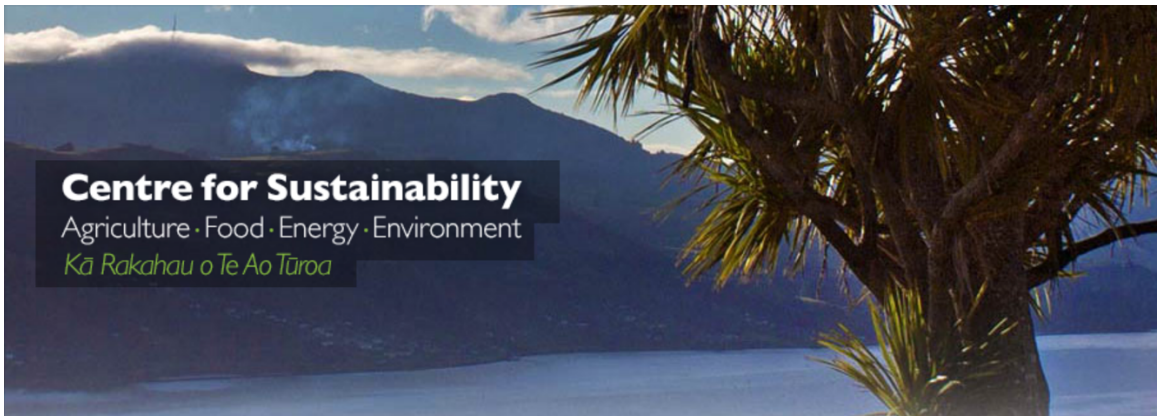

Technology Crises in Primary Production: The Transition from Wool to Artificial Fibres in New Zealand.

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Discussion Papers

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Kaye-Blake, B., Campbell, H., Plummer, C., Kitto, L., Polson, C., McKay, W., Fitzgerald, R., and Saunders, C. *The GM Food market: A Current analysis*. CSAFE Discussion Paper No. 4. December (2003).

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https://ruralis.no/en/projects/protein2-0-overgangen-til-biosyntetisk-protein-evaluering-av-effekter-utfall-og-muligheter-for-norges-post-animalske-biookonomi/

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1. Introduction:

This Research Report is part of a series of publications examining historical precedents of primary industry responses to major technological disruptions. Much mainstream literature and analysis consider technological innovation to be either: 1) an intrinsic part of continual, manageable, change in industry sectors, or 2) part of cycles of 'creative destruction' that are needed to eliminate old industry norms and practices and usher in new creative phases of industry development. While these are important historical dynamics – particular in long established economic sectors like primary production – they are not extensively examined at a granular historical level. This gap hampers the ability of contemporary researchers to then predict the future impact of novel technological disruptions – like the imminent arrival of artificial proteins as an element of global agrifood systems.

In order to be able to more accurately predict the future impact of technological disruption, or, at the very least, to be able to more critically engage with the potential scope and character of such disruptions, this report will examine the arrival of one major technological disruption – the invention of artificial fibres. It will then examine this new technology's impact through a historical case study of the New Zealand's wool industry.

This analysis is intended to provide a case study of:

- One of the kinds of technological disruptions that have happened in primary production over the last 100 years.
- How industries respond to these kinds of disruption.
- How this might be understood within a wider theoretical framework of theories of appropriation and substitution.
- How this case study might inform subsequent theorisation and analysis of these kinds of transitions.

Through undertaking this analysis, the material covered in this paper will then be incorporated into wider research activities and discussions in the Protein 2.0 research project.

2. The Protein 2.0 Project

The Protein 2.0 project is based at Ruralis – Centre for Rural Research in Trondheim, Norway, but incorporates a wide range of collaborators from across Norway, Germany, Scotland and New Zealand. The project is seeking to understand the future impacts of new synthetic proteins on Norway's primary production and resource sectors in order to sketch out scenarios for future opportunities and impacts and provide the opportunity for strategic responses by industry leaders and policy-makers. While the project is funded with the intention of drawing specific insights for Norway, the analysis is strongly grounded within a sense of who Norwegian dynamics might be understood in the context of wider shifts in global agri-food systems, policy frameworks and consumer responses.

One Work Package in the Protein 2.0 project (WP4) is specifically directed at questions of wider agri-food systems dynamics and how the emergence of artificial proteins is being understood and responded to by primary production sectors around the globe. This Research Report is directed towards the case study of New Zealand – with the original project intentions being to undertake a Delphi interview process with key stakeholders in the Dairy and Sheep/Beef sectors to gauge their understandings and expectations of the imminent arrival of synthetic proteins as either contributors to, or competitors for their sectors. Due to the timing of COVID-19, this interview process had to be abandoned, and was replaced by an alternative enquiry: examining how historical instances of massive technological disruption of sheep and dairy sectors had both taken shape and been responded to by industry leaders, politicians and other key stakeholders. This report is specifically directed to the situation of the once-powerful New Zealand wool industry when faced by the emergence of artificial fibres as a powerful competitor in world markets.

This analysis (alongside a parallel investigation into the arrival of margarine and the New Zealand dairy industry) then informs the wider scenario-building and forecasting of the Protein 2.0 project.

2.1: Theoretical Framework: Transitions in Agri-Food Systems.

The Protein 2.0 Project draws on a range of theoretical ideas to shape and inform an understanding of how technologies can disrupt, transform or even transition major primary production sectors.

This analysis is partly informed by the classical theoretical argument put forward by David Goodman and colleagues in the book *From Farming to Biotechnology* (Goodman et al. 1987). In that book the authors articulate two pathways in which industry sectors might travel when faced with disruptive new technologies. Goodman et al. (1987) reject orthodox framings of technology adoption in agrifood sectors, particularly those that posit linear processes of technological innovation and adoption leading to generally positive outcomes for industry sectors. Instead, agrifood industry sectors can often be faced by highly disruptive technologies, sometimes appearing from sectors outside agrifood economies, and these can cause a range of highly transformative effect. Their argument is that these disruptions can tend to take one of two forms:

- appropriation
- substitution

The term *appropriation* (or appropriationism) refers to dynamics in which new technologies are incorporated and adopted into agrifood systems without causing any structural unravelling of the wider system. In contrast, sometimes new technologies have the capacity to entirely disorder and disrupt agrifood systems and at times, lead to their complete *substitution*.

This approach was recently applied by Rob Burton and colleagues to major disruptions in primary production sectors that had previously been both powerful and seemingly impervious to disruption (Burton 2019; Burton and Fugelstad 2020; Helliwell and Burton 2021). In all those sectors, power substitutory technologies unleashed a range of effects. A similar use of Goodman et. al. (1987) was used by Julie Guthman to inform her analysis of the emerging transformative potentials and possible threats being generated by synthetic proteins in Californian food production (Guthman 2022).

This theoretical frameworks point towards a key area of deficiency in orthodox frameworks for understanding technologically-driven change. There are at least two taken-for-granted assumptions that inform much of mainstream economic and policy commentary and prescription around technologically induced change, arguing that the arrival of highly disruptive technologies are either: 1) an intrinsic part of continual, manageable, change in industry sectors, or 2) part of cycles of 'creative destruction' that are needed to eliminate old industry norms and practices and usher in new creative phases of industry development.

When re-examined through the lens of appropriation/substitution models these two taken-for-granted assumptions seem to simply assume an internal logic and rationality to technology-driven change. In this report we present a case study that shows that in order to understand the contingent and highly varied outcomes of technological disruption and how they either can be incorporated into existing industrial sectors, or conversely result in the massive disruption or entire elimination of sectors, we need to include both:

1) A history of the emergence powers and materialities of the new technology, and
2) A nuanced analysis of how industry responses become coherent (or not) and how these assemble or dis-assemble in a range of not entirely predictable ways.

This approach is used to understand the great crisis of the New Zealand wool industry: first, examining the slow and complex emergence of artificial fibres as a material element of global trading in yarns, threads and fabrics, and then using a discourse analysis to situate the emergence of particular kinds of industry responses.

3. A General History of Artificial Fibres: Technologies and Materials

Artificial Fibres have been an emerging technological globally for well over a century, and interest in the potential for artificial manufacture of fibres to substitute for silk, cotton, wool and other staple fibres has been the subject of fascination for much longer. Yet, despite this long interest, there have been comparatively few accounts of the historical rise of artificial fibres and even less on their impact on the sectors they were substituting.

In the following sections, we provide a brief history of artificial fibres examining both their emergence as a technological innovation, and their interaction with wider social forces.

In 1664, English scientist Robert Hooke speculated on the possibility of replicating the products of a silkworm (Thurston 1955, p.1; Kauffman 1993, p.888). In his (1665) text *Micrographia,* he entertains the possibility while observing silk and other natural fibres under a single-lens microscope:

> *"And I have often thought, that probably there might be a way found out, to make an artificial glutinous composition, much resembling, if not as good, nay better, than that Excrement, or whatever other substance it be out of which, the Silk-worm wire-draws his clew. If such a composition was found, it were certainly an easie matter to find very quick ways of drawing it out into small wires for use. I need not mention the use of such an Invention, nor the benefit that is likely to accrue to the finder, they being sufficiently obvious." (p.7).*

However, it wasn't until 70 years later that practical steps towards artificial fibres were made. In 1734, French physicist René-Antoine Ferchault de Réaumur believed that the natural process of silk production could be superseded by a mechanical process involving a gum or resin (Thurston 1955, p.1; Kauffman 1993, p.888). His method to produce the fibre consisted of draining varnish through tin cans that had small holes poked in them (Kauffman 1993, p.888). He did not succeed in creating a fibre, but his method served as a template for future attempts (Kauffman 1993, p.888).

It wasn't until over a century later in 1846, Swiss chemist Christian Friedrich Schönbein created the first semi-artificial fibre which he called *Schiesswolle* (guncotton) or nitrocellulose (Kauffman 1993, p.888). However, Kauffman (1993, p.889) points out that the material is not nitrocellulose, it is in fact cellulose nitrate. According to Rossell (2000), Schönbein created *Schiesswolle* on accident:

> *'Distilling sulfuric and nitric acids one day in his kitchen in 1846, his glass bottle broke on the floor, spilling the acids, and in hastily cleaning up the mess Schonbein wiped the floor with his wife's cotton apron, which he then hung over the oven to dry: instead of drying, it burned up with a smokeless flame' (p.1).*

Excited by the potential of a new explosive, Schönbein patented the design and handed it over to the British gunpowder company John Hall and Sons (Rossell 2000, pp. 1-2). However, experimentation on guncotton proved to be dangerous and resulted in multiple factory explosions that killed a large number of workers (Rossell 2000, p.2). Schönbein's patent sparked other chemists to attempt to reproduce his new material (Tucker et al. 2012, p. 65). Louis-Nicolas Menard, while working for Theophile Pelouze, created a mixture of ether and ethanol to change the cellulose nitrate into a viscous liquid which they called collodion (Tucker et al. 2012, p. 65). In 1851, Frederik Archer discovered a practical use for collodion in photography with his wet-plate collodion process which had the revolutionary benefit of requiring much less exposure time (Rossell 2000, p.2). In

1856, Alexander Parkes proposed that film could be covered in this collodion to provide a light protective layer, which eventually led to commercial application much later in 1888 (Rossell 2000, pp.4-5).

In 1855, Swiss chemist George Audemars patents the first design for an artificial silk with his invention called 'Improvements In Obtaining And Treating Vegetable Fibres' (Kauffman 1993, p.889; Her Majesty's Stationery Office 1855: p. 2). In his patent, Audemars describes the method used.

> *"This invention consists of obtaining fibres from the bark of a mulberry tree, and other genus morus. When the tree is in full vigour, the young branches are cut off and stripped of their bark which is made into bundles and soaked in boiling water, which causes the outer bark to separate easily from the inner bark, which contains the fibre. This inner bark is to be boiled with a carbonate of soda, and afterwards with a solution of soap, and then washed with hot water acidulated with nitric acid, and dried by pressure; afterwards the fibre is to be soaked in a mixture of ammonia and alcohol, and bleached by chloride of lime, or otherwise. The fibre thus obtained may be hackled, combed, or carded, and then spun like cotton ; or it may be converted into an explosive compound by the action of nitric acid, and then dissolved in a mixture of alcohol or ether, then mixed with a solution of caoutchouc, and drawn out into fine filaments of thread." (Nº 283, pp.2-3).*

Audemars' silk was ground-breaking, but it was laborious to produce. Audemars drew each strand of silk with a needle, which was slow and impractical (Das 2017, p.25; Kauffman 1993, p.889).

In 1884, Louis-Marie-Hilaire Bernigaud, Comte de Chardonnet filed the first patent for a commercially successful artificial fibre called 'Chardonnet silk' (Kauffman 1993, p.889). He made his discovery while studying diseases in silkworms under the tutelage of Louis Pasteur (Kauffman 1993, p.889). The exact genesis of his discovery is unclear. One source claims that he discovered the potential for a fibre after accidentally spilling collodion while working on some photographs, and when he eventually went to clean it up, the alcohol had evaporated and left a gum that created small strands when he tried to wipe it away (Garrett 1963, p.48). However, According to Tucker et al. (2012, p. 66), he was instead influenced by a technique pioneered by Joseph Swann, who also discovered how to make a fibre out of cellulose nitrate on accident while attempting to make a better filament for his new invention the electric lamp (Kauffman 1993, p.889). In 1889, Chardonnet was awarded the grand prize at an exposition held in Paris for the first gown made of this artificial silk (Kauffman 1993, p.889). It was of course a highly explosive article of clothing. The Count eventually overcame this problem with a process called dentification (Kauffman 1993, p.889). Nitrocellulose rayon was the first commercially successful type of rayon, but would go on to fade into obscurity in the early 20th century because of its high production cost compared to newer alternatives (Kauffman 1993, p. 889).

In 1890, Louis-Henri Despeissis created and patented a process for creating a new type of rayon, that would later become known as cuprammonium, made from cellulose dissolved in Schweizer's reagent (Kauffman 1993: p. 890; Woodings 2001, p.5). However, he passed away in 1890, before he had the chance to initiate large scale production. In 1892, Max Fremery and Johan Urban open a lightbulb factory where they used Schweizer's reagent to create filaments (Kauffman 1993: p. 890). However, this was also to allow a space to covertly improve on Despeissis process (Kauffman 1993: p. 890; Woodings 2001, p.5). They spent years trying overcome technical problems, but eventually, they managed to create a patent that reiterated Despeissis' process with an addition of a method for spinning the silk (Kauffman 1993: p. 890; Woodings 2001, p.5). Their secrecy extended to the point where they filed the name of the new patent under the name of Herman Pauly, who was a director of technical school, in order to cover their intentions for business (Kauffman 1993: p. 890; Woodings 2001, p.5). Between 1898-1899, Fremery and Urban commenced industrial scale production of cuprammonium silk which they called *Glanzstoff* (Kauffman 1993 p. 890; Woodings 2001, p.5). Cuprammonium silk's success was short lived due to its higher production costs, even though it mimicked silks properties the best out of all of its competitors (Kauffman 1993 p. 890). By the time war hit in 1914, cuprammonium was almost completely abandoned (Woodings 2001, p. 5). However, given that it did resemble silk, it saw use by the companies J.P. Bemberg and Asahi Kasei for fashion purposes (Asahi Kasei 2020, p.10). Asahi Kasei (2020, pp. 10-19) proudly state that they are the only producer of cuprammonium silk today, and they believe in its superior qualities such as being able to retain heat, stay cool, its smooth surface, and its dye retention. According to Asahi Kasei (2020 p.20), the material is popular for traditional dresses across Asia.

The genesis of a third style of rayon occurs in 1891 when English chemists Charles Cross, Edward Bevan, and Clayton Beadle discover viscose (Woodings 2001, p. 5; Kauffman 1993, p. 891). They discovered viscose as an extension of their work for the pulp and paper industry to create alternatives to cotton and linen rags for wood pulp (Woodings 2001, p. 6). They had no intention of using the newly discovered material for the purposes of artificial fibres (Woodings 2001, p. 6). Two chemists from the same area of Kew, London, Charles Henry Stearn and Charles Fred Topham, after seeing the patent for viscose, seized this opportunity to develop a fibre that could rival Chardonnet Silk (Woodings 2001, p. 6). Stearn and Cross collaborated to research a viable method for spinning viscose, however, the next few years consisted of great difficulty because viscose proved to be unpredictable and immensely difficult to tame (Woodings 2001, p. 7). Eventually Topham developed a spinning box that would finally make industrial production of viscose plausible (Woodings 2001, p.7).

Prince Donnersmarck, a wealthy German nobleman, became the first licensee of viscose, and set up a plant in 1902 (Woodings 2001, p.7). But he soon discovered the unreliability of viscose as his plant could not create more than 100kgs a day (Woodings 2001, p.7). In 1904, Courtauld & Co Ltd. were lured into attempting to spin viscose (Woodings 2001, p. 8). They were eager to break into the market that Chardonnet silk had created, and estimated that viscose could be created at a third of the cost (Woodings 2001, p.8). They wove their first fabric in 1905, however, most of their product had to be thrown out due

to its low quality (Woodings 2001, p. 8). Only 25% of the yarn they produced could be used (Woodings 2001, p. 8). Dr Paul Koppe, A technical manager from Donnersmarck's plant, created a new spinning bath technique would overcome the problem posed by the delicate threads (Woodings 2001, pp.8-9). Courtaulds would take this process and refine it over the coming years, which would overtime increase the amount of quality fibres they could produce (Woodings 2001, p. 10). By 1911, the addition of zinc sulphate to its bathing process would finally push the thread into the realms of viability and increase the percent of saleable fibres to 90% (Woodings 2001, p. 10). Courtauds would go from producing 400,000 pounds of viscose in 1911, to producing 10 million pounds of viscose in 1920 (Woodings 2001, p. 10). According to Woodings (2001):

> *"The acquisition of the rights to the viscose process by Courtauds was to become one of the most profitable investments of all time, and the opening up of the American market was key to this success." (p. 10)*

In 1901, the two brothers Henry and Camille Dreyfus commenced study on the cellulose acetate, which they grew interested in during their postdoctoral studies at La Sorbonne (Dinsmoor 2000). Dinsmoor (2000), who was the president of The Camille and Henry Dreyfus foundation, paints a glorious picture of turning a backyard laboratory into an industrial empire. Their first breakthrough came with the development of a cellulose acetate film that could replace the problematic cellulose nitrate film that was prone to accidental ignition (Dinsmoor 2000). The advent of World War 1 meant that the brothers directed their attention to the war effort, and subsequently they turned cellulose acetate into a dope that could be used to strengthen canvas planes (Dinsmoor 2000). After the war, the brothers spent years experimenting with cellulose acetate as a fabric, however, they faced many issues with its properties (Dinsmoor 2000). The first major issue was its inability to be weaved by traditional equipment; they had to create new designs that would be appropriate for cellulose acetate (Dinsmoor 2000). The second issue was its resistance to traditional dyes which would go on to plague acetate for many years, and held it back from being widely accepted (Dinsmoor 2000). The solution to this problem was to treat it with a caustic soda, which partly turned the fibre back into cellulose (Kauffman 1993, p. 892). In 1921, the Dreyfus brothers commenced industrial scale production of cellulose acetate known by its brand name of Celanese (Kauffman 1993, p. 892). Initially, Celanese did not have consumer acceptance for fashion, but the yarn filled a niche for crocheting, trimming, and effect threads (Reference for Business N.D.). However, Celanese suffered during the textile depression of 1923, where all of their orders had to be cancelled (Reference for Business N.D.). It took until 1939 before the yarn started turning large amounts of profit (Reference for Business N.D.). In 1929, Dupont bought the rights to the fibre, and in 1950 so did Courtauds (Kauffman 1993, p. 892). Acetate faded into obscurity in the 50s with the arrival of nylon, polyester, and polyacrylonitrile. The physical properties of these new threads would beat out acetate: they held their shape better, were more resistant to wrinkles, and dried faster (Reference for Business N.D.). As a result, the Celanese corporation had to diversify and expand into these new fibres, well aware that the new threads would be in direct competition with their main business of acetate (Reference for Business N.D.).

In 1926, Charles Stine, the director of the chemical department at Du Pont, invited the young and talented Wallace Carothers to join the Du Pont chemical department to spearhead their research program (Kohan 1986, p. 19). Carothers and his team were given a great amount of freedom in terms of research and ended up expanding on an alternative approach to polymers pioneered by thinkers such as Staudinger, Svedberg, and Meyer (Kohan 1986, p. 19).

In 1920, Hermann Staudinger argued that polymers such as rubber were in fact long chains of high weight, valence-bonded molecular units rather than special aggregates of small molecules (American Chemical Society 1999, p. 1). At the time, this was a heavily disputed line of reasoning, and was certainly not accepted by many within the technical establishment (Kohan 1986, p. 19). In 1923, Theodor Svedberg confirmed this hypothesis by using an ultracentrifuge to estimate a protein weight that exceeded 50,000 (Kohan 1986, p. 20). In 1928, Kurt H. Meyer x-rayed cellulose to find evidence of glucose in chain formation. In 1929, Carothers publishes his own theory on polycondensation, and separately his results of testing on esters. In this research, he confirms that the nature of polymers is in fact high weight valence bonded molecular units (Kohan 1986, p. 19).

According to Kohan (1986), Carothers' work contributed immensely to the understanding of polymers and he developed a series of terminology that is deemed to still be correct today. As a result of his research, he made rapid progress in developing new polymers. While using the newly invented molecular still, he discovered that in order to convert the polymer to a higher molecular weight, he needed to remove water that was creating equilibrium (Kohan 1986, p. 21). This discovery unlocked the potential of creating 'superpolymers' (Kohan 1986, p. 21). Carothers managed to convert an ester of an initial molecular weight of 2300 to a molecular weight of 25,000 (American Chemical Society, 1995, p. 1). In 1930, Julian Hill, a member of Carother's team, developed a technique called 'cold drawing' which would allow them to pull lengthy threads from the molten superpolymers (American Chemical Society 1995, p. 1). This fibre was exciting for the team because of its qualities such as strength and lustre indicated commercial viability for superpolymer fibres (Kohan 1986, p. 21). In 1935, Gerard Berchet, a member of Carother's team, successfully synthesised Nylon 66.

> *"Gerard Berchet... heated hexamethylene diamine (1,6-diaminohexane, H_2N-$(CH_2)_6$-NH_2) with adipic acid (Hexane-1,6-dioic acid, HOOC-$(CH_2)_4$-COOH) and meta-cresol at 215°C; water distilled off, then the temperature was raised to 255-260°C to distil off the cresol in vacuo."* (Cotton, 2010).

With the creation of Nylon 66, DuPont was well-aware that they had a fibre that was destined for success: it didn't corrode, it was easy to dye, and it was flexible (Cotton 2010). They kept the fibre secret until its reveal in 1938 in tandem with a marketing campaign focusing on women (Cotton 2010). Nylon exploded in popularity during 1940 with the release of Nylon stockings (Cotton 2010). On the first day, 5 million pairs were sold in a day across the United States, with consumers lining up outside of stores to get their cheap $1.15 stockings (Cotton 2010).

In 1933, Eric Fawcett and Reginald Oswold Gibson inadvertently discovered polymerized ethylene during an experiment on the effects of high pressure on chemical reactions (Hutley & Ouederni 2015, p.16). In one of their many experiments of varying chemicals, they found a waxy substance within a tube of one of their experiments to combine ethylene and benzaldehyde which they concluded could possibly be a polymerized ethylene (Hutley & Ouederni 2015, p.16). However, Fawcett would not receive much recognition for this discovery for at the time the science of polymers was still new (Hutley & Ouederni 2015, p.17). In 1935, Fawcett presented his findings at the first major conference for polymer science at Cambridge (Hutley & Ouederni 2015, p.16). His presentation came right after the chairman of the conference, Herman Mark, gave a presentation offering multiple theoretical explanations to why ethylene would not polymerise (Hutley & Ouederni 2015, p.16). Fawcett was dismissed from his job at Imperial Chemical Industries for the embarrassment he had caused (Hutley & Ouederni 2015, p.16). However, the ICI continued with his line of research, and patented a process for the polymerisation of polyethylene in 1936 (Hutley & Ouederni 2015, p.16). During the following years, World War 2 would reserve all polyethylene production for war uses such as the insulation of radar cables (Hutley & Ouederni 2015, p.16).

In 1941, British chemists John Whinfield and James Dickson filed a patent for ‘polythhylen terephthalate’ which was based off the unfinished work of Carothers who unfortunately took his own life in 1937 (Hendrickson et al. 2014, p. 728). DuPont and the British Imperial Chemical Company (ICI) agreed to share research in exchange for noncompetition in various nations (Hendrickson et al. 2014, p. 728). In Britain, the polyester fibre was branded as Terylene, and the patent was handed over to DuPont in 1945 (Hendrickson et al. 2014, p. 728). DuPont developed the fibre in order to produce it under a separate license which resulted in the creation of Dacron in in 1950 (Hendrickson et al. 2014, p. 728). The polyester family of artificial fibres was successful due to its durability and ease to wash. The fibre required no extra care for washing and would dry quickly which became a selling point for clothing manufacturers (Hendrickson et al. 2014, p. 728).

Also in 1941, Ray Houtz, another DuPont chemist, discovered how to spin polyacrylonitrile in a manner that provided good fibre strength and a high melting point (Hounshell et al. 1988). This fibre was first synthesised by IG Farben chemists Claus Heuck and Hans Fikentscher in 1930, but it was resistant to conventional solvents. In 1931, Herbert Rein found that 1-benzylpyridinium was an adequate solvent, and much later in 1942, he found that dimethylformamide was an even better solvent. Rein’s work was cut short by the allied seizure of IG Farben in 1945, and due to wartime secrecy, his work had no influence upon Houtz’s. Houtz had been led to pursue polyacrylonitrile by a colleague while trying to improve rayon, but decided that the compound could make a sufficient fibre on its own. In 1948, DuPont announces the industrial scale production of polyacrilonytrile under the brand name Orlon. After the creation of a polyacrilonitrile fibre, DuPont had now three members of its artificial fibre family that would inevitably replace their rayon fibres. Even though the replacement of those rayon fibres would result in a massive destruction of capital, DuPont was confident that they would be able to exploit the new product cycle.

In 1943, Karl Ziegler would develop a method to improve the process for the creation of polyethylene through the use of triethyl aluminium. In 1952, Giulio Natta invited Ziegler to visit Montecatini, the company he worked closely with, for the exchange of scientific information. Ziegler accepted and visited Milan to show Natta and his fellow scientists the process for linear polymerisation for ethylene. Natta instructed his research group to commence the study of the polymerisation of propylene using what he called the "Ziegler catalysts". Natta filed for a patent for polypropylene in 1954. Polypropylene would serve to be a far better material for the application to textiles and would go on to become popular for carpets, upholstery, and thermal underwear etc. (Collier & Tortora 2001, p. 201-209).

From the point at which polypropylene was invented, the trajectory of artificial fibres as a contributor to the global market for textiles, threads and yarns began to rapidly increase. The following section describes the wider conditions and changes that enabled this transition from niche industrial innovation to the dominant supplier to world fabric markets.

4. Artificial Fibres: Industry and Social Changes

Over the course of the 19th and early 20th century, a multitude of societal changes catapulted artificial fibres from being deemed as inferior substitutes to being lauded as the desired alternative:

> *"The early history of artificial silk is one of bankruptcies and reorganization of companies that did not exist long enough to solve the problem of economically producing and selling a product that could compete with natural fibres."* (Mussey 1957, p.143).

According to Keist (2009), in the United States prior to the First World War, rayon failed to take off due to four main reasons:

> *"First, was the industry's portrayal of the fiber rayon. Terms such as "real" and "true" silk made consumers think that silk was the optimal choice, but they might have to settle for rayon, the imposter. Cost perceptions was the second major reason that rayon was seen as inferior. The majority of rayon products were priced less expensively than silk products. For many consumers, cheaper prices equalled lower quality. Third was the terminology used. A variety of terms were used to describe rayon: artificial silk, art silk, fiber (fibre) silk, fiber (fibre), chemical silk, scientific silk, rayonner, wood silk, and rayon silk. With this list of terms, consumers would not necessarily know what specific product they purchased, or the correct fiber content. The fourth, and final reason, was the poor information provided about rayon to the consumer." (p. viii).*

A key change that enabled the expansion of artificial fibres was America's development of a domestic chemical industry that was spurred on by chemical shortages during World War One (Field 2001, p. 77). When the war broke out in 1914, the US textile industry was not compelled to alter their production due to the nation's neutral stance (Field 2001, p.77). However, in 1915, when the British blockaded German ports, this caused a domestic shortage of dyes and chemical products in the US (Field 2001, p.77). Haynes (cited in Field 2001, p.77), a historian of chemistry, noted:

> *"Hindsight is so astute, it seems incredible today that in 1913 nobody in the United States realized the pivotal importance of coal-tar dyes ... or the meaning of the abject reliance of our textile, paper, and leather industries upon imported colours."*

As a result of this shortage, the US was forced to create its own industry, and redirected many leading chemists towards its development (Field 2001, p.77). When the dye shortage hit in 1915, many believed that the shortage would only be temporary given that the war was not going to have a long duration, so mills made no effort to conserve dye (Field 2001, p.78). But by 1916, mills had gone through most of their stock of dyes, and the American dying and chemistry industry hadn't taken off yet due to vital resources being withheld for war purposes in Europe (Field 2001, p. 78). Desperation began to take hold in the US textile industry, and many in the industry turned to previously discarded natural dyes such as madder and woad (Field 2001, p. 79). Styles changed to lighter tones, stripes, and checkers, in an effort to conserve more dye (Field 2001, p. 79). Luckily for America, France was also experiencing the shortage, so Parisian designers had made an effort to promote black and white clothing as the new style of fashion (Field 2001, p. 80). By 1918, the dye and chemical shortage was alleviated due to the creation of Americas own industry, but the severe shortage had taught a harsh lesson.

According to Fielder (2001, p. 86), there were four main impacts: The first being the raised awareness surrounding the importance of chemicals in a modern society. The second was that US now had a substantial chemical industry that had multiple plants and teams of engineers which provided the US with a vast amount of reliable chemical products. The third was the general sentiment that if war could stop dye from crossing the Atlantic Ocean, then war could also stop silk from crossing the Pacific Ocean. The fourth impact was now financiers saw value in artificial silk that had previously not existed. By 1921, America now had three producers of viscose, and one producer of acetate (Field 2001, p. 86). Over the coming decade, rayon consumption would experience a meteoric rise. Viscose consumption in the US went from 2.5 million pounds in 1912, to 110 million pounds in 1928 (Field 2001, p. 86). The two most prominent catalysts for this rise in consumption was a) the 'ready-to-wear' revolution and its expansion into women's clothing, and b) the increased rate of seasonal consumption that would accompany the ready-to-wear phenomenon.

The ready-to-wear revolution has its roots within the mass production of standardised clothing for the military (Aldrich 2007, p. 2). Over the 18th century, an increase in war across Europe and tension in colonial hinterlands meant an increase in soldiers and subsequently uniforms (Aldrich 2007, p. 2). This demand was met by clothier contractors

who would mass produce garments (Aldrich 2007, p. 2). By the end of the 18th century, slop sellers would sell second hand clothing and cheap readymade clothing to the public (Aldrich 2007, p. 2). These articles of readymade clothing would be rudimentary and loose-fitting, typically created by sketching the outline of the pattern from the body (Aldrich 2007, p. 2). The creation of well-fitting patterns by tailors were closely guarded trade secrets (Aldrich 2007, p. 3).

According to Aldrich (2007), there is a high probability that tailors were experimenting with ideas of proportion and scale and applying them to the measuring of cheaper clothing. The crucial turning point comes in the early 19th century with the development of standardised measurements, coupled with the creation of the tape measure (Aldrich 2007, p. 5). The imperial system was standardised long before in the 12th century and there are some examples of needlewomen applying the yardstick to measuring clothing in the 17th century, however, such practices were not widespread (Aldrich 2007, p. 5). Around this period of time, tailors were using the yardstick for measuring cloth, but did not use it in their theories of pattern creation (Aldrich 2007, p. 5). In 1799, France created the metric system and over time it became the standard across Europe (Aldrich 2007, p. 5). Also in 1799, George Atkinson invented the tape measure (Aldrich 2007, p. 5). However, use of the tape measure was uncommon among tailors and many preferred to still use their old systems (Aldrich 2007, p. 5). Gradually over the coming decades use of the tape measure increased, and as the inch and centimetre took over as the standard of measurement, tailors were able to create pattern drafts with algorithms (Aldrich 2007, p. 6). During this period of time, instead of keeping their work secret, tailors would publish their algorithms and argue their merits, further proliferating the inch and centimetre (Aldrich 2007, p. 6). These shared algorithms would integrate well with the creation of industrial machinery for creating clothing. In 1846, the creation of the sewing machine is monumental in the furthering of the slop industry. Other inventions included:

> *"[the] long cutting knife..., snap-fastening machine, felling machine, pinking machine, and the buttonholing machine."* (Keist 2009, p. 18).

According to Zakim (1999, p. 62), in the United States during the early 19th century, the ready-to-wear revolution started to take off for the general population due several key shifts in American industry:

> *"Clothing was tied to the dumping of British cloth in America after 1815, the fitful rise of a domestic textile industry during the same period, the concomitant decline of household manufacturing, the creation of transportation infrastructure connecting distant and disparate regions of the country, the consequent growth of demand for finished manufactures in the hinterlands, and the mass mobilization of cut-rate labor in the country's major cities by means of a system of subcontracting which the New York feuilletonist George Foster began to call 'sweating' in 1849." (Zakim 1999, p. 62).*

By the mid 19th Century, clothing manufacturing had become the number one industry within the largest American city: New York. Other major city centres such as Cincinnati,

Boston, and Philadelphia were also trending in a similar direction (Zakim 1999, p. 62). An article of *Hunts Merchant Magazine,* written in 1849, espouses the benefits and conveniences of ready-to-wear clothing:

> *"It used to be one job to seek for the cloth, and another to repair to the tailor, causing not unfrequently great loss of time and much vexation. We now see everywhere, not only the economist, but the man of fashion, saving his time and his money by procuring the very articles he requires made to his hand."* (cited in Zakim 1999, p. 61).

For a majority of the 19th century, the ready-to-wear revolution was mostly for men's clothing (Keist 2009, p.18). Women were able to buy a few articles after the 1860s, but gradually outfits such as dresses became available as the century progressed (Keist 2009, p.19). But most women continued to either make their own clothing, and those who could afford it would rely on dressmakers (Funderburk 1994). By the start of the 20th century, however, women were able to buy mostly all their items of clothing readymade from department stores (Keist 2009, p.19).

During the start of the 20th century, several changes to society were impacting fashion. The first major impact was the increased in prosperity across America (Funderburk 1994, p. 2). The growing middleclass had more money to spend on clothing and desired to partake in bourgeois fashion at an affordable price. This demand made readymade clothing far more appealing. The second major shift occurred with the changing of women's roles in society:

> *"Active women were interested in practical clothing for work, sports, and public activities. They had less time for planning or making clothes. Separate skirts and shirtwaists and they increased the ready-to-wear market. They were moderately priced, easy to manufacture, needed little fitting, and increased a women's wardrobe."* (Funderburk 1994).

More people were shifting to urban areas and becoming exposed to advertising, meaning women were more likely to be up to date with the latest fashion (Keist 2009, p. 20). And the fashion industry itself was speeding up (Keist 2009, p. 20). Magazines were vital for the increase in consumption pace for ready to wear fashion. The more that women began to consume images of seasonal clothing, the more women would partake in the seasonal approach to fashion (Keist 2009, p. 20). During this period of time, the idea that clothing was made to last began to be overtaken by the idea that clothing should only last until the next fashion cycle (Keist 2009, p. 20).

Once quality had been dethroned by quantity, rayon became a viable fabric within the fashion industry. Over the 1910s, rayon became more popular than silk for hosiery (Keist 2009, p. 20). Women were demanding cheaper silk stockings, and genuine silk was difficult to make cheaper (Keist 2009, p. 21). The only reasonable way was to use less silk, which would have the undesired outcome of making the stocking too sheer (Keist 2009, p. 21). Rayon on the other hand was selling at $2.80 per pound compared to silk's

$8.65 per pound (Keist 2009, p. 17). Rayon met the expectation of an adequate and cheaper stocking, while also its shorter lifespan was deemed inconsequential (Keist 2009, p. 21).

In combination, these changes in technology, industry and wider social practices and cultures set the basis for a gradual and then rapid emergence of artificial fibres as the key element of the world clothing market. At the start of the 20th century, they were a tiny niche. By World War II it was clear that artificial fibres were going to become a significant element of the world market. By the 1960s and 70s, they had taken over and begun to trigger significant crises on the two traditional suppliers of fibre to world clothing markets: cotton and wool.

5. The Wool Sector in New Zealand and the rising threat of Artificial Fibres

While much of the first half of the 20th century saw significant erosion of the place of cotton on the world market, this report is more specifically focused on wool. As one of the world's most important wool producers New Zealand provides an excellent case study of the impacts of, and responses to, the crisis created by the rise of artificial fibres in the world market.

5.1: Background to the Wool Industry in New Zealand

In the immediate period after British colonisation and again in the mid-20th century, the wool export industry was the most important economic sector in New Zealand.

During the first decades of British acquisition of Maori land to convert into farms – through formal mechanisms laid down in the Treaty of Waitangi of 1841, or through illegal invasion and confiscation – there were a limited number of farm products that could be successfully transported back to the 'home market' in Britain in the era before the advent of refrigerated shipping in 1882. The two most significant export products during this period were wheat and wool. As the farm sector moved out of a period of ecological (and political) chaos in the decades after colonisation, the New Zealand production environment became less favourable for wheat production and wool remained as the key product for exporting (Pawson and Brooking 2002; Brooking and Pawson 2011). This continued even after the arrival of refrigerated shipping in 1882, and, by the mid-20th century, the farm economy still operated with wool as its staple product.

The wool sector went through significant boom in the 1950s spurred, in part, by the Korean War and the sudden need for wool for winter uniforms for US and UN troops as well as a surge in post-WW2 demand for strong wools for carpets to supply the international boom in suburban housing. The Oxford History of New Zealand reports that pastoral products were contributing over 90% of New Zealand's export earnings during

these decades, and that wool was the most significant component of those exports (Oliver 1981). In short, the economic and political fate of wool production was a matter of compelling concern for New Zealand through most of the 20th century, and particularly in the decades immediately after WW2.

During this period, the key institution at the centre of wool industry - and thus New Zealand national politics - was the Wool Board (Nayga and Rae 1993: 96). This was an institution that emerged to provide a solution to a complex set of New Zealand's colonial obligations to Britain. During the two World Wars (1914-18, 1939-45) Britain had signed an agreement with the New Zealand government for compulsory purchase of all New Zealand's wool exports to supply the war effort. In between the wars, various government interventions were undertaken to prevent a total collapse in wool prices due to the combined effect of the Great Depression and the release into the world market of stockpiles of wool accumulated during World War 1. By the end of World War 2, some level of government management of the entire wool clip had been the norm for nearly three decades. This governmental role as sole exporter was transferred in 1944 (The Wool Industry Act, 1944) to a new producer board – the New Zealand Wool Board – which would operate from 1944 – 2000 (Nayga and Rae 1993; Belich 2001: 307-09). Alongside the Wool Board, the government also maintained various agencies to intervene if necessary to maintain a floor price for wool, or to dispose of massive wool stockpiles after WW2 without undermining world market prices (the New Zealand Wool Disposal Commission, then the New Zealand Wool Commission). These large institutions, and the prior decades of high levels of government participation in the wool industry, resulted in complex and close relationships between wool industry leaders, government departments and parliamentary politicians.

These coordinated state/private collaborations operated in parallel to wider international collaborations through the actions of the International Wool Secretariat (Abbott 1998). The Secretariat was the creation of wool industry representatives from New Zealand, Australia and South Africa in 1937 who agreed to collaborate on the development and marketing of wool as a product. This was partly in response to the potential threat of artificial fibres, but Abbott (1998) argues that it was even more driven by declining wool prices during the Great Depression.

While the Secretariat appears to be a private industry initiative in collaboration between the three countries, the close relationship between the industries and state producer boards makes this distinction less clear.

As a result of all this government and industry activity, the history of the decades before and after World War 2 is characterised by vigorous parliamentary and media debates about the governance, marketing and science of wool production. In terms of world markets, these debates occurred post-WW2 during a significant boom in wool prices and production from 1946 to 1966, followed by two significant crises: a crash in world wool prices in 1966/67 and then the catastrophic effects for pastoral farming of Britain's decision to enter the European Common Market in 1973 which resulted in a cessation of New Zealand's privileged terms of market access into Britain.

5.2: Institutional Responses to the rise of Artificial Fibres and declining Wool Prices

Into this heightened world of wool industry politics and debate, the rise of artificial fibre production in distant countries to New Zealand received a relatively small amount of attention in industry and parliamentary discussions compared to the wider crisis of wool prices during the Great Depression and the ongoing arguments about the structure of wool governance institutions. This is in spite of the fact that the artificial fibre sector was going to have a massive impact on the long term future of wool as a viable and profitable product for pastoral farmers in New Zealand – at that time, immediate price concerns and industry control were the dominant topics of discussion. But there were key moments in which the rise of artificial fibres did achieve cut-through into discussions usually dominated by more traditional industry concerns.

5.2.1: The International Wool Secretariat

The creation of the International Wool Secretariat in 1937 was partly due to rising industry concerns about the increasing market share being achieved by artificial fibres in the 1920s and 30s:

'wool growers… responded with a cooperative research and promotional effort rather than some form of `orderly marketing'. This was because of the distinctive problems faced by the industry, notably the strong competition to the industry by the research and promotion-orientated synthetic fibre industry.'(Abbott 1998: 259).

Abbott (2003) characterises the rise of artificial fibres as a direct threat to wool producers as starting to become a matter of concern in the 1920s and 30s:

"During the 1920s the rayon industry began to intensify its competitive edge by improving production methods, establishing scale economies and seeing the entry of new firms, all of which helped to create a highly competitive climate which in turn led to lower unit costs and declining prices. The rapid growth of the industry was dependent to some degree on research which was stimulated by the competition of the natural fibres wool and cotton; there placement of viscose by acetate and competition by foreign firms that began operating in the United Kingdom. The technologically progressive nature of the industry and creation of large-scale companies meant that these companies had both the incentive and resources to conduct research into quality and production improvements. British Celanese, for instance, was said to have spent around £1 million on research in the mid- to late 1920s (Harrop,1968). In 1933 Courtaulds intensified this competition by announcing substantial reductions in prices, the main purpose of which was to deter further entry into the industry. The steady fall in prices meant that rayon production and sales in Great Britain grew at a steady rate, production of yarn and staple fibres rising from 6 million lbs in 1920 to 55.3 million lbs in 1929 and 172.8

million lbs in 1939 (Hague, 1957). During the 1930s within the textile industry there was continuous rivalry between wool and rayon with some displacement of wool in knitwear and dress-goods occurring. Courtaulds' salesmen in particular made great efforts to sell rayon to woollen manufacturers in Yorkshire. Similar, or even greater, levels of expansion of the rayon industry in the United States, Japan, Germany, France, and Italy occurred at this time" (Abbott 1998: 263).

Abbott (2003) goes on to argue that the initial formation of the Secretariat was fully conscious of the growing share of the wool market being lost to rayon:

'The growing proportion of the market taken by rayon helped to convince wool growers that the depression was not simply a short-term downturn, that promoting wool internationally would eventually rectify itself, but might be the beginning of the long-term replacement of wool by synthetics. As the rayon industry was a research- and technology-based industry which also placed considerable importance on salesmanship and advertising, the natural reaction on the part of wool growers was to establish some sort of wool research and promotional body.'(Abbott 1998: 263-4).

As the Secretariat had limited funding in its early years, it concentrated on promotional activity and research, much of which was directed towards countering the threat of artificial fibres:

"In terms of research the Secretariat initially did not conduct any directly, but instead made grants to organizations that were capable of conducting specific programs for the Secretariat. These programs were in the technical development of textile fibres rather than biological research, which was carried out by the national wool authorities in Australia, South Africa, and New Zealand. The bulk of the funds were granted to the British woollen manufactures research laboratories at Torridon in Leeds, these being made available for research into fleece and top measurement and manufacturing performance… In particular the Secretariat was keen to see the development of the production of unshrinkable wool by the gas chlorination method. The washability of the new synthetic fibres was one of their great selling points and the Secretariat was keen to have research undertaken at Torridon that would lead to the development of a woollen fibre with similar qualities." (Abbott 2003: 272).

Yet, while this was clearly part of the considerations of the Secretariat, it was always only a subsidiary concern to marketing during the Great Depression, and then making headway in a world market while other institutions were disposing of wool surpluses post-WW2.

5.2.2: The Creation of the Wool Board

A parliamentary debate over the Wool Industry Act of 1944 to create the Wool Board demonstrates some presence of New Zealand wool grower's alarm over the rise of

artificial fibres mixed in with a more familiar fear over the precariousness of the world wool price while post-war surplus stockpiles were distributed.

'The accumulations are such as to cause considerable concern and anxiety, more particularly when it is [realized] that one of the grave dangers confronting the wool grower is the competition to be expected from manufacturers of artificial fibres. We know that those engaged in the production of artificial fibres have at their command some of the best brains in scientific world, and year by year we have seen the articles they have produced becoming better and better, until [to-day] they are, undoubtedly, keen competitors with fine wool. Speaking generally, producers of fine wool feel that scientists have completely neglected the wool industry. They believe that those concerned have relied upon the fact that at the beginning of the competition wool was so superior to the artificial fibre that it had nothing to fear from competition, and that increased demands could absorb all the artificial fibres produced, and at the same time provide a profitable market for woollen products. However, as competition became keener, the woolgrowers [realized] that they had been living in a fools' paradise, and that they should have enlisted the help of the scientists. They believe – I think rightly – that if the same amount of energy had been put into the development of woollen products, wool would have nothing to fear from artificial fibres.' (Mr Bodkin, cited in New Zealand Parliament 1944, p. 562).

The bill itself is met with unanimous support. The members who spoke during the debate agreed that wool will always be the superior product, but it's future needed to be safeguarded (New Zealand Parliament 1944).

'Because of the utility and usefulness of wool to the human body, I consider wool will hold its own against any synthetic fibres. At the same time, we must acknowledge that there is keen competition from synthetic fibres, and, in order that the wool industry shall continue in a reasonably prosperous condition, it is necessary to be on the alert by establishing the best possible organisation to look after the interests of the producers.' (The Hon. Mr Parry, cited in New Zealand Parliament 1944, p. 568).

'At the moment, a dangerous position is looming in respect of wool. We ought to find a way of meeting that position half-way or earlier not for the purpose of stopping people from getting access to goods they ought to get, but we ought to find a way of making available to them that which is best for them. That puts the onus on us to produce the wool best for them. I have seen some outstanding wool garments. I handled a little piece of wool two days ago ; some on wrote, and I sent on a piece of the woollen garment. I have never seen anything better. Silk does not compare – indeed, it is better than anything I have seen in silk, synthetic, or other material. If we utilize the knowledge and brains of the people of Australia, Britain, South Africa, and other wool-raising countries, to make wool more useful than synthetic fibres – And I believe we can – then we shall go a long way towards assisting our producers. I do not know much about the matter from a synthetic point of view. I have read a little, and I have gained a little surface knowledge. I believe that the constituents of wool are such that they provide a warmth that is not to be found in any type of synthetic fibre. Wool is much better than synthetic fibre, from that

point of view ; and I have handled it and sold it in its complete form. We should lose no opportunity in making our woollen fabrics much better ; and that means hard work and much money. Australia has decided to set aside 2s. a bale to be subsidized, probably, by the Government with a like sum, and that should provide £600,000 for research alone. I think that if a like decision was made by the Wool Board here, and if we co-operate with Australia, we can make much progress.' (The Hon. Mr. Nash, cited in New Zealand Parliament 1944, p. 572).

With the passing of the Wool Industry Act of 1944, these responses to artificial fibres were posed as abstract ideas that weren't followed up with any substantive parliamentary actions. The practical reality of what the Act achieved is that it established and empowered the Wool Board to resolve the tensions and exploit the opportunities of the post-WW2 world wool market. In essence, they delegated to the huge new wool export organisation the task of contemplating the strategic future of the wool industry and, if necessary, to solve the artificial fibre problem.

From this point on, emerging discourses about wool and artificial fibre can be found in the discussions and pronouncements of both the Wool Board and the International Wool Secretariat. The next section of this discussion paper will consider the changing discourses of wool/artificial fibre that emerged around this challenge.

6. Wool Industry Strategies/Discourses on the Threat of Artificial Fibres

Both the International Wool Secretariat and the Wool Board generated extensive documentation that was available for a discourse analysis of the wool/artificial fibre crisis. These exist within a wider set of texts about the science of agriculture in New Zealand, emerging debates and policy discussions on the regulation of farming in general and managing of the rural economy by the New Zealand government, and wider popular culture expressions and reflections on wool, artificial fibre and New Zealand.

The following sections comprise a discourse analysis of these texts.
In both parliamentary discussions, and in the strategies of the International Wool Secretariat, it is possible to identify distinct discursive positions. What is evident are a few different ideas of how to approach the threat of artificial fibres:

- First, to simply ignore it, or to issue an initial call to action.
- Second, to use scientific innovations in production to attempt to dramatically reduce the cost of wool production to match the cheaper market price of synthetics or to expand the potential end-uses of wool in things like carpets.
- Third, to boost the popularity and claims about the virtues of wool – particularly by turning to science to provide justifications for the superiority of wool.

- Fourth, to traverse accommodations with the artificial fibre boom and seek ways to expand markets in tandem with synthetics and also to use science to blend artificial fibres into wool products.
- The final discourse emerges later – suggesting an end to government action and intervention as part of the wider neoliberalisation of agriculture and an injunction to the wool industry to 'sink or swim'.

Into the heightened world of wool industry politics and debate, what is immediately notable was that the rise of artificial fibre production in distant countries to New Zealand did not capture anything more than a small amount of attention in industry and parliamentary discussions, despite the fact that the artificial fibre sector was going to have a massive impact on the long-term future of wool as a viable and profitable product for pastoral farmers in New Zealand. But there were key moments in which the rise of artificial fibres did achieve cut-through into discussions usually dominated by more traditional industry discussion topics.

6.1 Early Industry Responses: Ignore it/Sleepers Awake!

It is important to note that there were a number of decades in which artificial fibres began to enter the consumer market, but seemed to provoke almost no response from the wool sector.

As detailed in this discussion paper, fabrics and yarns made from artificial fibres were becoming commercially available by the end of the 1800s, with multiple fibres – particularly Rayon - entering large-scale commercial production in the 1920s. Despite this, there is no discernible textual evidence for concern about artificial fibres as a threat until the 1930s.

Figure 1 shows the rising proportion of artificial fibres used by US mills after the 1890s although during this period through to the 1950s, the main decline is in cotton. Nevertheless, in 1930 wool still has a greater market share than artificial fibres (then Rayon and Acetate), but by 1948 the synthetics have reversed this and more.

During the 1930s a series of calls begin to emerge arguing that the industry and country needed to start to respond. For example, in a letter to the Editor of the *Christchurch Press* in 1932 (around the time of the negotiation of the significant Ottawa Agreement which determined the market access status of British colonies for the next decades), the correspondent – signing as 'WAKE UP' - demands:

"Will you allow me to draw attention to a matter which concerns New Zealand's prosperity more than any conference yet called, even Ottawa, which those who know England and its free trade policy recognise as a failure of no little magnitude, considering it has already caused Cabinet Ministers to resign. One thing the

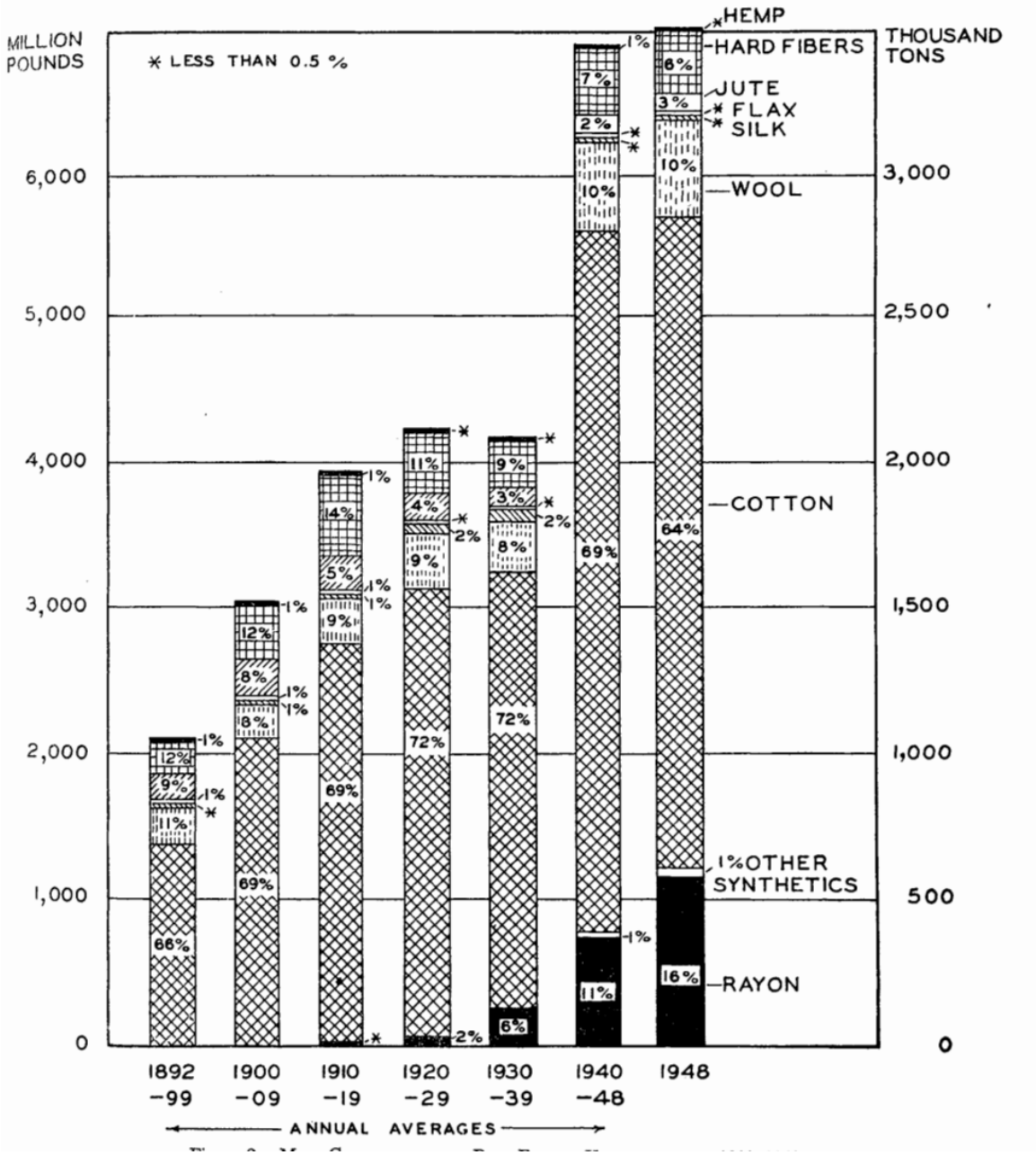

Figure 1: Mill Consumption of Fibres in the USA. 1892-1948
Source: USDA (1950).

farming community has failed to realise is the danger of countries producing synthetic goods, i.e., wool and butter under the names of silk wool and margarine, allowing these articles to be placed on the market as " just as good, warmer and nourishing," without even attempting to have an inquiry as to their true merits and values.

Silk wool looks very becoming, and when you have said that you have said everything, for it cannot possibly have any of the wonderful values of cotton, and

> *least of all wool. Every English school child was taught the value of wool compared with cotton from a health point of view, and the sooner the New Zealand farmers get the greatest medical authorities, also the analytical chemists' report, and broadcast it they will have done more for their fellow man and New Zealand than all the conferences yet to meet…*
>
> *The worker who buys synthetic foods and clothing is a traitor who has lost his self-respect.—l am, etc., WAKE UP.'* (Christchurch Star, 10th November 1932, p. 8).

With the formation of the Wool Board and the International Wool Secretariat, this began to change as a small number of emerging concerns from diverse sources found themselves able to reside and be amplified by the large emerging institutions directing the wool sector.

The parliamentary debate over the Wool Industry Act of 1944 to introduce the Wool Board reported in the previous section demonstrates some presence of New Zealand wool grower's alarm over the rise of artificial fibres mixed in with a more familiar fear over the precariousness of the world wool price while post-war surplus stockpiles were distributed.

Within these debates, there are a couple of different ideas starting to take shape about how to approach the threat of artificial fibres:

· The first idea is to turn to science and discover solutions.

· The second idea is to extend the uses of wool similar to what had been attempted in the rubber industry.

But the broad opinion among woolgrowers in New Zealand was that wool was the superior product which led many to be dismissive towards any potential threat from artificial fibres (Hall 2017, p. 279). According to Hall (2017), New Zealand's woolgrowers' attitude towards artificial fibres was best typified by a quote from a British woollen mill manager.

> 'Artificial wool? Rubbish! There's no need to lose sleep over that – now or ever... They may in time succeed in making a more cheaply produced fibre... but, at best, it will be a poor imitation. Take the health-giving properties of wool. Only nature can produce those. You'll never get those in any substitute.' (cited in Hall 2017, p. 279)

In 1945, the New Zealand government contemplated manufacturing rayon in New Zealand given the complementary relationship between wool and rayon at the time (Hall 2017, p. 281). The government invited Sir Percy Ashley, Chairman of the British Rayon Federation, to discuss possibilities (Hall 2017, p. 281). Ashley claimed that wool and rayon would not compete with one another, instead, rayon would open new markets for wool to also exploit as a blended product (Hall 2017, p. 281).

In 1946, Dr. I. E. Coop, a professor of agriculture at Lincoln College, claimed that New Zealand was not paying enough attention to developments in America and Europe

pertaining to both the expansion of uses for artificial fibres and the replacement of butter with margarine (Coop 1946, p. 2). He believed in the virtues of wool and claimed that it is the best fibre for cold and temperate climates. However, Coop went on to elaborate on two major pitfalls for wool in comparison to artificial fibres: wool had a low yield per acre, and it had a lengthy and costly process to prepare wool for weaving (Coop 1946, p. 3). Coop was concerned with how cheap and easy artificial fibres were to produce, and how blends were replacing pure wool garments by lowering the cost of production yet retaining the good qualities of wool (Coop 1946, p. 3).

> 'The fibres are very strong, stronger than wool, but they are not elastic and do not stretch, and are not very warm. Nevertheless, manufacturers have begun incorporating some of these fibres with wool in about a 50-50 mixture, where a compromise is made between the cheapness of the synthetic and the good qualities of the wool. Materials of this nature are being sold all over the world, even in New Zealand, both for ladies' and men's wear, where previously 100% wool was used. In other countries, for instance, in Germany during the war, all so-called woollen garments, such as suits and coats, have been made of about 80% fibre from wood and straw, and 20% natural wool. Whilst no one would agree that the German garments compare in quality with 100% wool, it illustrates the point that the practice of blending is already well established all over the world.' (Coop 1946, p. 3).

Coop was also presciently sceptical towards the claim made by artificial fibre manufacturers that synthetics would also benefit wool producers (Coop 1946, p. 4).

> 'It is stated by many synthetic fibre manufacturers that the synthetics will actually increase the sale of wool by reducing the price of the garments containing the mixture. In the long run more wool would be used as new markets were opened to these cheapened fabrics. Whilst this may be true, one cannot help feeling that the synthetic fibre manufacturers will not be satisfied with a 50-50 mixture, but will attempt to produce a fibre that will stand on its own with any admixture with wool. When this happens it will be an ill day for us.' (Coop 1946, p. 4).

Coop (1946, p. 4) proposed three lines of action for retaining the rightful superiority of wool.

> 'Wool-producing countries should be striving above all to maintain by research the undoubted superiority of wool, though this superiority seems to be declining. Secondly, we should keep production costs as low as possible as to be able to compete on a price basis ; and thirdly, we should be looking for new uses for wool.'

His observations in 1946 were telling – both in terms of the degree of threat that was being downplayed as well as in terms of where the wool sector might turn to respond once it did realise the danger it was in.

6.2. Science to the Rescue: Cut Costs, Innovate and Expand Uses

The discourse of keeping wool production costs low transpired to be an ineffective measure for protecting wool. It was unrealistic for wool to remain competitive with artificial fibres in terms of price given technical limitations of processing wool. However, the discourse of discovering new uses emerged as one pathway forward for wool. IWS and WRONZ research did manage to secure the New Zealand wool clip one pathway forward as an input into luxury carpets, but this one area of success was not the landscape envisioned – like rubber – of a product that occupied a plethora of markets through a range of new products. Every single market that wool occupied was outcompeted by artificial fibres in the lower to middle cost bracket. Consequently, between the 50s and the 70s, the New Zealand wool clip trended towards becoming coarser as the markets for wool uses in apparel declined and the significance of use in carpets grew.

The market for worsted products was already in decline before the arrival of competitive synthetics due to the change of machinery in mills (Carnaby 1981, pp. 17). New Zealand crossbred wool relied on the Bradford system which would involve oiling the wool to reduce static and the use of a circular comb to get rid of shorter fibres (Carnaby 1981, p. 18). The newer Continental system involved completely different machinery that would create a moist atmosphere to reduce static and use an intermittent combing system (Carnaby 1981, p. 18). The Continental system was incompatible with New Zealand crossbred wool (Carnaby 1981, p. 18). A declining U.K. industry mixed with developing nations opting for the Continental system as it was more efficient meant that development of the Bradford system halted (Carnaby 1981, p.18). The New Bradford system was then developed in the 60s, but its market had almost vanished during its hiatus (Carnaby 1981, p. 19). Machine builders were not going to develop a system that had low demand (Carnaby 1981, p. 19).

> *"Thus it can be seen that many of the recent advances in worsted spinning technology have been unfavourable to New Zealand wool. While there is considerable scope for overcoming some of these problems, as has been demonstrated by WRONZ with Repco (self-twist) spinning, the overall trend has been to increase the cost of conversion for crossbred wool relative to man-made fibres as these can be processed on modern plant." (Carnaby 1981, p. 19).*

On the other hand, the end use of woollen products faced a lessened decline due to the fact that processes of conversion were more indiscriminate with what type of fibre was used, and the process itself had changed little over the previous 50 years (Carnaby 1981, p. 19). But, the allure of synthetics for mills was that the material had no contaminants in it, which had been a source of complaint about wool about for years, and would thus cut out extra steps that wool required:

> *"However, once again this system of conversion is only of minor concern to the textile machinery-building industry in Western Europe and the U.S.A. Where new technology has been developed it has been primarily directed at the synthetic-*

fibre section of the industry. Moreover, when wool is processed on the system it is often given a special finishing treatment involving the process of milling (felting) followed by raising and cropping. Many of these processes are specific to wool and have changed little in the last 50 years. As a result the cost of producing traditional woollen cloth has risen rather more rapidly than that of competing synthetic-fibre substitutes in which area a major effort has been expended on product development." (Carnaby 1981. p. 19).

Not only that, but synthetics would also prove to be more convenient for manufacturers regarding their techniques for pushing better profit margins (Carnaby 1981, p. 20). Wool encountered difficulties with the new trend towards package-dying, and would instead rely on the labour intensive method of hank-dying (Carnaby 1981, p.). Furthermore, synthetics would absorb less water and therefore lessen drying costs:

"One of the main cost factors in the production of textiles is the need for a manufacturer to hold large inventories of semi-finished products in order to maintain his machinery in full production. Stocks in fibres held by manufacturers can exceed in value the total of all other assets. Indeed in 1969 stocks represented 45 % of the total assets of the U.K. textile industry and there have always been numerous vague references to a general belief held in Yorkshire that more money can be made by wool processors by manipulating their stock levels according to the price of wool than by actually converting the wool into products. Accordingly a major factor in improving the profitability is the reduction of these stocks. One of the most effective ways of doing this, and at the same time reducing delivery times, is to leave colouration until as late as possible in the processing sequence. It is often easier to do this when dealing with man-made fibres than when processing wool." (Carnaby 1981, p. 20).

Wool also experienced problems due to broader social changes. The introduction of central heating within homes and the heating of vehicles heavily influenced apparel markets (Carnaby 1981, p. 26). The most prominent effect was the trend away from heavier 18 oz suits towards lighter 12 and 13 oz suits (Carnaby 1981, p. 26). This resulted in a decline in the amount of the New Zealand wool clip going towards apparel as the wool clip was trending towards a greater proportion of coarser wools (Carnaby 1981, p. 26).

Over the 1950s, it became more popular to carpet houses due to the new level of income the middle class was experiencing across the Developed World (Carnaby 1981, p. 32). During this period, the United States became the world's leading producer of carpets with an initial demand of 70m kgs of wool then soaring to 100m kgs of wool by the end of the 1950s (Carnaby 1981, p. 32). In 1958, the U.S. revised one of its tariff acts which allowed for the duty-free importation of New Zealand wool (Carnaby 1981, p. 32). This meant that New Zealand could supply up to a third of US wool requirement for carpets (Carnaby 1981, p. 32). At the same time, wool exports were being banned from large suppliers of carpet wool such as China, Pakistan, and India (Carnaby 1981, p. 32). Meanwhile, the United States was moving to gain control of the international wool

market (Carnaby 1981, p. 32). The carpet boom meant that wool was experiencing a golden era in terms of its price. This high price, however, meant that rayon carpets would be able to significantly penetrate the carpet market based on a large price differential (Carnaby 1981, p. 33). Before the carpet boom, rayon carpet sat at around 40% of the price of wool carpet. After the boom, rayon carpet would drop to being 13% of the price of wool carpet, which would allow rayon carpet to become a serious competitor despite being an inferior product (Carnaby 1981, p. 33).

Eventually, the U.S. would no longer be a significant user of the New Zealand wool clip (Carnaby 1981, p. 36). By the 1980s, the U.S. produced mostly synthetic carpets of the tufted variety (Carnaby 1981, p. 36). The second largest wool producer in the world, West Germany, had also followed suit (Carnaby 1981, p. 36). In Europe however, wool still had a foothold due to IWS R&D promotional activity (Carnaby 1981, p. 36). The main problem excluding wool from use in the new tufting process was the high-speed spinning that was involved (Carnaby 1981, p. 36). IWS technologists found that New Zealand wool of the 35-38 micrometer type would work in a 70-30 blend with a stronger and bulkier wool such as that from the fleece of Welsh, Masham, or Irish Cheviot breeds (Carnaby 1981, p. 36). These blends were successful in tufting, but they still had issues with breakages (Carnaby 1981, p. 36). The new wool tufted carpets also experienced promotional issues due to the fact that they resembled synthetic tufted carpets and they needed to be distinguished in order to sell in the higher price bracket (Carnaby 1981, p. 36). One breakthrough for wool tufted carpets was the invention of the Berber fashion which was picked up and heavily promoted by the IWS (Carnaby 1981, p. 36). The Berber fashion used heavy yarns in conjunction with wide gauge tufting components which allowed for the use of less expensive wool blends (Carnaby 1981, p. 36). The Berber fashion contributed to a large growth in the tufted carpet market as carpet manufacturers found that pure wool tufted carpets attracted a premium (Carnaby 1981, p. 36). Despite holding on to these niches, they shouldn't be overstated in terms of the global market for carpet. Conforte et. al. (2011: 151) report that by 2009, 98% of the world carpet market was supplied by artificial fibres.

6.3. Wool Boosterism

While much effort went into scientific innovation and technical aspects of wool production and processing, an important parallel effort was the deployment of strategies to promote the qualities of wool.

Over the 50s, the Wool Board's main approach to dealing with the artificial fibre threat consisted of increasing the promotion of wool (Hall 2017, p. 281). For example, in 1953, the Wool Board launched a musical named *The Inspiration of Wool* which was produced by Mary-Annette Burgess, the Wool Board's Promotion officer, in cooperation with Federated Farmers and the Auckland Wool Brokers' Association (Te Papa Tongarewa 2007). The musical depicted a dramatised version of the story of wool while showing off woollen garments created by 'the greatest fashion designers in the World' (Te Papa Tongarewa 2007).

The Inspiration of Wool – A Musical

"The Inspiration of Wool"

"THE INSPIRATION OF WOOL" is a musical, dramatised story of wool—acted on a stage.

"THE INSPIRATION OF WOOL" is educational and spectacular; a unique production for New Zealand.

"THE INSPIRATION OF WOOL" is costumed by the greatest fashion designers in the World and is of interest to every man, woman and child in Auckland.

"THE INSPIRATION OF WOOL" has been produced, and will be narrated by the N.Z. Wool Board's Promotion Officer, Mary-Annette Burgess.

"THE INSPIRATION OF WOOL" has been produced with the co-operation of Federated Farmers and the Auckland Wool Brokers' Association.

Figure 2: The Inspiration of Wool – A Musical.
(All images Te Papa Tongarewa: Museum of New Zealand)

Also during the 1950s, the Wool Board advised woolgrowers on matters regarding the contamination of wool that had long been complained about by manufacturers in Europe: an issue that did not exist with synthetics (Hall 2007, p. 282). The Wool Board encouraged farmers to thoroughly clean their woolsheds before use, and to not use tar or paint while branding (Hall 2007, p. 282). However, according to Hall (2017, p. 282), farmers relied heavily upon tradition and were reluctant to change.

In 1954, The IWS developed the IWS prize to be awarded to outstanding fashion garments consisting of pure wool (Woolmark n.d.). This was later rebranded as the International Woolmark Prize.

In 1959, the Wool Board came under criticism from woolgrowers in response to falling wool prices (Hall 2007, p. 283). Between 1956-1957, wool had dropped by 42% in price (Hall 2007, p. 283). The Wool Board's Chairman, Harry Wardell, refuted the criticism on the basis that the Wool Board and IWS had been promoting wool more than ever, and the fact they are receiving criticism is most likely due to remote woolgrowers being disconnected from their promotional activities (Hall 2017, p. 283). The only blame Wardell would accept was the fact that the Wool Board had not done enough to make wool growers aware of their promotional activities (Hall 2017, p. 283).

Whie the significant price drop later in the 1950s was concerning, it was not nearly as significant as the major slump in wool prices in the second half of the 1960s – See Figure 3 - followed by a quick recovery, and then a series of slowly declining cycles of wool prices. This slump massively increased demands for industry reform and restructuring.

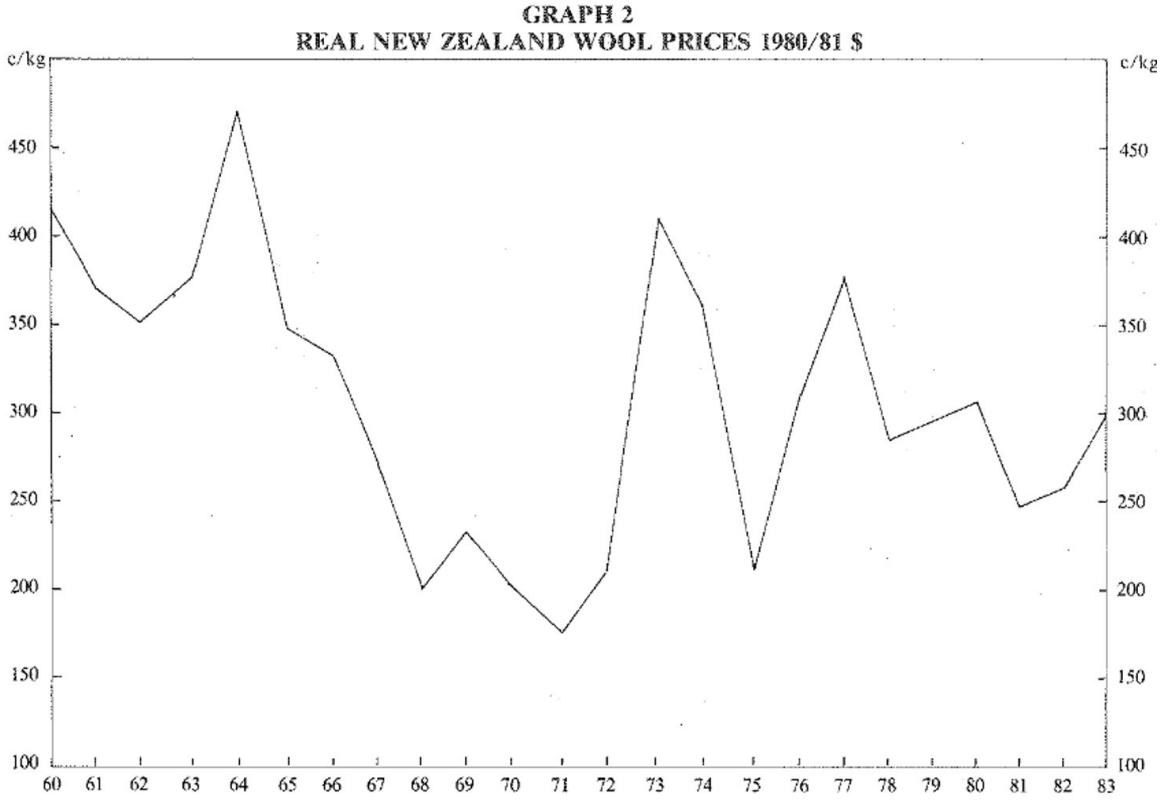

Figure 3: Real New Zealand Wool Prices 1960 - 1983
Source: Reserve Bank of New Zealand (1982), p. 256

In 1962, the IWS transformed into a competitive private enterprise with Australia given more control than New Zealand and South Africa (Hall 2017, p. 284). Bill Vines, who had previously worked as a director of the Berger Paint organisation, was brought in to be managing director of this new business entity (Hall 2017, p. 285). However, this private enterprise would have a unique income structure as it would continue to rely on the levy paid by wool growers (Hall 2017, p. 285). The general sentiment in the IWS was that the levy was needed to increase to match the promotional activities of synthetics, a decision that was backed by the New Zealand Wool Board (Hall 2017, p. 285). But members were aware that it would be an unpopular decision amoung wool growers given it was a time of economic downturn (Hall 2017, p. 285). In 1964, Bill Vines proposed the idea of creating a symbol to communicate to consumers that an article of clothing was pure wool (History n.d.). This led to the creation of the iconic Woolmark logo, designed by Francesco Saroglia (History n.d.).

> *"The premium now paid for wool products is largely related to the amount of product differentiation as seen by the consumer. The preference by consumers for*

many types of wool articles is due to the promotional activity of the IWS, a continuing preference by consumers for natural products, the resistance of consumers to change, prestige associations, and in many cases to superior aesthetic and functional properties. In the last 25 years the IWS has attempted to reinforce these characteristics of wool through its Woolmark programme. While there is probably little effect of IWS activity on the short-term fluctuation for wool, it is now clear from the growing number of Woolmark licensees internationally that these past technical marketing and promotional activities have extended the differential that consumers are prepared to pay in order to have many types of wool as opposed to man-made fibre products." (Carnaby 1981, p. 21).

While the Woolmark would go on to become a celebrate brand icon, the value that it generated was eventually swept up in the subsequent deregulation of the wool sector during the period of neoliberal reforms in Australia and New Zealand and it was sold into increasing levels of private ownership becoming the Woolmark Company Pty Ltd. – a subsidiary of various Australian wool sector groups that were progressively sold into private ownership.

In contrast to the Woolmark campaign, a great deal of energy began to be expended in the exact opposite direction – not so much purifying and branding the unique qualities of wool, but advocating and adopting various wool blends with synthetic fibres.

6.4. Blend with the Enemy

The practice of blending wool long predates the genesis of synthetic fibres. Wool has often been blended with a mixture of wool types or with reused cotton and wool (Carnaby 1981, p. 15). Generally speaking, wool has blended to reduce costs, or in response to changes in consumer lifestyles.

"Particular types of wool are bought only so long as they can be manufactured in articles of clothing with suitable functional and aesthetic qualities at a competitive price. There has always been some opportunity for substituting one type of wool for another in any given product, but the scope for substitution has been greatly increased in the last 40 years by the advent of man-made fibres." (Carnaby 1981, p. 7).

The early rayon/wool blends saw some commercial success but weren't a breakout product (Carnaby 1981, p. 26). The first market that rayon/wool blends entered was the worsted market where the rayon would work well with coarser wool to provide a cheaper product (Carnaby 1981, p. 26). Despite this benefit, it was not enough to outweigh the drawbacks of poor durability and creasing (Carnaby 1981, p. 26). Manufacturers who had mass produced this fabric during the Korean War struggled to sell their product after the boom had subsided (Carnaby 1981, p. 26). However, rayon did completely displace New

Zealand medium quality wool as a carrier fibre for the working-class wool blends that were produced in Europe (Carnaby 1981, p. 29).

The breakthrough for blended wool products came with the arrival of polyester. The 55/45 polyester/merino wool blend developed in the 50s was the killing blow to the worsted industry (Carnaby 1981, p. 26). Over the 60s the price of the 45/55 blend only dropped and cleaned out merino wool in the suiting market in all but the luxury bracket (Carnaby 1981, p. 26). The polyester/wool blend became especially popular in women's and children's clothing (Carnaby 1981, p. 26). The benefit of such a blend was that it didn't need to be ironed after washing which was dubbed "wash-and-wear" and allowed for a novel permanent crease to be added as a finish (Speakman 1959, p. 743).

> *"[f]abrics made from blends of Terylene staple fibre and wool (55:45) can be given creases or pleats which are resistant to both dry-cleaning and washing by simple treatment with superheated steam. When, however, an all-wool fabric is formed into pleats between pleating papers and steamed for 20 minutes at atmospheric pressure, as is customary, the pleats disappear during dry-cleaning and even more quickly during washing. Similarly, the creases imparted to all-wool trousers during pressing in the Hoffman press are not resistant to either dry-cleaning or washing." (Speakman 1959, p. 744).*

In response to this new development, the wool industry adapted by researching how to produce similar novel effects with wool fabrics.

> *"It is, however, known that reagents such as alkalis, sulphites and bisulphites act as powerful assistants in setting processes, and simple methods of using them to obtain permanent creases and pleats in all-wool fabrics have been evolved. The most successful is one in which the manufacturer treats the fabric with a 2 per cent solution of sodium bisulphite for 15 minutes at room temperature. At the end of this time, excess bisulphite is removed by rinsing, and the fabric is then centrifuged and dried at a low temperature. The process can be combined with London Shrinking, and the dried fabric is finally pressed between press papers. To obtain permanent creases with the treated fabric the tailor has merely to steam in the Hoffman press in the usual way, preferably with the fabric between damp cloths." (Speakman 1959, p. 744).*

Peters and Stevens discovered that the dyability of wool could be increased if a solvent such as butyl alcohol was added to the dyebath (Speakman 1959, p. 746). Treating wool with bisulphite allowed the wool to be embossed with permanent patterns (Speakman 1959, p. 745). These types of setting patterns also had been developed to provide an enduring lustre to pure wool products (Speakman 1959, p. 746).

What is clear from the developments of synthetics and blends is that they were innovating new marketable effects which wool products needed to imitate to remain relevant. The wool industry succeeded in doing so, which points in the direction of the main differential factors being cost and consumer perception. According to Schneider (1994 p.

2), although the creation of nylon was initially hailed as miracle of science, the younger generation pushed back against synthetics. Many middle-class individuals came to distain pure synthetics. However, blending was a way forward to tolerably undermine the cultural distaste of synthetics.

> *"Scores of college educated American men and women with whom I have spoken on the subject of polyester – the most versatile and emblematic of the synthetics – are convinced that it does not 'breathe'; that it 'feels' inferior; that it comes in garish or less than subtle colors. Polyester, I have been told, feels like Saran Wrap on a hot day; provokes uncontrollable itching and sweating; is a 'yucky' plastic. My casual probing has also elicited numerous references to class stigma: the word polyester conjures up the image of a lower middle class tour group filing off a bus at Disneyland in pastel leisure suits. To one of my informants, a self-described cotton person, 'polyester is K-mart." (Schneider 1994, p. 2).*

> *"Of course, like all taboos, there are degrees of vigilance in practice. Older advocates of the naturals, if their jobs involved a lot of travelling, welcome wrinkle-free clothing, even if it means lowering their standards. And a younger would-be purist told me that she will 'tolerate up to 20% polyester if it feels good.'" (Schneider 1994, p. 2).*

On the end of manufacturers, the different classes were seen as markets to capture. The advent of synthetics and blends ushered in a new era of experimentation. According to Thurston (1956, p. 31), no longer was there a strict dichotomy between natural and man-made, instead, there were new and more flexible materials that could open up a great deal of possibility in providing the consumer with new and exciting clothing.

6.5. Sink or Swim

Despite all these efforts, the situation of wool in the world market continued to deteriorate – going through a series of cyclical declines. While the total market for yarns and fabrics continued to increase from the 1980s, the proportion of market share of wool continued to decline, becoming a marginal element of the total market with only 2.1% market share in 2010 (see Figure 4).

For New Zealand, the Wool Board faced a significant crisis after 1967 when the wool price steeply declined, ending a period of solid returns that had held since the Korean War in the early 1950s. From this point onwards, wool would experience a deepening crisis of economic viability, which would then destabilise the previously secure position of institutions like the Wool Board.

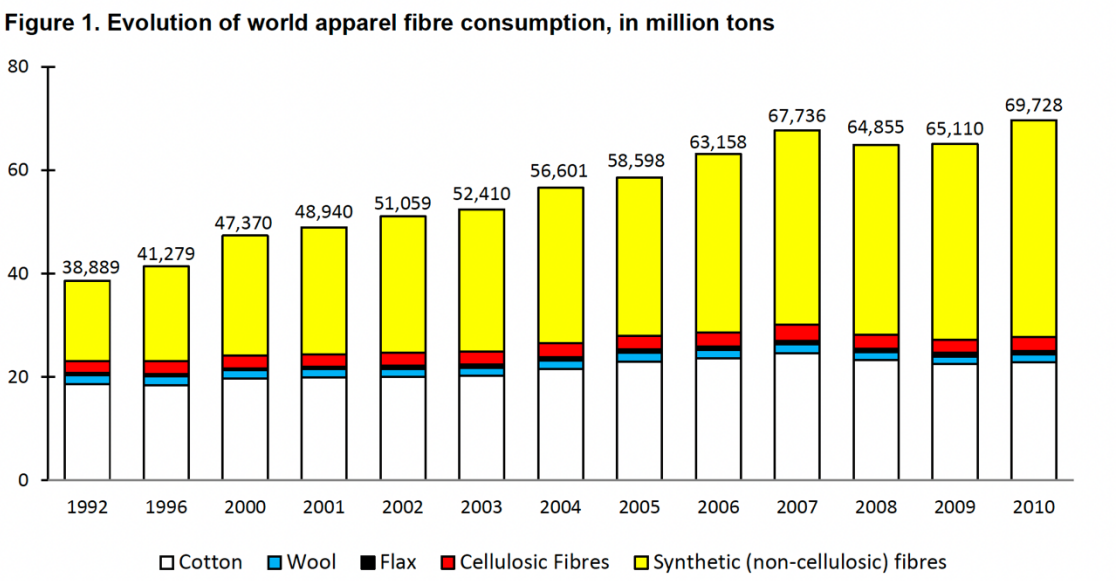

Figure 4: World Market Share of Apparel Fibres.
Source: FAO World Fiber Survey 2013

The pastoral farming economic crisis of the 1970s has usually been attributed to the loss of access to the British market for pastoral products after 1973 once the UK joined the European Common Market. After a period of subsidisation by the Muldoon National Government between 1978 and 1983, during which pastoral farmers received a range of emergency supports, the discursive tenor of pastoral farming industry strategy took a dramatic new turn with a broad embrace of neoliberal economic theory.

While the policy and economic dynamics and consequences of neoliberalisation in New Zealand farming have been much discussed elsewhere (for a review see Campbell and Lawrence 2003; Lawrence and Campbell 2014), for the purposes of this discussion paper it is worth briefly considering the discursive dimensions of neoliberalisation and their effect on wool industry strategies to artificial fibres.

First, neoliberal discourse (and policy outcomes) were strongly oriented towards ‘market rule’ and large quasi-governmental institutions like the Wool Board were directly targeted as ‘market distorting’ entities.

This led to second set of discursive claims: market rule could only be established by eliminating government agencies, and privatising those agencies that could potentially be supported through private industry and consumption. As part of this, a long-simmering tension over the political role of the Wool Board transitioned into a direct plan to break up the functions of the Board and privatise its various elements.

The final result of this was the demonising of ‘government intervention’ into markets as ‘distorting’. Hence, programmes to support, promote or manage products and markets were targeted for elimination. Wool marketing and branding was privatised, with various

companies taking ownership over, or creating their own wool branding (Conforte et. al. 2011: 154).

The dismantling of the Wool Board unfolded through the 1990s, and the discursive power of the new neoliberal policy environment was so strong that by 1999, two thing happened:

1) The Wool Board itself commissioned McKinsey and Co to conduct a review and provide recommendations on the full privatisation and disestablishment of the Board, and
2) When put to a vote of wool producers, over 90% of growers supported the recommendations of the McKinsey report.

From then, the sale of the Wool Board, and the disestablishment of various functions was rolled out. By 2004, the Wool Board ceased to exist, and its prior advocacy functions were transferred to a new organisation: Meat and Wool NZ. In 2010, after a continued decline in the economic fortunes and income-earning capacity of wool, the organisation changed its name to Beef and Lamb NZ.

The one segment of the wool industry that ran counter to this trend towards deregulation and privatisation was the fine wool sector. Pawson and Perkins (2013, 2018) characterise the emergence of a resurgent fine wools sector as happening around the margins of mainstream institutions like the Wool Board. A select group of High Country wool producers – already holding considerable social status and capital – began an initiative to directly contract Italian suit manufacturers, or access these manufacturers through an elite auction in Australia which combined 'fine wools' from Australian and New Zealand merino sheep. From the success of this emerged a private company to market New Zealand merino wool, followed by a series of niche private ventures facilitated by the metrological elaboration of 'fine wool' grading scores.

The arrival of this elite supplier network aligned with the emergence of a manufacturing, design and branding initiatives around the new market niche of LOHAR (Lives of Health and Recreation) consumers, most notably the New Zealand-based company Icebreaker. These small-scale initiatives succeeded in breaking out of the low-value, commodity trading in New Zealand wool and began to reap significant new value from fine wool as a product.

In effect, they also become the most successful proponents of the 'blend and join' strategy and managed to market and brand their products to capture many of the older pro-wool attributes that were established by earlier generations of wool scientists, but also to move their products up the market to capture high value niches. Many of their products at the highest value-end of their product range were 'pure merino', a significant number of products were wool/synthetic blends designed for specific high-performance functionality, and a range of cheaper synthetic-only products filled out their suite of products.

The full extent of their strategy is revealed in a change of terminology: Icebreaker no longer refers to its products as made from wool but instead describes the composition of its fabrics from superior combinations of 'fibre'. As a sector they are notable as one niche that has moved against the tide of declining fortunes and values for wool. In short, they reveal the full extent to which the mainstream wool sector has continued to decline.

7. Discussion: Artificial Fibres and New Zealand's wool industry?

The intention of this research report is to investigate:

- One of the kinds of technological disruptions that have happened in primary production over the last 100 years.
- How industries respond to these kinds of disruption.
- How this might be understood within a wider theoretical framework of theories of appropriation and substitution.
- How this case study might inform subsequent theorisation and analysis of these kinds of transitions.

Seen from the broad sweep of 20th century agricultural history in New Zealand, the wool sector and its relationship with synthetic fibres experiences a particular pattern of appropriation and substitution.

The artificial fibre industry emerges out of a series of technical innovations in the last decades of the 1800s, then went through the start of a period of expansion of market share into the textiles and apparel sector after WW1. The really dramatic upsurge in the market situation of artificial fibres occurs in the 1950s. The market success of Nylon in the 1940s ushered in an era of legitimacy and market recognition for artificial fibres that then spurred the rapid development of multiple artificial fibres. Once new fibres like polypropylene were introduced to the market in the 1950s, a rapid take-off occurred which resulted in the eventual capture of a massive share of the global fibre, fabric and apparel markets.

A series of social changes progressively shifted the level of public acceptance of synthetic fabrics constructed from artificial fibres. The ready-to-wear revolution that took place in the years immediately before and after WW1 - facilitated by changing clothing retail strategies, accompanied by the cheapening of the cost of fibres/fabrics - saw a much great level of retail purchasing of pre-made clothing by both women and a wider socio-economic range of households. While the early retail history of ready-to-wear saw synthetics associated with the poorer classes, this stigma – while never entirely overcome – began to erode due to the superior colouring of synthetic fibre, and their durability and wearability both as wholly synthetic fabrics and in wool blends. By the 1970s, synthetic fabrics are established as the market norm in many countries, with natural fibres like

wool (but only to a lesser extent in cotton) increasingly marginalised to niche parts of the fabric market.

As artificial fibres became more technologically feasible, cheaper and more reliable, they posed, in hindsight, an obvious threat of potential market substitution of wool products.

For the first decades of market growth after the 1920s, the different institutions in the wool industry approached this threat of substitution with a range of underwhelming responses. The Wool Secretariat suggested that artificial fibres were a potential threat and were eating into market share in the 1930s, but they initially seemed to treat this as a very minor threat compared to two other things: disposal of surplus wool stockpiles from WWI (then WWII) and economic depression. In sum, the Wool Secretariat initially recognised the threat, but diminished it relative to other pressing concerns.

The newly established Wool Board also took a similar line in the subsequent decade. Debates indicate that while artificial fibres existed as a threat, wool had inherently superior qualities, was natural and healthy and would thus always be the superior and successful product.

In sum, for both these major institutions, artificial fibres and synthetic fabrics weren't their biggest problem, and there were plenty of reasons that were familiar and easily accessible as to why they didn't have to worry about them.

After WW2, as the wool sector was fully focused on disposing of surpluses, the artificial fibre industry was starting to create the conditions for a boom in synthetic fibres and fabrics. From the 1950s onwards, the potential for a total substitution of wool products became a hypothetical possibility, and industry figures began to coalesce around a range of strategies and discursive positionings to try to evaluate where the sector was heading:

1) Confront and push back - use science to stop the loss of markets. There was a strong reliance on the virtue of agricultural science to redirect wool in directions that would beat back the threat of artificial fibres. Scientists were enjoined to find more evidence of the healthy qualities of wool, as well as its natural qualities being superior in multiple ways to synthetics. They also were enjoined to seek out new uses for wool, with coarse wool carpets being the single most obvious area of success. Science was also seen as the avenue to reducing the cost of wool production on farms, with a view to achieving greater efficiencies that would allow wool to compete on price with synthetics.
2) Blend. There were two strategies that appear to follow the logic of appropriationism. First, one discursive position that circulated in the industry suggested that wool and synthetics would co-benefit in markets, as synthetics 'opened up' new markets, and wool then benefited as consumers in these new markets turned towards a higher quality product. The second was the elaboration in textile science of 'wool blends' which combined the cheapness and durability of synthetic yarns with the 'naturalness' and perceived higher-quality of wool. There is no evidence that the expansion of synthetic markets also improved the

market size of the wool export industry. However, the ‘blending’ strategy persisted and became part of the eventual strategy for ‘fine wools’ that has allowed a small niche of wool producers to remain profitable.

3) Surrender. In innumerable market segments, wool became outcompeted and was almost entirely eliminated. Faced with almost total substitution of the sector, governments and leading institutions underwent a process of semi-planned restructuring resulting in a downscaling of the sector into a series of ‘hopefully’ profitable niches. This strategy recognised that in most parts of the market, wool had been substituted by synthetic fabrics and artificial fibres.

Seen through the lens of appropriation and substitution, the decline and fall of the New Zealand wool industry reflects Burton’s insight about industries like vanilla (Burton 2019). In that case, vanilla was almost entirely substituted by artificial flavourings, and retained a niche in world markets as the natural alternative with ‘superior’ qualities. In those situations where scientific innovation in textile science, or radical innovation in industry business approaches created a successful niche of blended products, the usefulness of these appropriationist strategies nevertheless only preserved niches, and the mainstream industry still experienced widespread substitution.

This transition also strongly resembles the predictions for the Norwegian beef industry laid out in Burton and Fugelstad (2020) in which the initial engagement with synthetic proteins suggests a series of appropriationist discourses which could potentially benefit farmers, but the long term trajectory is towards substitution which entirely eliminates farms and farmers from the production chain.

What this case study does, however, is also expose the limits of value of the appropriation/substitution framing for understanding industry transitions. While this framework undoubtedly does provide a better picture of what happens in situations of technological disruption compared to orthodox models of ‘innovation cycles’ and ‘creative destruction’, they are, at best, a form of descriptive heuristic that allows for an identification of a particular shape or pattern to the overall transition, without opening up much in the way of complex engagement with the different agencies and contingencies that lead to appropriation, substitution or some complex mixture of the two.

As a result, it is important to look for more nuanced and complex frameworks to understand transition, rather than simply rely on appropriation/substitution. The subsequent publication of these historical case studies of technological disruption will attempt to undertake just such a task.

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