

**Infestations as a Natural Disaster:**  
**The Economic Impacts of the Fonterra Whey Protein**  
**Concentrate Contamination Incident**

By

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## Abstract

This paper presents the results from an investigation into the economic implications for New Zealand of the 2013 Whey Protein Concentrate contamination incident (popularly known as the Fonterra Botulism scare). It assesses the impact of this incident to dairy exports using synthetic control methods. A synthetic counterfactual scenario where the incident did not occur is developed using weighted averages of the dairy exports of countries unaffected by the scare. The research finds that there was an initial negative shock to the exports of products that were thought to have been contaminated, but that there were no significant sustained impacts on other dairy products. The affected products make up only a small proportion of New Zealand dairy exports, with the vast majority of dairy exports being unaffected products. Infant formula exports appear to have recovered somewhat in the long run, however whey product exports remain lower than they otherwise would have been.

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# Chapter One: Introduction

## 1.1 Research Motivation

This research identifies the potential impacts of a biological infestation on the agriculturally dependent New Zealand economy. It focuses on a case study of the Whey Protein Concentrate (WPC) contamination incident. The WPC contamination incident was one of the largest food scares to implicate New Zealand dairy giant Fonterra. It was drawn out over four weeks and surrounded by much uncertainty.

On the 3<sup>rd</sup> of August 2013, Fonterra released a statement that it was concerned that three batches of its “WPC80” (80% whey protein concentrate) had been contaminated with a botulism causing bacterium, *Clostridium Botulinum*. The company announced they were initiating a precautionary recall. Due to testing requirements, it was only able to be confirmed that the scare had been a false alarm on August 28<sup>th</sup>.

A significant complicating factor during this period was that Fonterra was unsure about the exact location of the affected product, or what it had since been used as an ingredient in. It was known however that a common use of WPC powder is in the production of infant formula. This increased concern and scrutiny around the incident because historically, quality issues regarding infant formula were known to have had horrific consequences. Past crises included the Israeli thiamine deficiency crisis of 2003 and the 2008 melamine contamination incident in China. In the former, 15 babies were hospitalised and two died (World Health Organisation, 2003). In the melamine contamination incident, 126,000 babies became ill, 53,000 were hospitalised, and at least four died (BBC News, 2010).

Botulism is a paralysis inducing illness that can potentially be fatal. Given the severity of the issue and the implication of infant formula, Sri Lanka, Russia, and China introduced total bans on the import of certain New Zealand Dairy products. Throughout the saga it was suggested in the media that this incident would have a devastating long run impact on the New Zealand dairy industry. After the Chinese melamine incident of 2008<sup>1</sup>, and the DCD

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<sup>1</sup> This was an incident where melamine, an industrial chemical, was intentionally added to infant formula in order to increase the apparent protein content. The formula was produced by Chinese company San Lu, in which Fonterra had held a 43% stake

contamination in 2012<sup>2</sup>, news media in New Zealand and abroad had become more sensitive to food safety issues. New Zealanders grew accustomed to headlines such as “Is New Zealand Milk safe to drink?” (Wall Street Journal Video, 2013) and “Chinese still think New Zealand dairy less safe” (Adams, 2014).

### **1.1.1 Local and Global Significance**

Historical research has shown that the New Zealand economy is impacted significantly by developments in its dairy industry, be they positive or negative. Fundamentally, any competitive advantage held by the New Zealand dairy industry is not based on price, but rather on the perceived quality of its products (Woods & Coleman, 2012). It would have therefore been sensible to conclude that a scare such as the WPC contamination incident could have significantly impacted the New Zealand economy had it damaged this reputation.

Despite the media furore surrounding the event, this is the first research that attempts to empirically quantify the event’s impact on New Zealand exports, or any element of the New Zealand economy. Attempting to quantify the impact of the scare is interesting for two reasons: there has been little research done into the long-term impacts of food scares, and it is not common for a developed country’s economy to be so heavily reliant on the exports of one food based industry— an industry in which it is also important on the world stage.

### **1.1.2 Research Approach**

This research estimates the economic impact of the botulism scare through an analysis of the size of the shock to dairy exports. New Zealand exports are used as a proxy for aggregate sales of dairy goods by New Zealand. This is a fitting assumption given that New Zealand exports 95% of the dairy it produces, and Fonterra has represented up to 95% of New Zealand farmers (Fonterra, 2014). It is hypothesized that sales would have been the first point of impact from the scare. Therefore, identifying the size of the shock to dairy exports would also detect any possibility for future research on the wider economic impacts from this incident.

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(Underhill, 2008). Fonterra’s relationship to San Lu was purely financial, and they were not implicated in the production of San Lu infant formula.

<sup>2</sup> Dicyandiamide (DCD) is a fertiliser of which traces were found in New Zealand milk products between late 2012 and early 2013. The New Zealand Ministry of Primary industries announced that the DCD posed no risk to human health, and was cited as saying that the main reason for suspension of the use of the product was due to the potential for negative public perception of the contamination.

The impact on exports is analysed through the development of a synthetic counterfactual; a scenario where the scare did not occur is modelled and then compared to actual export values. The synthetic counterfactual makes it possible to quantify the shock in terms of sales lost. It also makes it possible to identify any potential long run reputational damage.

In this research the counterfactual is developed from the actual exports of a group of control countries, so no forecasting is required. This means that the shock can be more accurately quantified because the counterfactual takes into account changes in the global dairy industry that occurred after the scare as result of other factors.

The remaining sections in this chapter set the scene: they describe the role of the dairy industry in the New Zealand economy, the role of Fonterra, and briefly the nature of the global dairy market. They also discuss the nature of modern contamination incidents as investigated by past literature. The literature is drawn from the fields of both economics and marketing, in order to analyse how consumers in a real life setting view the topic of food safety and what factors influence the way in which they react to food safety incidents.

The second chapter describes each element of the data set constructed for this project. It includes a range of summary statistics to help the reader better understand the context in which this event occurred. The third chapter presents the synthetic control methodology that was used to construct the counterfactual. The final chapter presents the results from the study, drawing conclusions about their causes and implications. A detailed timeline of the crisis can be found in Appendix I; a brief summary is presented in Table 1.

**Table 1: Summarised timeline of the WPC contamination incident**

May 2012	A torch is sucked into a processing machine at Fonterra’s Hautapu plant in the Waikato while manufacturing WPC80. Product is filtered using unconventional equipment, and the contamination occurs.
Late 2012	A customer rejects Fonterra’s product because of high levels of sulphite reducing clostridia detected during customised testing for that customer.
March 2013	Fonterra launches a technical investigation following advice that botulism causing bacteria may be the contaminant. The results of testing are inconclusive.
May/ June 2013	Intermittent discussions are held between Fonterra staff about what to do

	with the rejected product and other affected product which had already been sold. Limited tracing efforts are made.
26 <sup>th</sup> June 2013	Fonterra commissions AgResearch at Massey University to conduct explicit testing for Clostridium Botulinum, despite the laboratory not being accredited to perform such tests.
31 <sup>st</sup> July 2013	Testing (incorrectly) confirms the presence of Clostridium Botulinum.
3 <sup>rd</sup> August 2013	Fonterra makes a media release through NZX at 12:20 am advising that there is a “quality issue” with the associated product. They initiate a precautionary recall.
18 <sup>th</sup> August 2013	Fonterra announces that all of the affected product has been located.
28 <sup>th</sup> August 2013	Following the results of further testing by accredited laboratories in the United States, Fonterra announces that the affected product had never been contaminated with Clostridium Botulinum, but rather Clostridium Sporogenes, which does not cause botulism in humans.

## 1.2 Fonterra and the dairy industry in New Zealand

### 1.2.1 The role of the dairy industry in the New Zealand Economy

Globally, New Zealand is the world’s largest exporter of dairy goods, exporting 51% of total exported Whole Milk Powder (WMP) and around a third of total dairy exports (OECD/ FAO, 2015; Fonterra, 2011). As a result, dairy exports make a direct contribution to the New Zealand economy by accounting for 26% of total New Zealand exports, and directly accounting for 2.8% of New Zealand GDP (NZIER, 2010). The dairy sector also makes a direct contribution to both national and regional employment, with 35,000 to 45,000 workers employed in farming and processing alone (NZIER, 2010).

The dairy sector also impacts the New Zealand Economy in many indirect ways (NZIER, 2010). Over time, there have been increases in efficiency in both industries that support, and those that compete with dairy farming. Outcomes include was increased production, development, and employment in the fertilizer and animal feed industries. Conversely, there has been a decline in farmland being used for beef and lamb production due to specialisation

in dairy trade (NZIER, 2010). It has led to increased efficiency in the meat industry as the meat industry attempts to remain competitive. Over time, the large shift of resources and investment towards dairy has also led to increases in productivity within the dairy sector itself (RBNZ, 2014).

A booming dairy sector over a number of years has also impacted the living standards of New Zealanders. At the national level, it has funded government expenditure through taxation. The New Zealand Institute for Economic Research (NZIER) estimated that schools, hospitals and the police force received 0.7, 0.6, and 0.2% more funding respectively in 2009 than they would have if the dairy industry had not grown in the preceding decade (NZIER, 2010). Their report also noted that the economic benefits of a strong dairy sector are nationally significant because farmers buy the majority of their goods and services outside the districts in which they live.

The impact of dairy farming on standards of living is amplified further at the regional level. Development within the sector has been credited with buffering the impact of the global recession in rural areas, where 20-25% of the population work in dairy (NZIER, 2010). This was possible because dairy demand, particularly from China, remained strong over this period. Conversely, rural communities suffer significantly when the dairy outlook is weak, as has been the case in 2015 (New Zealand Inc., 2015).

### **1.2.2 Fonterra**

Fonterra is by far New Zealand's largest dairy company; it is the world's largest dairy company. Fonterra was formed in 2001 through the unification of Kiwi Co-operatives Dairy Limited, New Zealand Co-operative Dairy Company Limited, and the New Zealand Dairy Board (Ministry For Primary Industries, 2014). The unification required legislative authorisation through the Dairy Industry Restructuring Act (2001). Fonterra inevitably inherited significant market power from the merger, so legislation was necessary to moderate the resulting risks to competition and efficiency (Commerce Commission New Zealand, 2014).

Like its predecessors, Fonterra is a co-operative, meaning it is owned by the farmers who supply it. Each farmer must own a number of Fonterra Co-operative Group (FCG) shares that is proportionate to the quantity of milk solids they supply to the company. This is known as the share standard. These shares are called 'wet shares'. Farmers can also own shares in

excess of the share standard, which are known as ‘dry shares’. It is not possible for investors who are not farmers to own Fonterra Co-Operative Group shares. However, investors can, along with farmers, own Fonterra Shareholders’ Fund (FSF) shares which entitle them to the same economic returns as FCG shares, but carry no voting or ownership rights<sup>3</sup>.

Fonterra’s size means that its performance can have a tangible effect on the New Zealand economy- through employment, as well as affecting farmers’ wealth and the performance of rural economies in general. However, it is not possible to use the Fonterra share prices to quantify the impact of the WPC contamination incident on the New Zealand economy, or even on Fonterra itself. This is partly because the share standard limits how many shares farmers can sell. Furthermore, the share structure means that FCG and FSF prices cannot move separately, as this would create arbitrage opportunities which are quickly plugged by the market. The reasons why it is not applicable to assess changes to the share price for this project are discussed in depth in Appendix II.

When Fonterra was formed, it represented 95% of New Zealand dairy farmers and exported 95% of the milk based goods they produced (Ministry For Primary Industries, 2014; Fonterra, 2014). In mid-2015, Fonterra’s representation of farmers had fallen to 87%, though they still export almost all of the product they collect (BrettKelly, 2015). The drop in representation has partially resulted from a new trend where international companies such as Danone and Yashili have been purchasing production plants in New Zealand (Ministry for Primary Industries, 2015).

Around eight per cent of dairy goods produced globally are traded on international markets, with a third of that trade coming from New Zealand (Fonterra, 2014). Fonterra accounts for around 2% of global dairy sales from its New Zealand production alone. The company also has a number of international partnerships. These include partnerships with Nestlé and Dairy Farmers of America, giving Fonterra significant weight on the world dairy stage. Such ties reflect the increasingly complex nature of the New Zealand dairy industry.

Fonterra’s business is split into two main areas. They supply international food and pharmaceutical companies with ingredients and specialty products, as well as owning a range

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<sup>3</sup> The Fonterra Shareholders’ Fund was launched in 2012 “facilitate liquidity of trading of Co-operative shares on the Fonterra Shareholders’ Market” (Fonterra, 2012). FSF shares are targeted to make up 7-12% of total shares (Fonterra, 2012).

of brands that are sold directly to consumers. The large number of business to business customers supplied by Fonterra complicates any potential recalls in the event of a product harm incident.

Over recent years Fonterra has moved to expand production globally. They aim to associate their brand with high quality dairy products in general, as opposed to merely New Zealand dairy products which are perceived to be of high quality. Currently, Fonterra is moving to establish its position as a dairy producer within China, with a commitment to producing “New Zealand quality milk,” (Fonterra, 2014). This could be as a result of recognition that developing countries will want to increase local production as demand for dairy remains high. The company similarly has offices in a number of other Asian countries.

Fonterra has also recently founded “Europo,” a company that provides European procured whey protein products to the European market (Fonterra, 2014). The company has recently also begun to expand into dairy production in South America (Fonterra, 2014). Much of Fonterra’s reputational standing which has allowed it to expand in this manner is the result of New Zealand’s overall ‘clean green’ image and internationally recognised institutional frameworks. Its efficacy in expanding globally reflects the notion that New Zealand has a strong reputation for producing quality dairy and that this reputation is profitable.

### **1.2.3 The Global Dairy Market**

While there continues to be a profit stream to be taken advantage of as Asian markets increase their dairy consumption, heavy reliance on a single industry, and overwhelmingly a single company, Fonterra, exposes the New Zealand economy to increased risk. As previously stated, when New Zealand sells its dairy produce, it does not (and cannot) compete on price, but attracts a premium due to the perceived quality and safety of the goods (Woods & Coleman, 2012)<sup>4</sup>. New Zealand’s ability to maintain this positive reputation is perceived to be crucial in helping the dairy industry retain its market share. It will be important if the company is to continue to perform relative to other dairy producers in a competitive market place. New Zealand is, after all, not the only country to have a solid reputation for providing safe dairy produce.

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<sup>4</sup> Historically, New Zealand and Australia benefited from relatively lower production costs than the European Union and United States. However, more intensive farming systems globally and growing input prices locally mean that New Zealand no longer holds this advantage.

Although demand for dairy goods is expected to continue to increase along with standards of living in developing countries, the upsurge stems from a small group of mainly Asian countries (Moore, 2009). This narrow base increases uncertainty around the long term trajectory of the global dairy market.

Typically, New Zealand and Australia have dominated exports of dairy powders, while the European Union has focused on the export of high quality cheese (Moore, 2009). Since the imposition of Russian Sanctions on European goods, there has been increased supply in the market. In March 2015, European dairy quotas were lifted, thus increasing supply and competition even further. The enactment of the Trans Pacific Partnership Agreement (TPPA) will remove tariffs on some dairy goods, further liberalising trade.

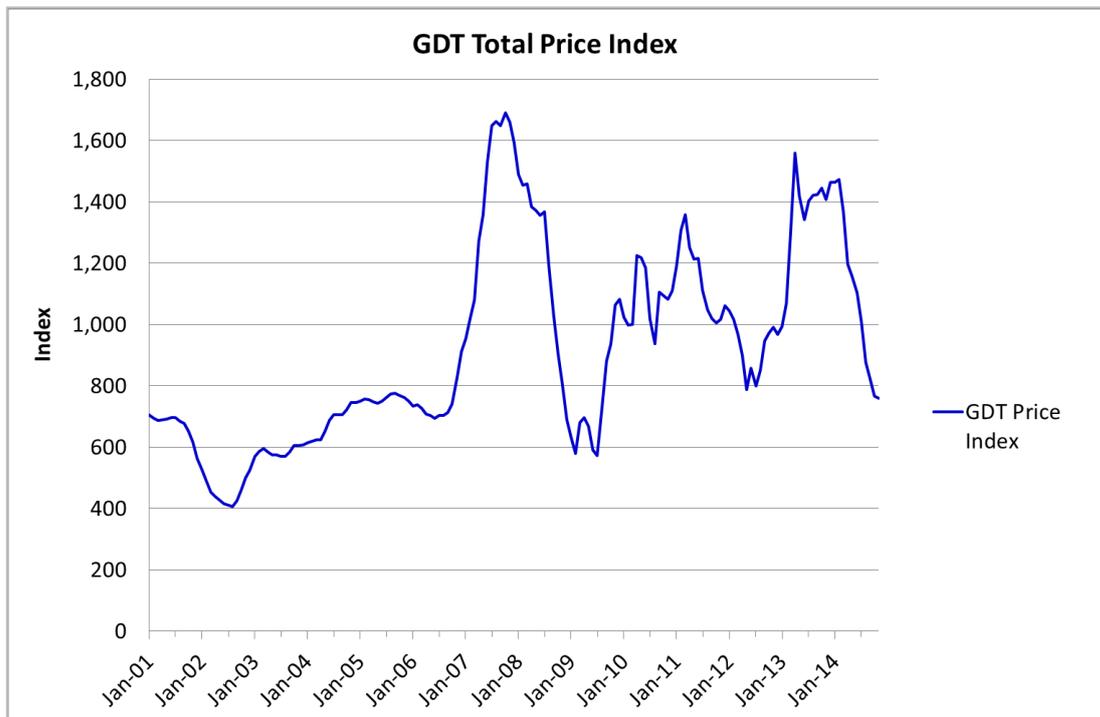
While New Zealand is a leading world exporter of many dairy products, it is not a comparatively large producer of dairy goods. India has been investing in, and is expected to continue to develop local milk production to meet increases in demand, while “the development of Chinese self-sufficiency in milk and dairy products is a main determinant of future price development on world dairy markets” (OECD/FAO, 2014) .

It has also been widely acknowledged that as international trade continues to expand so will the frequency of international food scare incidents, and the need for mechanisms through which to approach them (Knowles, Moody, & McEachern, 2007). While they do not specifically address food contamination incidents, the OECD Agricultural outlook identifies infestation as having the potential to “alter the setting [of dairy trade] rapidly” (OECD/FAO, 2014). This information posits the significance of this research for future food safety policy at both the business and national levels, and for the New Zealand dairy industry as a whole.

Dairy is one of the most volatile commodities globally, and has been particularly volatile since 2007. This is because trade is highly sensitive to market forces and cycles. The price has the potential to become even more volatile as tariffs are removed under the Trans-Pacific Partnership Agreement. When the price is high, this triggers a supply response; producers want to supply more at the high price. It also causes a demand response whereby demand decreases. It is easier for buyers to decrease their demand for dairy exports because the products that are exported are predominantly powders; fresh produce is not a major dairy export. Dairy powders have a shelf life of up to two years. The flow on effect of the supply

increase and demand decrease is then often a price collapse, and once again constrained supply. This volatility is aptly exhibited by the time series of dairy prices in Figure 1.

**Figure 1: GDT Total Price Index, which takes into account the prices of all goods sold on Global Dairy Trade.**



Due to this inherent volatility, a large proportion of dairy is sold in futures. Trading in futures contracts of varying lengths mitigates the risk to buyers and sellers. Futures contracts decrease these risks because they allow parties to agree on a price, within some range of the current price, to be delivered in the future. In 2008, Fonterra established the Global Dairy Trade online auction platform, now seen as a lead indicator of global dairy prices. Fonterra sells around 24% of its produce on the dairy platform, with the future contracts ranging from two to six months (Fonterra, 2015).

## **1.3 The Literature: Understanding Consumer Markets and Perceptions**

### **1.3.1 Attribution of Blame and Interpretation of Information**

Economics literature investigating food scares identifies subjective consumer beliefs regarding reputation and trust as being a key determinant of consumer decision making following a contamination announcement (Smith, van Ravensway, & Thompson, 1988; Mazzocchi, 2006; et. al). Significantly, these subjective perceptions of risk have been found to be vastly different from the true scientific risks of harm or fatality (Boker & Hanf, 2000). This disparity is likely a result of imperfect information and information asymmetries in the market. The nature of the information available to consumers therefore plays an important role in determining how quickly the market returns to an equilibrium, and the size of economic costs that result from the incident.

Richards and Patterson (1999) find that the economic costs of food scares are immediate and that reputation is difficult to restore. Their study is of a contamination incident that occurred in 1996 in which Californian strawberries were falsely announced to be the source of an outbreak of Hepatitis A. California is a major strawberry producing state. The authors found that even when only one brand is implicated, “all growers are made to suffer” (Richards & Patterson, 1999). It is interesting and significant to this research that Richards and Patterson (1999) find both immediate impacts on sales and long lasting impacts on reputation because as in the case of the WPC contamination incident, the Californian strawberries were never actually infested.

The literature also overwhelmingly finds that consumers respond disproportionately to negative information compared to positive information (Mazzocchi, 2006; Richards & Patterson, 1999; Smith, van Ravensway, & Thompson, 1988). In the Californian strawberry case, sales were affected for two years even after the source of the contamination was found to be Guatemalan raspberries (Richards & Patterson, 1999). Richards and Patterson do discover however, that in the fruit and vegetables market, drops in sales of a particular product are offset by increases in sales in other fresh produce. Unfortunately this would not mitigate the vulnerability of New Zealand exports because there are other countries that also have a reputation for producing safe infant formula and dairy goods (Adams, 2014).

Therefore, the substitution would likely be away from New Zealand goods, as opposed to away from dairy based infant formula.

The perceived credibility of a source of information is identified a key determinant regarding the ability of that information to impact consumers' decisions (Richards & Patterson, 1999). Particularly, "biases in the media coverage towards dramatic events or exaggeration of technological dangers are identified as a possible reason for drastic response by consumers" (Boker & Hanf, 2000, p. 472). This bias could help to explain why the Fonterra incident continued to be an event of interest in New Zealand even long after the threat to health was no longer a valid concern.

It should be highlighted that consumers from different international markets respond differently to information. The differences are determined by country and industry specific characteristics, as well as the way in which individuals within institutions behave (Holtbrugge & Baron, 2013; Folkes, 1991). This can be used to contextualise the way in which consumers respond to information about food scares. China, Fonterra's biggest market, operates in a different institutional framework and under a different set of cultural norms compared to New Zealand.

Cross cultural studies within attribution theory identify that, in the Chinese market, it is more common for individuals to adopt person perception when attributing blame and interpreting information (Holtbrugge & Baron, 2013). This means that rather than forming their opinions through official media streams who "seized the opportunity to cast doubt on foreign brands" (Civil China, 2013), Chinese consumers will give weight to opinions of other people who they know more closely (Alhabeeb, 2006). A reason for this style of attribution is the high level of corruption and a "deep mistrust of state run media," (Civil China, 2013). Therefore, high levels of news media coverage of an event will not necessarily have the same effect in China as one might expect them to have in New Zealand.

For this reason, when hypothesising about the effects of the WPC scare on Chinese consumer perceptions, it is also valuable to look at the social media response, which may more accurately reflect customer opinions. The think-tank 'Civil-China' conducted an empirical study whereby they tallied the number of positive, neutral, and negative social media posts over the progression of the WPC contamination incident (Civil China, 2013). They found that after the announcement, negative posts increased, but positive posts

increased also as a response to Fonterra initiating a precautionary recall. Following the announcement that all product was being recalled, there were instances in which positive posts about Fonterra outnumbered negative posts. That study contradicts New Zealand media reports which have iterated how “Chinese consumers still think New Zealand milk is less safe,” (Adams, 2014) despite perceptions not being investigated before the scare, only after.

### **1.3.2 Consumers Value Traceability in a Global Economy**

In recent years, increasing globalisation and international trade have allowed countries to reap economic benefits by producing goods in which they have a comparative advantage. However, specialisation has also meant that supply chains are becoming increasingly complex, and product traceability is becoming more difficult. These factors both make it easier for infestations to occur, and make it more difficult for companies to trace the affected product when an issue arises.

Additionally, consumers are becoming increasingly aware of issues relating to food scares as information about food quality features prominently on the political agenda of both developed and developing countries (Grunert, 2005). Fonterra manufactures products that are intimate for consumers; food, and especially food that is given to babies, is likely to invoke increased levels of emotion when discussed in the context of product defects. This will be due to consumers accounting for the possible harm to health. Correspondingly, Fonterra’s advantage in the market has stemmed from their reputation as being able to provide high quality, safe products.

A key issue in the WPC contamination incident was that when Fonterra announced the precautionary recall, they did not know the location of the affected product. All of the affected product was not located until 18<sup>th</sup> August (Norris, et al., 2013). This would have made their reputation and customer base more vulnerable, increasing the risk of a long-term impact from the incident. As mentioned in Table 1, very few attempts were made to trace affected product in the critical months before the specific bacterium was confirmed (Norris, et al., 2013).

The literature identifies traceability as being highly valued by consumers, and a crucial way to increase their perceptions regarding safety. China makes up a third of New Zealand’s dairy customer base (RBNZ, 2014) and Chinese consumers are increasingly valuing traceability of their food (Zhang, Bai, & Wahl, 2012). This is likely because consumer value of traceability

has been found to be positively correlated with increases in per capita income and education (Zhang, Bai, & Wahl, 2012). Ensuring traceability will become increasingly critical as much of the growth in dairy demand is still stemming from increases in standards of living in developing countries.

### **1.3.3 Quantifying impacts of food scares and other exogenous economic shocks**

The literature identifies three key methods by which the market effects of food scares are quantified. They are: a comparison of average prices, event studies, and comparisons of observed to predicted prices (Carter & Smith, 2007). The comparison of predicted prices to observed prices is done through various methods of modelling demand for the good, or an analysis of changes in price relative to the price of a substitute good.

It is not possible to use these methods in the instance of the WPC contamination scare because the global dairy price did not respond in this incident. This is depicted and discussed in Figures 2-5 in the export data summary statistics of Chapter 2. Developments in New Zealand do not generally affect the global dairy price (Kamber, McDonald, & Price, 2013). Prices are often considered exogenous, with the exception of large disruptions to supply that can arise from significant and sustained periods of drought. These have the ability to cause short term changes in the price (Kamber, McDonald, & Price, 2013)<sup>5</sup>.

This study estimates the economic impact of the Fonterra WPC contamination incident on the New Zealand economy by analysing the effect that the event had on New Zealand dairy exports. The estimation is done using a comparative case studies approach. Rather than attempting to find a country that was ‘similar’ to New Zealand in terms of dairy exports and drivers, or attempting to model dairy exports in this unique global environment, a data-driven approach is used to construct the synthetic counterfactuals.

The synthetic control method that is used to analyse the impact of the WPC contamination incident was developed by Abadie et al. It was formalised in their 2010 paper which analysed the effects of changes in tobacco regulation in California (Abadie, Diamond, & Hainmueller,

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<sup>5</sup> It is expected that any supply shock from this incident would not have been sustained enough to cause a shift in the price. If there was a long run impact from the scare, it is expected to have been demand side, as buyers would have no longer wanted to purchase New Zealand product.

2010). This method can be used to assess the impacts of any exogenous economic shock, subject to data availability. Panel data from similar but unaffected locations is required as a control group. The control group data is then used to construct a counterfactual.

The synthetic control method has been used to analyse a variety of contexts where an exogenous event in one region, be it economic, social, or natural; has impacted the trajectory of a collection of outcome variables. Apart from the original analysis of the effects of regulatory changes (Abadie, Diamond, & Hainmueller, 2010), examples include the analysis of affirmative action bans on college enrolment (Hinrichs, 2012), the effects of terrorist attacks in Spain on electoral behaviour (Montalvo, 2011), and the impacts of earthquakes in Italy on GDP per capita (Barone & Mocetti, 2014). Furthermore, it seems applicable to use a method that has been used in disaster economics literature (Barone & Mocetti, 2014; Coffman & Noy, 2012) for a case study of the WPC contamination incident because the potential impacts to the economy of an agricultural infestation could be likened to a natural disaster in New Zealand.

## Chapter Two: Data Set Construction

### 2.1 The Data: Source, Description, and Summary Statistics

A data set was compiled in order to apply the synthetic control method to the WPC contamination incident. The data collected for this project can be categorised into export data for New Zealand and a control group of countries, and other predictors of dairy exports for New Zealand and the control group. Other predictors of dairy exports used are exchange rates and climate. The global dairy price is also analysed, although this is by definition the same for New Zealand and the control group. The data for each variable is described below.

#### 2.1.1 Dairy Price Data

Dairy price data were collected from the Global Dairy Trade (GDT) auction platform. The data include a time series of the Global Dairy Trade Price Index, as well as time series of the prices of the three main export products: WMP, SMP, and AMF. The series are across contract lengths of 2-6 months. There is also a total price index for each product. From July 2008 to August 2010, there was one auction per month and from September 2010 onward,

there have been two. In the months where there were two auctions, a simple average was taken to create the series.

Price information was not included in the data set used to construct the synthetic controls, however the series are analysed as summary statistics to help contextualise the environment in which the WPC contamination incident took place. The global dairy price is assumed to be consistent between countries. Therefore, price data would not help to distinguish which countries should be used as controls. The technical details of the synthetic control method are discussed in Chapter 3.

Figure 2 is a time series of the GDT total dairy price index, with the date of the scare marked. It is the same time series of the GDT price index that was used to exhibit the volatility of the global dairy market in Chapter 1. Prices were historically high at the time of the scare. This was partly due to significant supply constraints resulting from an extreme drought that had affected Oceania in 2013 (Kamber, McDonald, & Price, 2013). However, no remarkable change is observed during or soon after the scare.

Figures 3, 4, and 5 depict the prices indices of the three main export products: WMP, SMP, and AMF, across contract lengths of 2 to 6 months, as well as the total price index (depicted as C2- C6 and total)<sup>6</sup>. Visually, there seems to be no impact from the scare on the prices of the individual export goods either. This is true for all contract lengths, as they continue the trends that they were following prior to the crisis. This would suggest that the scare did not have a major impact on global markets. It would also suggest that if there was any impact from the scare, it was contained to the affected product, WPC80, and that concern did not extend to other dairy goods.

If demand had been significantly constrained due to fear surrounding New Zealand's reputation, or a lack of traceability of the product, it is expected that this would be visible through a sharp decrease in the price. No such decrease is visible. There is also no evidence of a sharp increase in the price, meaning that there was not a significant supply response. The lack of a large supply response is expected to an extent, because the affected product made up only a small proportion of exports. Disruptions to the supply of other products would have

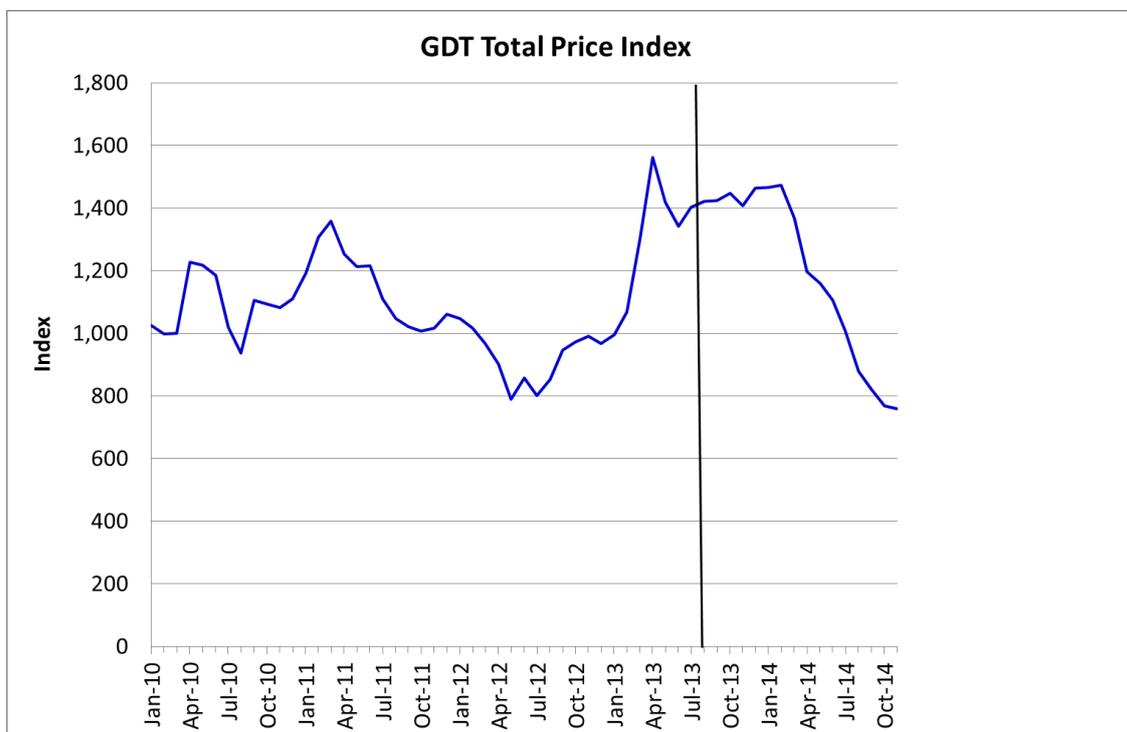
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<sup>6</sup> Where there is a break in the series, it is because the specific contract length for the specified product was not offered in that auction.

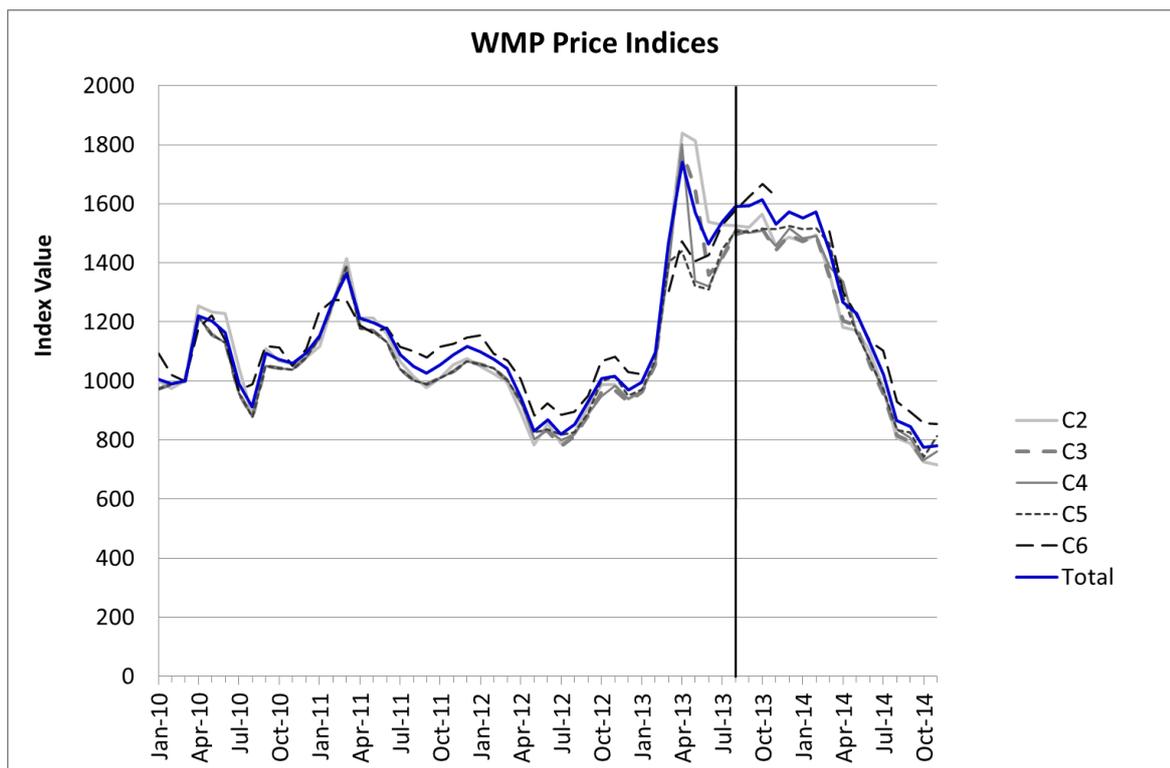
been limited as they would have probably been driven by logistical disruptions from the incident, as opposed to safety concerns (Fonterra, 2015).

The lack of a price response in the case of the WPC contamination incident in August 2013 can be contrasted to the turning point visible in all three series in March 2014. Around this time the market became flooded. There was a positive supply response from the high prices in the previous season, and also from a large amount of European goods that could no longer be exported to Russia due to sanctions (OECD/ FAO, 2015). Additionally, Chinese imports had slowed (OECD/ FAO, 2015). The result was a sharp, sustained decrease in the price.

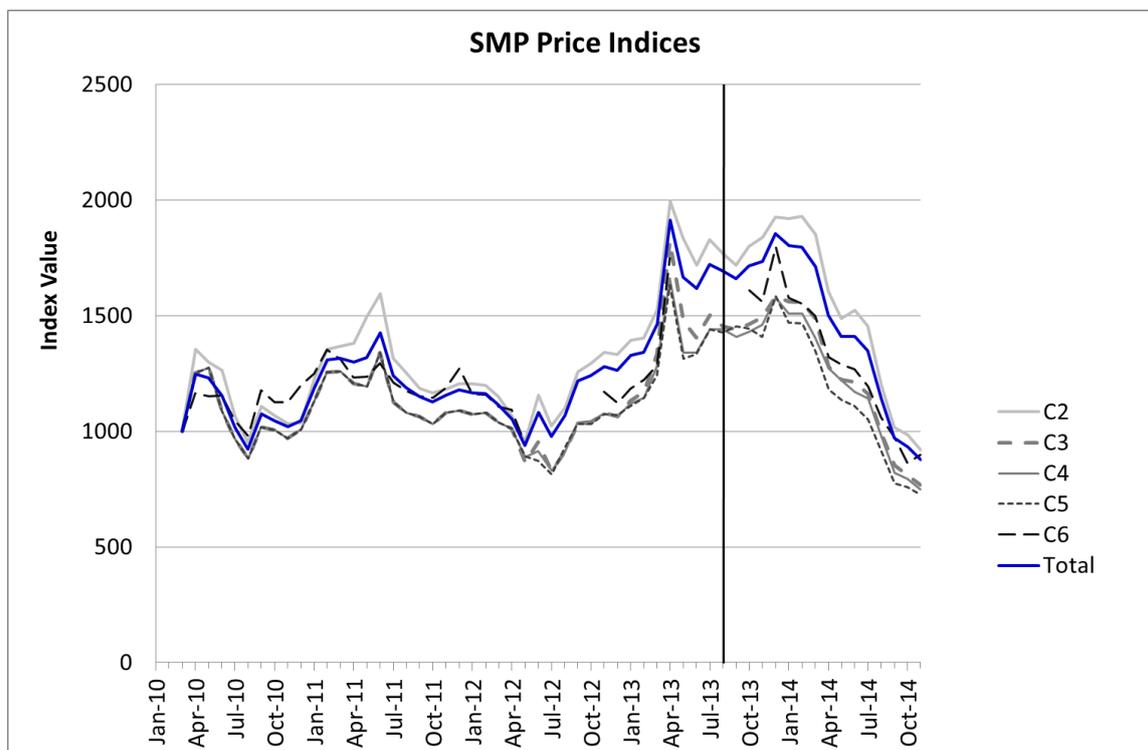
**Figure 2: Time series between 2010 and 2014 of Global Dairy Trade price index, taking into account all dairy goods**



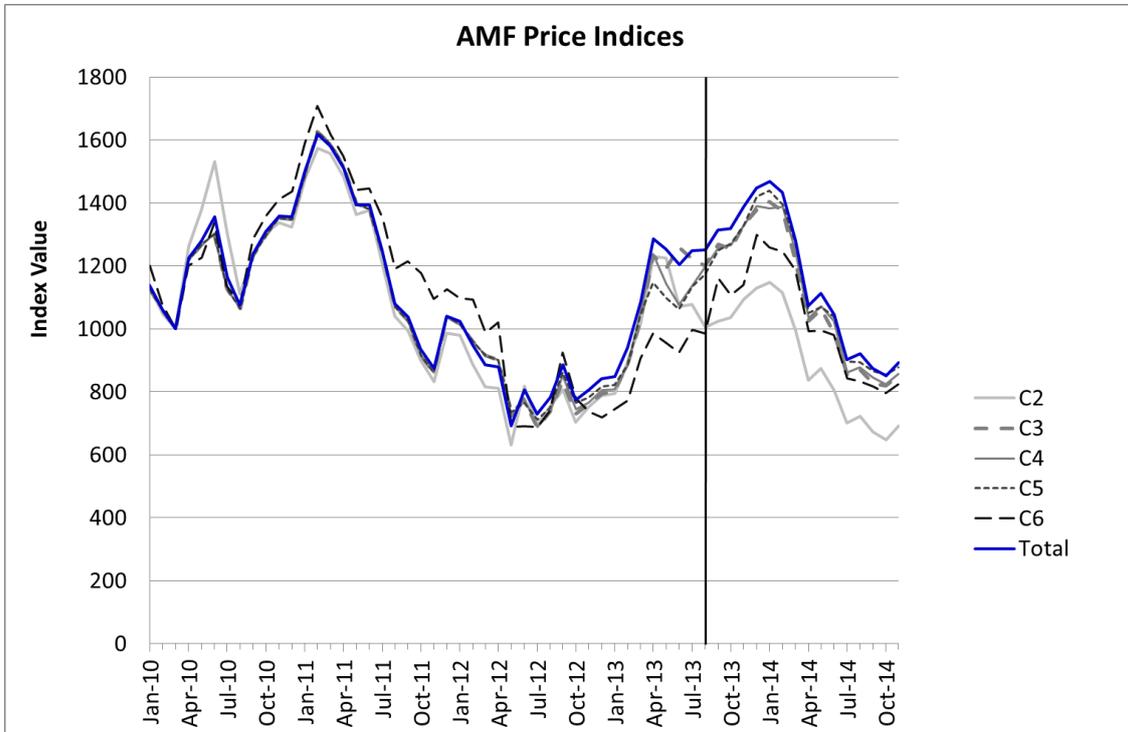
**Figure 3: Time series of Global Dairy Trade WMP Price indices over 2 to 6 month contract lengths, as well as a total WMP index between 2010 and 2014**



**Figure 4: Time series of Global Dairy Trade SMP Price indices over 2 to 6 month contract lengths, as well as a total SMP index between 2010 and 2014**



**Figure 5: Time series of Global Dairy Trade AMF Price indices over 2 to 6 month contract lengths, as well as a total AMF index between 2010 and 2014**



### 2.1.2 Export Data

Export data was collected for New Zealand and the control group. From this point, ‘export data’ refers to dairy export data. The New Zealand export data was collected from the Statistics New Zealand website, while the export data for the control group was collected from the UN Comtrade database. Including New Zealand, the data set constructed for this project covers between 70-75% of global dairy exports. The time series is monthly, covering the period from January 2010 to November 2014. January 2010 is the earliest data point available in the monthly Comtrade time series. November 2014 was the most recent data point available as at May 2015. This means that there are 59 data points in the time series.

The data from the Comtrade database was in United States dollars. There are 32 control countries included in the data set. A list of the countries can be found in Appendix III. The Statistics New Zealand data was in New Zealand dollars. It was converted to US dollars using

the average monthly exchange rate, which was obtained from the International Financial Statistics (IFS) database.

Two data sources (Statistics New Zealand and Comtrade) were used to create the dairy export dataset. It would have been possible to use only the Comtrade database, but two sources were used in the interest of achieving maximum accuracy. New Zealand exports are the primary variable of interest in this project and for this, Statistics New Zealand is the most reliable source.

In theory, the data from both sources should be identical, because Comtrade obtains its New Zealand export data from Statistics New Zealand<sup>7</sup>. However, in practice, using secondary data could potentially introduce measurement error. It is acknowledged that a possible drawback to using two sources is in the consistency of the data; however there was a minimum correlation of 90% between the New Zealand export data from Statistics New Zealand and Comtrade<sup>8</sup>.

Export values are the outcome of interest. Lagged export values are also introduced in the model to deal with the autoregressive components of the export data. It was not possible to use quantity data. The Comtrade database, which is the only comprehensive source of export data detailed enough for this project, only records export values. Nevertheless, it is applicable to use export values because there was no impact from the WPC contamination incident on dairy prices. The drawback from using export values is that they may be influenced by the exchange rate over time, as dairy is traded in United States dollars. On the other hand, the advantage is that the effects of the 2013 drought in Oceania will be dampened when values are used, because there was a partially offsetting price response to the decrease in supply (Kamber, McDonald, & Price, 2013).

Statistics New Zealand were contacted in order to identify what products were classified as dairy exports. There is no official list, however Statistics New Zealand did provide a suggested list of products. This list is available in Appendix IV.

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<sup>7</sup> In theory the only source of difference would be the exchange rate that was used to convert the series to US dollars.

<sup>8</sup> The least correlated good had a correlation of 90% when comparing the data from the two sources.

While New Zealand data was available for all of the products that Statistics New Zealand identified as dairy, many countries in the control group were missing most observations for minor export goods. As is described in the methodology in Chapter 3, if there are few suitable control units available, the synthetic control method should not be used. It is for this reason that the research only focuses on the directly implicated products and dominant dairy export items, for which there were a sufficient number of observations. These items are Whole Milk Powder (WMP), Skim Milk Powder (SMP), and Anhydrous Milk Fat/ Butter (AMF)<sup>9</sup>. Cheese products are also included as they are New Zealand's next largest dairy export. Whey products and infant formula are the products that were directly implicated in the scare.

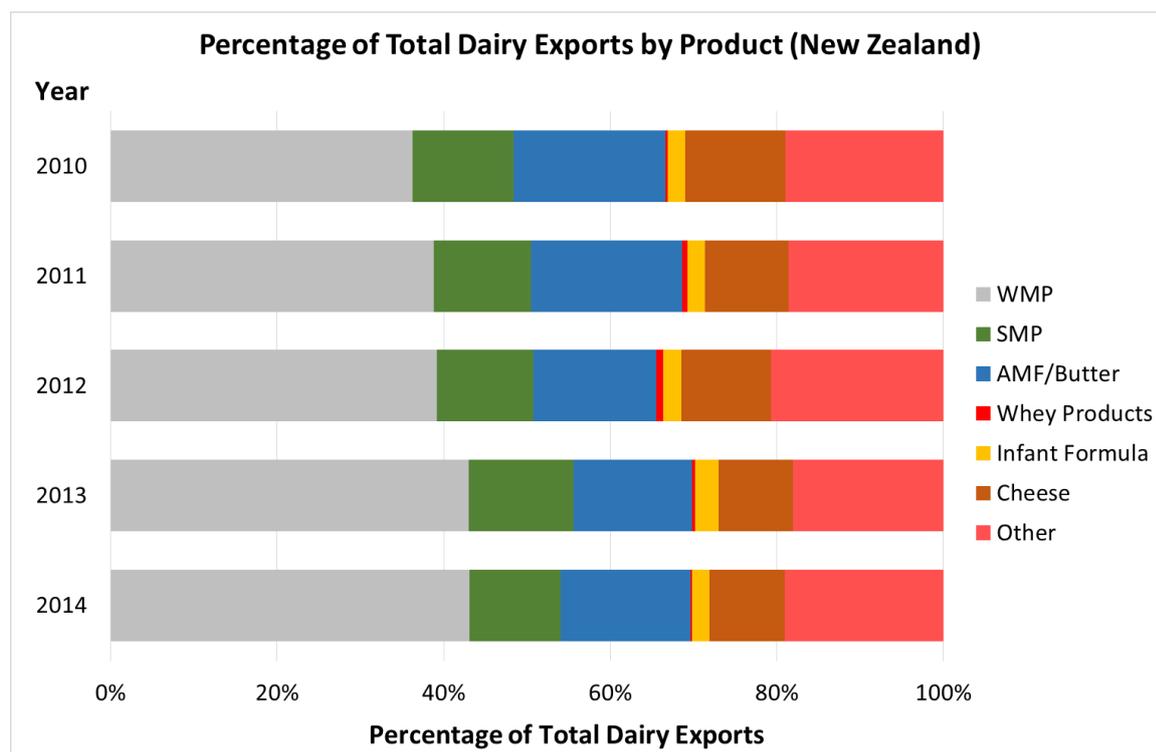
When comparing the complete Statistics New Zealand list of dairy products to the products that are actually analysed, a mean of 83.5% over 5 years of New Zealand dairy exports are captured in this study<sup>10</sup>. Figure 6 shows each of these products as a proportion of total New Zealand dairy exports. It is noteworthy that whey products, which include the affected WPC80, make up only around 0.5% of total New Zealand dairy exports. Infant formula, the other affected product, makes up between 2-3%. On the other hand, WMP exports make up around 40% of New Zealand dairy exports. This confirms that if there was a significant impact to New Zealand exports from this scare, it was from a loss of reputation or market share, rather than short term falls in revenue.

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<sup>9</sup> AMF is a major New Zealand dairy export but could not be assessed separately from butter because the Comtrade Harmonised System tariff codes were not specific enough to isolate it.

<sup>10</sup> The exact products that are included are specified in Appendix IV.

Figure 6: Percentage of total New Zealand dairy exports by product over the period 2010-2014



All goods that are exported are classified under the ‘Harmonised System’. The Harmonised System is an internationally consistent numeric classification system whereby each type of good exported is assigned a ten digit code. The system was introduced in 1988 and most recently revised in 2012 (Global Tariff, 2014). The codes range from two digits in length to ten digits, with longer codes signalling an increasingly specific description of the product (Global Tariff, 2014). All countries using the system use identical codes up to the six digit level, but beyond that there is variation (Global Tariff, 2014). The codes provided by Statistics New Zealand were specified to the ten digit level<sup>11</sup>.

The data in the Comtrade database is recorded at the six digit level. It is for this reason that ‘the affected product’ in this study is taken to be all whey products, rather than merely whey protein concentrates. It would not have been sensible to compare the six digit code in the Comtrade database to a more specific code in the Statistics New Zealand dataset. However, whey protein concentrates are products with a high value per kilogram compared to other

<sup>11</sup> The list provided by Statistics New Zealand included a record of both the old and the new code if a product code changed over the period covered by the data.

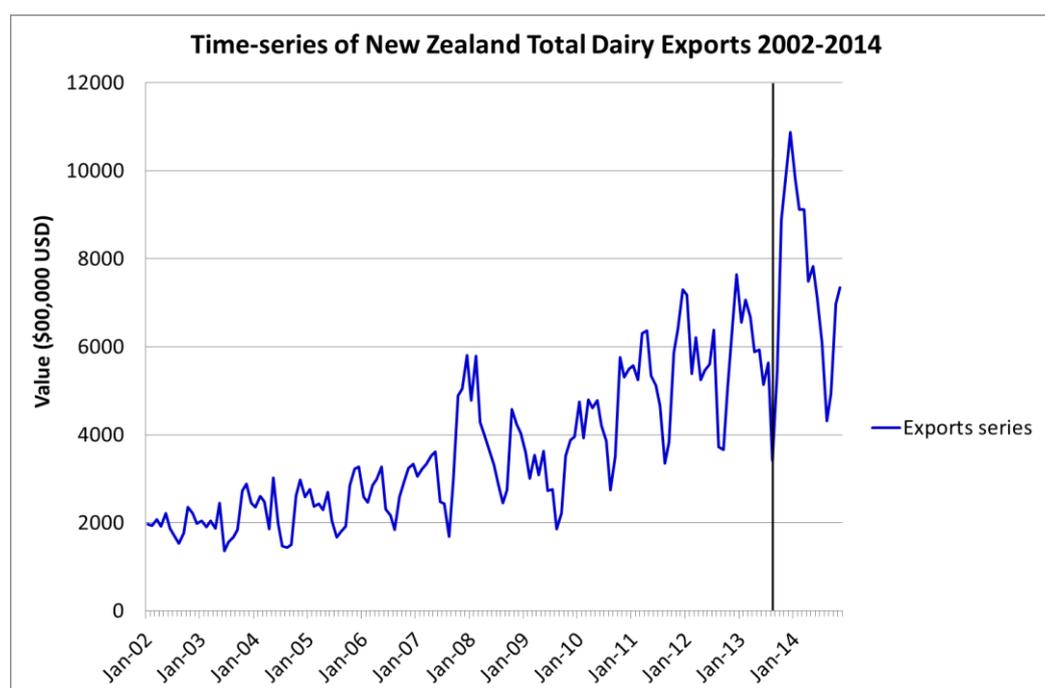
dairy products. As the research analyses export values, this would increase their proportion within the whey product category.

Ideally, whey protein isolates (WPIs) would have been aggregated with whey products, given that the affected product was WPC80. They were not automatically in this category because they are in a different HS group, even though they are ultimately used for similar purposes as WPCs. Whey protein isolates are actually whey protein concentrates with a concentration of greater than 80%. There was unfortunately very little data on WPIs. Only ten control countries had available data on these products. WPIs could not be included in the research as there would not have been enough controls with which to construct a counterfactual. A mitigating factor is that WPIs make up a very small proportion of New Zealand dairy export quantities and values overall.

### 2.1.3 Export Data: Summary Statistics

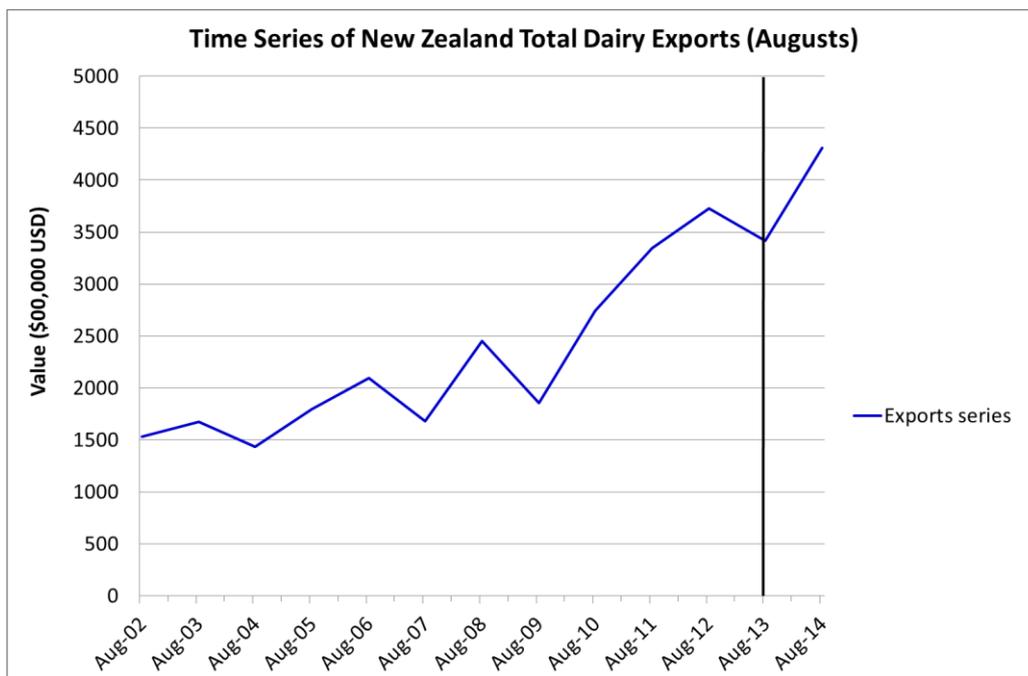
Aggregated New Zealand dairy exports are graphed in Figure 7. The vertical black line denotes August 2013, the month in which the scare occurred. In the figure it appears that there is a large downward spike in August 2013 coinciding with the time of the incident, though the data is clearly very seasonal. This is because the dairy season runs from August to April with May-July being the ‘dry off’ period (Hartwich).

Figure 7: Time series of Total New Zealand Dairy Exports (value) between 2002 and 2014



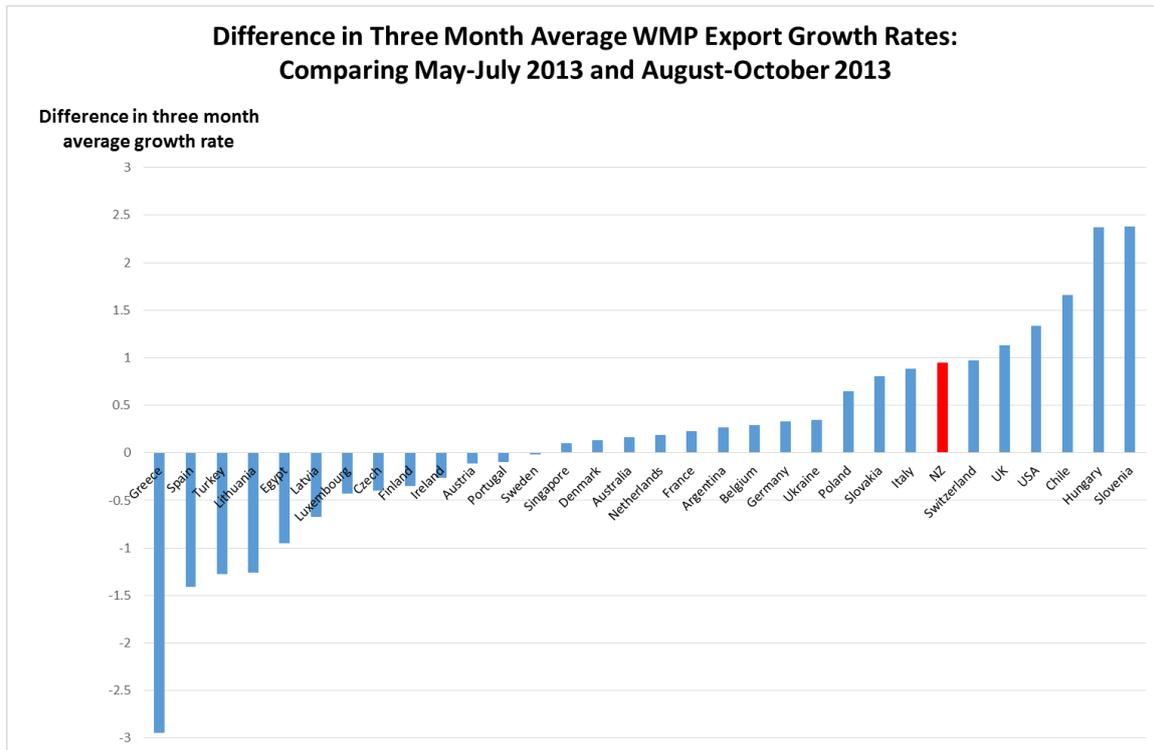
In Figure 8, consecutive months of August are graphed in order to exclude the seasonal disruptions. A potential shock to dairy exports is visible in 2013, but appears less dramatic. Furthermore, there appear to have been larger year to year declines in 2009 and 2007, when no shocks were recorded. The overall trend of dairy exports appears to have continued to increase over time. The time series in Figures 7 and 8 run from the year 2002 because it provides a better description of the trend than merely graphing the five years of data used in the construction of the counterfactual New Zealand.

**Figure 8: Time series of Total New Zealand dairy exports for consecutive months of August between 2002 and 2014**

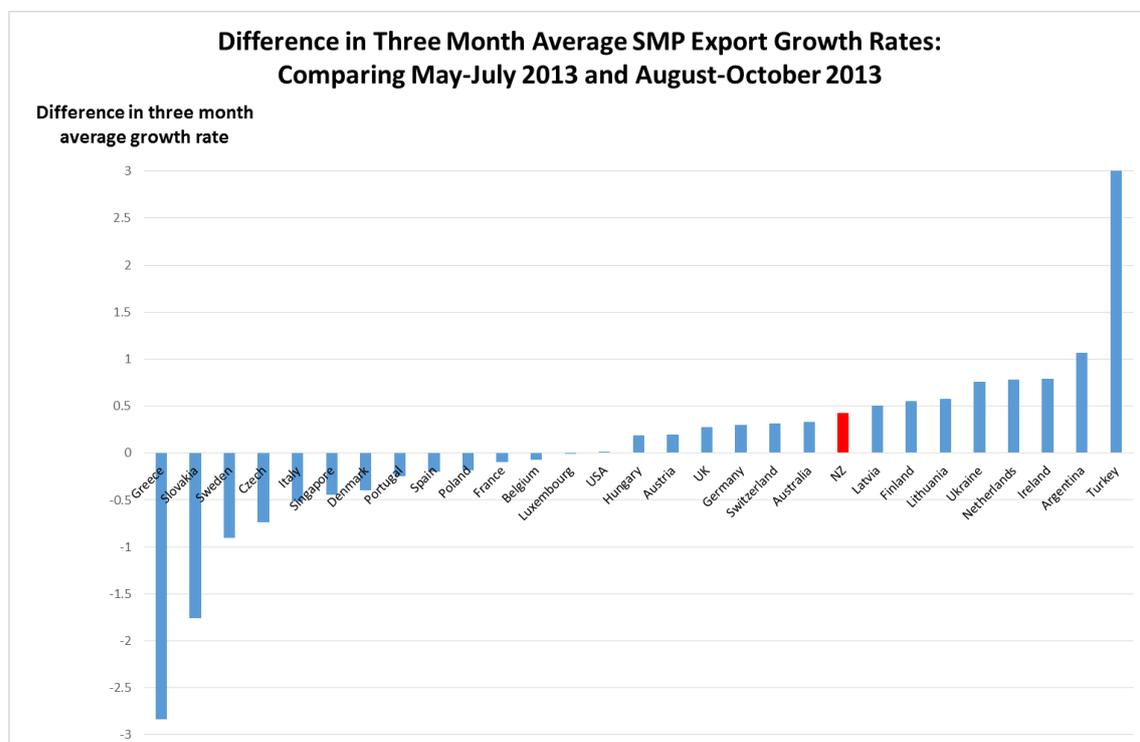


Figures 9 to 14 analyse the change in the three month mean of the growth rate of exports for each good in this study. Growth rates are analysed because this makes the three months prior to the contamination incident comparable to the three months after, as any seasonal variation is stripped out. This preliminary makes it possible to identify any potential impact from the scare: if the difference in the growth rates is negative, it indicates that dairy exports were growing more slowly on a year on year basis in the three months following the scare, compared to the three months prior. Exports growing more slowly would suggest that the WPC contamination incident may have had an impact on New Zealand dairy exports.

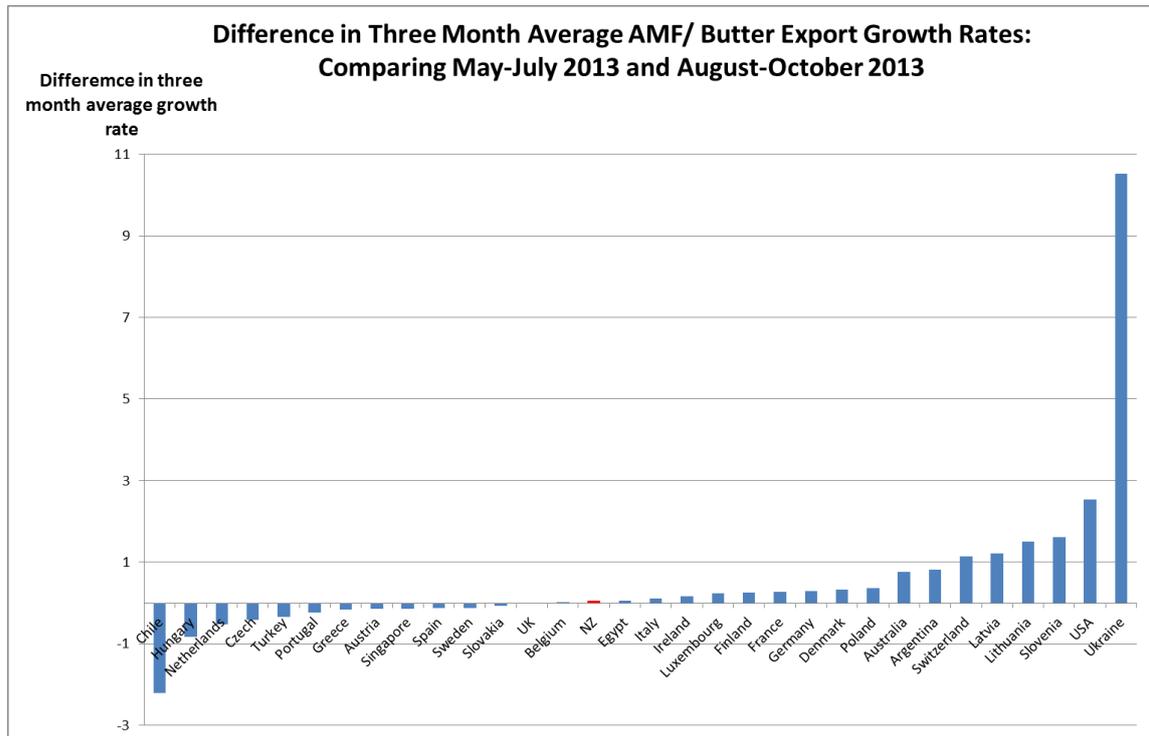
**Figure 9: Difference in three month average WMP export growth rates: comparing May to July 2013 (before the scare) and August to October 2013 (during and after the scare)**



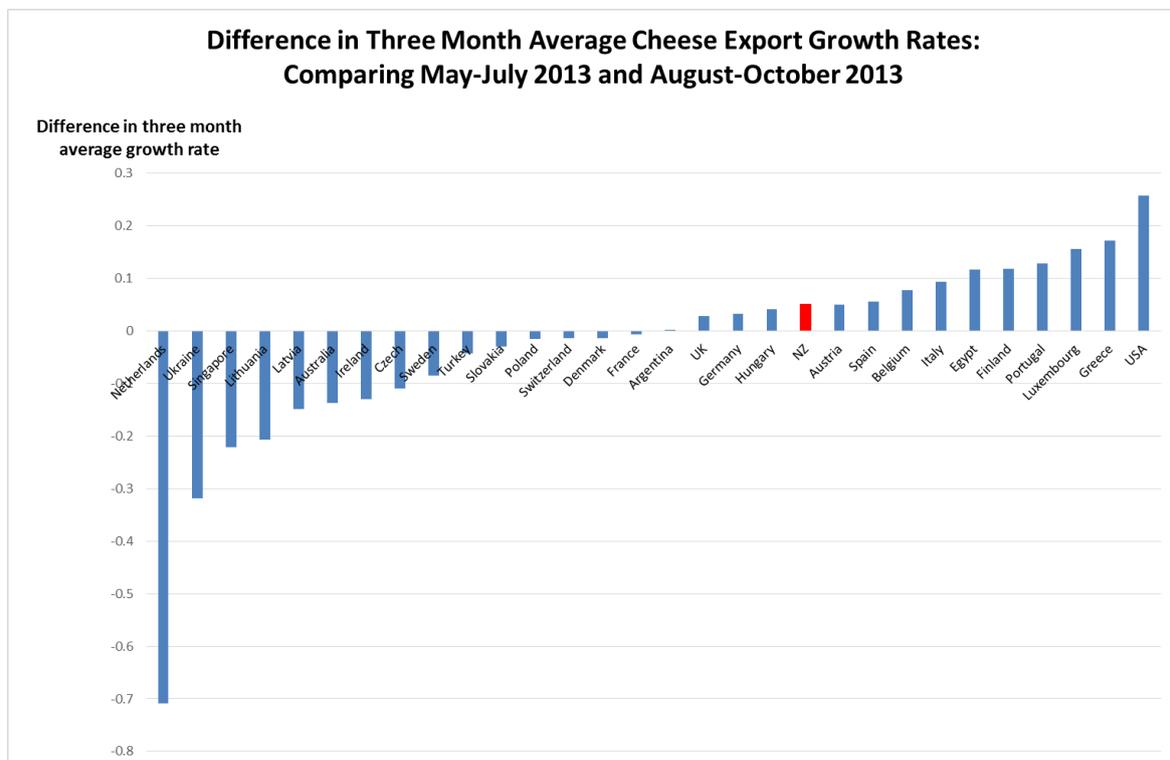
**Figure 10: Difference in three month average SMP export growth rates: comparing May to July 2013 (before the scare) and August to October 2013 (during and after the scare)**



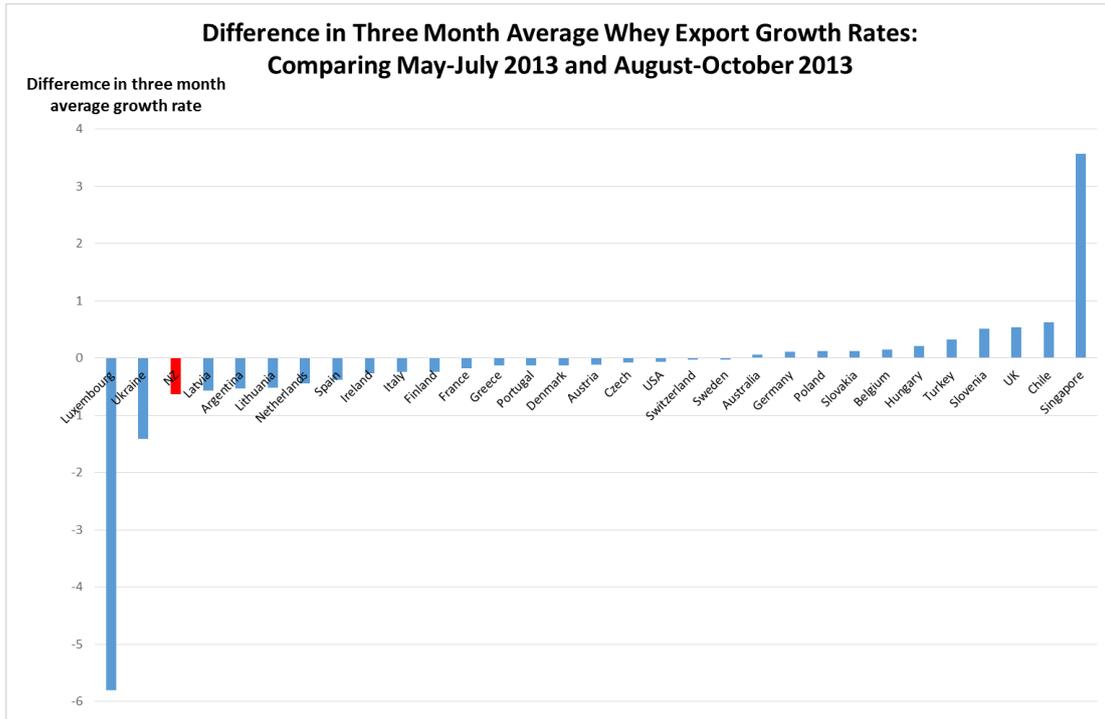
**Figure 11: Difference in three month average AMF/butter export growth rates: comparing May to July 2013 (before the scare) and August to October 2013 (during and after the scare)**



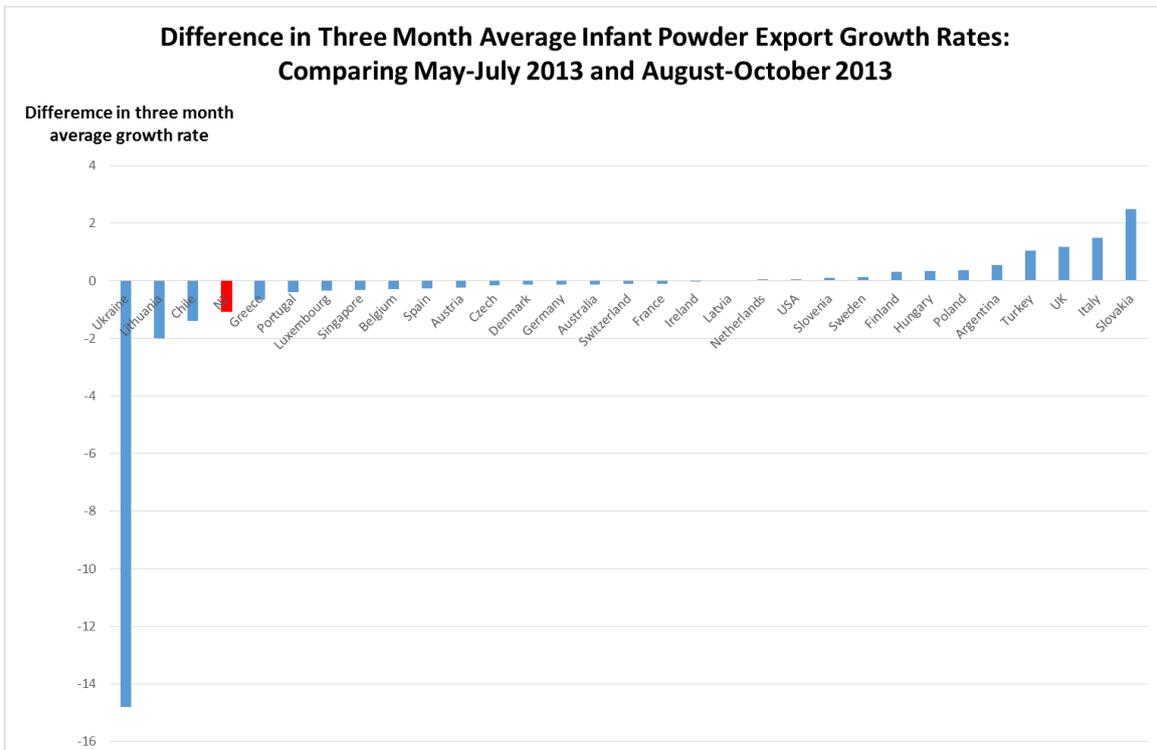
**Figure 12: Difference in three month average cheese export growth rates: comparing May to July 2013 (before the scare) and August to October 2013 (during and after the scare)**



**Figure 13: Difference in three month average whey product export growth rates: comparing May to July 2013 (before the scare) and August to October 2013 (during and after the scare)**



**Figure 14: Difference in three month average infant formula export growth rates: comparing May to July 2013 (before the scare) and August to October 2013 (during and after the scare)**



The figures show the differences in the growth rates of New Zealand's dairy exports across time compared to the differences in the growth rates of other countries' exports. For all three of the dominant products, WMP, SMP, and AMF/butter, New Zealand exports grew more in the three months following the contamination incident than in the three months leading up to it. In fact, in the cases of WMP and SMP, the New Zealand export growth rate differences are also in the top third of differences relative to the countries in the control group. This means that not only did New Zealand exports grow more, they grew by more than other countries' exports. For AMF/butter, New Zealand's change in growth rate is roughly in the middle of the control group. The growth rate difference of cheese exports is also positive, and higher than more than half of the control group. This is preliminary evidence against a very large impact from the contamination incident for these products.

In the cases of the affected products, whey products and infant powders, New Zealand's difference in growth rate is negative. The values are some of the most negative when compared to the control countries. This is visible in Figures 13 and 14. Of the countries that have the more negative differences in growth rate all bar Chile, that is, the Ukraine, Luxembourg, and Lithuania export only very small amounts of whey products and infant formula respectively. This could potentially explain their very negative growth rates because small changes in the quantities exported can have significant impacts on their average growth rates. It is less likely that this explanation would apply to the New Zealand results. While infant formula and whey products are not major New Zealand dairy exports, New Zealand nevertheless exports a moderate amount of these goods relative to the control group. This makes it more likely that these negative values are a result of the contamination incident.

These preliminary statistics would suggest that overall, there was potentially an impact on New Zealand dairy exports from the WPC contamination incident. In particular, they suggest that any potential impact was more prominent in the implicated goods, that is, in whey and infant products. The results show that in the cases of the other goods, New Zealand exports on average grew more quickly in the months following the incident than preceding it.

However the summary statistics do not necessarily indicate that there was not any impact on the goods that were not implicated directly in the scare. They do not shed light on whether these exports would have grown even faster had the incident not occurred. To determine this, it is necessary to use the synthetic control method to predict what the time series of exports would have been had the incident not occurred.

## 2.1.4 Exchange Rate Data

Exchange rate data between the domestic currencies of the countries in the data set and the US dollar was included as a control variable in the model. This is because dairy is predominantly traded in United States dollars. The exchange rate observations were monthly averages. The time series covered the period January 2010- November 2014. They were sourced from the IMF's International Financial Statistics database.

## 2.1.5 Climate Data

Late 2012 and early 2013 saw New Zealand experience one of its worst droughts in at least 40 years (Kamber, McDonald, & Price, 2013; NIWA 2013). This had a significant impact on milk production. Fonterra reported that collected milk volumes were down 2.3% in February, 16.3% in March, and 34.4% in April which was the height of the drought (Fonterra, 2013). Shortfalls continued, with 31.9% less milk collected in May and 11.8% less in June. These values refer to production of raw milk product, meaning that Fonterra would have been unable to take on extra one off orders outside of their regular contracts during this period, as they normally do (Fonterra, 2015).

The observations are in line with the findings of Kamber, McDonald, & Price (2013) which show that a drought in the first quarter is expected to have its largest impact on milk collected towards the end of the dairying season, namely in April and May. Furthermore, in their analysis of the economic implications of droughts in New Zealand, Kamber, McDonald, & Price (2013) find that droughts in the first and fourth quarters of the year have larger negative impacts on the economy than droughts at other times of the year. While the drop in supply generally does lead to higher prices, they find that the price effect does not dominate the decrease in supply until the third quarter, which would have been after the contamination incident in this case (Kamber, McDonald, & Price, 2013).

The size of the discrepancy between expected and actual collected raw milk product suggests that the effect of the drought on exports was large. Its impact also coincided with the timing of the WPC contamination incident. Therefore effects of the 2013 drought needed to be accounted for in order to construct an accurate counterfactual using the synthetic control method. Climate data was hence introduced into the model, but only for New Zealand and Australia. It was only included for New Zealand and Australia because these are the only two

countries in the dataset that use predominantly pasture based methods of dairy production. It is expected that the seasonal changes in climate would have a much greater effect on exports when this is the dominant form of production. Australia and New Zealand would therefore be the only countries where production would directly be associated with the weather. Indirect time variant effects for the other countries, such as those caused by higher feed costs in winter, would be captured in the time variant fixed effect term included in the model.

The Ministry for Primary Industries commissioned the National Institute of Water and Atmospheric Research (NIWA) to investigate the severity of the 2012/13 drought in New Zealand (National Institute for Water and Atmospheric Research Ltd., 2013). The results, released in June 2013, used an accumulated potential evapotranspiration deficit index (PED) to conclude that the drought had been the worst in 40 years, and in some regions, 70. It was not possible to use this same index in the model of dairy exports for this research because the index is specially calculated by NIWA for New Zealand. The same index is not available for Australia. It would not have been consistent or sensible to use two different indices for Australia and New Zealand. However, an index on a similar basis was used.

The climate index that is used in the model is the Global Drought Monitor Index (GDMI), accumulated at the six month level. It was downloaded from the website of the developers of the index (Vicente-Serrano & Begueria, 2015). The GDMI takes into account precipitation levels and temperature, as well as potential evapotranspiration. Evapotranspiration, essentially, is the rate at which water evaporates from the soil. Taking this into account as well as rainfall is very important when analysing the effects of drought on agricultural production. It is also in line with the methods of both NIWA (2013) and Kamber, McDonald, & Price (2013).

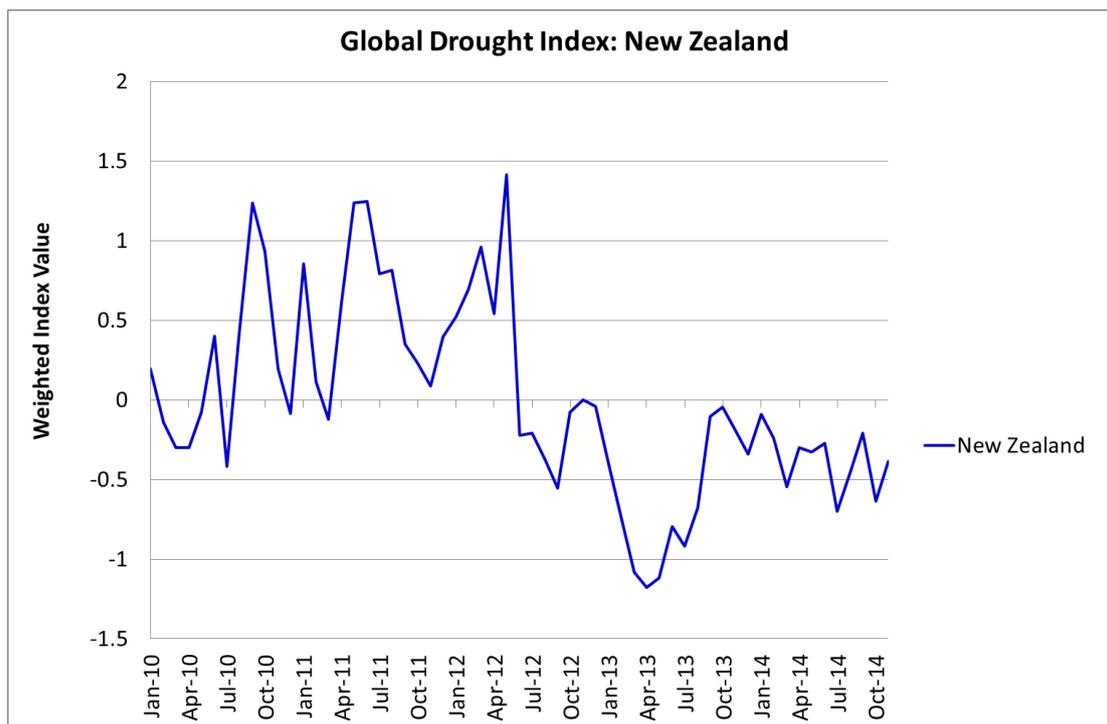
The GDMI is an adaptation of two widely renowned indices, the Palmer Drought Severity Index (PDSI), which has the benefit of being able to account for both wetness and dryness, and the Standardised Precipitation Index (SPI) which is comparable through time and across space (Vicente-Serrano, Begueria, & Lopez-Moreno, 2010)<sup>12</sup>. Figure 15 shows the New Zealand time series of the GDMI that was included in the model to help account for variation

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<sup>12</sup> The GDMI is very similar to the Standardised Precipitation Evapotranspiration Index (SPEI). The difference between the two is that the Global Drought Monitor Index is based on a slightly different estimation equation than the SPEI, in order to allow it to be calculated in real time. The GDMI is thought to generally be less robust than the SPEI, however it was chosen over the SPEI because the SPEI database is only complete to the end of 2013. For a more detailed description of the SPEI, refer to (Vicente-Serrano, Begueria, & Lopez-Moreno, 2010).

in exports that was due to the drought<sup>13</sup>. The mean of the GDMI is 0 and the standard deviation is 1. A long dry period is clearly evident from September 2012 to September 2013. This period encompasses August 2013, the month of the scare. The severity and persistence of the drought would suggest that it accounts for at least some of the lower exports observed in 2013.

**Figure 15: Weighted New Zealand GDMI time series between 2010 and 2014 showing the 2013 drought accumulated at the six month level**



The GDMI time series in Figure 15 is in line with NIWA’s analysis, which describes lower than normal rainfall over the period from mid-October 2012 through 2013, with a small recovery in November 2012 (National Institute for Water and Atmospheric Research Ltd., 2013). MPI officially declared the drought to be over in October 2013 (New Zealand Veterinary Association, 2013).

Dummy variables denoting the month were also added to the model. They were included to account for seasonality as southern hemisphere countries experience opposite seasons to Northern Hemisphere countries in any given month. The months were labelled in opposite patterns. That is, February in the southern hemisphere was labelled as February, but February

in the northern hemisphere was labelled the same as August in the southern hemisphere. There were dummies for all month except January, which was treated as the base case to avoid perfect collinearity.

## **2.2 Methodology: Data Set Construction**

A panel dataset was constructed using the variables described above, to be used to develop a synthetic counterfactual for New Zealand dairy exports. The synthetic control method was implemented using the package “synth” in Stata. The technical details of how synth operates are described in Chapter 3. For further details, refer to Abadie, Diamond, & Hainmueller, 2010.

### **2.2.1 Export Data**

Data on all New Zealand merchandise exports were first downloaded from the Statistics New Zealand website in the form of yearly spreadsheets. Each spreadsheet included tariff codes, descriptions, quantities, and dollar values for every type of good that New Zealand exported, for every month in which it was exported. It was not limited to dairy. The spreadsheets were then consolidated into one data set.

Next, using the Statistics New Zealand list of New Zealand dairy exports, dairy items were purged of all other exports. The data were then split into the six main groups: whole milk powder (WMP), skim milk powder (SMP), butter and dairy fats (predominantly AMF), whey and whey protein concentrates (WPC), infant powders, and cheese. Initially, there was also a category for dairy goods ‘other,’ but since not all countries exported all products, this category is only used in the summary statistics in Figure 6. This is also the reason why this research does not analyse the impact of the contamination incident on total dairy exports: it would not be sensible or robust to compare countries where ‘Total Dairy Exports’ consisted of different bundles of goods.

Aggregation into the six categories required manual analysis of codes and descriptions for each time period. This was necessary because in some cases items which descriptively belonged to the same categories (as defined by the scope of this project) were not grouped under the same HS codes. For example, infant formula is grouped under Chapter 19: Preparations of Cereal, Starch, Flour, or Milk; rather than Chapter 4: Dairy Produce, Birds’ Eggs, Honey, and Other edible products of animal origin not elsewhere classified- where

most of the dairy products were. A similar process was followed for data from the Comtrade database. Data was aggregated by product type, month, and country.

Not all countries exported all types of dairy product in all periods, even for the six main categories. In cases where one or two data points were missing, but in the surrounding months significant exports were recorded, a simple linear interpolation was done to balance the panel. This can be contrasted to the countries where for specific products, over half of the data were missing, or export values were negligible. In all cases except for the two described below, countries were excluded from the control group for the products for which they did not have sufficient data.

Argentinian exports are a significant case where some data were missing. Argentina is a major southern hemisphere exporter of dairy so it was important to include it as a possible control, even though data was only available until June 2014. The final 5 data points were missing, but that there were still 11 data points after August 2013 that were available. Similarly, Singapore is a major exporter of infant formula, exporting nearly \$600 million worth in 2010. Again, the last 2 data points were missing for all products. In order to be able to include these countries, it was necessary to forecast what their exports would have been in the missing time periods. The Holt-Winters forecasting method was used.

Using the Holt-Winters method was appropriate because the method is computationally simple, but takes into account both an overall trend in the data as well as a seasonal pattern. It uses exponential smoothing, weighting all data in the series to some degree. This means that there is no concern surrounding the non-stationarity of the data.

### **2.2.2 Climate Data**

Figures 16 and 17 are the digital maps that were created for this project to allow GDMI values to be calculated for each dairy producing region. For New Zealand, the regional boundaries and distribution of dairy production was sourced from DairyNZ's 'New Zealand Dairy Statistics 2013-14' publication (DairyNZ, 2014). Australian dairy production data and boundaries were sourced from the Dairy Australia website (Dairy Australia, 2013). It was necessary to create the maps in Figures 16 and 17 because the original maps are non-digital, and therefore not compatible with ArcGIS software, meaning their boundaries could not be used to calculate the GDMI values for the different regions. Once Figures 16 and 17 were drawn, the GDMI values

for each region were then weighted by the percentage of dairy production that came from that region in each country. This resulted in one GDMI time series.

Figure 16: New Zealand Dairy Production by Region as a Percentage of Total Dairy Production 2013-14

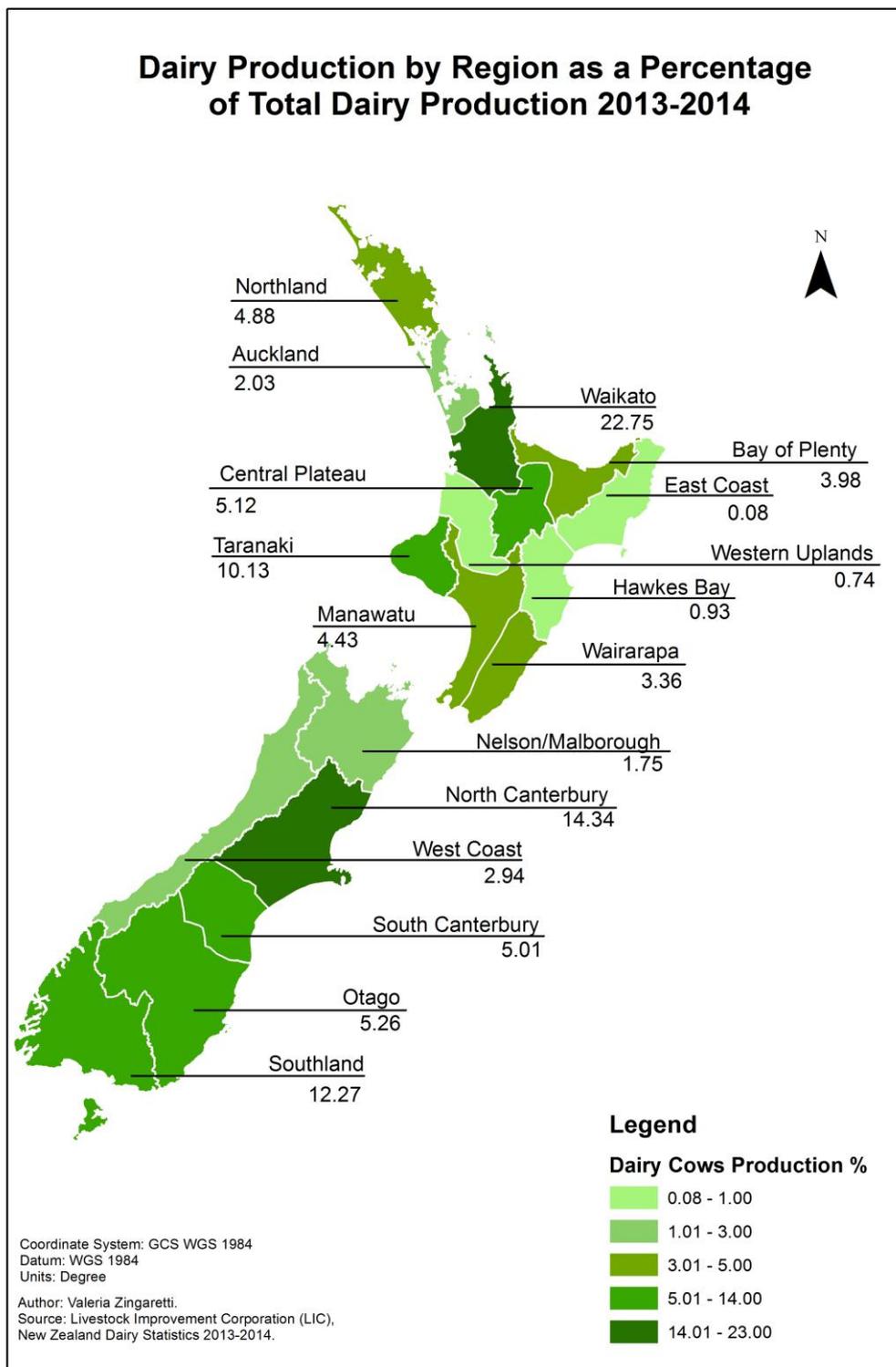
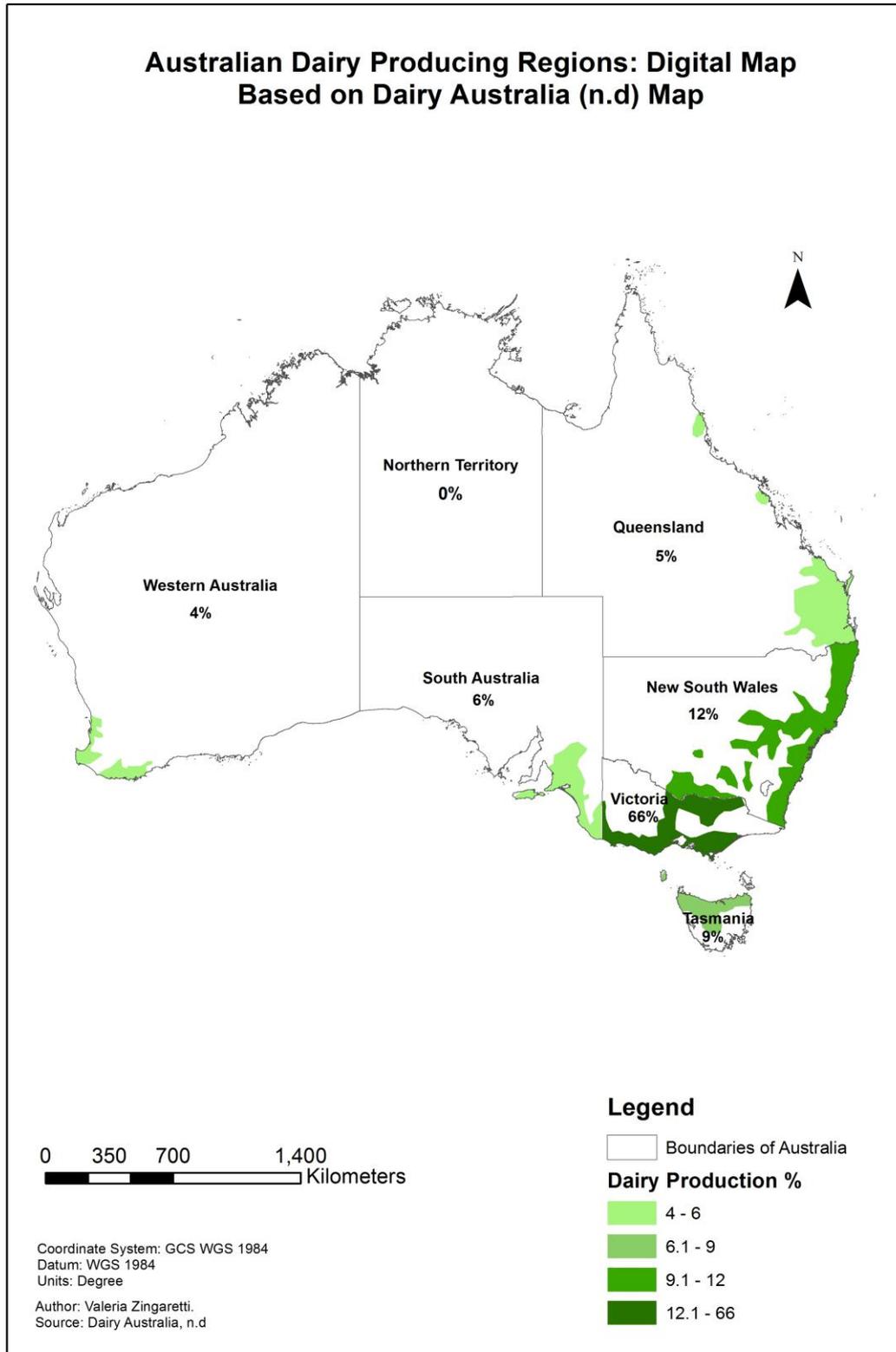


Figure 17: Australian Dairy producing regions and dairy production by state as a percentage of Total Dairy Production (Dairy Australia, 2013)



The GDMI drought data downloaded for New Zealand and Australia needed to be weighted by region because it would have been misleading to take a simple average of the drought index across a whole country. Firstly, the weather in a region where there are no dairy cows would have not impacted dairy production. Secondly, the severity of the drought varied geographically. The weighting was particularly necessary in the case of Australia, where only a small proportion of the land is used for dairy farming. This is depicted in Figure 17.

# Chapter Three: Methodology:

## Implementing the Synthetic Control Method

### 3.1 Introducing Synthetic Control Methods

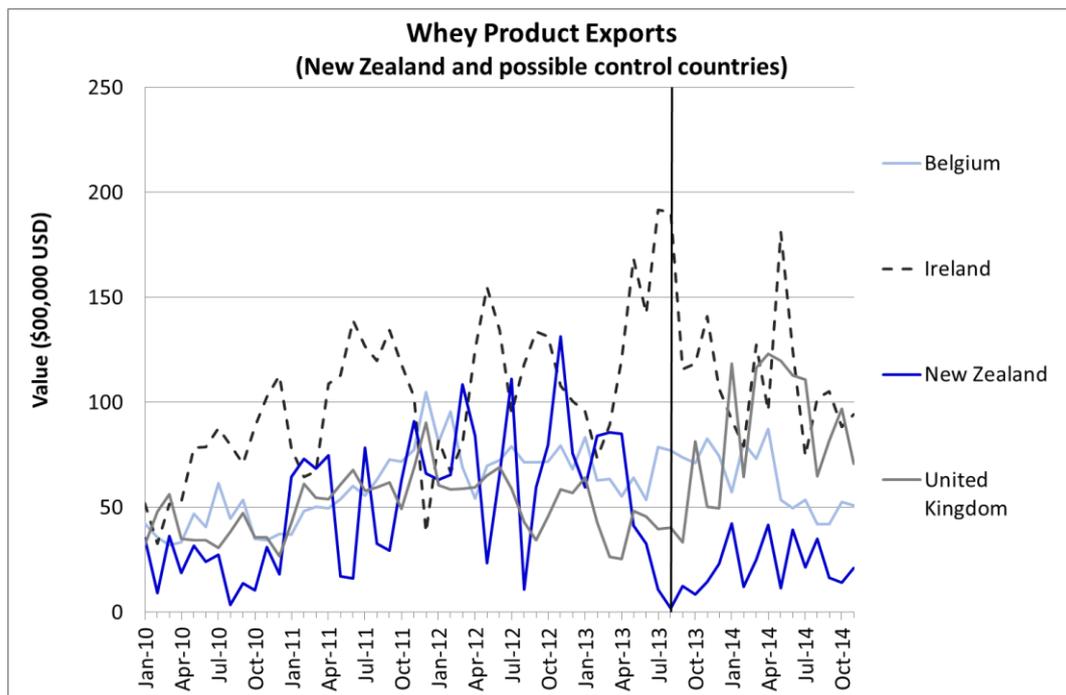
In the synthetic control method, a weighted average of selected control countries' exports is used as a counterfactual of New Zealand exports. The weights are allocated such that the counterfactual imitates New Zealand exports and other predictors in the period before the shock. This same weighted average is then used in the months after the shock as a prediction of what New Zealand exports would have been had the scare not occurred. The 'optimal' counterfactual will be the one that minimizes the root mean square error from observed New Zealand exports in the pre-treatment period. The counterfactual is compared to observed exports in the post-treatment period to quantify the effects of the scare.

The other predictors that are included in the averaging process are exchange rates, GDMI drought data, and monthly seasonal dummies. These additional predictors are hypothesised to be drivers of dairy exports. Implicitly, choosing a weighted average of controls that also imitates these variables will help to construct a more accurate counterfactual. Their inclusion decreases the chances that the relationship that is found between New Zealand and the control group is spurious, because both the outcome variable and other important drivers of dairy exports are imitated by the synthetic counterfactual.

Using a data driven approach can be preferable to allowing the researcher to choose a counterfactual or a group of counterfactuals based on a range of characteristics. This is

because it eliminates subjectivity bias that a researcher could inadvertently impose (Abadie, Diamond, & Hainmueller, 2010). As an example of the difficulty a researcher would be faced with in choosing a counterfactual, New Zealand whey exports are graphed against the exports of countries exporting similar quantities in Figure 18. It is clear that none of them are a particularly good predictor of the New Zealand pattern, and it is not immediately clear which country would make a better control than another.

**Figure 18: Time series of New Zealand whey product exports against possible control countries' whey exports**



The synthetic control method enables the construction of the most efficient synthetic New Zealand for each dairy product included in the data set. The results, including those from significance tests, are completely visual in this method which makes them easier to interpret.

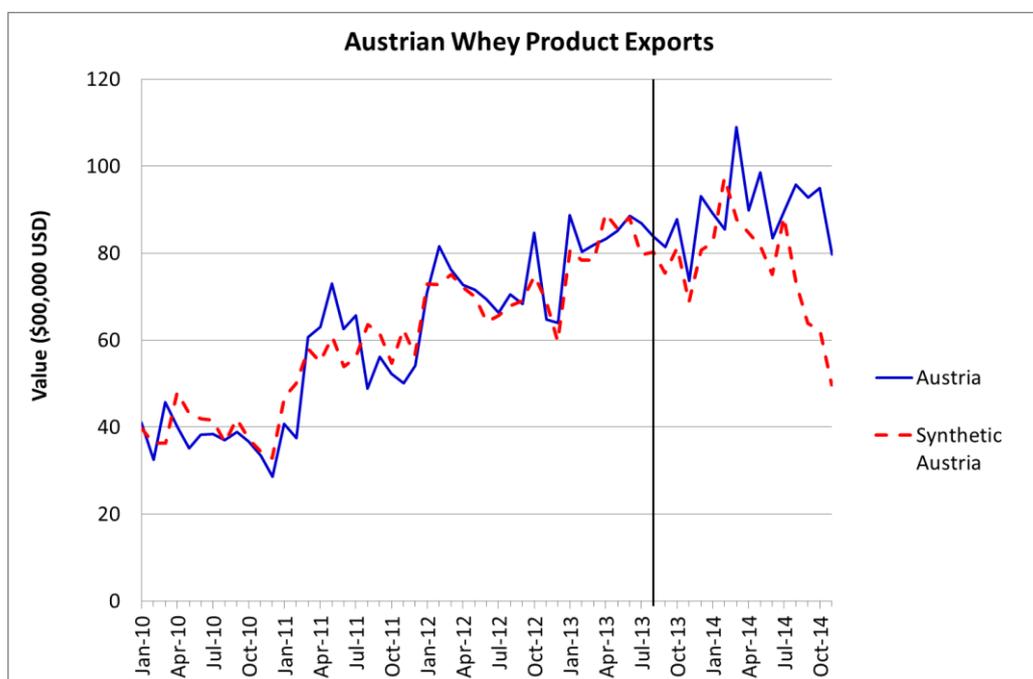
### 3.2 Inference and Robustness of Results

There is, naturally, a high degree of uncertainty regarding the ability of a synthetic New Zealand series to predict what exports would have been had the contamination not occurred. This would be the case even if the fit in the pre-treatment period were exceptional, because it will never be possible to actually observe the counterfactual scenario. Abadie et al. (2010) propose permutation tests for determining the robustness of the result obtained through the synthetic control method.

The permutation tests are done by using the synthetic control method to estimate a counterfactual for placebos— countries that did not experience the economic shock. The placebo tests are carried out using all of the control countries in the data set. The synthetic control method should not predict an export gap in the post-intervention period in the placebo cases because the control countries were not embroiled in the botulism scare. Of course even when it is estimated for placebos, the counterfactual will not match true exports exactly in the post-intervention period. These discrepancies are deemed to be the margin of error that is used for the test.

Figure 19 is an example of how the synthetic counterfactual closely matches actual exports for the duration of the time series in the case of a placebo country. Synthetic exports are able to closely predict actual Austrian whey exports in the ‘post treatment’ period. It is expected that, as in the case of any forecast, the accuracy of the synthetic prediction decreases as it is required to predict further into the future. The optimisation procedure for the placebo trials is set up in the same way as for New Zealand, but New Zealand is not included as a control variable because New Zealand experienced the shock.

**Figure 19: Example of running the synthetic control method accurately predicting exports of a country that did not experience any shock**



The placebo tests make it possible to examine whether any gap between actual New Zealand exports and the predicted counterfactual can be thought of as statistically significant. If the

contamination incident had impacted the value exports, it is expected that after August 2013 there would be a negative prediction gap which is larger than the gaps from the control country counterfactuals. The test is completed by graphing the gaps from the estimation of New Zealand with the gaps of the control countries and noting the treatment period.

### 3.3 Process

The data set described in Chapter 2 was used to develop a synthetic counterfactual of New Zealand dairy exports for the six categories: WMP, SMP, AMF/butter, cheese, infant formula, and of course the affected whey products. The methodology is the same in all cases.

Actual exports were simulated for cheese, infant formula, and whey products. However for WMP, SMP, and AMF/butter; the year on year growth rate was simulated. Growth rate counterfactuals were constructed for these products because New Zealand exports such large quantities of these goods relative to most countries that there were too few with which to construct a synthetic counterfactual. Countries' exports need to be of similar sizes in this method. This is because the method does not allow country weightings to exceed one as this may introduce an extrapolation bias (Abadie, Diamond, & Hainmueller, 2010)<sup>14</sup>. Using growth rates meant that the number of data points in the time series became 47 instead of 59 for these products.

For each product, the export values that are observed are

$$Y_{it} = Y_{it}^N + \alpha_{it}D_{it} \quad (1)$$

where  $Y_{it}^N$  is what exports would have been had the contamination incident not occurred. The interacted term  $\alpha_{it}D_{it}$  is the effect of the contamination on country  $i$  at time  $t$ . The size of the effect is quantified in  $\alpha_{it}$ . The term  $D_{it}$  is a dummy variable that is one if country  $i$  faces the contamination incident and  $t \geq T_0$ .  $T_0$  is the period in which the contamination incident occurred. In all other time periods, for all other countries  $D_{it}$  is zero. In this data set,  $D_{it} = 1$  when  $i = 1$  (New Zealand) and  $t \geq 44$  (August 2013). The task of this research is to figure out

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<sup>14</sup> Equally, it would not be appropriate to scale down New Zealand exports, run the simulation, and then re-scale New Zealand exports to their true magnitude. This is because the method relies on the assumption that when a well-fitting counterfactual is observed, this is because a group of observed and latent predictors of dairy are accurately recreated using weighted averages. If exports were scaled or adjusted, it would make it more likely that any relationship found would be spurious. If there is no true relationship, it calls into question whether that spurious relationship would hold when extrapolated past the treatment date.

the size of  $\alpha_{it}$  in the case of New Zealand. To do this,  $Y_{1t}^N$  are estimated and subtracted from the observed  $Y_{1t}$ .

Exports when there is no contamination incident,  $Y_{it}^N$ , are hypothesized in the following way:

$$Y_{it}^N = \delta_t + \gamma E_{it} + \theta Z_{it} + \nu S_{it}^P + \beta_i Y_{i(t-n)}^N + \lambda_t \mu_i + \varepsilon_{it} \quad (2)$$

Here,  $\delta_t$  is an unobserved time variant factor. It does not vary between countries and essentially sets an ‘intercept’ level of dairy exports in each time period. It could be thought of as the effect of global factors that influence a base level of demand and supply for dairy exports in a given period (for example, feed costs or economic conditions in China).

$E_{it}$ ,  $Z_{it}$ , and  $S_{it}^P$  are the observed predictors of exports included in the model. They are exchange rates, drought data, and selected seasonal dummies respectively. The values of the predictors vary across countries and over time. The terms  $\gamma$ ,  $\theta$ , and  $\nu$  are the coefficients on these observed predictors that influence the dairy industry. The  $Y_{i(t-n)}^N$  are lagged exports which are included to deal with autoregressive components of the data. The  $\varepsilon_{it}$  are assumed to be random shocks with a mean of zero. They are assumed to be independent over countries and periods.

The vector  $\lambda_t$  represents unobserved time variant factors that influence dairy exports. Their factor loadings vary across countries, which is depicted in the vector of coefficients  $\mu_i$ . The actual factors are not observed; they are latent variables. It is not necessary to know what these unknown factors are, however an example could be the trend over time in the demand for each country’s exports.

Therefore,  $\lambda_t \mu_i$  is a matrix of interactions between unknown factors which vary over time, and their unknown factor loadings which vary across countries. Their structure is hypothesised such that they explain the maximum amount of variance and correlation between variables observed in the model. The inclusion of these unobserved factors can be thought about by rearranging the model to:

$$Y_{it}^N = \delta_t + \gamma E_{it} + \theta Z_{it} + \nu S_{it}^P + \beta_i Y_{i(t-n)}^N + u_{it} \quad (3)$$

such that

$$\lambda_t \mu_i + \varepsilon_{it} = u_{it} \quad (4)$$

The theory is that the variance of each variable in the model will have two parts. The first part will be the traditionally conceptualised random variance that is unique to each variable. The other part will be due to underlying factors that are not observed.

If we did not allow for the  $\lambda_t\mu_i$  term, which represents unobserved factors that influence dairy exports, then there would be omitted variable bias. The variance from the latent variables would be incorrectly grouped with the  $\varepsilon_{it}$  term as it would appear that  $u_{it} = \varepsilon_{it}$ . This would be an issue because  $u_{it}$  is correlated with both the outcome and the predictor variables. Setting  $u_{it} = \varepsilon_{it}$  could also lead to collinearity between the predictor variables if they are influenced by the same underlying factors. The factors are assumed to be uncorrelated themselves.

The observed data in the model described above is weighted to construct a synthetic counterfactual of New Zealand exports. This is done by choosing a vector of weights,  $W$ . Each element of the vector is the weight placed on country  $i$  in the synthetic control.

$$W(V) = (w_2, \dots, w_I)'$$

In this case,  $i = 1$  represents New Zealand and  $i = 2, \dots, I$  are the control countries. As noted previously, the following two constraints are placed on the elements of  $W$ :

$$\sum_{i=2}^I w_i = 1 \quad (5)$$

$$0 \leq w_i \leq 1 \quad \forall i \quad (6)$$

Then, transformation using each possible  $W(V)$  results in a counterfactual such that:

$$\sum_{i=2}^I w_i Y_{it} = \delta_t + \sum_{i=2}^I w_i \gamma E_{it} + \sum_{i=2}^I w_i \theta Z_{it} + \sum_{i=2}^I w_i \nu S_{it}^p + \sum_{i=2}^I w_i \beta_i Y_{i(t-n)} + \sum_{i=2}^I w_i \lambda_t \mu_i + \sum_{i=2}^I w_i \varepsilon_{it} \quad (7)$$

Abadie, Diamond, and Hainmueller (2010) suggest finding the optimal  $W(V)$ , denoted by  $W^*(V)$ , by minimising  $\sqrt{(X_1 - X_0 W)' V (X_1 - X_0 W)}$ , where  $X_1$  is a vector of the observed predictors and a collection of simple and weighted averages of the outcomes in all of the pre-intervention periods for New Zealand. Similarly,  $X_0$  is a matrix of the equivalent for all of the control countries.  $V$  is a diagonal weighting matrix which looks at the different elements of the predictor matrices  $X_1$  and  $X_0$  weighing their significance such that the synthetic control

estimator's mean squared error is minimized. It also indirectly determines what countries will be used as controls, as  $W^*$  will be a function of  $V$ .

After the minimisation,

$$\sum_{i=2}^I w_i^* E_{it} \approx E_{1t} \quad \forall t = 1, \dots, T_0 \quad (8);$$

$$\sum_{i=2}^I w_i^* Z_{it} \approx Z_{1t} \quad \forall t = 1, \dots, T_0 \quad (9); \text{ and}$$

$$\sum_{i=2}^I w_i^* S_{it}^P \approx S_{1t}^P \quad \forall t = 1, \dots, T_0 \quad (10)$$

will approximately hold.

As  $\mu_i$  are unobserved, it is not possible to directly choose  $W$  such that

$$\sum_{i=2}^I w_i^* \mu_i = \mu_1 \quad (11)$$

It is important that  $\sum_{i=2}^I w_i^* \mu_i = \mu_1$  holds because traditional methods such as differencing cannot be used to make the export series stationary, as is necessary for forecasting. This is because  $\lambda_t$  vary over time so a differenced model does not remove the unobserved effects of  $\mu_i$ .

However, Abadie et. al (2010) prove that in theory, if the synthetic control method is able to construct a counterfactual where the observed predictors are matched, then  $\sum_{i=2}^I w_i^* \mu_i = \mu_1$  will hold as well.

The result is that

$$\sum_{i=2}^I w_i^* Y_{it} = \hat{Y}_{1t}^N \approx Y_{1t}^N \quad \forall t = 1, \dots, T_0 \quad (12)$$

Finding the closest possible prediction of New Zealand exports in the pre-treatment period by assigning weights  $w_i^*$  allows the estimation of the size of the shock to New Zealand exports,  $\alpha_{1t}$ . This is done via:

$$\hat{\alpha}_{1t} = Y_{1t} - \hat{Y}_{1t}^N \quad (13)$$

The size of  $\hat{\alpha}_{1t}$  is then compared to the placebos

$$\hat{\alpha}_{it} = Y_{it} - \sum_{i=2}^I w_i^* Y_{it} \quad \forall i \neq 1 \quad (14)$$

which are assumed to not be statistically different from zero. Using this comparison it is then possible to conclude whether there is evidence that  $\hat{\alpha}_{1t}$ ,  $t \geq T_0$  is different from zero.

It is assumed that the  $W^*(V)$  that best models New Zealand exports when  $t \geq T_0$  is the same as when  $t < T_0$  because the underlying determinants of dairy exports have not changed.

### 3.4 Further Limitations and Assumptions of Synthetic Control Methods

Historically, the synthetic control method has been run on annual data (Abadie, Diamond, & Hainmueller, 2010; Hinrichs, 2012; Barone & Mocetti, 2014; Coffman & Noy, 2012). A limitation of the method is that it does not translate as well to monthly time series. In a monthly series it is more difficult to develop an accurate control because monthly series tend to be more volatile. This is an issue given that the method is fundamentally reliant on weighted averages. The volatility would only be maintained if all countries had matching patterns of volatility.

As the countries do not all have matching patterns of volatility, it is difficult to match the monthly variation of some New Zealand exports. However, it is equally difficult to match the patterns of volatility in the placebo iterations. This means that the permutation tests are still applicable because they are assessing the quality of New Zealand's counterfactual relative to those of the control countries. The fit of the counterfactual should be of reasonable quality in order for the synthetic control method to be used, but it does not have to be perfect. Only if the fit is exceptionally poor, do Abadie et. al. caution against the use of the synthetic control method (Abadie, Diamond, & Hainmueller, 2010).

It would not be applicable to conduct the synthetic control methodology using annualised data, moving averages, or a seasonally adjusted time series in the case of the WPC contamination incident. Seasonal adjustment is questionable at best, requiring strong and consistent seasonal patterns over at a minimum of three, but optimally at least seven years of data (Australian Bureau of Statistics, 2008). Such seasonal patterns are not a feature of the monthly export data used in this project.

Annualising data would not be suitable because it would reduce the number of observations to five, with only one post-treatment observation. It would not be possible to single out the duration of short term effects, and any effects in 2013 would be subdued by earlier unaffected exports, as the incident occurred in the 8<sup>th</sup> month of the year and lasted only one month.

Similarly, using moving averages would be problematic because the intervention period would become the first period in which August 2013 is weighted. The initial impact would seem smaller because of the partial weighting, and the duration of impact would appear longer because historical data would carry weight in later observations. There would be fewer observations and the effects of the scare would be difficult to discern.

A second caveat to the model is the assumption that in the time periods prior to the announcement of the incident  $Y_{it}^N = Y_{it}$ . This assumes that the contamination incident did not have an effect on exports prior to its public announcement, meaning that Fonterra did not change their exporting manner before they had (false) confirmation from AgResearch that the contaminant was *Clostridium Botulinum*.

It is known that Fonterra knew that there was at least some kind of issue prior to the announcement of the scare, even though they did not understand the severity (Norris, et al., 2013). If there had indeed been a leakage of information, or other disruptions from the event had led to a negative impact on exports, this could lead to a sub-optimal group of control weights being chosen for the counterfactual. Furthermore, the total impact of the scare would appear smaller than it actually was, because some of the downward trend prior to  $T_0$  would be assumed to be normal when it was actually due to the contamination.

If the true ‘treatment’ date was long before the assumed treatment date, and the initial shock was very large, this may even bias the synthetic control downward. A biased counterfactual starting from an incorrect treatment date could make the post treatment impact seem smaller, as well as ignoring any impact before  $T_0$ . However, as stated, the synthetic control will likely only be biased if the impact before  $T_0$  is very large. Otherwise, it is unlikely that even an incorrect  $T_0$  would bias the counterfactual. This is because there are still many observations from the true pre-treatment period which will be used to establish the trend of exports.

Therefore, most likely consequence is that weightings on controls will be sub-optimally allocated<sup>15</sup>.

## Chapter Four: Results and Conclusions

### 4.1 Impact on Dairy Exports

The results from the synthetic control optimisation are presented below. The weights that were assigned to the control countries in each case are recorded in Appendix III. This is also where a list of the placebos used for the permutation tests can be found. The fit of the synthetic counterfactual to the true series in the pre-treatment period is significantly better for all of the estimates that involve growth rates. This is likely because most exporters are experiencing similar market effects.

Firstly, the analysis of WMP is presented, because it is by far New Zealand's largest export product. Next, there is an analysis of the directly implicated products: whey products and infant powders. Following this are the analyses of the remaining products: SMP, AMF/butter, and cheese.

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<sup>15</sup> In the results section, the only instance where this is a possible concern is in the analysis of whey product exports. To account for it, the counterfactual is re-estimated with an earlier treatment date in Appendix V. As discussed in Chapter 4, re-running the process with the earlier treatment date increases the estimated size of the shock, but does not change the significance of the result.

## 4.1.1 WMP Exports

Figure 20: Time series of actual and synthetic counterfactual growth rates of New Zealand WMP exports

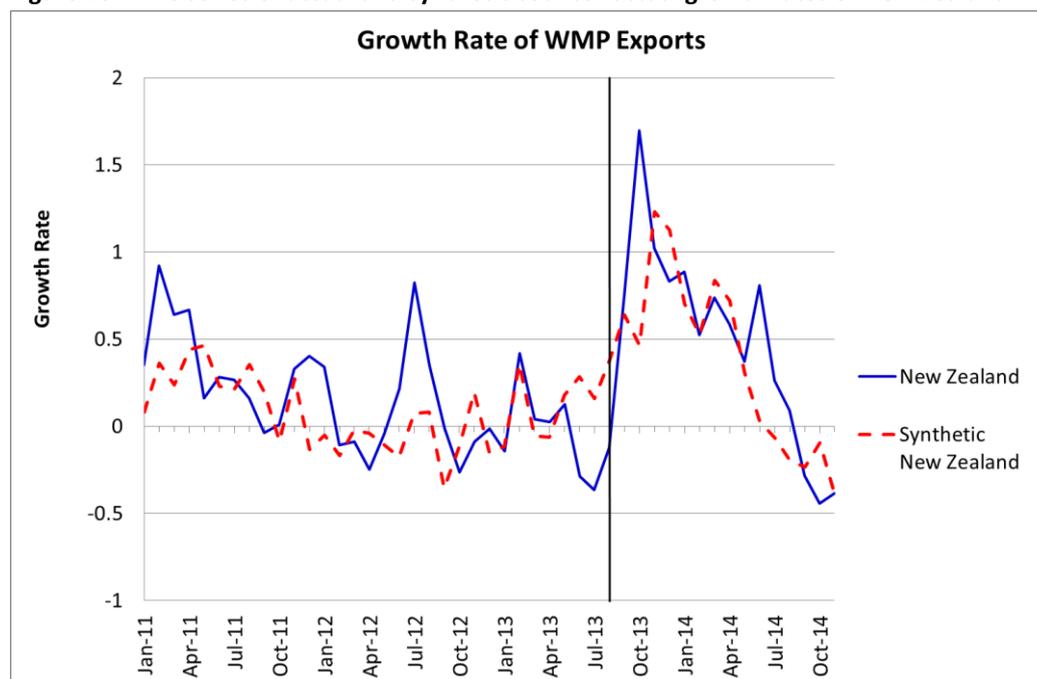


Figure 20 shows that in August 2013, WMP exports were only around 87% of what they were the previous August. The synthetic counterfactual predicted that they should have been 37% higher than they were the previous year. It appears that the synthetic control method was able to identify the peaks and troughs in the data, both in the pre-intervention period and after the scare. However, the counterfactual struggled to predict the magnitudes of these variations. This is expected as the data series is very volatile, even when analysing growth rates.

Notably, the synthetic counterfactual does not predict the decline in exports that was seen in the months from May 2013, only predicting slightly decreased growth in June and July. This could be because the effects of the drought around this time have not been fully stripped out, and the collection of controls was not able to accurately emulate New Zealand conditions. It is also notable that while they are negative, the growth rate declines were at their lowest in July, and began a recovery in August. This is not indicative of the negative growth rate in August 2013 being the result of a shock from the WPC contamination incident.

Given that the counterfactual was unable to predict the size and timing of this trough before the contamination incident, it is unclear whether the positive growth rate expected but not achieved in August 2013 shows an impact from the contamination incident, or if the discrepancy is merely within the margin of error of the synthetic control. It is important

however that the synthetic control closely matches the actual growth rate trend of WMP exports from September 2013 onwards. This would suggest that irrespective of whether the lower exports in August are significant, the effects of the scare were short lived; New Zealand’s reputation or share in the market of WMP was not affected.

Figure 21 shows the results of the placebo tests, where an artificial shock is imposed on the control countries. Countries where the gap between the observed growth rate and the synthetically predicted growth rate was greater than 2 in numerous observations have been removed from this graph. Also excluded are placebos where the absolute value of the mean of the gaps was greater than 0.5. This is because when the fit is exceptionally poor, synthetic control methods should not be used<sup>16</sup>.

**Figure 21: Gaps between actual WMP export growth rates and the synthetic counterfactual predictions for New Zealand and the control group**

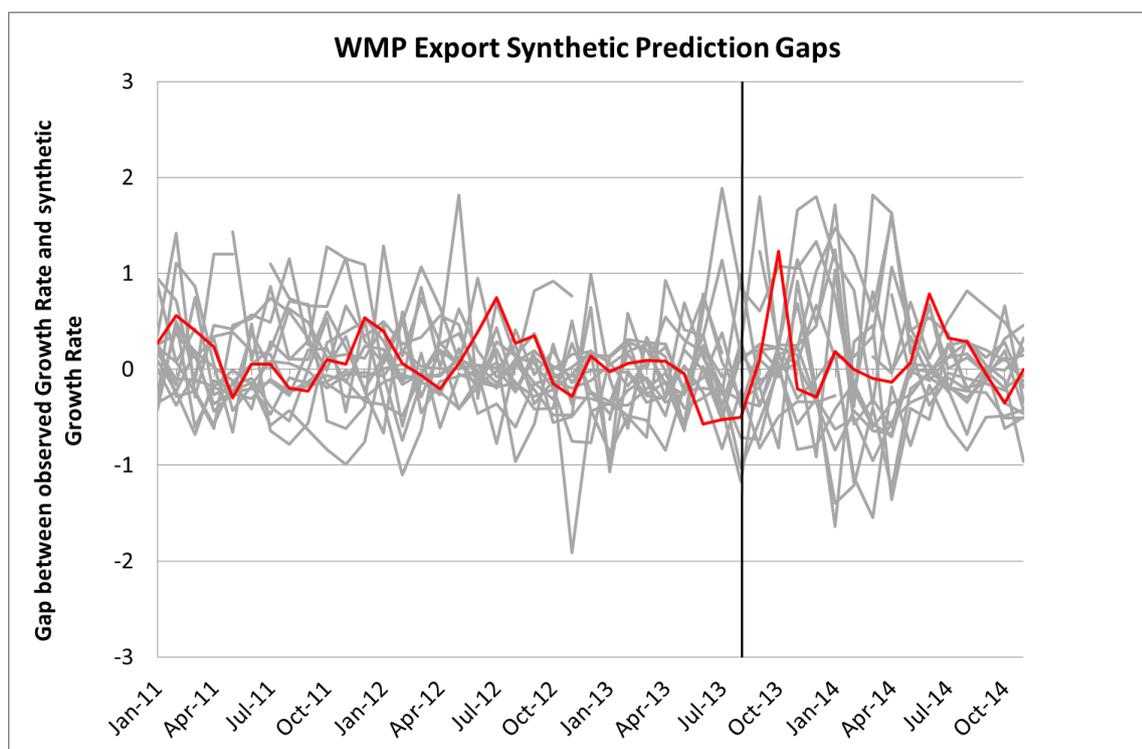


Figure 21 shows that the magnitude of the gap in the prediction for New Zealand WMP growth rates is roughly in the middle relative to the magnitude of the gaps in the control

<sup>16</sup> The thresholds chosen are ad hoc and generally arbitrary (Abadie, Diamond, & Hainmueller, 2010).

countries for the duration of the series<sup>17</sup>. This indicates that the discrepancy between the actual growth in WMP exports in August 2013 and the synthetically predicted growth rate is not statistically significant. Therefore, it is sensible to conclude that the WPC contamination incident did not affect New Zealand’s largest dairy export, WMP.

### 4.1.2 Whey Product Exports

Figure 22: Time series of actual and synthetic counterfactual New Zealand whey product exports

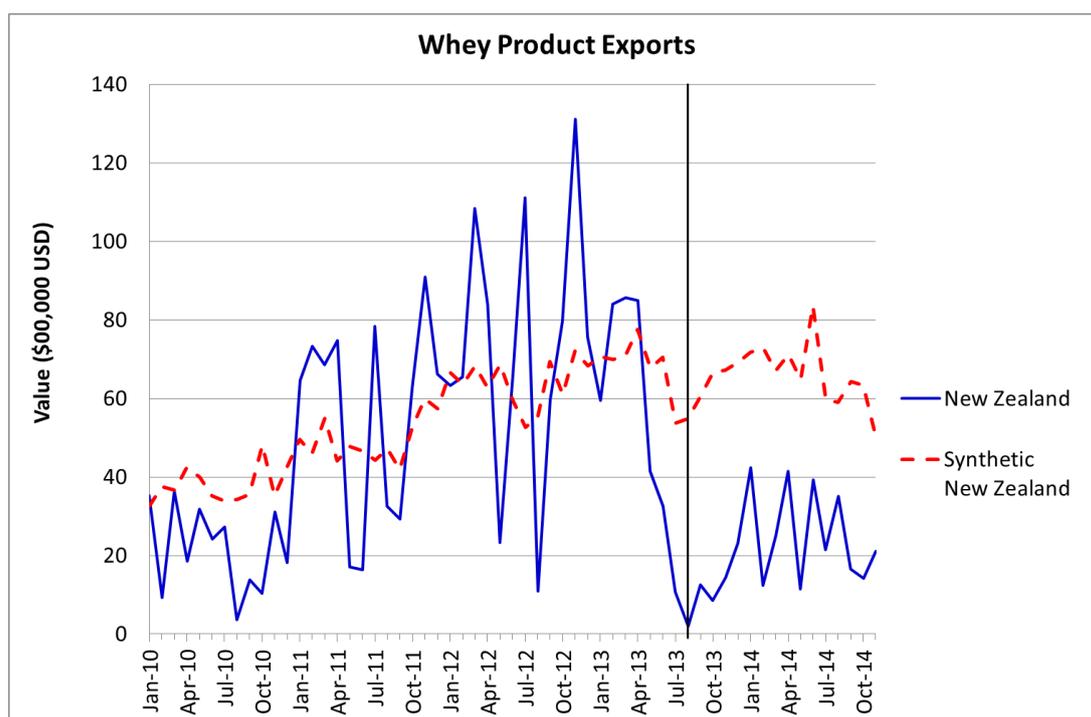


Figure 22 shows that comparing the synthetic New Zealand to true exports of whey products, there appears to be a significant unexpected drop in exports after August 2013. The gap between the true series and the counterfactual is persistent throughout the post treatment period. The synthetic counterfactual predicts a much higher average level of exports than the actual values of exports after the contamination incident. This is in contrast to the pre-intervention period where the synthetic prediction is close to the average level of exports.

It is acknowledged that in the pre-treatment period, the fit of the synthetic counterfactual is poor; while the counterfactual is able to predict the average level of exports over the period, it

<sup>17</sup> It appears there may have been a short-term impact from the 2013 drought that is visible in April and May that was not fully accounted for, however the result is not sustained and thus not conclusive.

is unable to predict the large upswings and downswings in exports. The extreme volatility could be explained either by profit maximising actions of Fonterra, or because small quantities of this good are used by customers, and with its long shelf life it can be stored. Nevertheless, the result in the post-treatment period is stark.

An initial shock to exports is to be expected as WPC was the contaminated product. Not only did buyers reject the product at the time, the New Zealand’s Ministry of Primary Industries was also actively withholding product from export due to the serious nature of the safety threat (Ministry for Primary Industries, 2015). The fact that lower exports persist for over a year suggests that New Zealand’s reputation as a provider of quality whey goods may have been somewhat tarnished. Another possible reason for the persistently lower levels of exports is that New Zealand exporters lost market share during the time of uncertainty. Russia and China, both major importers, maintained bans on some New Zealand whey products even after the scare was announced to have been a false alarm. China’s complete ban was lifted in October 2013, but Russia’s partial bans were only partially lifted in August 2015 (Reuters, 2015).

**Figure 23: Gaps between actual whey exports and the synthetic counterfactual predictions for New Zealand and the control group**

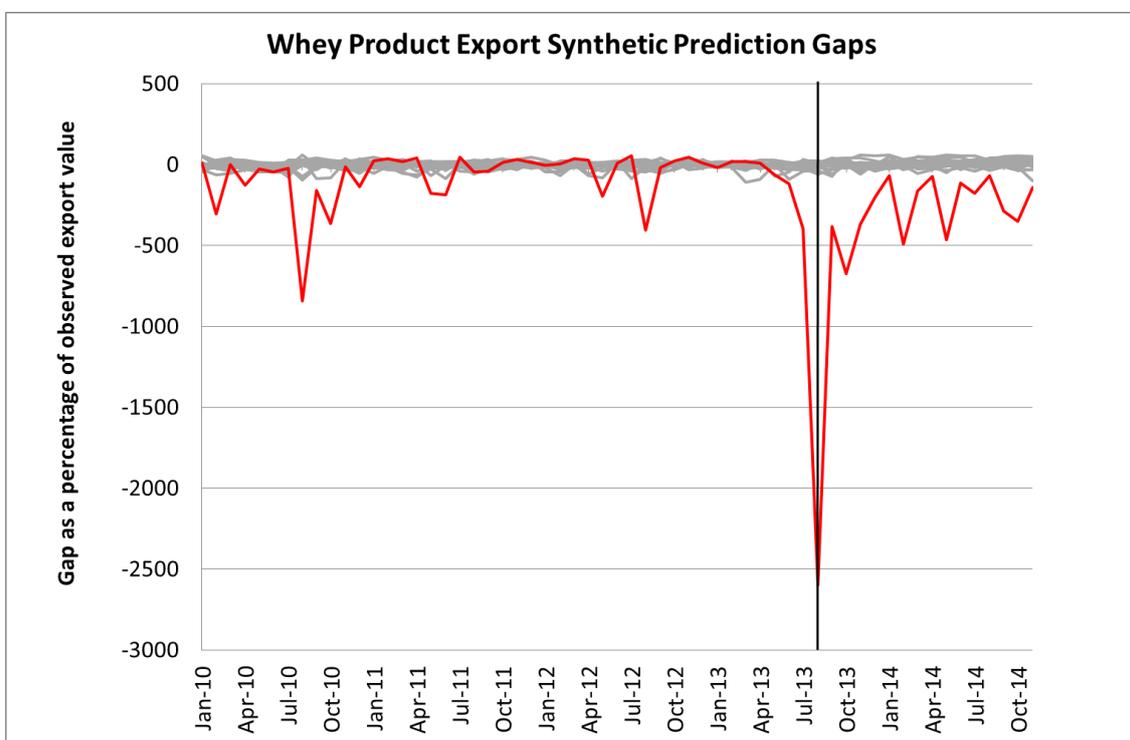


Figure 23 depicts the placebo test. It graphs the gap between the synthetic counterfactuals and actual observations as a percentage of observed exports. This is so that the variation in absolute quantities exported by different countries does not affect the result. Placebos with gaps consistently greater than 100% or where the absolute value of the mean gap was greater than 10% were removed from the test. This is again because it is expected that on average, the synthetic control will be accurate. It is clear that the gap following the WPC contamination incident in the case of New Zealand is significantly larger compared to other countries. However it is also visible that the fit of the synthetic counterfactual was generally worse in the case of New Zealand than for other countries in the pre-treatment period.

Given that a significant result is observed, the total loss of New Zealand exports from whey products has been calculated. Over the post-treatment period to November 2014, New Zealand exports were \$71 million USD lower than the synthetic counterfactual suggest they would have been had the scare not occurred.

Another interesting feature of Figure 22 is that between April 2011 and May 2013, there appears to be a fairly clear pattern of peaks and troughs in whey exports, which subsequently breaks down. After May 2013, a persistent downward trend is observed. There could be multiple reasons for this change. Firstly, the original pattern may be a statistical anomaly; it features less than three years' worth of data. It could also be the result of the drought, although the drop is much larger when compared to the drop in WMP, at over 50% in the first month alone and 87% by July. Another possibility however, is that Fonterra changed its export patterns due to disruptions from a customer having rejected a product, or from the testing that was on-going around this time. Fonterra and the customer were after all aware of a quality issue.

In Appendix V, a synthetic control is constructed where the treatment period is assumed to be May 2013. The significance of the result does not change, but the predicted impact of the scare doubles to \$140 million USD. Furthermore, it appears that the fit of the counterfactual in the pre-treatment period is improved when the treatment date is set to May 2013.

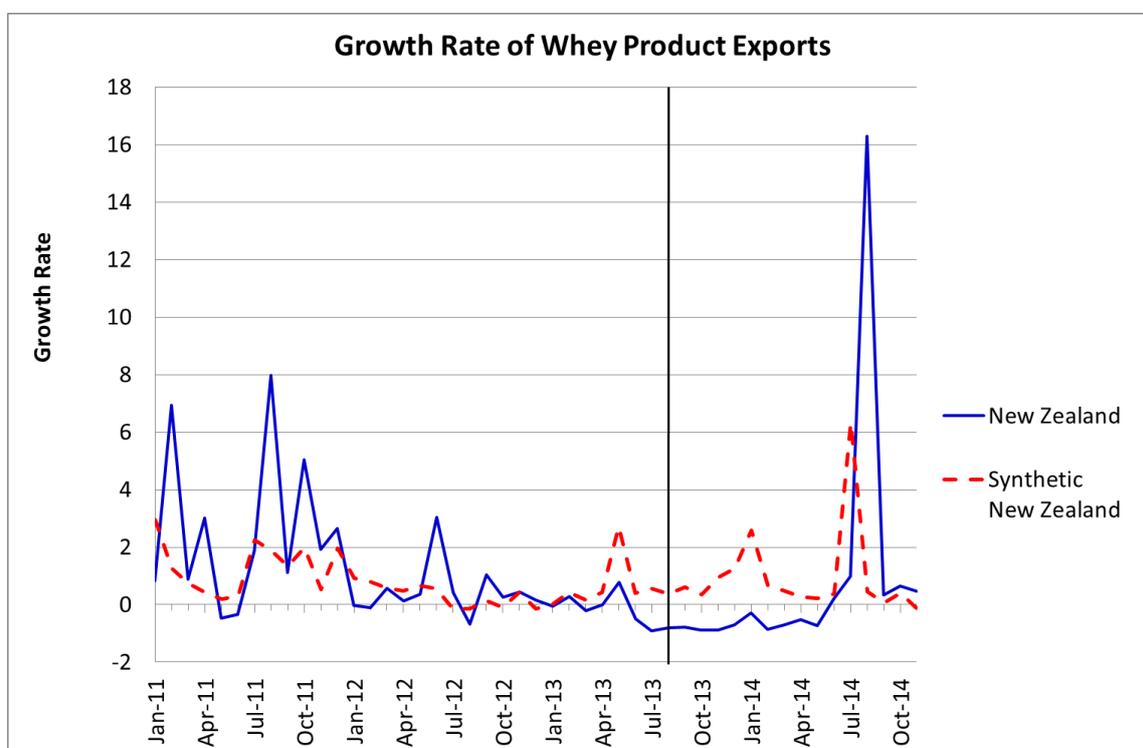
To check the robustness of these results, given that the fit of the synthetic counterfactual was relatively poor in the pre-treatment period, year on year growth rates of whey products are also analysed. Analyses of WMP, SMP, and AMF/butter show that it is easier to construct

synthetic counterfactuals for growth rates. Figure 24 shows the growth rate of New Zealand whey exports and the corresponding synthetic counterfactual.

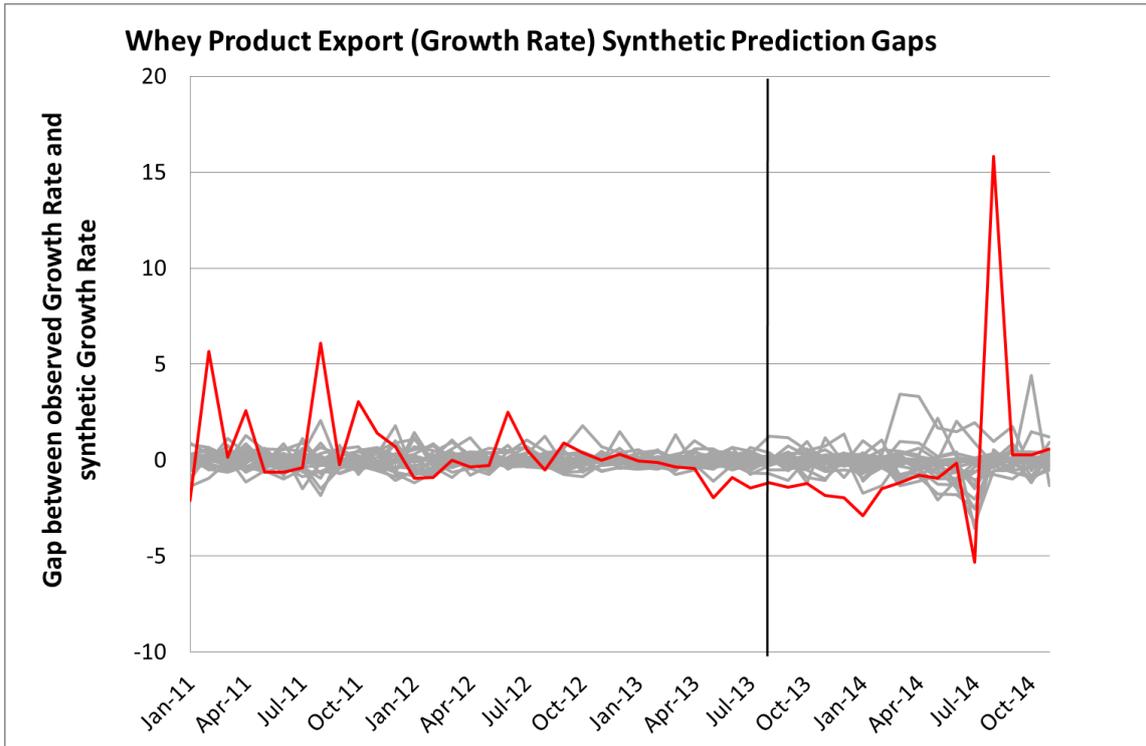
Again it is visible that from May 2013, there is a prolonged period of decline in exports which is not predicted by the synthetic counterfactual. The growth rate series is flatter, suggesting that the volatility seen in Figure 22 is partly due to seasonal patterns. After May 2013, there is a level shift downward in the growth rate following which the growth rate continues to be flat. This would suggest that the drop in the growth rate- the lower exports observed between May 2013 and August 2013- are not seasonal, but rather due to a shock.

Furthermore, in August 2014, we see a significantly larger than expected positive growth rate in the actual series. This suggests a rebound from the previous year's August. It is a reflection of how very low exports were in August 2013, but does not necessarily indicate a full recovery of exports. A spike is predicted by the synthetic control around this time so it is necessary to analyse the results of the placebo, to see if these observed results are significant, or within the margin of error.

**Figure 24: Time series of actual and synthetic counterfactual growth rates of New Zealand whey product exports**



**Figure 25: Gaps between actual whey product export growth rates and the synthetic counterfactual predictions for New Zealand and the control group**



From Figure 25 it is visible that between May 2013 and March 2014, the gap between the New Zealand counterfactual growth rate of whey exports and actual exports is significantly greater (and negative) relative to the gaps for the placebos. Furthermore, the gap in New Zealand growth in August 2014 is significantly greater than in any placebo country. This would confirm the observations from Figure 24, and suggest that the WPC contamination incident has had a significant and long running impact on both the level and growth rate of New Zealand whey exports. However, it is important to emphasise, that although whey products and protein powders are high value products, their total export value makes up only 0.5% of New Zealand dairy exports.

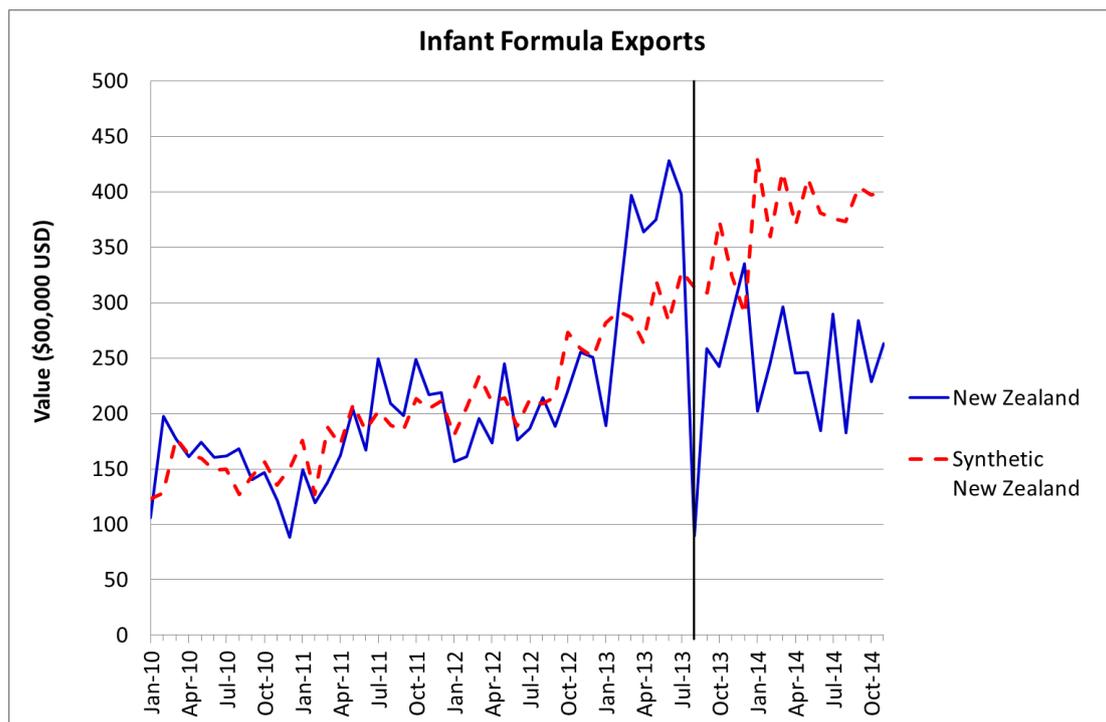
### 4.1.3 Infant Formula Exports

Another product that was directly impacted by the scare was infant formula. This is because whey protein powders are an ingredient. As in the case of whey products, Figure 26 shows that that the contamination incident had a significant impact on New Zealand exports of infant powders in August 2013 that may have persisted over time. Again, part of the extreme drop in exports in August 2013 was due to the New Zealand Ministry of Primary Industries

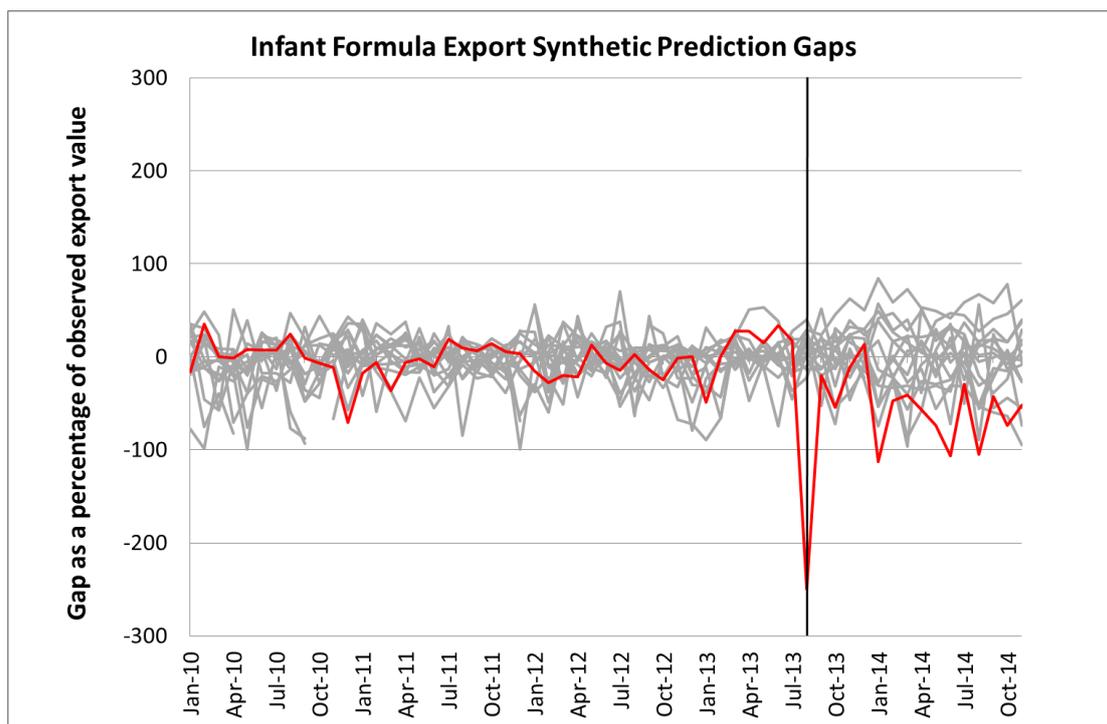
preventing product from leaving New Zealand. It is also likely that the effect was large because infant formula is an intimate consumer product.

It is interesting that infant formula exports appear to rebound in December 2013, and then fall below the counterfactual prediction once more. This would suggest that while New Zealand's reputation was not permanently damaged, New Zealand suppliers have potentially lost their market share in infant formula.

**Figure 26: Time series of actual and synthetic counterfactual New Zealand infant formula exports**



**Figure 27: Gaps between actual infant formula exports and the synthetic counterfactual predictions for New Zealand and the control group**



The placebo significance test in Figure 27 confirms that the results in Figure 26 are significant. The discrepancy in the New Zealand case between actual infant formula exports and the predictions of the synthetic control are roughly average relative to those of the placebo countries in the pre intervention period<sup>18</sup>. However, in August 2013, a significant negative gap is recorded, which is much larger than in any of the placebo cases. However the placebo test would suggest that infant formula exports initially recovered as early as September 2013. However, the recurrence of the significantly negative discrepancy post December 2013 again suggests that it was not expected that New Zealand infant formula exports would plateau at a level as low as they did. It may be the case that the September rebound that is observed is the result of contracts with New Zealand exporters not having expired yet at this stage, but buyers later shifting to other suppliers of formula.

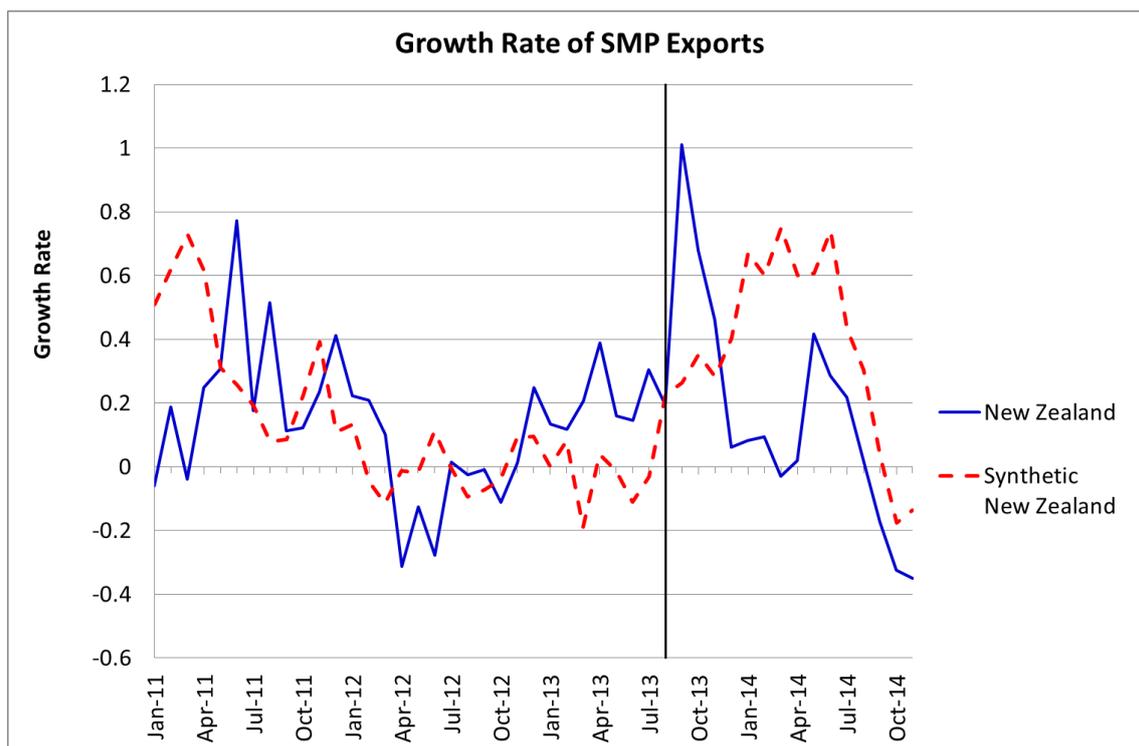
The total calculated loss in exports between August 2013 and the rebound in September 2013 is \$22 million US dollars. Over the whole period to November 2014, the loss is \$207 million US dollars. This is the aggregate difference between actual exports and the predictions of the

<sup>18</sup> Placebos where the gap was consistently greater than 100% of exports, or where the mean of the gaps was very different from zero were excluded from the permutation test, as these were deemed to have a poorly fitting counterfactual, which is not reliable.

synthetic counterfactual. The infant formula industry was one of New Zealand’s fastest growing industries prior to the contamination incident and expanding globally (Fonterra, 2014)<sup>19</sup>. If New Zealand has lost its market share it will likely be difficult to re-establish.

#### 4.1.4 SMP Exports

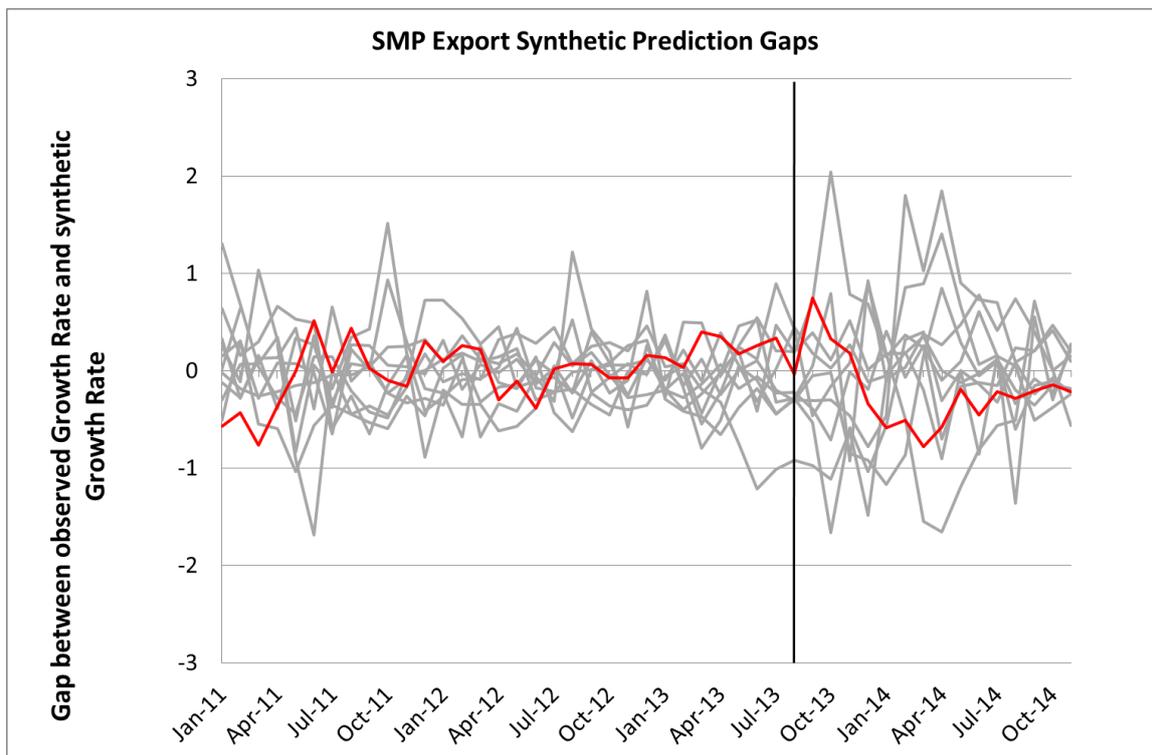
Figure 28: Time series of actual and synthetic counterfactual growth rates of New Zealand SMP exports



When analysing the growth rate of SMP exports, it is, again, not possible to conclude that there was a decrease in the growth rate due to the WPC contamination incident. In Figure 28, there does not appear to be an impact even visually in the month of August, as would be expected if there had been concern surrounding the safety of the product, or even logistical disruptions. From around December 2013, the true growth rate of exports dips below the synthetic counterfactual, before they once again become close in the latter half of 2014. However, there is no reason to believe that this deviation was a lagged impact from the contamination scare.

<sup>19</sup> Fonterra staff consulted during this project were sceptical about whether the high exports seen in early 2013 represented such a drastic increase in the long term trend of infant formula exports (Fonterra, 2015). In Appendix V, the results are repeated with the months between March and July 2013 treated as outliers. This did not change the outcome of the analysis; the incident had a significant impact on infant formula exports.

**Figure 29: Gaps between actual SMP export growth rates and the synthetic counterfactual predictions for New Zealand and the control group**

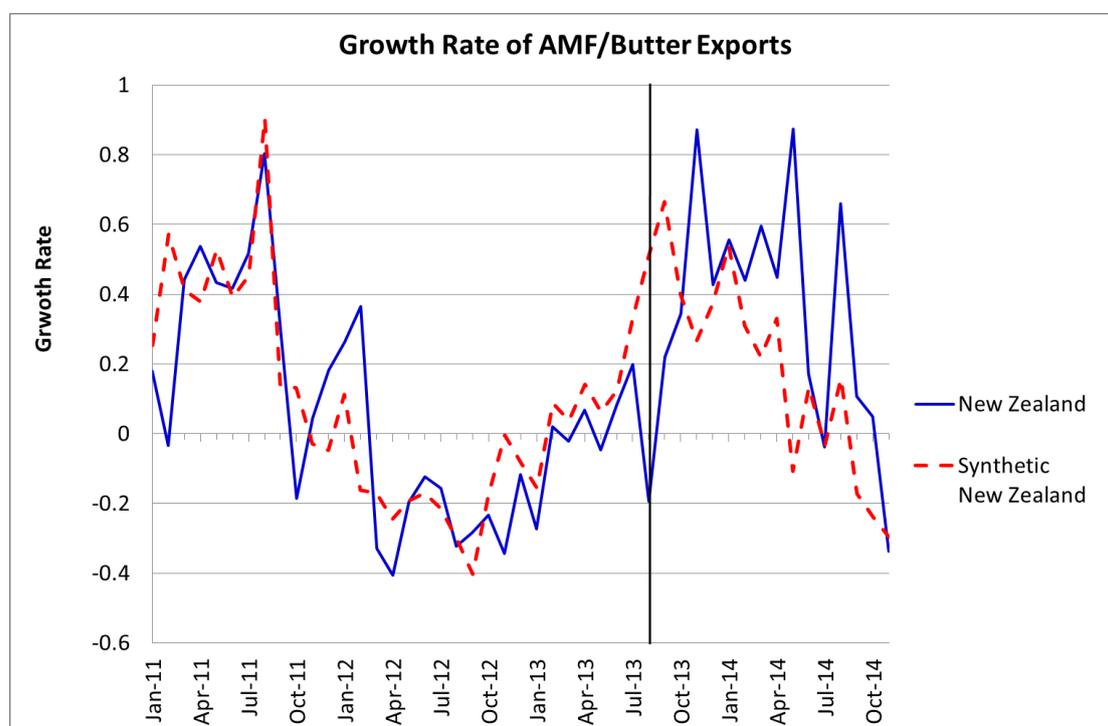


When the placebo test in Figure 29 is analysed, it is not possible to conclude that there was a negative impact from the WPC contamination incident on the growth rate of SMP exports<sup>20</sup>. Furthermore, even the lower than predicted growth rates observed between December 2013 and August 2014 are within the range of errors of the placebo countries. The conclusion is that New Zealand is exporting less SMP than previously, but this decrease cannot be attributed to the WPC contamination scare.

<sup>20</sup> Note that countries with errors greater than a factor of five were removed from the graph. It is assumed that synthetic control methods are inappropriate for these countries. However, removing them does not change the result.

## 4.1.5 AMF/ Butter Exports

Figure 30: Time series of actual and synthetic counterfactual growth rates of New Zealand AMF/butter exports

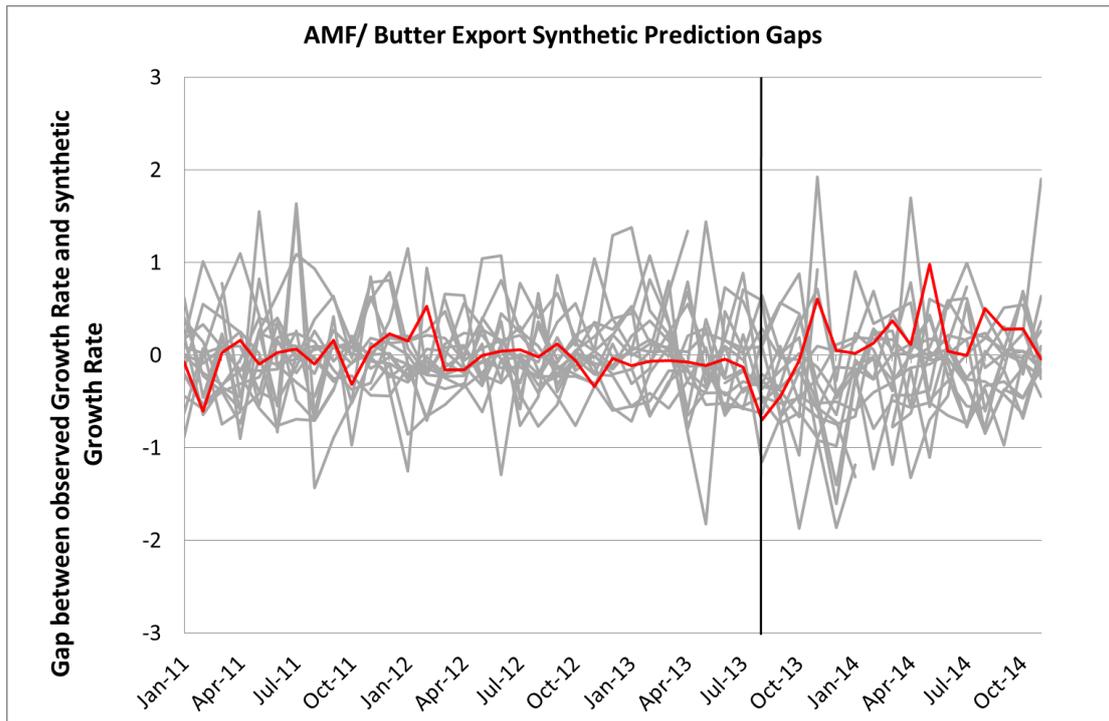


Upon initial inspection of Figure 30, it appears that there was a large unexpected drop in the growth rate of AMF and butter exports in August 2013 relative to the previous year. The drop is unexpected given that it was not predicted by the synthetic counterfactual, which otherwise maps export growth rates well in the pre-treatment period.

Interestingly, the placebo trials depicted in Figure 31 are inconclusive. The gap between true New Zealand growth rates and counterfactual growth rates is certainly among the largest following the incident, but it is not convincingly greater as in the cases of whey products and infant powders. Given the good fit of the model in the pre-treatment period, it is possible but not certain that there was a small, transient negative impact from the WPC contamination incident on the growth rate of New Zealand AMF and butter exports.

If there was indeed an effect, it was only for one month. The growth rates of exports of the product are completely aligned with the expectations of the synthetic counterfactual by September 2013. This would support the results of WMP and SMP which suggest that New Zealand's reputation as a provider of dairy goods has not been damaged by this scare.

**Figure 31: Gaps between actual AMF/butter export growth rates and the synthetic counterfactual predictions for New Zealand and the control group**



It is interesting that there may have been a short term effect on AMF and butter exports, but not on WMP and SMP exports. It is not explicitly clear why there would be more of a relationship between the affected products and AMF compared to WMP or SMP. It is possible that there is less demand for AMF/butter, giving buyers relatively more bargaining power and choice. The fact that the prices of AMF were lower at the time than those of SMP and WMP would support this theory. The prices of the three goods are observed in Figures 3-5. Fonterra staff support this hypothesis, stating that markets for fats are more limited; there are not as many buyers of AMF/ butter as there are for WMP and SMP (Fonterra, 2015).

## 4.1.6 Cheese Exports

Figure 32: Time series of actual and synthetic counterfactual New Zealand cheese exports

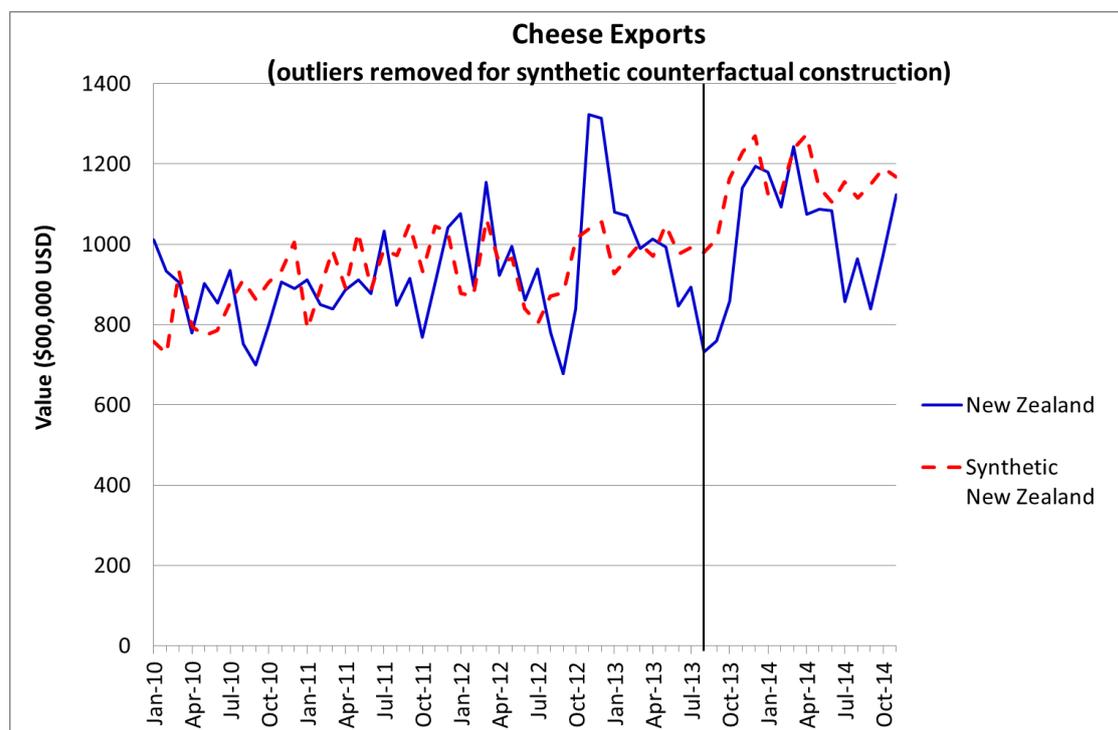


Figure 32 presents actual New Zealand cheese exports and the synthetic counterfactual of New Zealand cheese exports had the WPC contamination incident not occurred. Cheese exports are New Zealand's next largest dairy export after WMP, SMP, and AMF. The value of cheese exported is greater than the values of both infant powders and whey products combined, and hence they have been included.

Firstly, focusing on observed exports in the pre-treatment period, a very large dip is observed in September 2012, followed by a sharp recovery in the following four months. This downswing and the following upswing exhibit much higher volatility than was exhibited in the series prior to September 2012. Private discussions with the Ministry for Primary Industries revealed that these observations were outliers: delays in a series of negotiations resulted in very low exports in September 2012, and the resolution that followed resulted in very high exports between November 2012 and January 2013. As these observations are outliers, when the synthetic counterfactual was constructed for Figure 32, these outliers were omitted from the averaging process. The synthetic control method is less effective if the outliers are not removed, because the fit is significantly poorer relative to the control countries. The consequence of the poorer fit is that usual volatility associated with New

Zealand's cheese exports appears as though there were multiple shocks lasting one month when the placebo test is done<sup>21</sup>.

Comparing true cheese exports to the predictions of the synthetic counterfactual in Figure 32, the counterfactual does not predict the decline in cheese exports that occurred in August 2013. However, there also appears to be a seasonal element in cheese export values. In all of the previous years in the series, cheese exports are at their lowest in the months of August and September. The synthetic counterfactual does not predict any of these seasonal troughs.

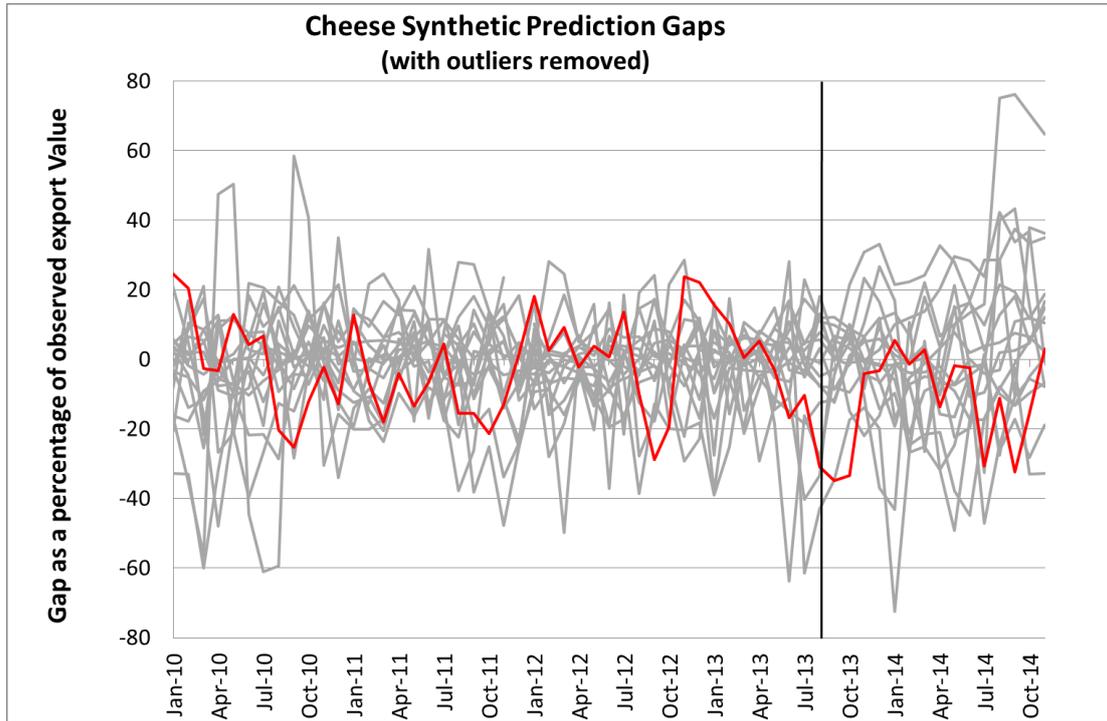
As in the case of AMF/butter, the placebo test in Figure 33 is somewhat inconclusive. In August 2013 the New Zealand gap is the second largest, and in September and October it is the largest. It could be argued that from August to October 2013, the value of New Zealand cheese exports was affected by the scare. There is further evidence of this if the gaps for other Augusts are also analysed. As noted, August and September result in seasonally low cheese exports. However, the seasonal dips in 2010 and 2011 do not trigger speculation regarding whether there was a shock to cheese exports in these months. They are some of the largest gaps, but they only last one month. Only the 2012 and 2013 observations appear to be at the lower bound of the placebo country gaps in multiple months. It has already been noted that the 2012 observation is indeed an outlier. In 2013, the WPC contamination incident occurred.

The possible impact is short term. Given there is no sharp drop in August, again it is possible that cheese exports were more sensitive to the scare because globally, buyers are less dependent on New Zealand for cheese products. Given that the gap is largest in September and October, it is unlikely that disruptions to cheese are due to safety concerns around the product. The fact that after a few months cheese exports return to what they would have been had the scare not occurred supports this hypothesis. As in the case of the other products that were not directly implicated in the scare, there has been no long run impact.

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<sup>21</sup> Following discussions with both the Ministry for Primary Industries and Fonterra, there is no reason to believe that there were really multiple shocks lasting only one month. The results of the analysis of cheese exports where the outliers were not removed can be found in Appendix V.

**Figure 33: Gaps between actual cheese exports and the synthetic counterfactual predictions for New Zealand and the control group**



Alternatively, supply chains were still recovering from the scare. Fonterra has also suggested that cheese exports were lower in the months immediately following the scare because delivery of cheese products had slowed as it was not a priority at the time (Fonterra, 2015). This means that some orders which were placed were delayed as Fonterra was responding to the crisis. There was a backlog of operational and logistic challenges even after it had been confirmed that the scare was a false alarm.

## 4.2 Limitations

Abadie et al. (2010) warn against using the synthetic control method in instances where the fit is very poor because it is likely that the resulting predictor of  $Y_{it}^N$  will not be reliable. Abadie et. al show that  $\sum_{j=2}^{J+1} w_j^* \mu_j = \mu_1$  only holds if a good fit can be found for a set of pre-intervention time periods. As previously discussed, there is no way to separately impose  $\sum_{j=2}^{J+1} w_j^* \mu_j = \mu_1$  because  $\mu_i$  is unobserved. An additional issue is that what is considered a “good” fit is subjective. In this investigation, the fit is generally good in all cases except the whey product analysis, which is why whey export growth rates are also analysed.

It is extremely important to note that while this study finds little long term impact to New Zealand's key dairy exports, this investigation considers only the impact of a false alarm, not a serious contamination incident.

### **4.3 Conclusion**

In early August 2013, it was announced that there was concern of a botulism causing contaminant in WPC80 that had been exported by Fonterra. On the 28<sup>th</sup> of August, the contamination was confirmed to have been benign. New Zealand is a small open economy that is very dependent on agriculture. This research evaluated whether the Whey Protein Concentrate Contamination incident, which implicated the world's largest dairy exporter, affected the New Zealand economy.

An investigation of the economic environment in which the New Zealand dairy industry operates found that a true contamination would have the potential to directly impact the economy through lost sales, as well as indirectly through effects on other industries. A large and sustained downturn could eventually be reflected in lower consumption and government revenues.

However analyses of export patterns, which would have been the most direct point of impact, before and after the scare show that the incident had no long term significant impact on the value of most dairy exports. Comparisons with a synthetic counterfactual showed that there was no impact at all to WMP and SMP, which together make up over 50% of dairy exports. The results in the cases of AMF/butter and cheese export values were inconclusive, with the possibility of a small short term effect, but no long term effect.

There has been a large, statistically significant, and persistent negative impact on whey products and infant formula, in which WPC80 is an ingredient. Exports of these products have not returned to levels from before the scare, as of the most recent data available in June 2015. Given an initial recovery of infant formula exports, it is likely that the relatively weak performance of these products is the result of missed business opportunities and lost market share, rather than fear regarding the safety of New Zealand dairy goods.

These results indicate that while New Zealand's reputation is likely less robust than before the scare, New Zealand is still viewed as a safe source of dairy goods. Furthermore, they

reflect that Fonterra's strong reputation and New Zealand's general 'clean green' image operate in a feedback loop. Fonterra's status as a provider of quality and safe products stems largely from New Zealand's overall clean green image, and the quality institutions that New Zealand is known for. This status drives demand from consumers in developing economies who are consuming increasing quantities of dairy. On the other hand, Fonterra as a large global milk exporter will have an impact on how New Zealand is perceived overseas with respect to this clean green image.

This research has estimated that the impact of the Whey Protein Concentrate contamination incident on New Zealand dairy exports was between \$105 million and \$347 million from the start of the scare to November 2014<sup>22</sup>. It is \$93 million if it is assumed that Fonterra did not change their whey product export patterns prior to the announcement of the scare, and if only the immediate impact to infant formula is associated with the scare. Conversely, \$347 million corresponds to the case where both the true treatment date for whey products is May 2013, and the entire of the impact to infant formula, including lower exports after the recovery in December 2013, are considered a flow on effect from the incident. These figures can be put in the context of \$15.5 billion in New Zealand dairy exports between August 2013 and November 2014, or \$17.5 billion between May 2013 and November 2014. Based on the scenarios above, this would mean that total dairy exports were between 0.6 and 1.9% lower than they would have been had the scare not occurred. Dairy exports make up 26% of total New Zealand exports annually.

It is critical to note that the economic impacts of this incident and the implications for Fonterra's reputation would have certainly been much greater had the scare been confirmed as a *Clostridium Botulinum* contamination incident. Overall, the conclusion is that the majority of the impact from this scandal has likely stemmed from lost market share as well as import and export bans in whey and infant formula markets. It is highly unlikely that the WPC contamination incident has had a long run impact on New Zealand's reputation as a provider of safe dairy goods.

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<sup>22</sup> The figures are in United States dollars.

## **Appendix I: Timeline of the crisis (summarised from Fonterra independent inquiry (Norris et al., 2013))**

In May of 2012, a torch was sucked into a processing machine at Fonterra's Hautapu plant during the process of manufacturing whey protein concentrate (80%), commonly referred to as WPC80. The dry product was removed from the machine, but two pieces of the torch could not be found. The decision was made to re-wet the product and filter out the small pieces of torch. However, given that this was not standard procedure, non-standard equipment was used. This included a pipe which was not adequately sterilized, leading to the contamination. The pieces of torch were successfully filtered out and three batches of WPC80 totalling 38 metric tonnes were produced.

The product underwent all routine testing procedures. Routine tests did not involve testing for sulphite reducing clostridia (SRCs), a class of bacteria which includes many types of harmless bacteria, but also the botulism causing *Clostridium Botulinum* (Norris, et al., 2013). The decision was also made not to downgrade the product, which undoubtedly contributed to the severity of the crisis. In late 2012, 21 metric tonnes of the product were sold directly to customers. The other 17 tonnes were retained to be processed further into Fonterra consumer products. Infant formula would be one of these products.

While SRC testing is not standard procedure for dairy products, nor is it considered international best practice to test for SRCs (Dean, Astin, & Nowell, 2013), the tests were part of the specification requested by one Fonterra customer. The tests on that customer's portion of product resulted in a higher than normal count being detected and resulted in the customer rejecting the product. The most common reason for high SRC levels is *Clostridium Perfringens*, which leads to food spoilage. However, but tests to identify the specific bacterium responsible were not conclusive. This resulted in extended communications between Fonterra and the customer in question regarding the cause of the contamination, with Fonterra ultimately aiming to convince the customer to take the product that did not meet their specifications. It was at this point that an advisor to the customer noted that high SRCs could be the result of the presence of a botulism causing bacterium.

In March 2013, Fonterra began a technical investigation. Molecular analysis again did not provide conclusive results, however it was identified that the contaminant was a form of clostridia. Fonterra initially rejected the proposal to test for *Clostridium Botulinum*

specifically, stating that “all of the affected product had been rejected by the customer” (Norris, et al., 2013, p. 42). This also meant that there were only very limited tracing efforts during May, June and July; focus was shifted onto how the costs of the rejected product would be divided between different factions of Fonterra.

Another issue was that not only are the tests required to identify botulism causing *Clostridium Botulinum* very technical, with no laboratories in New Zealand accredited to conduct them, they also take four weeks to produce results. Only two of four phenotypic groups of *Clostridium Botulinum* have been identified to cause illness in humans, and not all of the toxin types produced by bacteria within these groups are illness causing (Sugiyama, 1980). The standard way to test for the harmful bacteria is largely reliant on a mouse bioassay, but it is not uncommon for the exposed mice to die from other causes (Norris, et al., 2013).

It is of critical importance that the issue was not escalated to higher authorities at Fonterra at this stage. Fonterra staff focused on the low risk of the presence of *C. Botulinum*, rather than the severity of the consequence if the botulism causing bacteria had been present (Norris, et al., 2013). This highlights the failings of crisis management contingencies within Fonterra’s organisational structure as they were unable to make connections between the economic value of Fonterra’s reputation, the potential severity of the crisis, and the way in which consumers in different markets were likely to respond.

Fonterra finally commissioned testing by AgResearch, an unaccredited laboratory, on the 26<sup>th</sup> of June. On the 19<sup>th</sup> of July AgResearch first indicated to Fonterra that the contaminant may be toxin-producing, but Fonterra did not commit to wide-scale tracing of the affected product, nor preparing for a product recall. On July 31<sup>st</sup>, AgResearch identified botulism causing *Clostridium Botulinum* as the contaminant in the WPC80. Only then did Fonterra form a crisis management team.

On the 2<sup>nd</sup> of August, eight customers were identified as having received the contaminated product. This included two that were producers of goods for infant consumption. New Zealand’s Ministry for Primary Industries was also contacted. At 12:20 am on the 3<sup>rd</sup> of August Fonterra made a media release through NZX of the “quality issue,” and a precautionary recall was initiated. Fonterra refused to name the affected customers. In a press conference on the 5<sup>th</sup> of August, Fonterra apologised to its consumers in New Zealand and China, also stating that 90% of the affected product had already been located. On the 6<sup>th</sup> of

August infant formula producer Nutricia, subsidiary of the French giant Danone (Danone, 2014), recalled all of their Karicare Infant and Follow-up Formula.

Fonterra and the Ministry for Primary Industries worked together to investigate the incident and decide how the issue would be handled. Both commissioned separate independent inquiries into the incident. New Zealand Prime Minister John Key travelled to China to reassure the Chinese market.

The final trace-back of the affected countries was not completed until the 8<sup>th</sup> of August for product that had been exported directly from New Zealand and the 18<sup>th</sup> of August for product which had gone through Fonterra's Australian plant at Darnum. It was eventually confirmed that the affected countries had been Australia, China, Malaysia, Saudi Arabia, Thailand and Vietnam. The initial lack of clarity about which countries had been affected led to at least China, Russia, and Sri Lanka stopping dairy imports from New Zealand after Fonterra's initial media release.

It is however significant that China, who is New Zealand's largest importer of our largest dairy export, Whole Milk Powder, only suspended the imports of some products. They did not suspend imports of Whole Milk Powder or Skim Milk Powder. This could be linked to New Zealand's reputation as a leader in food safety practices, and more significantly, a sign that the Chinese government trusted information coming from Fonterra during the crisis. This trust would have been a mitigating factor in both the initial costs of the scare, as well as sending a signal to Chinese consumers that the contamination was not the result of systemic issues with Fonterra's food production.

It is also interesting that on the 23<sup>rd</sup> of August, Fonterra achieved a record price on Global Dairy Trade. The price was up 27% from August 2012 and the total revenue was up 107%. These prices were achieved before it was announced that the contamination incident had been a false alarm. Given that most dairy is traded through futures contracts (NZX, 2013), this would indicate that buyers did not expect the scare was a result of systemic failures at Fonterra, which would have long lasting ramifications.

On the 28<sup>th</sup> of August, it was finally announced that results from two US based accredited laboratories had concluded that the botulism scare had been a false alarm. On the 11<sup>th</sup> of September, Fonterra released the findings of its operational review. The independent inquiry into New Zealand's dairy food safety and regulatory system commissioned by the New

Zealand Government was completed on December 11<sup>th</sup>. It found no issues with general food safety practices adopted in New Zealand, and identified them to be in accordance with international best practice (Dean & Nowell, Report on New Zealand's Dairy Food Safety Regulatory System, 2013). The results of a compliance investigation by the Ministry of Primary Industries were not released to the public.

## **Appendix II: Why the Fonterra share price is not expected to have moved from this shock**

Movements in a company's share price are thought to be generally indicative of how the company is performing. However, research into the costs of product recalls to shareholders has not found conclusive evidence of an effect (Salin & Hooker, 2001). Large companies in particular seem robust to large movements in the share price following food product recalls. This is likely because an isolated quality issue has less power to tarnish an established brand's reputation, whereas in the case of a fledgling or small company, it could be very damaging.

Thomsen and McKenzie (2001) find that shareholder returns are only affected when a food contamination incident is extremely severe, in other words, when there is a reasonable chance that consumption of the product would lead to serious health issues or death. In other instances, they do not find an effect. Salin and Hooker (2001) importantly note the difference in reactions between investors and consumers. It is suggested that investors, or farmers and their representatives in this case, will be much better informed than the average consumer. They will therefore be less likely to respond to media hype surrounding product recalls. While there was concern that the WPC contamination incident could have had very severe health effects, investors would have known that the contamination was not confirmed when the risk was announced in August 2013, and that the recall of products was only precautionary at that stage. For these reasons, in terms of the share market response, it can be argued that the WPC contamination incident was only of moderate severity.

There is another, more significant reason why it is not expected that the economic and reputational implications of the WPC contamination incident would be quantifiable, or even observable, through movements in the Fonterra share price. This is because of interactions between the FCG and FSF markets, as well as the share standard.

The share standard means that farmers must hold a minimum of one FCG share per kilogram of milk solids they supply to Fonterra<sup>23</sup>. Additionally, the maximum number of shares a farmer can hold is limited to double the number of kilograms of milk solids supplied to Fonterra. These restrictions mean that potential reactions to announcements and market incidents are also restricted.

Farmers could only sell shares after an announcement such as the WPC contamination announcement if their current share holdings exceed the share standard, and they cannot sell below the share standard<sup>24</sup>. In a traditional market, if a farmer did have excess shares and there was a negative announcement, they could sell their shares. If enough farmers did this, the price would drop, but only a limited amount because farmers must still comply with the share standard.

FCG are not the only type of Fonterra shares. There are also FSF shares on the market. FSF shares can be purchased by both farmers and investors, and it is common for farmers to hold a mix of both (ANZ, 2015). Holders of FSF shares have the same economic rights as holders of FCG shares, though FSF shares carry no voting rights. Upon a negative announcement, farmers and investors can sell as many of their FSF shares as they wish. In such a case, supply would exceed demand and the price would be expected to drop. The price would also have more freedom to drop as there is no equivalent of the share standard in the FSF market.

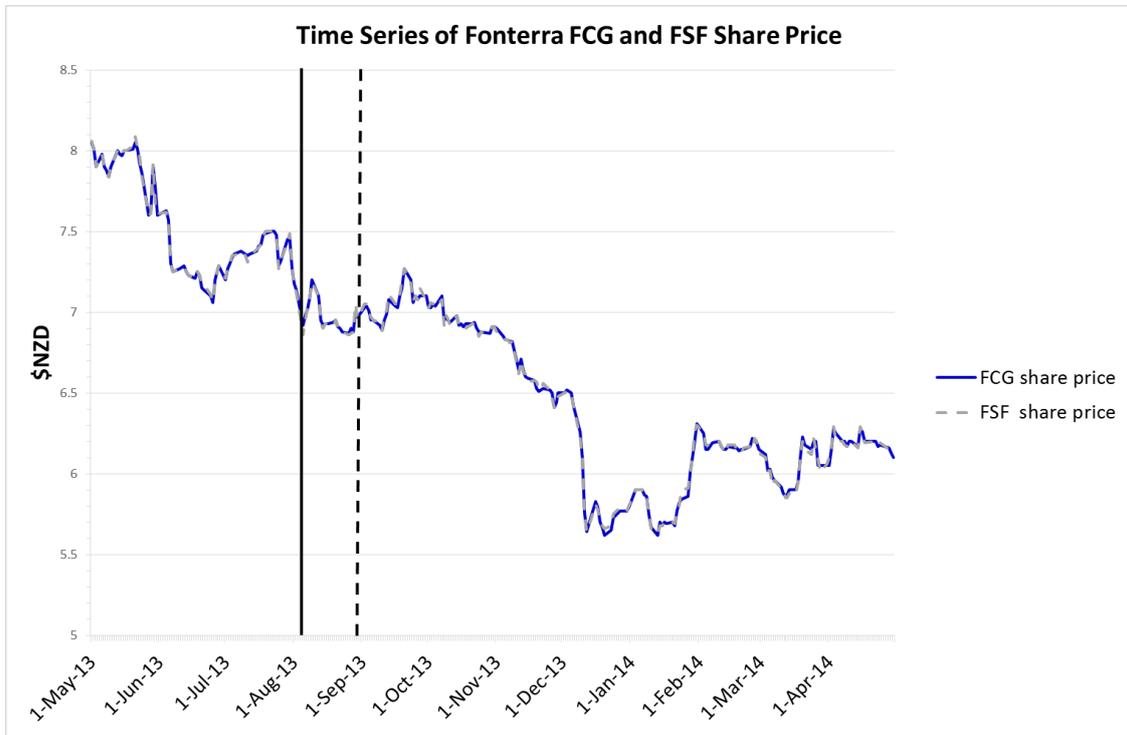
However, it is not expected that these traditional movements would be observed in the Fonterra Shareholders' Market (FSM). FCG and FSF shares generally trade at very similar prices; this is observed in Figure 34. As farmers can easily convert their shares between FCG and FSF, there would be arbitrage opportunities if the price of one type of share fell. Therefore, the other type would quickly adjust.

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<sup>23</sup> For the share standard calculation purposes, the quantity supplied is taken to be the three season moving average of a farm's production.

<sup>24</sup> It is possible for farmers not to hold the requisite number of shares at a point in time as they have six months from the measurement date to comply (Fonterra, 2014)

**Figure 34: Time series of FCG and FSF share prices over the year May2013 to May2014. The solid black line indicates the announcement of the scare and the dotted black line indicates the announcement the scare was a false alarm (Source: NZX Company Research, 2015).**



This means that the price of an FSF share is essentially pegged to the price of an FCG share. It means that even the FSF share price would not have the freedom to fall upon a negative announcement. If the price did fall, farmers would purchase FSF shares as the economic return would be the same as holding FCG shares above the share standard, but the cost would be lower. This is an arbitrage opportunity. As farmers began to take advantage of the arbitrage opportunity, the price of FSF shares would be bid up until they were again effectively equal to the price of FCG shares.

Similarly, if the price of FCG shares were to fall slightly, despite the share standard, it would create an arbitrage opportunity for farmers who hold FSF shares. They would sell their FSF shares and buy FCG ones until the prices of the two were again the same.

It is still possible that negative announcements that significantly affect Fonterra's value or reputation could move the share prices of FCG and FSF shares. However, these movements would be gradual due to the constant adjustments between the share types as farmers try to capitalise on arbitrage opportunities. Trying to measure these movements would not be an effective way to quantify the economic impacts of the WPC contamination incident. It is not

clear how long these kinds of adjustments may take, and again, by the end of the August 2013 it had become clear that the event had never posed serious risks to consumers.

The only type of shocks that could potentially have a sudden effect on the value of Fonterra FCG and FSF shares would be ones that directly affect the value of payoffs (ANZ, 2015). This is because when farmers stop supplying to Fonterra, they have around three years to sell their FCG shares. It is predictable that they will wait to receive dividends, and wait for a time when the share price is favourable. If a cut in forecast dividends was announced,<sup>25</sup> enough former farmers may become willing to sell their shares such that there is a sudden movement in the share price, particularly if FSF shareholders are selling also.

### **Appendix III: Countries included in the Control Group and their assigned Weightings**

The countries that were included as control units are 22 countries from the European Union, the United States, Argentina, Chile, Egypt, Turkey, Singapore, Ukraine, Switzerland and Australia. This 13 of the 15 largest dairy exporters in the world, who together account for over 85% of world dairy exports (Fonterra, 2013). Top 15 countries that were excluded are Belarus and Uruguay, because sufficient data was not available from the Comtrade database.

This group of control countries was chosen for the following reasons:

- The European Union was identified as having similar total exports of dairy to New Zealand, all the while including several major dairy exporters (such as Germany and the Netherlands). European Union countries that are not included in the control group are Bulgaria, Croatia, the Republic of Cyprus, Estonia, Malta, and Romania. They were excluded either because there were issues with the consistency of data availability, or because they exported almost no dairy products.
- Australia was added because Australian goods would likely have a similar reputational advantage in the market. Additionally, the major exporting state, Victoria, has a similar climate to New Zealand (PwC Australia, 2011).

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<sup>25</sup> The sharp drop visible in Figure 34 in December 2013 occurred in the week that Fonterra announced a large cut in their forecast dividend, from 32 cents to 10 cents (NZX, 2013).

- The United States is the world's largest single country exporter of SMP (OECD/FAO, 2014) and is also an efficient producer of whey products (Fonterra, 2015).
- Argentina and Chile are significant South American exporters of dairy products, and it was important to include southern hemisphere exporters because they would experience similar cycles in the dairy season to New Zealand.
- Singapore was included because it is one of the the world's largest exporters of infant formula.
- Egypt, Switzerland, and Turkey were included because the OECD and Food Agriculture Organisation deem them to be significant exporters of cheese in their 2014 Agricultural Outlook (OECD/FAO, 2014).

The weightings placed on each control in the construction of the synthetic New Zealand are listed in Table 2. The countries that are used as placebos in each permutation test are listed in Table 3.

Table 2: Weighting allocations to control countries in constructing 'Synthetic New Zealand'

Country	WMP (Growth Rate)	SMP (Growth Rate)	AMF/ Butter (Growth Rate)	Whey Products	Whey Products (Growth Rate)	Whey Products (Treatment Date May 2013)	Infant Formula	Infant Formula (Excluding potential outliers)	Cheese	Cheese (Excluding outliers)
Argentina	0.00	0.00	<b>0.16</b>	<b>0.05</b>	<b>0.60</b>	0.00	0.00	0.00	0.00	0.00
Australia	0.00	<b>0.44</b>	<b>0.24</b>	<b>0.26</b>	0.00	<b>0.02</b>	0.00	<b>0.48</b>	<b>0.23</b>	<b>0.14</b>
Austria	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Belgium	<b>0.20</b>	0.00	<b>0.29</b>	0.00	0.00	0.00	0.00	0.00	0.00	<b>0.27</b>
Chile	N/A	N/A	N/A	0.00	0.00	0.00	0.00	<b>0.17</b>	N/A	N/A
Czech Rep.	0.00	0.00	0.00	<b>0.64</b>	0.00	0.00	0.00	0.00	0.00	0.00
Denmark	0.00	0.00	0.00	0.00	0.00	0.00	<b>0.76</b>	0.00	0.00	0.00
Egypt	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.00	0.08
Finland	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	<b>0.06</b>
France	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	<b>0.07</b>	<b>0.10</b>
Germany	<b>0.75</b>	<b>0.51</b>	<b>0.23</b>	0.00	0.00	0.00	<b>0.14</b>	<b>0.24</b>	<b>0.06</b>	0.00
Greece	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Hungary	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ireland	<b>0.05</b>	<b>0.05</b>	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Italy	0.00	0.00	0.00	<b>0.06</b>	0.00	<b>0.42</b>	0.00	0.00	0.00	0.00
Latvia	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Lithuania	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Luxembourg	0.00	0.00	0.00	0.00	<b>0.10</b>	0.00	0.00	0.00	0.00	0.00
Netherlands	0.00	0.00	<b>0.07</b>	0.00	0.00	0.00	<b>0.10</b>	<b>0.10</b>	0.00	<b>0.06</b>
Poland	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Portugal	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Singapore	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	N/A	N/A
Slovakia	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Slovenia	N/A	N/A	N/A	0.00	0.00	0.00	0.00	0.00	N/A	N/A
Spain	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sweden	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Switzerland	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	<b>0.52</b>	<b>0.15</b>
Turkey	0.00	0.00	0.00	0.00	<b>0.30</b>	<b>0.56</b>	0.00	0.00	0.00	0.00
Ukraine	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
United Kingdom	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
United States of America	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	<b>0.12</b>	<b>0.17</b>

**Table 3: Control countries used as placebo in the permutation test for each product**

<b>WMP</b>	<b>Whey Products</b>	<b>Whey Products (Growth Rate)</b>	<b>Infant Formula</b>	<b>SMP</b>	<b>AMF/butter</b>	<b>Cheese (Outliers removed)</b>	<b>Whey Products (Treatment date May 2013)</b>	<b>Infant Formula (Potential outliers removed)</b>	<b>Cheese</b>
Argentina	Argentina	Argentina	Austria	Australia	Argentina	Australia	Argentina	Belgium	Chile
Australia	Austria	Australia	Denmark	Belgium	Australia	Austria	Austria	Czech Republic	Czech Republic
Austria	Czech Republic	Austria	Finland	Czech Republic	Belgium	Czech Republic	Czech Republic	Denmark	Denmark
Belgium	Denmark	Belgium	France	Denmark	Czech Republic	Egypt	Denmark	Finland	Egypt
Czech Republic	Finland	Czech Republic	Germany	France	Denmark	France	France	France	France
Denmark	France	Denmark	Ireland	Germany	Finland	Ireland	Germany	Germany	Greece
France	Germany	Finland	Lithuania	Greece	Germany	Italy	Hungary	Latvia	Hungary
Germany	Italy	France	Poland	Ireland	Hungary	Latvia	Ireland	Lithuania	Ireland
Ireland	Lithuania	Germany	Portugal	Latvia	Italy	Lithuania	Italy	Portugal	Italy
Italy	Netherlands	Greece	Slovenia	Netherlands	Netherlands	Luxembourg	Lithuania	Slovenia	Latvia
	Poland	Hungary	Spain	Poland	Poland	Poland	Netherlands	Spain	Lithuania

Netherlands	Slovakia	Ireland	Switzerland	Portugal	Portugal	Portugal	Poland	Sweden	Luxembourg
Poland	Slovenia	Italy	Turkey	United States of America	Singapore	Slovakia	Portugal	Switzerland	Poland
Portugal	Spain	Latvia	United Kingdom		Slovakia	Spain	Slovenia	Turkey	Spain
Sweden	Switzerland	Lithuania	United States of America		Spain	Sweden	Spain	United Kingdom	Switzerland
United Kingdom	Turkey	Netherlands			Turkey	Turkey	Switzerland	United States of America	Turkey
	United Kingdom	Poland				United Kingdom	Turkey		United Kingdom
		Slovakia					United Kingdom		United States of America
		Slovenia							
		Spain							
		Sweden							
		Turkey							
		United Kingdom							

## **Appendix IV: New Zealand Dairy Products**

Table 4 presents the Harmonised System codes for the products that were used in constructing the data set for this research. Table 5 presents the list of products exported by New Zealand that Statistics New Zealand suggested can be considered as dairy products, although there is no official list (Statistics New Zealand, 2014). When summary statistics are presented in Chapter 2 total New Zealand dairy exports are presented in the summary statistics, the data for all of the products in Table 5 are used.

**Table 4: Dairy products used in the construction of the data set**

<b>Product Description</b>	<b>Harmonised System Code</b>	<b>Category Assigned</b>
Butter and other fats and oils derived from milk	0405	AMF/Butter
Cheese and curd	0406	Cheese
Infant foods of cereals, flour, starch or milk, retail	190110	Infant Formula
Milk powder < 1.5% fat	040210	SMP
Whey, natural milk products not elsewhere specified	040410	Whey Products
Milk and cream powder sweetened > 1.5% fat	040229	WMP
Milk and cream powder unsweetened > 1.5% fat	040221	WMP

**Table 5: Dairy products exported by New Zealand**

<b>Product Description</b>	<b>Harmonised System Code</b>	<b>Category Assigned</b>
Anhydrous Milkfat/Ghee	0405.90.00 01J; 0405.90.00 05A	AMF/Butter
Butter	0405.10.00 01K; 0405.10.00 09E; 0405.10.00 11G; 0405.10.00 19B	AMF/Butter
Dairy Spreads	0405.20.00 00E	AMF/Butter
Other Milkfat	0405.90.00 09D	AMF/Butter
Blue Cheese	0406.40.00 00L	Cheese
Fresh Cheese/curd	0406.10.00 01; 0406.10.00 09C	Cheese
Grated/Powdered Cheese	0406.20.00 01A ; 0406.20.00 09G; 0406.20.00 19D; 0406.20.00 29A	Cheese
Other Cheese	0406.90.00 11D ; 0406.90.00 19K; 0406.90.00 29G; 0406.90.00 31J; 0406.90.00 39D	Cheese

Processed Cheese	0406.30.00 00G	Cheese
Dairy Preparations chapter 19/ Infant powders bulk	1901.90.01 00A ; 1901.90.09 28B	Infant Formula
Infant Powders retail	1901.10.09 00C	Infant Formula
Beverages, ready to drink, with a basis of milk	2202.90.09 09E	Other
Buttermilk Powder	0403.90.19 01E; 0403.90.19 19H	Other
Casein	3501.10.00 01K; 3501.10.00 11G; 3501.10.00 19B	Other
Caseinates	3501.90.00 01J Expired Dec 2012; 3501.90.00.10 New code introduced Jan 2012	Other
Dairy Flavour Concentrate	3302.10.90 11A	Other
Fat blend Annatto	3203.00.00 01C	Other
Fat blend Beta Carotene	3204.19.00 00H	Other
Fat Mixes N.E.S.	1517.10.00 01E; 1517.10.00 19H; 1517.10.00 29E	Other
Globulins/Peptones (Hydrolysates)	3504.00.00 15L expired Dec 2012; 3504.00.00.19 New code introduced Jan 2012	Other
Ice cream	2105.00.10 00E; 2105.00.59 00D	Other
Lactalbumin/WPC and WPI >80% protein	3502.20.00 00C	Other
Lactose	1702.11.00 00F; 1702.19.00 00B	Other
Liquid Milk and Cream	0401.10.01 00; 0401.10.09 00F; 0401.20.09 01H; 0401.30.09 00C; 0401.40.00.10; 0401.40.00.19; 0401.50.00.10; 0401.50.00.19	Other
Milk Based Animal Food	2309.90.19 19A	Other
Milk Calcium	2835.26.00 09D	Other
Miscellaneous chapter. 21 preparations/PEF/Dairy Crisps	2106.90.99 01E ; 2106.90.99 79A	Other
MPCs/Protein Blends	0404.90.19 00E	Other
Phosphoaminolipids	2923.20.00 09K	Other
Preparations with >5% cocoa on defatted basis	1806.20.00 10A ; 1806.90.00 01H	Other
Sauce	2103.90.00 15D	Other
Starter Cultures/Yeasts (active)/Single cell micro- organisms (dead)	3002.90.00 19H; 3002.90.00.29; 2102.10.00 19K; 2102.20.19 00E	Other

Sweet Fat Blends	2106.90.99 19H	Other
Total Milk Proteins	3501.90.00 19A ; 3501.90.00.29	Other
Yoghurt	0403.10.00 00E	Other
Skim Milk Powder	0402.10.00 02C	SMP
Whey/WPC ≤ 80%	0404.10.00 00C	Whey Products
Milk and cream powder / granules or other solid forms	0402.21.00 29C	WMP
Whole milk powder	0402.21.00 19F	WMP
Whole milk powder and blended full cream powder less than 26% butterfat	0402.21.00 09J	WMP
Whole milk Powder, sweetened	0402.29.00 19B	WMP

### **Appendix V: Results of repeating Synthetic Control Methodology with Modified Specifications**

Figures 35 and 37 respectively present the results of reconstructing the synthetic counterfactuals with hypothesized outliers removed for whey products and infant formula. Figures 36 and 38 are their corresponding placebo tests. The nature of the outliers is discussed in Chapter 4.

Figure 39 presents the result of reconstructing the synthetic counterfactual for cheese exports without removing the outliers. Figure 40 is the associated placebo test.

Figure 35: Time series of actual and synthetic counterfactual New Zealand whey product exports

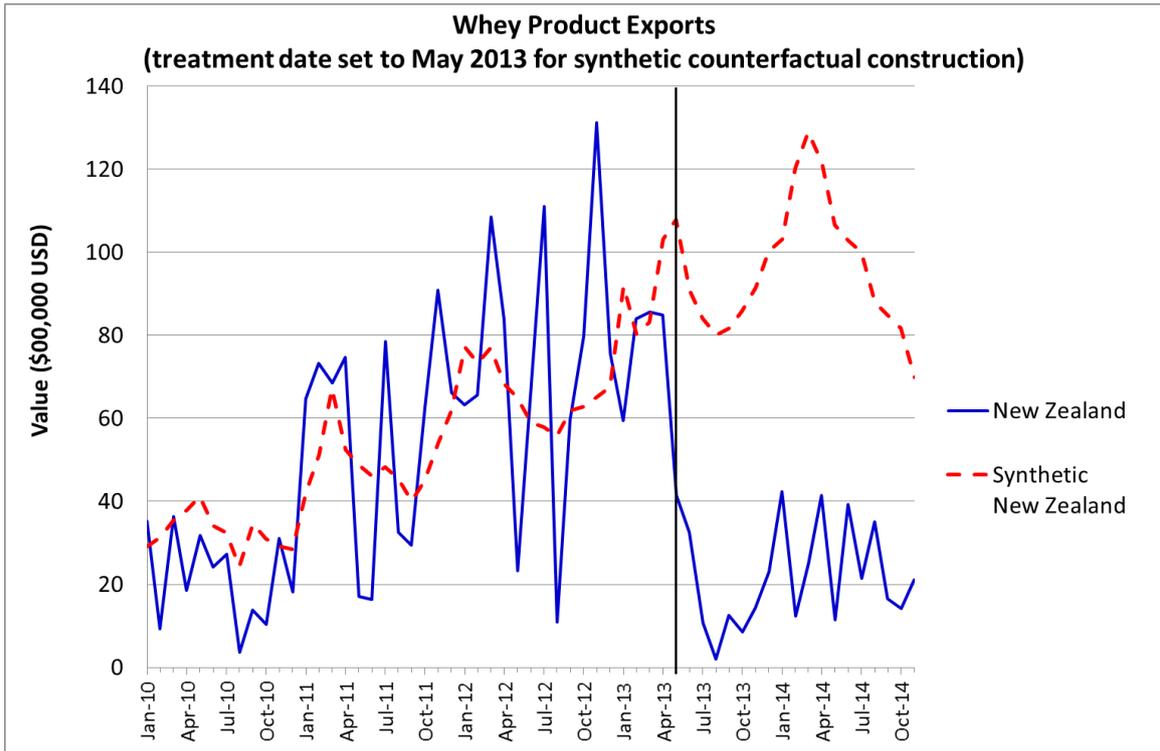
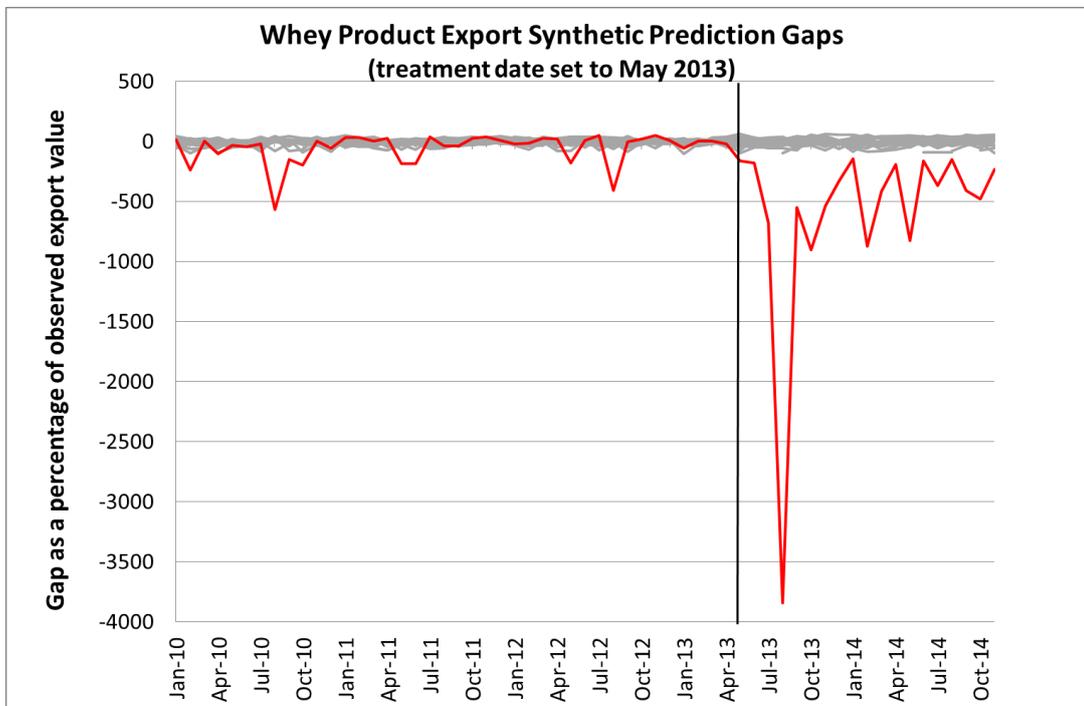
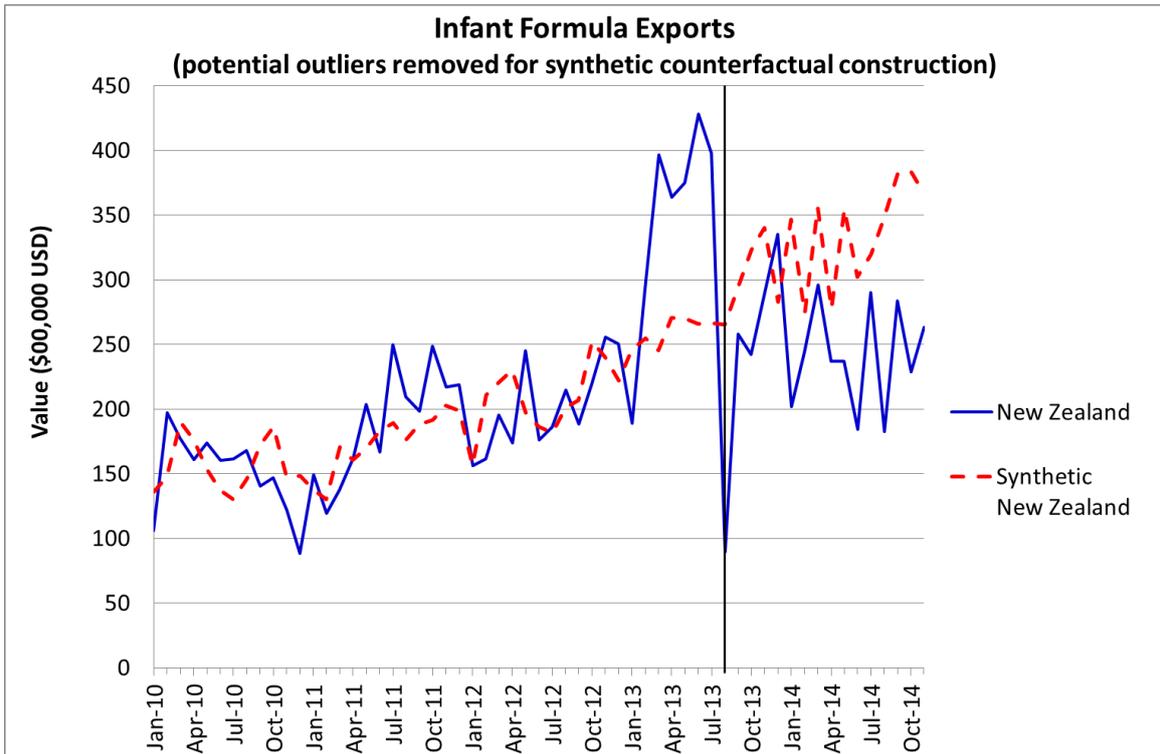


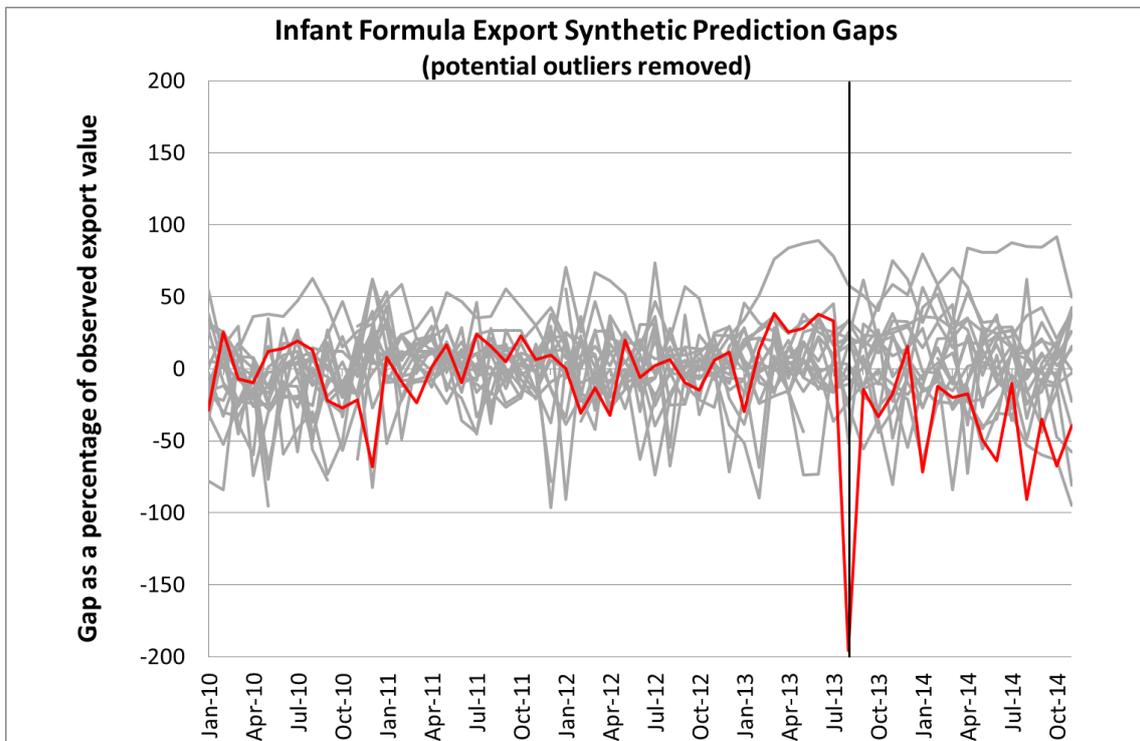
Figure 36: Gaps between actual whey product exports and the synthetic counterfactual predictions for New Zealand and the control group with potential outliers removed from the averaging process



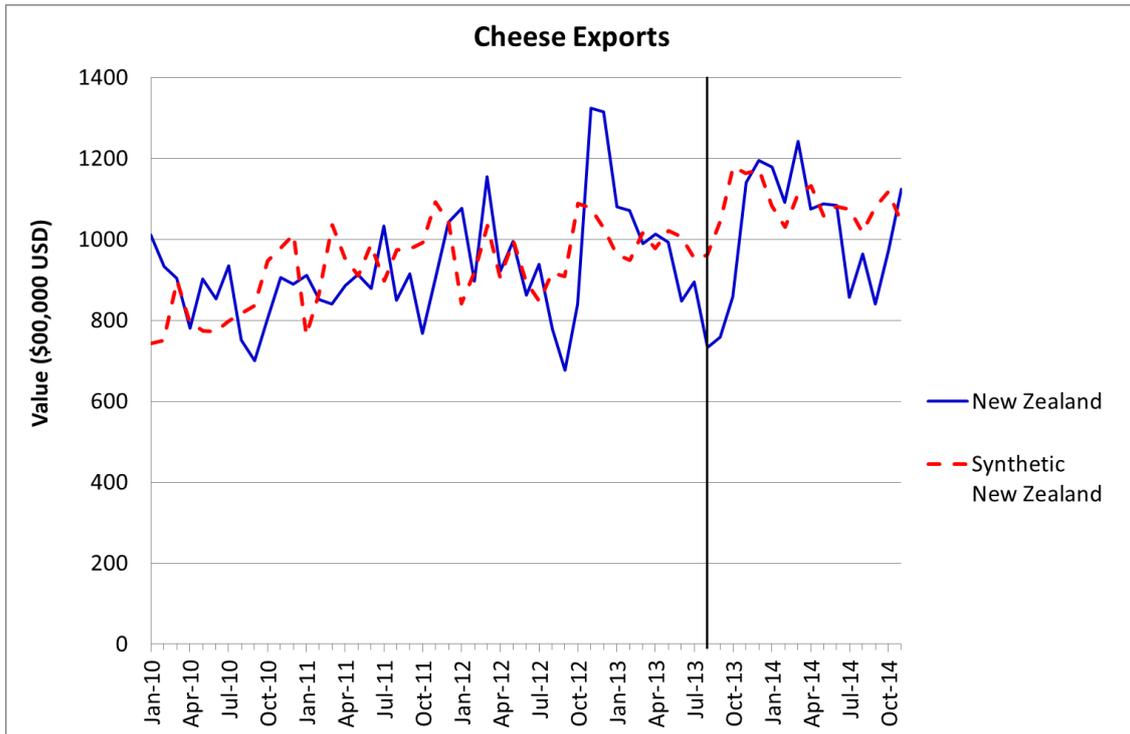
**Figure 37: Time series of actual and synthetic counterfactual New Zealand infant formula exports with potential outliers removed from the averaging process**



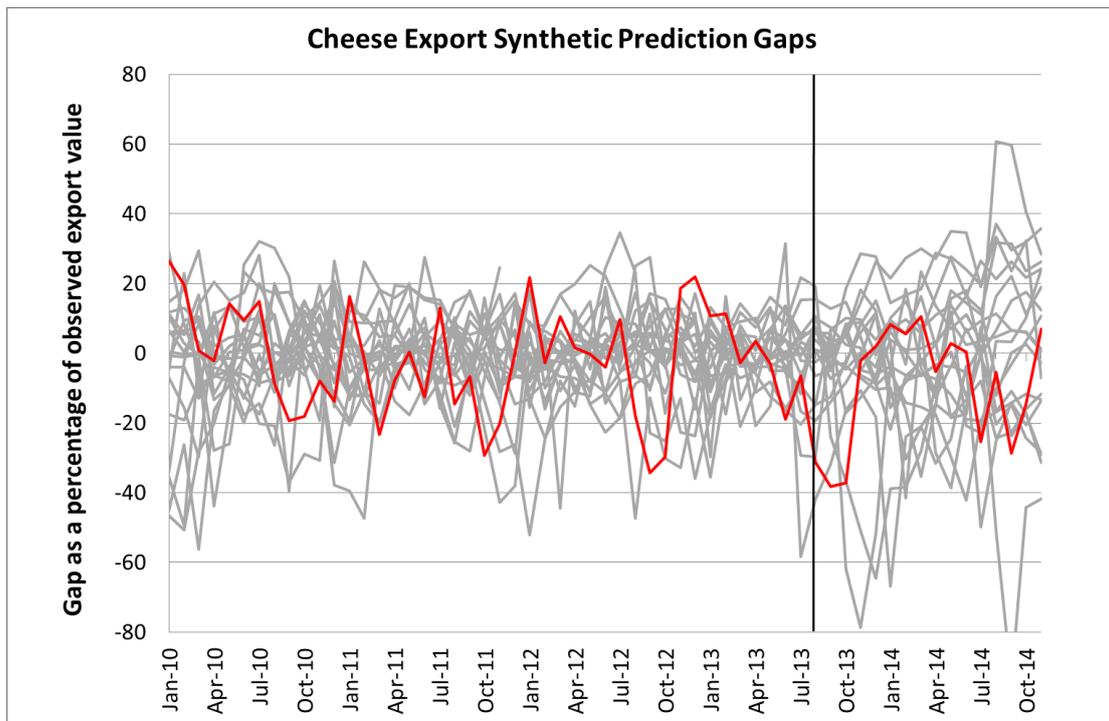
**Figure 38: Gaps between actual infant formula exports and the synthetic counterfactual predictions for New Zealand and the control group with potential outliers removed from the averaging process**



**Figure 39: Time series of actual and synthetic counterfactual New Zealand cheese exports without outliers removed from the averaging process**



**Figure 40: Gaps between actual cheese exports and the synthetic counterfactual predictions for New Zealand and the control group, without outliers removed from the averaging process**



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