict GM—such as the Cartagena Protocol⁴—pose a bigger risk to health and the environment than GM itself. GM's lack of acceptability has led to 'selective breeding practices' that involve irradiating plants to generate mutations (Surakshitha & Soorianathasundaram, 2017). Since this is not 'technically' GM it is an accepted practice, despite the higher risk and total lack of precision.

Coles and Frewer (2013) draw a parallel between the current state of nanotechnology and the emergence of GM foods in the late 20th century. Their concern focuses on a lack of consumer information, regarding either risks or benefits to the new technology. They conclude that societal acceptance and ethical principles requires labelling nanotechnology use in food products. Mehta (2004) argues that a failure to consult with the public made biotechnology regulations unnecessarily complex, and that proponents of nanotechnology should learn from those mistakes.

In Aotearoa, Cook and Fairweather (2006) noted the high public concern towards GM and biotechnology. They warn that the introduction of nanotechnology would be difficult if its perceptions followed a similar trajectory to those of biotechnology. They suggest that the possible risks of nanotechnology could quickly

⁴ The Cartagena Protocol on Biosafety to the Convention on Biological Diversity. Signed by 170 nation states, it established rules and procedures on organisms produced through biotechnology. It emphasises the precautionary principle and upholds widespread restrictions of GM.

build resistance towards the technology, and this could set back research and development. They postulate that nanotechnology is likely to be better accepted than GM in food production, but without an advantage to the consumer is not likely to gain wide acceptance. They also suggest calls for identification of consumer products are likely.

Significantly, the international literature suggests that acceptance of, opposition to, and regulation of the nanotech revolution in agri-food will be influenced by the trajectories of GM (Coles & Frewer, 2013). This is not to say that levels of opposition or regulation will be the same or in any way lessened or intensified, but that attitudes are set in certain international and national trajectories. In Aotearoa, producers are typically self-governed by questions of market access in European and US contexts—especially for wine (Lewis and Le Heron, 2018). Regulators are similarly influenced by the challenges of achieving and managing market access. They are typically conservative and risk averse (McCoubrey, 2019). The GM story will be an important ‘actor’ in New Zealand wine’s nanotechnology narrative.

2.7 Conclusion

This chapter discussed the NZWI assemblage, and explored trajectories in nanotechnology developments in relation to how they might play out in ‘the industry’. The story is very much in its early days, with no research on the question. There are no wine specific nanotechnology initiatives and no regulations governing nanotechnology use in Aotearoa more broadly. Existing literature suggests that nanotechnology will have different combinations of risks, opportunities, and cost-benefits for different types of wine enterprises. Public awareness of nanotechnology is generally poor, and—in light of the GM experience—nanotechnology is likely to face significant acceptability challenges.

Chapter 3 Knowing wine

3.1 Introduction

This chapter begins by introducing the theoretical background and perspective of this research. The journey from ontologies of constructivism and post-structuralism to the research methods (section 4.3) is made clear. This concentric relationship is illustrated in Figure 1. This chapter ends with an exploration of how wine is constructed, including what makes wine acceptable and how this has implications for attitudes and values of nanotechnological interventions. Particularly, the role of collective branding and provenance in the construction and sale of New Zealand wine is considered.

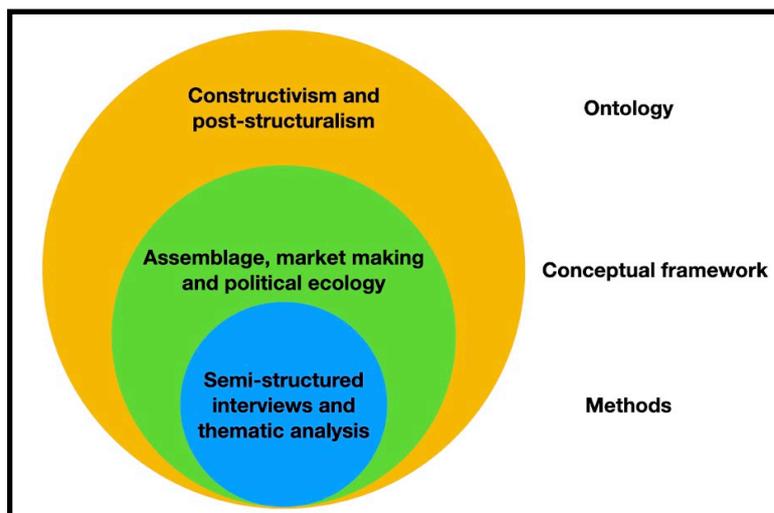


Figure 1: Methodological framework. Each section is informed and shaped by those surrounding it.

3.2 Epistemology to methodology

This research relies on a foundation of constructivism and post-structural political economy (PSPE). This research is cognisant of the work in the social construction of technology (SCOT) framework, that allows the exploration of multiple dimensions of nanotechnology (Cutcliffe et al., 2012). A social constructivist perspective on technology studies was first introduced around the 1980s and offered a respite from deterministic views (Pinch & Bijker, 1984). This perspective recognises that not only can technology influence society, but that society similarly influences technology. Social constructivism draws upon Foucault's work (1985) by focusing research on discourse, and how discourses are drawn and legitimised

through power, to privilege particular ways of seeing the world. Discourse can construct how people experience the world, so this research seeks to document such communications.

PSPE is the other ontology and framing which this research draws upon. Springer (2012) suggests that by combining political economy and post-structuralism an understanding of both 'agency' and 'structure' can be attained. Lewis et al. (2017) appreciate how detail on economy making is emphasised in PSPE, allowing a fuller view of complex economies. This makes it an appropriate choice for understanding the highly complex NZWI.

Relationality is a cornerstone of PSPE, and allows an understanding of the interaction of actors (Murdoch, 2006). Consequently, the world can be viewed as a web of relations which include the social, political, and economic. Returning to Foucauldian ideas, the power relations embedded within these relations are also worth uncovering and making visible. Çalışkan and Callon (2010) intentionally use socio-technical *agencements* as a framing of markets, in order to de-centre human agency and emphasise non-human actors and materialities. A political ecology approach similarly seeks to understand human-environment relations and sees nature as agential (Walker, 2005). Relationality therefore lends itself to assemblage thinking, and this project uses assemblage as methodology (see section 4.2.2). This project uses the concept of assemblage to understand the NZWI as dynamic and ephemeral. As constructivism and PSPE are ways of knowing and framing the world, assemblage allows us to see these things, practices, people, power relations, sites, and institutions as interconnected and related.

While markets are fundamental to our economic system, rarely are they studied themselves (Boeckler & Berndt, 2013). Callon (2007) frames 'economy' as a process rather than a predetermined thing. A market-making approach considers how markets are formed and looks at the actions and actors that create markets (Hall, 2012). This area of literature shifts the focus to how markets are constructed (Berndt & Boeckler, 2011). When markets are made, the basis of what is acceptable is socially constructed, and this infers acceptability and perceptions. Therefore, a market-making approach to understanding the political economy is utilised in order to assess the technical and market acceptability of nanotechnology. This research uncovers the perspectives of the human actors in particular (interviewees) as well as nanotechnology itself and how that interacts with wine.

3.3 What consumers want in wine

3.3.1 The social construction of wine

Wine quality is a rich source of debate in the literature. Commentators ask what is quality; how is it constructed; what is the role of materiality, social status, individual taste, and pricing in defining quality; is there a notion of quality beyond individual perception; is it stable; and how can it be measured and accounted for (Raftery, 2017; Parga-Dans & González, 2017; Benjamin & Podolny, 1999). At its core, wine is an alcohol with bodily effects and is commonly consumed in social settings—a social product that creates the conditions of its social consumption. As a pre-industrial product, wine has two central traditions. The first is as a locally produced, peasant object: the meanings (and qualities) of which are inherent in its collective consumption and the social conditions it creates. The second is as a traded object: the consumption of which connotes and creates social status. Quality is created by place of production and the intensity of viticultural and winemaking craft, often described together as ‘terroir’ (Van Leeuwen & Seguin, 2006; Lewis, 2014; Lewis & Le Heron, 2018). High status wines command high status prices and the source of that status is terroir, which is carefully regulated by its beneficiaries (Raftery, 2017).

For the purposes of this thesis, the key points in this debate are that intrinsic quality is uncertain, quality is constructed, place is central, reputation is important in higher-priced wines, and narratives of quality require careful management. From a market-making perspective, wines more than many other products must be qualified. Wines that travel out of local areas into national and international trade require branding and narratives. The more prosaic consumer preference literature confirms that extrinsic factors such as origin, label, place of bottling, and cues linked to tradition influence quality perception (Sáenz-Navajas et al., 2013). Consumers have no idea about the qualities of a wine without the technical and symbolic messaging conveyed on a wine label, or in background narratives associated with brand, varietal, or place of origin. Sensory perceptions and memory may impact later purchasing decisions. Wine is also an aspirational commodity, where consumers can imbue qualities onto wines and equally derive symbolic characteristics from them (Hayward & Lewis, 2008). Deliza and MacFie (1996) add that environmental considerations and the application of science such as nanotechnology can be part of this complex of messaging.

Marketing narratives often appeal to place and the artisanal tradition of winemaking, mixing peasant histories with those of more elite social status and positioning wines as unique (Overton & Murray, 2021). At the same time, fast-moving-consumer-goods wines produced at high volume for low margin by brand-led beverage conglomerates also tend to use place-based messaging (Hayward & Lewis, 2012). Brand and place are

often conjoined. While they too are vulnerable to brand or place-based reputational loss, they primarily rely on cost-reduction innovations to sustain their position in the market.

There are material differences in wine quality. Wines do have different 'tastes', that are to do with varietal composition, viticultural and winemaking craft, environmental factors, and business decisions including yields and cellaring. Wine has a wide range of aroma profiles that can be shaped in its making. They also taste differently to individuals (Hayes & Pickering, 2012). However, the social construction of wine qualities is evidently central to their perceived quality and their market values.

3.3.2 Brand New Zealand

Since the 1980s, New Zealand winemakers and wine industry authorities have pursued a national branding strategy for their wines. Aotearoa has long engaged in building a national brand to attract investment and migration, market primary products internationally, and promote tourism (Hall & Baird, 2014). The 100% Pure New Zealand tourism campaign was launched in 1999, positioning Aotearoa as 'clean and green'. BrandNZ remains of importance to exporters of a range of commodities including wine, cheese, lamb, and tourism (Overton & Murray, 2021). National narratives of quality have been used to position and differentiate New Zealand wine in international markets (Benson-Rea et al., 2011). Wine enterprises and authorities have adopted collective branding through their own Pure Discovery campaign and use of the BrandNZ fern. NZWG has promoted wines through BrandNZ, with the 'New Zealand' label carrying positive social, political, and environmental associations (Lewis, 2014). National branding further evolved in 2000 to include a focus on Aotearoa as cutting-edge and knowledge leading, which has meant that New Zealand wine has been marketed as both sustainable and innovative (Hall & Baird, 2014).

This strategy has been highly successful. This success is best illustrated by the success of Sauvignon Blanc, which makes up 85% of New Zealand wine exports and is understood to be a specific product with a clearly articulated and stable set of qualities (NZWG, 2021). Collective marketing through 'BrandNZ' and Brand Marlborough Sauvignon Blanc (MSB)⁵ has provided on-going success, attracting significant national and international investment and creating spectacular increases in production and exports.

⁵ In this thesis, 'MSB' and 'Te Taihu-o-te-waka' are used to refer to the wines and region respectively.

3.3.3 The construction of place: provenance and terroir

Wine is a product of provenance; the origins and production story of wine are framed as the key distinguisher of the product (Smith Maguire, 2013). Central to this is the French conception of 'terroir'. The term is often focused on the climates and soils of specific geographical locations, which impart particular material characteristics to wines through the agency of the grapevine. The microbial component of terroir is also gaining recognition (Knight et al., 2015), as are the effects of wild yeasts in wineries.

Terroir also includes place-based human factors. After all, it is how humans use the environment to craft wines and generate distinctive qualities that is at stake. Regulatory frameworks and accepted viticultural and winemaking practices are tightly entangled with environmental effects—from the trellising of vines, to pruning practices, yield controls, yeast selection, cellaring practices and so on (Moran 2000; Van Leeuwen & Seguin, 2006). Many of these practices involve tacit knowledge, know-how derived from grounded, place-based learning through practice. However, despite its essentially codified nature and short-term distinctiveness, science has become a part of place-based traditions—especially at more industrial scales of production. New Zealand wine gained distinctiveness for its rapid adoption of stainless steel tanks and screw cap closures. While these were quickly adopted elsewhere, they involved technical and market risks. Their success gave Aotearoa reputational advantages. This is not to say that adopting nanotechnology will result in similar gains, rather that science and experimentation are entangled in terroir, quality reputations, and product distinctiveness.

Overton & Murray (2021) stress that place is contested and malleable, and that a sense of place is actively constructed by various actors. They raise the question of the Te Ao Māori concept of *Turangawaewae*, one's 'place to stand' and where one is grounded (Morrison, 2020), as a deeper conceptualisation of terroir and one that has strong resonance with its use by French writers. Indeed the idea has been borrowed to encapsulate the geography, geology, and climate of vineyards (Forbes & De Silva, 2015). It has also been utilised by wine commentator Keith Stewart to think about the marketing of New Zealand wine (Stewart, 2001). While this thesis is focused more narrowly on perceptions of nanotechnology, it is important to see both individually oriented perceptions and the risks and opportunities of introducing new technologies in the broader PSPE of wine. Terroir and *Turangawaewae* are very much a shorthand for this constructed political economy.

3.4 Conclusion

Wine qualities are constructed, and the idea of terroir lies at the heart of this construction (Lewis, 2014). Brawner (2018) captures the idea neatly by referring to terroir as an assemblage of cultural and environmental factors. Nanotechnology will be another actor in this assemblage, with the potential to change these relations and how we observe wine.

Chapter 4 Methodology and methods

4.1 Introduction

This chapter outlines the project design, including the methods for data collection and analysis. The first section covers the methodology and theoretical perspectives which underpin this research. Then, the methods are presented, namely semi-structured interviews and thematic analysis. Finally, project ethics are discussed.

4.2 Methodology

4.2.1 Author positionality

It is prudent to begin a discussion of methodology with the positionality of the author. I am currently employed in technical viticulture and winemaking at a small-scale biodynamic and organic wine producer in Central Otago. My professional background is wine and I have spent most of my working life working either in winemaking, wine distribution, or on-premise hospitality. In this sense, I am a wine industry insider. This research brings to bear my esoteric expertise in the field and my determination to learn within it.

Positivists criticise interviews as researchers can bias the answers of participants leading to non-objective results. England (2004) argues that all social science research is informed by the researcher's own aims, interpretations, and experiences. There can be no such thing as objectivity in the social sciences. This is widely accepted in post-structuralist and other forms of constructivist research. Notwithstanding this ontological position, I also recognise the responsibility to present the data gathered as rigorously, honestly, and authentically as I can, for both ethical and scholarly reasons and to appropriately represent my interviewees.

4.2.2 Assemblage as methodology

Baker and McGuirk (2017) argue for the use of an assemblage methodological framework in understanding political-economic structures. Le Heron et al. (2013) challenge economic geographers to see wine as assemblages, and argue for the value in considering potential and future relations through assemblage

thinking. Assemblage can illuminate multiplicity, uncertainty, the labour of assembling, and emphasise the actively composed relations between heterogeneous actors and agential elements. Careful attention is paid to the diversity of the actors and interests that make up this assemblage, and this project seeks to represent the disparate views of these actors. This is achieved by following the material and discursive transformation of wine by all actors. As aforementioned, this includes a rejection of the conventional framing of the NZWI as a monolith singular entity and recognising its complexity (Lewis, 2014; Prince & Lewis, 2013). This challenge of setting aside *a priori* assumptions and preconceptions is vital to an assemblage methodological approach, and allows a fresh understanding of New Zealand wine as it relates to nanotechnology.

4.3 Methods

4.3.1 Research design

This project uses qualitative research methods to explain human experiences and environments. Winchester and Rofe (2010) pose two fundamental questions for qualitative researchers. First, “what are the shapes of societal structures, and by what processes are they constructed, maintained, legitimised, and resisted?”, and second, “what are individuals’ experiences of places and events?”. They highlight the potential that qualitative research offers. The alignment with the aims of this research is clear. As a project that asks questions concerning the individual perception of nanotechnology and the broader implied technical and market acceptance of nanotechnology, qualitative methods are the appropriate choice.

4.3.2 Data collection

Primary data was collected through semi-structured interviews. Interviews are a well utilised data gathering method in qualitative research (Legard et al., 2003). Webb and Webb (1932) define interviews as “a conversation with a purpose” and these conversations form a crucial part of social investigation and field research in the social sciences (Burgess, 2003). In this research, interviews were designed to elicit perspectives on nanotechnology from industry actors at various stages along the wine industry supply chain. Interviewees were asked to give their perspectives on nanotechnology and to reflect on its risks and opportunities for New Zealand wine.

Interviews are not intended to provide representative data, instead they provide a deeper understanding of individual circumstances (Valentine, 2005). Bechhofer (1974) explains that structured interviews do not allow sufficient follow up on interesting ideas and that overly formal interviews ignore everyday life. Semi-

structured in-depth interviews allow for the expression of informant experiences in a less constrained format, with the flexibility to follow unexpected turns (Valentine, 2005). Feminist research concepts assert that participants are humans to be engaged with and not subjects to be researched (Davidson & Layder, 1994). This project upholds that view, and hopes that the interview provided a beneficial space for self-reflection of the participants.

Key informants consisted of active members of the NZWI (as 'market makers'). Fifteen semi-structured interviews were completed in late 2021. The interview question schedule is included in Appendix I. These were conducted in a mixture of formats: in person, online through Zoom, and over the phone.

The study's interviewees included winemakers, viticulturists, technical directors, wine writers, salespeople, sommeliers, brand managers, and retailers as shown in Table 1. Many of the people interviewed worked across multiple functional areas such as a technical director who oversaw viticulture and winemaking, or a salesperson who also managed an education program. Table 2 highlights the interviewees primary location in Aotearoa. While most were based in either Tāmaki Makaurau or Te Taihū-o-te-waka, many of these informants had interests or responsibilities in other regions, including 3 who spent much of their time abroad. Table 3 shows their spread across a variety of scales of operation, with 4 interviewees from large companies (with significant market share) and 6 from small independent businesses.

Participants were recruited through various pathways. I used existing contacts in the wine industry to recruit 4 participants. Gatekeepers are individuals with the power to grant access to others (Valentine, 2005), and these helped me to recruit 5 participants. An appeal on social media and word-of-mouth yielded another 3 participants. Cold calling (more appropriately cold emailing) had a lower success rate than the other methods, but garnered 2 participants. Finally, Valentine (2005) suggests snowballing as a useful method in gaining trusting participants, where one contact recruits another contact; this provided the fifteenth participant.

The interviews, with prior permission from the informant, were audio recorded in order to retain an accurate record of what was said. Interview recordings were transcribed, with memos taken during the interviews. These informal notes provided reflexive qualitative data to complement the interviews.

Involvement in the industry	
Interviewee #	Self described industry role
1	Owner (sales & viticulture), South Island wine estate
2	Contract viticulturist, South Island
3	Wine writer
4	Fine-dining sommelier
5	Senior winemaker, North Island
6	Operations manager (viticulture & winemaking), large wine producer
7	Winemaker, South Island
8	Brand ambassador & Wine Educator
9	Chief winemaker
10	Winemaker & site manager, South Island
11	Wine writer
12	Distributor & retailer
13	Owner (sales & Winemaking), South Island wine estate
14	Vineyard/viticulture, South Island
15	NZWG

Table 1: *Interviewee role in the NZWI.*

Primary locations of participants	
Region	Number of participants
Tāmaki Makaurau	7
Te Taihū-o-te-waka	5
Te Matau-a-Māui	1
Whakatū	1
Ōtākou	1

Table 2: *Interviewee location.*

Scale of market share	
Size and nature of employer/business	Number of participants
Very large multinational	2
Very large NZ company	2
Medium sized NZ company	4
Small independent business	6
NZWG	1

Table 3: *Scale of employer/business of interviewees.*

4.3.3 Data analysis and interpretation

Thematic analysis (TA) was used to make sense of the qualitative data. TA is a method for identifying patterns and themes from a dataset in relation to the research question and is the most widely used method for qualitative data analysis (Braun and Clarke, 2013). Constructionist TA examines how topics are constructed and how these build the world. A key attribute of TA is it only applies to the analysis of data, and can work with any dataset or research question (Braun & Clarke, 2012).

The approach developed by Braun and Clarke involves six steps:

1. Reading the data for familiarisation.
2. Coding or labelling the data, and collating that for later stages.
3. Identifying initial themes. Using the collated data to find larger patterns and sorting the data by theme.
4. Reviewing and refining the themes. Ensure the themes reflect the data and answer the research question.
5. Defining and naming the themes. Analysing the themes creating a story for each.
6. Writing up. Using the themes to weave an analytical narrative and contextualising this with the literature.

This method works well with exploratory research and has the advantage of developing themes from within the dataset without being linked to a particular epistemology. This means it enables the analysis of semi-structured interview data and supports using assemblage thinking and a constructivist ontology.

4.3.4 The impacts of COVID-19 on methods

When this project was designed, field research was planned to include site visits and observations. This would have involved visits to wine businesses across Tāmaki Makaurau as well as travel to the major wine production areas of Te Taihū-o-te-waka and Te Matau-a-Māui. Unfortunately, community cases of COVID-19 in August 2021 meant the study had to be adjusted to rely predominantly on Zoom and telephone interviews. Restrictions also precluded the originally planned ethnographic activities, to observe either the use of technology or the associated narratives in vineyards, wineries, cellar doors and other sites of the industry. Additional desk-based work was performed in order to get a sense of the use and narratives surrounding technology. This consisted of analysing wine business websites and industry publications.

4.4 Participant ethics and data protection

Research comes with researcher responsibilities and obligations towards the participants involved. Ethics approval from the University of Auckland Human Participants Ethics Committee was gained prior to data collection (reference number UAHPEC23253).

The privacy and confidentiality of participants was upheld, with all data being de-identified prior to publication. All personal information and research data were securely stored, with audio recordings being destroyed once transcription was completed. All participants were provided with a project Participant Information Sheet (Appendix II) and informed consent was sought in writing (Appendix III).

4.5 Ethics of wine research

Studying wine from a critical perspective raises some ethical contradictions, especially when it is premised at some level on supporting those who produce and sell wine. Wine is fundamentally an alcoholic product. Rehm et al. (2017) note that alcohol is a significant contributor to morality, injury, and the burden of disease. Alcohol addiction is the third highest cause for loss of disability-adjusted life years in men (Rehm & Shield, 2019). Svensen et al. (2019) found that 7% of emergency department presentations in Tāmaki Makaurau were alcohol related, and stressed that 20% of New Zealanders are engaging in 'hazardous drinking'. Research that propagates an industry that causes such harm is ethically ambiguous.

Wine production can also cause significant environmental harm, and New Zealand wine has a chequered environmental history (Gabzdylova et al., 2009). This raises ethical issues both for knowledge production generally, and the potential implications of nanotechnology use especially if it enables greater intensification. While 96% of New Zealand's vineyards are certified under the Sustainable Winegrowing New Zealand (SWNZ) program (NZWG, 2021), SWNZ wine production still involves intensive farming with the associated water use, pollution, carbon emissions, and waste production. Most significantly, in parts of the country (most obviously Te Taihū-o-te-waka), it has become a monoculture. It has closed out other land uses and raises significant environmental risks.

Finally, wine is entangled in exclusive circuits of national and international capital. It involves the ownership of expensive land, the production of expensive products, and the construction and perpetuation of social status. As well as perpetuating capitalist and colonial economic structures, it has resulted in the foreign ownership of land and provides for few jobs other than those taken by cheap, seasonal, short-term migrant labour. It does not have to be this way, but this is how the industry has developed (Lewis & Le Heron, 2018).

The wine industry has much to answer for. Seymour (2021) argues that the social costs of existing agri-food systems have generally been normalised, making them resilient to critique. The wine industry is particularly problematic due to the alcoholic nature of the product. Wine's unseen and undiscussed externalities disturb me as both an industry participant and a researcher, and those involved tend to skirt these conversations.

Chapter 5 Results and discussion

5.1 Introduction

This is a mixed results and discussion chapter. Five key themes from the data are explored and contextualised with the literature and unique context of the NZWI using constructivist and PSPE ontologies. This chapter begins by discussing the awareness and perception of nanotechnology, as well as visualising the major actors and elements involved in the assemblage that is the NZWI. Then, financial imperatives are investigated. Namely, the cost of nanotechnology, the motivations of industry actors, and non-monetary incentives for nanotechnology adoption. The inherent tensions between Fordist-style industrial production and small scale niche differentiators are uncovered, and implications for nanotechnology are discussed. Next, the theme of the precautionary approach is examined. This includes the fears that informants expressed, their understandings of food safety, and regulatory requirements. The fourth theme is of innovation and current technology use in the wine industry. In particular, the eagerness of wine producers to trial new technology if it could solve the issues they face, and the widespread acceptance of technology use in the NZWI. Finally, how nanotechnology might play into the various social constructions and 'brands' of wine is discussed. This includes collective efforts under BrandNZ, organics, and the construction of wine production as artisanal, traditional, and boutique.

5.2 Nanotechnology as nebulous

Vineyard nanotech is ill-defined and uncertain as it has not seen adoption in Aotearoa, so wine actors have not yet been confronted with it. This research consists largely of nanotechnology futuring, examining how nanotechnology is defined, and revealing the assemblage of the NZWI and nanotechnology.

5.2.1 Nanotechnology awareness

Awareness of nanotechnology ranged amongst interviewees and could largely be divided into three camps. The first was those who had little awareness of nanotechnology as exemplified by Interviewee 1 "I must say, I've never really considered nanotechnology, you know? I mean it's not something that's in my lexicon or in my immediate sphere....maybe I just don't know about it." This aligns with the literature (in section 2.5) on

public perceptions such as Kidd et al. (2020) and Waldron et al. (2006) where a lack of awareness and understanding of nanotechnology was shown.

Some interviewees had heard of nanotechnology but not in the context of wine or grape growing. “I have not really thought of winemaking and nanotechnology in the same breath” (Interviewee 9). This winemaker was not alone in associating nanotechnology with other uses such as medical interventions, and being unfamiliar with its use (or potential) in the vineyard or winery. Interviewee 14 said “the more I think about nanotechnology, it’s just got a creepy connotation. Which is 100% just from science-fiction movies and pop culture because I don’t really know much about nanotechnology.” Their experience of nanotech was limited to movies and media where nanobots were weaponised, leading to a negative perception. Campbell and Fitzgerald (2001) suggest that the use of new technology in agri-food can highlight existing concerns over the role of technology and personal bodily integrity. In contrast, Interviewee 2 was fascinated by nanotechnology “because to me nanotech sounds like something that you’d see in an Iron Man movie. That’s really, really cool.” This shows that popular portrayals are not always negative, and that a science-fiction association is a positive for some individuals.

Several interviewees were aware of current nanotechnology developments in the wine industry, however these were exclusively from large and multinational companies such as Interviewee 6 “[I am] broadly aware of some of the opportunities in that space, some of the things that have been worked on” and Interviewee 8 “it’s something that we know about that, but really does not come up in terms of our day to day communications.” These larger companies appeared to be abreast of technological innovation and research, with a noticeable split of interviewee understandings based on their profile.

5.2.2 How nanotechnology is understood

While the technical definition of nanotechnology has been explored (see section 1.2.1), informants had their own understandings of the term. There was a general appreciation that nanotechnology was defined by size: “nanotechnology is just very small particles” (Interviewee 3), “it is just ultra small particles, that’s basically the simplest way to explain it” (Interviewee 5).

There was some scepticism towards the usefulness or purpose of this term. Some participants saw little distinction between nanotechnology and existing wine industry practices:

Nanotechnology sort of sounds a bit scientific, but if you think about what we do: we use microbes to ferment sugar and turn it into alcohol as part of the winemaking process. So there’s kind of a

nanotechnology approach in its own right...is it nanotechnology or is it just chemistry? I think there's a very fine line anyway, and it's just a matter of definition (Interviewee 6).

Here Interviewee 6 likens the use of nanotechnology to the extant use of yeasts and bacteria to manipulate grape juice into wine, and does not see nanotechnology use as particularly disruptive. This quote highlights how the minuteness of nanotechnology is poorly appreciated, by equating nanoparticles with much larger microbes.

Others appreciated the diversity of nanotechnology, and questioned whether the umbrella nature of the term rendered it meaningless.

There'll be a lot of things that I might like, and some things I might not like at all, depending on how it's applied and what it's made of.. it's quite a broad thing, isn't it? You couldn't just say I'm for it or I'm against it, you'd want to know what application you're talking about (Interviewee 9).

As this winemaker points out, the broad nature of this term limits the scope of the results from this research. An important caveat to a generalised discussion on nanotechnology is that any specific product or technology needs to be evaluated on its individual merits: effectively this discussion of nanotechnology is preliminary and general.

5.2.3 The assemblage

Using assemblage as methodology required following the relations of New Zealand wine from production to consumption. Figure 2 maps the relations of key actors and agential elements that make up the NZWI with respect to nanotechnology. Included here are human actors (such as wine writers), non-human actors (such as pests and diseases), socially constructed discourses (such as provenance), socio-technical devices (such as SWNZ), and key sites of governance (such as HSNO).

The arrows represent not only material transformations but include symbolic flows and mediations. The figure argues for an understanding of 'the industry' as multiple and relational. The disaggregation of the NZWI disrupts conventional industry led framing (Le Heron et al., 2013), and shows the many sites where nanotechnology can have an impact. For example, while the technical acceptability of nanotechnology is clearly important, so too is the potential impact on BrandNZ, MSB, and provenance. Figure 2 aims to present a fundamentally new way of ordering the New Zealand wine economy. In making this diagram, strategic choices were made deciding what to emphasise and what not to include. As far as was practical, actors and factors mentioned by interviewees as important to the nanotechnology story have been included, and many of these are explored in the discussions that follow.

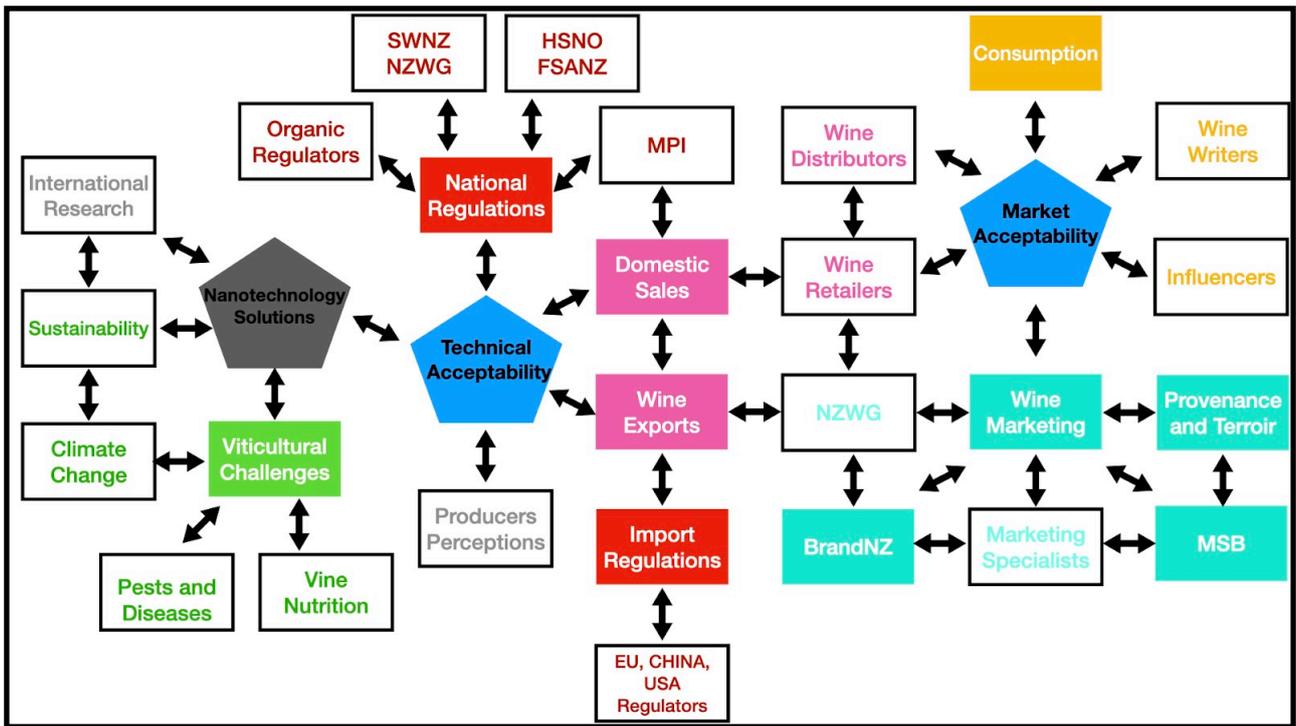


Figure 2: NZWI nanotechnology actor network. Colour coded: green for environmental; red for regulatory; pink for sales and supply chain; teal for marketing; yellow for consumption.

5.3 Financial imperatives

5.3.1 Cost as a deciding factor

Cost is one of the main factors considered when wine businesses invest in new technology, and nanotechnology will need to prove cost effective. The potential cost of nanotechnology featured in every interview. Interviewee 2 summarised this as “cost would be really one of my questions” and Interviewee 10 remarked “how much it will cost us? If it was a free trial, [then it’s] always welcome.” Nanotechnology that could reduce costs was seen as highly desirable. Interviewee 15 remarks:

Cost[s are] an interesting thing. They always tend to rise. When you look at labour costs, cost of regulation, cost of doing business, cost of inflation...cost tends to only go one way, cost is going to keep going up. And so if a technology is out there, which is going to reduce those costs significantly... it starts to make sense in terms of an investment.

As they point out, if costs are ever increasing it presents a constant challenge for the NZWI to maintain export competitiveness. This is especially important since the costs of production in Aotearoa are already high by international standards, therefore novel technology presents a solution to these pressures.

Interviewees suggested new technologies that result in long term savings—despite high upfront costs—can be highly desirable. Chippa (2017) suggests this may be the case with nanotechnology. Interviewee 2 spoke to nanotechnology spending replacing “chemical and/or mechanical” spending in the vineyard. Initial cost is not necessarily the determinant, rather the return on investment or cost-benefit ratio. Interviewee 15 said “if you can get early adopters who can then really highlight its benefit versus its cost...that’s the best thing you can do to promote any new technology” suggesting industry members can be powerful advocates as they are more trusted by other insiders. These benefits can be either quality based or resource-saving based, with Interviewee 10 explaining that “normally, the combination of both are the ones that are actually the easy ones to get across the line.”

5.3.2 Tensions between large and small producers

An unexpected theme from this research surrounds an intra-industry dichotomy between large and small producers. This has implications for technology needs, and the social construction of wine more generally. There were also several interviewees who expressed concern and animosity towards the actions and business models of larger wine companies.

The delineation between large scale producers whose focus was on cost of production and smaller wine producers focused on quality was evident through the interviews. A major distinction in attitudes was primarily driven by volume of market share and business model. Interviewee 5 speaks of the “two camps” consisting of “boutique small players” who retain “elements of winemaking that have been in play for generations” against the “bigger wine companies” who “are making a huge amount of volume wine.” This aligns with the existing literature discussed in section 3.2.1 such as Overton and Murray (2021). Interviewee 5 goes further to suggest that these differences mean that the technological needs are quite different: “there’s different technologies there that need to be considered when you’re producing larger volumes of wine. So for instance the clarification technology that’s around, and also the stability technology that’s coming on.” While many smaller producers attain wine stability naturally (with time, such as through barrel ageing of wines), this is not feasible at the industrial end where time to market is a key factor.

The interests of larger producers for nanotechnology lie in either decreasing costs, reducing production time, or increasing quality without increasing costs (Interviewee 6). There was a subtle animosity expressed by some informants for the sacrificing of quality to increase quantity by such producers. Interviewee 1 said “the big companies are different. Things are done by recipe...that’s sort of rote winegrowing...they all do the same thing because it’s all about efficiency.” This particular informant had previous experience with a

multinational wine company but had shifted their focus to quality with a smaller, organic wine estate. Interviewee 2 mentioned they were scared by the focus on high yields in some of the vineyards they managed: “it's all a numbers game...what scares me the most about that is you know that you're definitely reducing the quality just to gain the quantity.” Interviewee 13 agreed that to “a lot of the big people it's just about money.” This malaise mirrors what Overton and Murray (2021) reported, whereby high-end producers feel their pursuit of quality is undermined by opportunistic, Fordist-style producers. Interviewee 12 pronounced:

At the top end, it's about image, it's about quality, it's about what wine reviewers say...so it's not a made up thing. And then at \$18 and underneath, it doesn't really matter that much...there's no crafted story to that, there's no value proposition to that, other than a cheap price point. And they would argue with me about this.

This distributor/retailer was clearly aware of the contentious nature of this animadversion, but felt strongly that many of the collectively constructed narratives surrounding New Zealand wine (namely provenance, sustainability, and quality) were being exploited by larger producers. If nanotechnology use is led by these large producers, it could fuel this animosity and tarnish nanotechnology in the eyes of small producers.

Others, such as Interviewee 8 (who works for a multinational) framed the growing investment in the NZWI as a positive. When asked to name the biggest change they have witnessed in the industry, they responded:

The growing involvement of multinational companies in the New Zealand industry...You are beginning to see overseas companies buying into New Zealand, which is a good thing, because what it does is it provides us with ready access and distribution into markets that we may not have thought about previously...[small producers] create the image and desirability, and the [large producers] create the availability, or the accessibility. As an industry, category three, category two, category one wineries all work very well together.

They saw these two ends of the industry complementing each other as smaller producers can draw the high profile media attention but lack the volume and breadth of product offerings in the marketplace that the large companies provide. This corroborates the views of Lewis (2014) that while the NZWI contains both a fine-wine and bulk industry these are not necessarily at odds. This view was echoed by Interviewee 15 from NZWG who diplomatically said “our industry is very heterogeneous” and viewed the diversity of business models as a strength rather than a conflict.

5.3.3 Non-monetary drivers of technological shift

While financial motivations are central to the NZWI, there were several non-monetary motivations mentioned across interviews. Some interviewees were interested in nanotechnology based solutions to specific

challenges they face while others were interested in anything that offered quality improvements. Important areas where further solutions are desired include labour, sustainability, and pest and disease management.

There was a near universal acknowledgement of labour being a key issue for the NZWI. Interviewee 1 said “If anyone tells you [labour] is not an issue for them, then I don’t know what planet they are on.” Many producers expressed a willingness to implement technology that could reduce labour requirements, especially short-term casual workers during peak periods, the shortage of which was exacerbated by COVID-19 (as discussed by Interviewee 7). This drives automation, mechanisation, and an increasing interest in technologies that improve efficiency. Thus, for example, nano sensors that provide automatic monitoring or nano sprays—that through improved rainfastness last longer and require less frequent tractor passes—could appeal by reducing vineyard labour requirements.

The increasing compliance burden of health and safety, and the need to reduce hazardous activities in the vineyard and winery are another key motivation for the deployment of technology. Interviewee 7 emphasised that “in the future things like health and safety laws” will be a major driver since some existing practices are “seen as pretty bad from a health and safety perspective now.” Intermediaries such as wine writers also understood these labour challenges: “we can’t rely on the labour force, which puts an increasing pressure on mechanisation” (Interviewee 3). While nanotechnology is unlikely to be the silver bullet to labour issues, any workload savings would be appreciated by industry.

Many producers at the smaller end of the scale—those that were family owned rather than beholden to shareholders—expressed that profitability was not the only decision-making factor. Indeed, several informants expressed how profitability could be sacrificed to raise quality. The NZWI is also known to include businesses that are intended to be unprofitable (Sugand, 2014). While some are premised on tax strategies or capital value gain and have little intention of being profitable in their own terms, many small firms face profitability problems. Smaller wineries often rely on cellar door sales and face vintage to vintage struggles that have been exacerbated by the pandemic (NZWG, 2021), while many small-medium sized firms must balance scale with the highly competitive middle-price range markets (Lewis & Le Heron, 2018).

Consequently, it is reductive to frame technological investment as an essentially financial decision. Interviewee 2, for example, speaks of their experience with high end wineries “if money needs to be spent on something important it’ll just be done.” This sentiment is shared by Interviewee 1 who remarked “we are definitely compromising profit for quality a lot more.” This prioritisation of quality over profit undoubtedly contributes to the tensions explored in the previous section.

The other areas where technological solutions were most wanted surrounded pest and disease management and environmental sustainability. Interviewee 11 said “I think anything that makes the life of the grower easier, it's got to be good.” Interviewee 6 was more specific, stating, “I'm really always looking for technologies that might help us...in terms of reducing waste streams or water use...around sustainability. So anything that helps contribute to that would be something we'd be interested in.” Some interviewees mentioned specific vineyard pests and diseases that they hoped nanotechnology could assist in such as trunk disease, grass grub, and bronze beetles. Interviewee 2 stressed the need for the industry to reduce its climate impact:

I don't know if you've noticed but the Earth is not exactly getting any cooler anytime soon. It's not exactly a really great prospect for viticulture and winemaking in this country, in this world...what's it all for now, if we're not actually making a big difference.

Interviewee 13 spoke of their similar motivations “ours wouldn't be about cost, [but] if we could utilise something that would decrease inputs, yes we would be really interested.” Therefore, nanotechnology that can present solutions to major sustainability or pest and disease issues facing the NZWI will pique interest.

5.4 The precautionary principle, for human and environmental health

While nanotechnology is not new, it was new to many of the interviewees, some of whom suggested a precautionary approach was warranted.

Nanoparticles can get into the body and damage DNA cells, producing free radicals...the gloomy side too, plenty of that. So it's obviously a very fascinating piece of technology that has to be embraced with caution, I would think (Interviewee 3).

The perceived potential threat to human health was a non-starter for this wine writer, who went on to say “I would have to be assured that it was safe.” This section will explore regulatory and food safety concerns as well as the specific fears raised both of nanotechnology itself and the potential impacts on the image and reputation of the NZWI.

One version of the precautionary principle was raised by a winemaker who argues that the challenges Aotearoa faces are not yet existential, and therefore do not require the adoption of ‘unproven’ technology. “We're kind of in a holding period at the moment where we're actually okay to sit on our laurels for another few years” (Interviewee 7). Since the viticultural challenges Aotearoa faces are perhaps not as grave as

other regions such as Australia, perhaps we should allow them to experiment with new technologies first. This would insulate Aotearoa from any potential negative consequences, and allow us to wait until these technologies are well adapted and understood.

5.4.1 Regulatory framework: food safety and public health

There was a clear distinction made between nanotechnology use in the vineyards (with an expectation that no nanoparticles would be consumed) and the use in winemaking (where nanoparticles could remain in the product, and therefore be consumed). While vineyard use was generally considered to be acceptable, the idea of consuming nanoparticles was treated with heavy caution. “I can't imagine that would be very harmful to anyone unless it goes into the grapes and thus wine.” (Interviewee 3). This supports the findings of Cook and Fairweather (2006) who found a clear delineation between nanotechnology use generally, and nanotechnology use involving personal exposure to nanoparticles.

As wine is ultimately a product to be consumed, food safety and public health are of utmost importance. Interviewee 6 expresses that this does not preclude the use of nanotechnology, but it does require caution:

There's lots of tools we use which are simply manipulating molecules at that kind of nano level anyway, and so to me it's not something you necessarily need to be afraid of deploying. It's just doing it within the context of producing a food product.

There is a clear social, ethical, and legal obligation—as well as an economic imperative—to deliver a product that is ‘safe’ to consume. The unarticulated conflict in this narrative is, of course, that wines typically contain 12–15% ethanol which is a known carcinogen and poison.

There was an expectation that any nanotechnology was safe, “obviously, you will have to look at, especially in the case of winemaking, food safety” (Interviewee 1). A prerequisite for any novel technological adoption was regulatory approval. Interviewee 9 said “we're not a research facility, what we're making gets sold. So everything has to be certified before we can use it, that's for sure.” This expectation was additionally voiced by Interviewee 6: “as an industry it is reasonably highly regulated in terms of acceptable practices. And there are reasonable pathways for getting new technology accepted into that regulatory framework.”

Accordingly, regulators will need to be convinced of the benefits (and lack of risks) of nanotechnology before they become available to grape growers. Interviewee 15 from NZWG highlighted their advocacy role with the statement “it's about finding out what those rules and regulations are and acting consistently with them, or lobbying to change them if you think they're unworkable.” Interviewee 10 expressed frustration at the

complexity of satiating multiple export markets with a single wine “you've got restrictions going to China, you've got restrictions going into Europe. Making one wine that suits everyone is pretty much nearly impossible.” Industry bodies such as NZWG can advocate and lobby governments to streamline and simplify such regulatory hurdles, and this would be a crucial step prefacing widespread adoption of any novel technology.

One question that divided respondents was whether they thought nanotechnology use should be declared on wine labels. Some, such as Interviewee 8 thought the consumers would be ambivalent:

At the end of the day, people don't want to get too engaged and too involved in the process, they are more interested in the outcomes...all the consumer cares about is it makes them feel good, that it tastes great.

Others disagreed, such as Interviewee 14 who maintained that consumers should have a right to know. Interviewee 3, a prominent wine writer, suggested that “you'd be better to tell them...because in two seconds, they can start to do some research.” They suggested it was better to craft good messaging as an industry than to attempt to hide its use. Interviewee 9 claimed “nanotechnologies are probably not gonna sound sexy to many wine consumers.” In contrast, Interviewee 2 went as far as suggesting that “it would be quite cool to have a nanotech logo label that goes on the back of a bottle” as “it's an interesting piece of technology...you probably want your customers to know as much as possible.” This was certainly not the majority view, although practiced in other markets (Wright, 2016), but it highlights the multiplicity of perspectives on nanotechnology within a relatively small sample of industry members.

5.4.2 Fears

Some informants expressed specific fears of nanotechnology which will be explored here. One such fear was that technology use could go too far. Several likened nanotechnology to GM and this association was seen as a potential threat to the market acceptability and reputation of the NZWI. Vaccines were also mentioned, as these have been accused of containing nanobots by conspiracy theorists.

While most informants appreciated the role of technology in grape growing and wine production, there was a fear that nanotechnology could be taking this too far. Interviewee 4 said “technology is great in a way... nanotechnologies seem a little borderline. [The use of nanotech] shrinks the importance of a winemaker or viticulturist...so that's probably the danger of advancing too much.” They saw nanotechnology as upsetting the current power structures (which are centred upon the human actors) in wine production, and implied this would lead to lower quality wines. Interviewee 11 agreed that technology can be overused:

Have you ever drunk...California for example? I mean Christ, it all just tastes like alcoholic Ribena really. It tastes of blackcurrants, big alcohol, and Mega Purple....I think you can go too far in both directions.

These concerns are not solely levied at nanotechnology, and speak to unresolved questions surrounding the use of technology in the wine industry. Interviewee 3 explicitly categorised nanotechnology as “uber, uber invasive” suggesting this was an extreme technological intervention. Interviewee 10 compared technology to an umbrella “you have it and you only use it if you really have to.” Some of these ideas will be picked up in the coming discussion (see section 5.6).

Several informants feared an association of nanotech with GM. Interviewee 8 argues “you've got to be careful that nanotechnology doesn't become equated with GM. Because GM does not have a ‘positive consumer perception’.” This aligns with the literature (in section 2.5.3) such as Coles and Frewer (2013) on the parallels between nanotechnology and biotechnology. Interviewee 10, a winemaker, called GM technology “a no go” for their business, while Interviewees 11 and 14 expressed frustration at the unacceptability of GM in grape growing. “There's another thing where people misunderstand, because GM is different than what they think it is” (Interviewee 11). If nanotechnology was either associated directly with GM or garnered similar negative connotations, it could render its use untenable despite material benefits, as was the case with Golden Rice (Dubock, 2014).

Recent anti-vaccine conspiracy theories have included the suggestion that COVID-19 vaccines include nanobots and this was front of mind for Interviewee 12:

The first thought that came to mind [regarding nanotechnology] is the Pfizer COVID vaccination and that people are sticking little things in your arm. And I think it's really funny. Yeah, Bill Gates is putting nanotechnology into your arm.

Despite the absurdity of these false claims, there was some concern that these could hurt the image or reputation of the industry. Interviewee 2 notes:

There'll always be someone out there who thinks that it's going to control you. So if you're thinking of the bigger picture, there's always gonna be someone who [thinks] it's brainwashing or it's gonna give you really good 5G or something. It's a point to be considered.

They likewise compare nanotechnology to the current vaccination conspiracies. Interviewee 14 similarly states “people are very worried about what goes into their bodies these days,” and suggests that consumers may need to be reassured that “there's no trackers getting onto your bloodstream.” Not only will

nanotechnology be potentially lumped with such conspiracy theories, but the term 'technology' is itself loaded with potentially negative connotations. Interviewee 12 suggests:

Maybe it needs to be rebranded into something else rather than nanotechnology? Nano tech is like, whoa, hold on. Tech speaks of billion dollar US companies...mad scientists sitting there devising stuff.

Whether the unwanted baggage from discourses of nanotechnology warrant a rebranding of the term, or whether that would simply be disingenuous and misleading is worthy of consideration.

5.5 The wine industry needs innovation

In terms of viticulture, look if there's better ways to kill pests and disease without using agrochemicals that are cost effective; if there's better ways to do yield estimates or better ways to identify when [a] crop is ready for picking and that uses nanotech. Geez, I think it would be silly not to explore it. Because if there's things that can...improve quality or cost effectiveness in the vineyard let's look at it! I think there is real value (Interviewee 15).

The above quote epitomises the willingness to onboard new technologies into existing production regimes where tangible benefits exist. It also shows a discursive framing of anyone who is unwilling to embrace such technological change as "silly." This theme explores how technology has been pivotal to the past success of the NZWI and in particular MSB. Industry attitudes towards innovation and new technologies are then discussed.

5.5.1 A highly technical industry

Technology use is seen as a key to wine production. All informants expressed that technology is key to producing both quality and quantity of wine in Aotearoa. This belief was shared amongst producers such as Interviewee 5 "I think we've made a huge step in the quality of wines that we were making just from having state of the art equipment" and intermediaries such as Interviewee 3 "it's a highly technical industry at all levels. That's pretty important." Interviewee 11 had a clear message to the luddites of the world "its complete bollocks. Technology has been genuinely brilliant for wine. Looking at these days, how many bad vintages do you remember in the last 10?" The use of technology and technically qualified vineyard managers has meant that problems can be overcome and quality is not sacrificed.

The importance of technology in achieving the MSB style that the world loves was mentioned. Interviewee 8 explains that "people are always amazed at how we get the wonderful elevated aromatics and how we get that wonderful fresh fruit vibrancy." While some of this is attributed to provenance and the unique terroir of Te

Tauihu-o-te-waka, “our ability to manage a vineyard, our ability to use technology in the winemaking process” is key to achieving that MSB style.

Another interesting idea that emerged was the perceived threat of falling behind. Interviewee 3 suggested that “if you fall behind, it could seriously damage the viability of the industry, I feel that quite strongly... obviously Australia is ahead of us [vis-à-vis nanotechnology].” They are concerned that if Aotearoa does not keep abreast of international technological advances this could risk the competitiveness of the industry. NZWG does invest in research and development, especially through the newly formed Bragato Research Institute (NZWG, 2021). Interviewee 10 put forward that New Zealand is already behind: “some of the technologies we have adapted here in New Zealand have been up in the northern hemisphere for 15 years before it came [here].” They believe this places the NZWI at a disadvantage, and imply that nanotechnology should be embraced early.

5.5.2 Innovation, experimentation, and the curiosity of wine actors

Innovation was expressed as a key factor in the success of the NZWI, with the lack of lock-in allowing a young industry to be creative. This could partially explain the high degree of curiosity and interest towards nanotechnology that informants expressed.

When you look at the rapid growth of our industry over the last 40 years, from what was essentially a \$25 million export industry in the early 1990s, through to a \$2 billion export industry today, innovation has been critical to driving that success (Interviewee 15).

The dramatic changes that have occurred since the 1980s, combined with an established pattern of innovation suggest that technical acceptability of novel technologies is readily achievable. A viticulturist described the opportunities to use more technology as “awesome” (Interviewee 14). A number of producers expressed a willingness to be trailblazers including Interviewee 1 “we’re not scared of being first to try things” and Interviewee 7 “as a company we’re quite open to trialling new technologies.” This bodes well for nanotechnology, as it should be met with a similar interest.

One winemaker said “I like to think I’ve got an open mind” (Interviewee 9), while another stated that Te Tauihu-o-te-waka was not as forward thinking as it could be:

It’s more a bit of reluctance on [the part of] some of the local winemakers I reckon. They think they are new world, but the thinking is pretty old world. We may be one of the oldest family based wine businesses in New Zealand, but a key factor for us was always that we are open to new ways of dealing with things as well (Interviewee 10).

This view is contrary to the way other producers described themselves, suggesting a potential rift between discourses of innovation and actual practices. It is not unlikely that informants overemphasised their degree of innovation, especially in an interview about technology. That said, others were frank in rejecting the idea of giving it a go “I think that it’s got its place, but I just can’t see myself, and I don’t think that’s just because I’m old, but I can’t see myself using it a lot” (Interviewee 13).

5.6 Nanotechnology and ‘the brand’

In most markets, if you take China as an example, wine purchasing there is still a ‘ritual’. And people are buying wine not for what is in the bottle, but they’re buying wine for the cues. And you don’t necessarily know what is inside the bottle, but you know that Bordeaux is apparently very prestigious, you buy something expensive to honour and respect your business partner. And things like red and gold and black are important cues, and the wine inside tends to be secondary...It’s what I call social badging. You use a prestigious product to demonstrate your wealth or your success or your worldliness to the people around you... A lot of people really don’t care about the winemaking process or the grape variety that goes in so all they want is something that gives them pleasure. And hopefully something that enhances the occasion, be it company or food.

—Interviewee 8

5.6.1 Imagined and material realities

New Zealand wine is actively constructed (and therefore imagined by the consumer) as a very traditionally made, boutique, and artisanal product associated with sustainability, nature, and provenance. Interviewee 10 points to this process of market-making and identifies wine as socially constructed:

I think you don’t have to worry about the customer itself, you have to more worry about influencers or wine writers because they form certain opinions. If one of these guys don’t like it, then you’re pretty much bugged.

This does not equate to the material reality of wine production, which by volume is dominated by highly mechanised, industrial techniques that rely on economies of scale (Overton & Murray, 2021). Interviewee 9 notes that “people are getting a bit scared of technology...It’s not just wine...even as things get more progressive and better, there is pushback it seems, of ‘oh it’s not natural’.”

This research uncovered the existing conflict between the socially constructed discourses of wine and the actual, liquid reality. While nanotechnology could fit in the existing highly technical regime (as discussed in section 5.5), it may not have a place in this imagined reality. Interviewee 12 explains that:

If nanotechnology is used in something that’s technologically driven anyway, like a car or computers, they will say oh, yeah that’s cool. But when it is involved with nature and producing natural products, I think there could be some hesitancy around that.

This clash could limit the consumer and market acceptability of vineyard nanotechnology use. In a similar vein, Interviewee 14 suggests “nanotechnology would work really well” and “play into that image” for beer because unlike wine, beer does not have “the elegant and romantic side.”

How New Zealand wine is imagined is a result of deliberate and active construction of discourses and narratives surrounding the NZWI, motivated by sales. One such constructed characteristic is that of wine as artisanal and boutique, employing traditional and natural processes in its production. Interviewee 8 asserts “most consumers tend to think of wine as being a ‘natural’ product, as opposed to a ‘manufactured’ product.” Interviewee 9 said “putting ‘uses nanotechnology’ on the label is probably going to be a bit at odds with that feel good artisan thing that wine tends to have.” For Interviewee 14 this can be summarised as “the romanticism of wine” where “newfangled technologies always feels like a touchy subject.” They suggest that since this can be a difficult subject, it is often neglected or ignored. Similarly, Interviewee 11 describes how the story that wine marketers tell appeals to these ideals, rather than speaking about the more technical aspects such as vineyard sprays:

People get a bit precious about wine, they want it to be made by some old granddad in the hills of Burgundy somewhere, in the same way that his great-great-great-grandfather made it, when you know that's not realistic. Wine is, after all, for all the bullshit around it, it's a commodity that's there to be sold...The sprays you have to put on stuff, the pesticides you need to use, the weed killers, the insecticides, and so forth: People don't want to know about that, so marketers never tell them.

It is clear that wine marketers and intermediaries are culpable for some of the mismatch between discourse and reality. And yet, as the introductory quote to this theme highlights, a lack of consumer interest in the finer details of wine or wine production is also implicated. Interviewee 12 compares this to other areas of consumption “but really, let's say I buy a car or motorbike? How interested am I in servicing it myself, really understanding how the engine works, how the indicators, how all that stuff works, or do I just use it?” For the average consumer, delegating such decisions and tasks to experts is more prudent than studying car mechanics, and this is allegorical to how wine consumers rely on wine writers, retailers, and sommeliers to make purchasing decisions.

Respondents pushed back against the idea that tradition, or boutique-ness was incompatible with technology use. As has been explained, the NZWI is highly technical. Interviewee 10 claims “we can be authentic without being old fashioned” while Interviewee 6 identifies the labels of ‘artisanal’ and ‘mass produced’ as “a kind of perceptual thing, rather than real.” They identify these as socially constructed narratives without material meanings.

5.6.2 Nanotechnology and organics

Roughly 10% of New Zealand vineyards are farmed organically and this portion is expected to continue to grow (NZWG, 2021). Organic vineyards include small scale organic producers and larger companies that have an organic range as part of their portfolio. Interviewee 12 mentioned “organics are becoming more and more important, whatever [organics] means, [and] biodynamics, which people don't understand, which is really a big step up from organics.” From their perspective as a distributor and retailer, there is growing demand for wine that is considered natural and sustainable, and organic wine meets those narratives. Interviewee 8 argues that organic wine production is mutually beneficial to the ‘clean and green’ perception of the NZWI:

People have a perception of New Zealand being a clean green environmental oasis, it's not, but that is the perception...When you drill down further and something like 12% of all New Zealand wineries are organic and then you drill down further and a single digit percentage is biodynamic, it says a lot about the industry. And people are prepared to pay extra for that sustainable or environmental factor that New Zealand has.

An important question then becomes “will nanotechnology fit into this existing construction of organic farming?” And, “how will nanotechnology influence the constructed relationships between ‘clean and green’, BrandNZ, sustainability, and organic wine?”

As aforementioned for wine production generally, organics is particularly perceived “as people doing everything by hand” (Interviewee 1). Campbell and Liepines (2001) stress the importance of situating ‘nature’ and ‘organics’ as discursive constructions, to better understand their end role in production and consumption patterns. Neo-luddism is not the material reality of organic grape growing in Aotearoa “it's not really that, we have to include new technologies to improve” (Interviewee 1). However, this narrative poses a challenge for the acceptance of nanotechnology in organic production regimes.

Those that were personally involved in organics did not view nanotechnology as incompatible with their philosophy. Interviewee 2 posits “I don't see why you would consider it offensive to the principles of organics.” The promise of reducing vineyard inputs was seen as highly relevant to organic grape growing. They continued “the fundamentals of organics is to try and use [the] least systemic ‘chemical whatever’ in your vineyard.” If nanotechnology comes with environmental or sustainability benefits, it will better fit into the organic wine paradigm. Interviewee 10 agrees “if we define ways where we can signal that we can save energy, that we can decrease our carbon footprint, [then] it's not a problem.” Interviewee 15 concludes:

Our reputation for sustainability is absolutely essential to the value of our product. Sustainability is the nexus of environmental, social and economic success, isn't it? I think you cannot ignore some potential technological innovations when you've got sustainability as an end goal.

As Interviewee 10 points out, it is ultimately a decision for the auditing companies that grant organic certification: "Biogrow or AsureQuality, they make that call what's allowed and what's not, or our organic standards across the world, they make the choice." In Aotearoa, Biogrow, AsureQuality, and Demeter are responsible for organic and biodynamic auditing and they have guidelines which are largely based on overseas standards. These companies will have to approve of nanotechnology before it can be used within organic regimes.

Chapter 6 Conclusion

This study traced the view of key actors and elements on the risks and opportunities associated with nanotechnology use in New Zealand vineyards. It has made visible the social construction of nanotechnology in New Zealand wine, revealing five key themes at the core of this construction. At the same time it has helped cement the view of New Zealand wine as an assemblage, highlighting many of the divisions identified in the literature but also using a particular question to demonstrate how this assemblage is constructed and held together (see Le Heron et al., 2013). In this way it takes up the challenge posed by Le Heron and colleagues and advances both the literature on wine and on economic geographies of assemblage. It also shows how narratives of the national brand are constructed and highlights the ways in which narratives of sustainability, provenance, and terroir are entangled in that brand.

First, section 5.2 revealed nanotechnology as difficult to conceptualise, which is understandable given its nascency in wine. This is the first challenge to nanotechnology use identified by this research. While some interviewees had a good grasp of the potential of this technology, many lacked any awareness of its possible uses in the NZWI. An assemblage diagram of nanotechnology in the NZWI was presented that drew together the key actors and elements that were introduced in the earlier sections and dissected in the discussion that followed. Proponents of nanotechnology must increase the NZWIs understanding, and be aware of the multiplicity of this complex assemblage.

Then, section 5.3 discussed financial imperatives. While cost was identified as a key factor for investment decisions, the research showed that labour, sustainability, and pest and disease management were also driving technological adoption. However, a rift between the fast-moving-consumer-goods wine producers and those operating at the small scale was identified here, as the former tended to prioritise financial returns and cost reduction while the latter preferred technology that could improve quality. Nanotechnology has potential for both of these camps, and solutions that can offer both a financial and quality return will be best placed to succeed.

Next, section 5.4 focussed on the precautionary principle and its implications for nanotechnology. As was discussed in the literature review, the precautionary principle created major challenges for GM. Some interviewees suggested a similar approach to nanotechnology. There were clear expectations from interviewees across the supply chain that any nanotechnology product or process was safe, and would be

permissible under local and international laws and regulations. Informants were divided on the issue of labelling, with some arguing that consumers should be informed of nanotechnology use. No such labelling requirements currently exist in Aotearoa, but this may change following their introduction. Another key issue was the alignment of nanotechnology with anti-vaccine conspiracy theories, which raise the question of whether a better, less loaded term is required for vineyard nanotechnology.

Penultimately, section 5.5 showed the wine industry as highly technical, with technology playing a key role not only in wine production regimes but also in marketing narratives. Intermediaries pointed to the NZWI as highly innovative, while those involved in production expressed a willingness to experiment and trial nanotechnology. This bodes well for nanotechnology, and suggests high levels of technical acceptability by industry actors across the supply chain.

Finally, section 5.6 explored the impact that nanotechnology may have on the reputation and narratives of the New Zealand wine story. A pressing concern is that nanotechnology may disrupt existing framings of New Zealand wine as boutique and traditional, and could undermine the socially constructed associations with sustainability, nature, and provenance. Since these are imperative to the success of the NZWI, the risk is that nanotechnology could harm market reputation and consumer perceptions. Organic wine production faced similar challenges, although producers themselves did not see nanotechnology as incompatible. Rather, perceptions of organic farming were centred on artisanal and 'clean and green' production, which once again may not automatically be reconcilable with nanotechnology use. Highlighting the environmental benefits of such technology was seen as a way of justifying its use both to intermediaries and consumers.

This research was primarily concerned with viticultural uses of nanotechnology. However, winemaking uses of nanotechnology were raised by several informants and are being developed internationally (see section 2.3.2). These discussions suggested that acceptability will be more difficult for winemaking applications than vineyard uses. This is due to the perceived greater risk of personal contact and ingestion of nanoparticles. Whether well-grounded in molecular science or otherwise, participants pointed to the view that winemaking produces the final product (the wine), and it is this that is the qualified object in market terms and the object that is ingested. The burden of disproving material transformation of qualities or adverse health effects is seen to be higher for such applications.

There is also a difficult conversation to be had about Te Ao Māori relationships with nanotechnology if nanotechnology-influenced future wines are to be branded in national terms. This conversation will need to

involve Māori as environmental guardians and co-owners of national brands as well as vineyard owners and wine producers. If Aotearoa wishes to pursue nanotechnology use, that conversation needs to begin now.

Future work must also grapple with consumer perceptions. This research talked to ‘market makers’ of the NZWI, but successful adoption of nanotechnology will hinge on widespread consumer acceptance. It would be prudent for nanotechnology proponents to better study how the public views nanotechnology in wine before it is deployed. Such research will aid the NZWI in maintaining its reputation and market position, particularly for MSB.

In short, interviewees argue that technical acceptability is possible—and the promises of vineyard nanotechnology are realisable—should nanotechnology achieve regulatory approval in Aotearoa *and* its major wine markets internationally. The question of market acceptability is more problematic. Even among intermediaries, attitudes towards nanotechnology varied from fascination, to fear and uncertainty, to opposition. While some are excited by its promise, others link it negatively to GM, vaccine conspiracies, and science-fiction weapons. The responses suggest that thought leaders (intermediaries or ‘influencers’) will be pivotal in shaping public opinion. Equally important will be the management of any adversely negative events or influential counter-opinions. The successful application of nanotechnology will depend at least as much on discursive strategy and narrative management as it will on scientific and technical success. Achieving what will only ever be a national competitive edge will require good management and good fortune. Here, the appropriate strategy might be to position Aotearoa as a fast-mover.

Chapter 7 Appendices

Appendix I Interview schedule

Nanotechnology in wine – Semi-structured interview schedule

Informed consent process for interviews:

- 1) Before the interview, ask participants to confirm they have received and read the participant information sheet.
- 2) Following this, ask participants if they have any further questions.
- 3) If fine, request signed return of the consent form
- 4) If they have no further questions, ask participants to confirm they consent to the audio recorded interview.

Questions for participants:

- Please tell us about your role/involvement with wine production/retailing/ marketing/ writing?
- What kinds of facts and figures can you tell us about this system? [Prompt – volume/ capacity, people employed, operational costs, outputs etc].
- How did you get involved in wine production/retailing/ marketing/writing ?
- Tell us about a normal day for you?
- Does your work change seasonally?
- What changes have you observed over the time you have worked in this area/field?
- What parts of this work invigorate you?
- How would you describe the current key debates or challenges in ‘wine’ and technology broadly speaking?
- Now specifically about nanotechnology, how would you describe the current key debates or challenges for wine?
- Based on your experience, what factors are most important when the industry (can be on an individual or collective basis) decides what kinds of technology to invest in?
- What barriers or challenges (legislative/regulatory, economic, social, embodied) do you currently experience when trying to implement/write about technology in your work?
- What questions/concerns do you have about nanotechnology for wine? [Prompt – maybe these might relate to centralised versus decentralised systems, climate resilience, livelihoods, biodiversity, costs, social licence/acceptance etc].
- What research/work is needed in relation to nanotechnology to help inform better decision making and resolve key questions/concerns?
- We are interested in how we invest in different kinds of systems, and what the ‘returns’ on investment are. If you were to describe how you have invested in nanotechnology (or *technology* generally, if no nanotech) systems, how would you describe it? If you had to describe the returns, what would they be, and who would see the benefits of those returns?
- Is there anything else you would like to tell us about nanotechnology or technology in wine systems from a policy/market/accessibility or other perspective that we haven’t discussed?

Appendix II Participant information sheet



SCIENCE
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PARTICIPANT INFORMATION SHEET For participants

Project title: Perceptions and Acceptability of Nanotechnology in the New Zealand Wine Industry

Research team:

Researcher: Nikolai Siimes

I am a Masters student researcher studying a Master of Wine Science at the University of Auckland.

Primary Investigator: Dr Emma Sharp, School of Environment, University of Auckland

What does the study involve?

This project is interested in the perceptions and acceptability of nanotechnology by those involved in the making, marketing, or selling of wine. Technology already has a key role in viticulture and winemaking, and this project seeks to understand if nanotechnology could be similarly used in a New Zealand setting.

We invite you to take part in this research if you are an adult member of the New Zealand wine industry. Data collection will involve an one on one interview lasting approximately 30 minutes at a time and location of your choice. An interview can also be conducted by phone or video call if Covid-19 or other practicalities require. We are recruiting 20 participants across a range of industry stakeholders (as wine 'market makers') including winemakers, viticulturists, grape growers, those involved in the sale and marketing of wine, wine writers, wine educators, retailers, and sommeliers.

The period of data collection will be October-November 2021. Data collected from the interviews will be analysed by the researcher/s.

Recordings and review:

In order to ensure an accurate record of what was said, it is preferred to audio record interviews however this is optional. Participants can ask to stop or pause the recording at any time during the interview. This recording will then be transcribed for analysis by Nikolai Siimes (student researcher). Participants can request to review the transcription of their interview, and they may suggest changes or edits however these are not guaranteed. Participants can request a copy of the audio recording and if they are uncomfortable with having the interview recorded written notes can be taken instead. Audio recordings will be destroyed as soon as transcription and review is completed.

Rights of the participant(s)

Participation is voluntary:

Participation is voluntary.

Withdrawal from participation and withdrawal of data:

Participation in this research is voluntary and you have the right to refuse to participate. You have the right to withdraw from the research at any time; and you may withdraw your data up to two weeks after the interview date.

Confidentiality and anonymity:

Total anonymity with respect to the participant's identity cannot be guaranteed. Any material published out of this study will be presented in a way that is de-identified, and raw data will be treated as confidential by the researchers. Interview recordings will not be shared to anyone other than the participant themselves. Your identity will remain separate from any data once recorded (identifying information will be securely stored). Consent forms are restricted to the Researcher and Principal Investigator and will be securely stored separate to the research data.

What will happen after the study:

Hard copy consent forms and identifiable data will be stored in a secure room at the University of Auckland for six years and then destroyed. Digital data will be stored on a password protected computer in a secure room at the University of Auckland. Electronic data will be backed up and stored on the University of Auckland server. Data will be stored for seven years for potential use in future research, accessible by the Principal Investigator. If you identify as Māori you may request to have your data returned for your ownership at the conclusion of the study and/or shared with your whanau, hapu or iwi.

The data collected during this research project will be used to inform conference papers, academic publications, and a Master's thesis. A summary of findings will be prepared for industry circulation and participants can request a copy of this to be sent to them.

Contact Details

Student Researcher

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For any queries regarding ethical concerns you may contact the Chair, The University of Auckland Human Participants Ethics Committee, Office of Research Strategy and Integrity, The University of Auckland, Private Bag 92019, Auckland 1142. Telephone 09 373-7599 ext. 83711. Email: humanethics@auckland.ac.nz

Approved by the university of Auckland Human Participant Ethics Committee on 19/10/2021 for three years. Reference number UAHPEC23253.

Appendix III Consent form



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Consent Form For Participants

This Form Will be Held for Six Years

Research Project Title: Perceptions and Acceptability of Nanotechnology in the
New Zealand Wine Industry

Researcher: Nikolai Siimes

Primary Investigator: Dr Emma Sharp

- I have read the participant information sheet and understand how the research will be conducted. I have had the opportunity to ask questions and they have been answered to my satisfaction.
- I understand I may withdraw from this research at any time, and that any data may be withdrawn within two weeks of the interview.
- I understand that this form will be restricted to the researcher and PI and will be kept for 6 years.
- I understand that all information and data will be stored securely for seven years

I would like copy of the transcript/audio file/written notes from this interview YES / NO

I identify as Māori and wish to have my data returned to me at the conclusion of the study
YES / NO

I would like to receive a summary of the research results when this project is completed
YES / NO

The interview will be audio recorded in order to ensure an accurate transcription can be made.

- I understand that I will be recorded
OR
- I have requested that only written notes are taken
- I agree to take part in this research

Signed: _____

Name: _____

Date: / / _____

Approved by the University of Auckland Human Participants Ethics Committee on 19/10/2021 for three years, Reference Number UAHPEC23253.

Chapter 8 References

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