The trade impacts of a food scare: The Fonterra contamination incident

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The Trade Impacts of a Food Scare: The Fonterra Contamination Incident

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Abstract: This paper presents the results of an investigation into the economic implications for New Zealand of the 2013 Whey Protein Concentrate contamination incident. It assesses the impact of this incident on dairy exports using synthetic control methods. A synthetic counterfactual scenario where the incident did not occur is developed using weighted information from other countries unaffected by the scare. We find 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 made up only a small proportion of New Zealand dairy exports, with the vast majority of dairy exports being unaffected. Infant formula exports appear to have recovered somewhat in the more than a year after the scare, however whey product exports (the contaminated product) remain lower than they otherwise would have been.

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1. Introduction

On the 3rd of August 2013, Fonterra – the largest global milk products exporter - released a statement stating 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 it was initiating a precautionary recall. 25 days later on August 28th, after some further testing, Fonterra was able to confirm that the scare had been a false alarm. Our aim in this paper is to identify and quantify the impact of this 'contamination' incident on milk exports from New Zealand, Fonterra's headquarters and the location of most of its production.

There were several complicating factors that could potentially have exacerbated the impact of this contamination. One primary problem was that Fonterra was unsure about the exact location of the affected product. The second was that WPC80 is used as an ingredient in several consumption goods, and as Fonterra was only supplying the ingredient, it did not know what goods it was being used in. Third, it was known that a common use of WPC powder is in the production of infant formula. This fact 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. [1] Fourth, Botulism, the suspected contaminant in this case, is a paralysis inducing illness that can potentially be fatal. Fifth, any competitive advantage held by the New Zealand dairy industry is based on the perceived quality of its products (Woods & Coleman, 2012). It is therefore sensible to conclude that a

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[1] In the Israeli incident, 15 babies were hospitalised and two died (World Health Organisation, 2003). In China, 126,000 babies became ill, 53,000 were hospitalised, and at least four died (BBC News, 2010).

scare such as the WPC contamination incident could have significantly impacted New Zealand's exports, had the scare damaged this reputation.

Given the severity of the issue and the compounding factors, Sri Lanka, Russia, and China introduced total bans on the import of certain New Zealand Dairy products. Throughout this month-long saga, it was repeatedly suggested by the media that the incident would have a devastating long-run impact on the reputation of the New Zealand dairy industry. After the Chinese melamine incident of 2008, and a more minor contamination incident in New Zealand in 2012[2], news media in New Zealand had become more sensitive to food safety issues. The news was also reported elsewhere, with 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).

Despite the media attention surrounding the event, this is the first piece of research that attempts to empirically quantify the event's impact on New Zealand exports, and on any other element of the New Zealand economy. More importantly, as far as we have been able to find, it is the first attempt to quantify the impact of a food-scare on trade more generally, especially when such a heavily traded commodity is involved. The well defined time-frame in which this event took place, also allows us to differentiate between impacts that were caused by a loss in confidence (brand value) vs. a decline that is associated with exposure to the contamination itself.

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[2] Traces of Dicyandiamide (DCD), a fertiliser, 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 impact in terms of reduced sales. It also makes it possible to identify any potential longer-run reputational damage.

The next section sets the scene, describing the role of the dairy industry in the New Zealand economy, the role of Fonterra, and briefly the nature of the global dairy market. The following section discusses modern contamination incidents as investigated by past literature. The literature that is examined is drawn from economics and marketing, in order to analyse how consumers view food safety and what factors influence the way in which they react to food safety concerns.

Section 4 describes the data we collected. It includes a range of summary statistics to help the reader better understand the context in which this event occurred. Section 5 presents the synthetic control methodology that was used to construct the counterfactual, and section 6 presents the results of the study as well as drawing conclusions about their causes and implications. A detailed timeline of the crisis and additional empirical analysis can be found in the online appendix.[3]

2. Fonterra and the dairy industry in New Zealand and Globally

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,

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[3] The online appendix is available at: https://sites.google.com/site/noyeconomics/research/natural-disasters.

2015; Fonterra, 2011). Dairy exports account for 26% of total New Zealand exports, and directly account for 2.8% of New Zealand GDP (NZIER, 2010).

Fonterra is the world's largest dairy company, and is far larger than any other dairy company in New Zealand. It 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), authorised by the Dairy Industry Restructuring Act (2001). Like its predecessors, Fonterra is a co-operative that 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. 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.

Fonterra's size means that its performance can have a tangible effect on the New Zealand economy – through effects on employment, farmers' wealth, and the performance of the rural economy. In mid-2015, 87% of farmers were represented by Fonterra, and it was still exporting almost all of the product it collects (Brettkelly, 2015).

Unfortunately, it is not possible to use 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. The reasons as to why it is not possible to assess changes to the share price for this project are discussed in depth in Stojkov (2016).

Fonterra also has a number of international partnerships, including partnerships with Nestlé and Dairy Farmers of America. It supplies international companies with ingredients and specialty products, and also owns a range of brands that are sold directly to consumers. The large number of business-to-business customers and brands supplied by Fonterra complicate any potential recalls. Fonterra's reputational standing has allowed it to expand globally and is the result of New Zealand's overall 'clean green' image and internationally recognised institutional frameworks.

Demand for dairy goods has been increasing along with standards of living in developing countries, with the upsurge in recent years stemming from a small group of mainly Asian countries. 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). While New Zealand is the leading world exporter of many dairy products, most dairy goods are not traded internationally, so it is not a comparatively very large producer.[4]

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 tackle them (Knowles, Moody, & McEachern, 2007). This prediction illustrates the significance of this research for future food safety policy at the firm, industry and national levels.

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[4] India has been investing in local milk production to meet increases in demand, and is expected to continue to developing this, 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).

One more important observation from our perspective is that dairy prices are very volatile; dairy is one of the most volatile commodities globally, and has been particularly volatile since 2007. This volatility is aptly exhibited by the time series of dairy prices in Figure 1.

**Figure 1: Global Dairy Trade Total Price Index,
(accounting for the prices of all goods sold on Global Dairy Trade)**
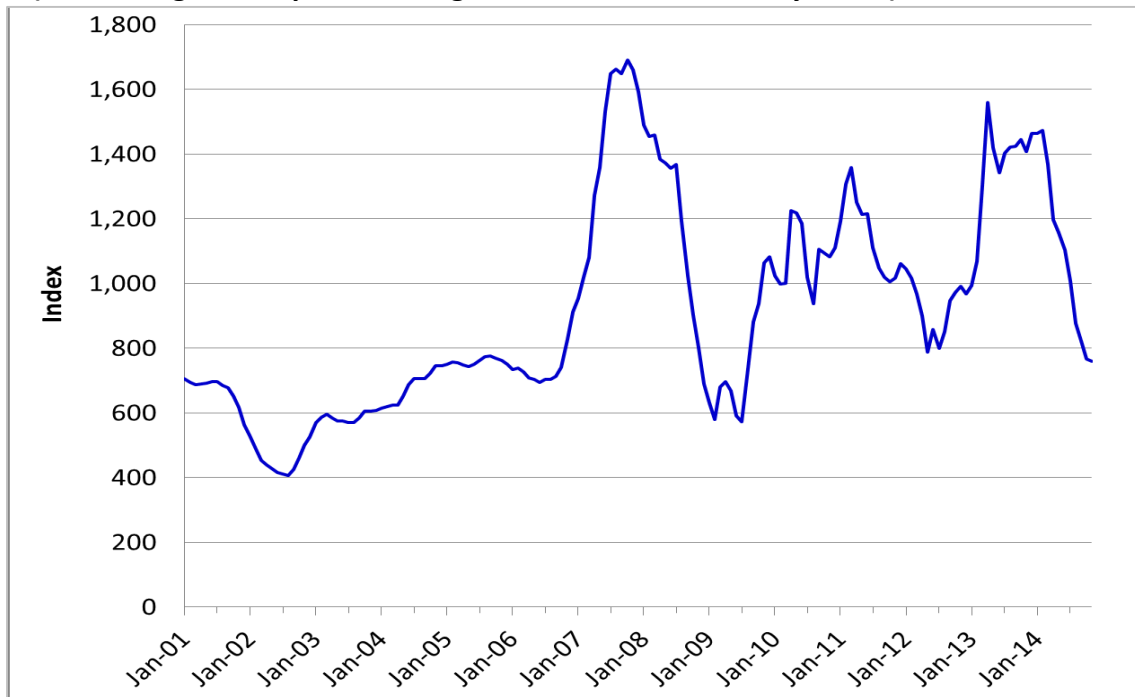
3.   The literature on Product Scares

Research that investigates food scares identifies subjective consumer beliefs regarding reputation and trust as key determinants of consumer decision-making following a contamination announcement. As is true for risk assessments in other spheres, subjective perceptions of risk have been found to be very different from the objective, statistically observed, levels of risks of harm or fatality (Boker & Hanf, 2000).

Richards and Patterson (1999) find that the economic costs of food scares are immediate and that reputation is difficult to restore in the wake of such an incident. Their study is on a contamination incident that occurred in 1996, in which Californian strawberries were falsely

announced to be the source of an outbreak of Hepatitis A. They found that even when only one brand is implicated, "all growers are made to suffer" (Richards & Patterson, 1999). It is both interesting, and significant to this research, that Richards and Patterson (1999) find both immediate impacts on sales and long lasting impacts on reputation.[5]

The literature also overwhelmingly finds that consumers respond disproportionately to negative information, as compared to positive information (Mazzocchi, 2006; Richards & Patterson, 1999; Smith, van Ravensway, & Thompson, 1988). In the case of the WPC80 contamination incident, the substitution would likely be away from New Zealand goods, as opposed to away from dairy, as there are several other exporting countries with a similar 'clean' image.

We have however found that consumers from different international markets may respond differently to information. The differences are determined by the specific characteristics of countries and industries (Holtbrugge & Baron, 2013; Folkes, 1991). The think-tank 'Civil-China', for example, tallied the number of positive, neutral, and negative social media posts over the progression of the WPC contamination incident (Civil China, 2013). It found that after the announcement, negative posts increased, but positive posts increased also, as a response to Fonterra initiating a precautionary recall. There was a perceived difference between Fonterra's transparency and Chinese producers' obfuscation during the 2008 melamine contamination incident.

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[5] In the Californian strawberry case, (Richards & Patterson, 1999) conclude that sales were affected for two years even after the source of the contamination was found to be Guatemalan raspberries.

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, as developments in New Zealand do not generally affect the global dairy price (Kamber, McDonald, & Price, 2013).[6]

4.   Methodology

We estimate the economic impact of the WPC contamination incident on New Zealand dairy exports. The estimation is done using a comparative case study approach. The synthetic control method we use was formalised in a paper which analysed the effects of changes in tobacco regulation in California (Abadie, Diamond, & Hainmueller, 2010). This method can be used to assess the impacts of any exogenous economic shock, though panel data from similar but unaffected locations is required as a control group to construct a counterfactual. This method has been used to analyse the impact of exogenous shocks in a variety of contexts. 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 (Barone & Mocetti, 2014) and Japan (duPont et al., 2015).

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[6] 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 on demand, as buyers would have no longer wanted to purchase New Zealand product.

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. These same weights are 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, the GDMI drought index, 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 ad-hoc criteria. This approach eliminates the subjectivity bias that a researcher might inadvertently insert (Abadie, Diamond, & Hainmueller, 2010). As an example of the difficulty a researcher would be faced choosing a counterfactual, New Zealand whey exports are graphed against the exports of countries exporting similar quantities in Figure 2. It is clear that none of them are a particularly good predictor of the evolution of whey exports from New Zealand, and it is not immediately clear which country would make a better control than another.

Figure 2: New Zealand whey product exports against possible control countries' whey exports
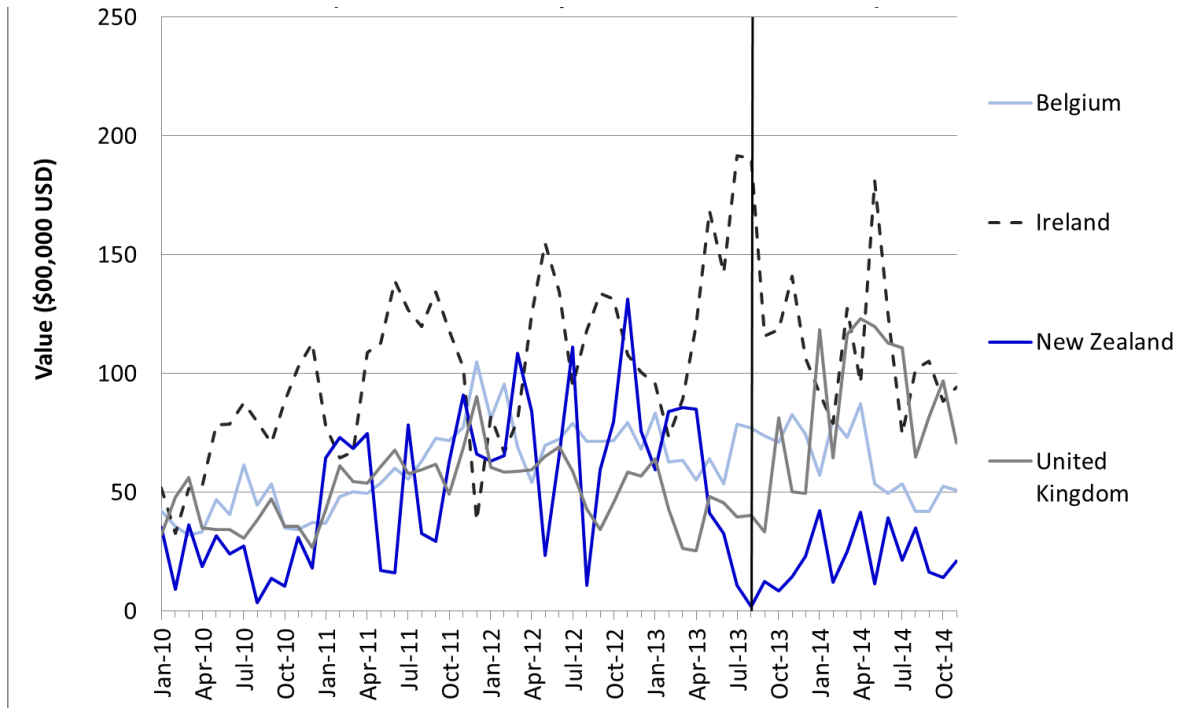
The synthetic control method, described formally below, enables the construction of the most efficient synthetic New Zealand for each dairy product included in the data set. The description and notation below follow closely the formalization in Abadie et al. (2010). For each product, the export values (Y_{it}) that are observed are assumed to be:

$$Y_{it} = Y_{it}^N + \alpha_{it} D_{it} \tag{1}$$

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 α_{it}. The term D_{it} is a dummy variable that takes the value of 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, and for all other countries, D_{it} is zero. In this dataset, $D_{it} = 1$ when $i = 1$ (New Zealand) and t ≥ 44 (August 2013). The task is

to estimate α_{1t} (impact on 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:

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

Here, δ_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 can be thought of as the effect of global factors that influence a global level of demand and supply for dairy exports in a given period (for example, feed costs or demand of very large importers). $E_{it}, Z_{it},$ 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 ν 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 ε_{it} are assumed to be random *iid* shocks with a mean of zero.

The vector λ_t represents unobserved time variant factors that influence dairy exports. Their factor loadings vary across countries, and this variance is depicted in the vector of coefficients μ_i. The actual factors are not observed; they are latent variables. It is not necessary to specify what these unknown factors are, though 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 considered by rearranging the model to:

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

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. Without the $\lambda_t \mu_i$ term, which represents unobserved factors that influence dairy exports, there is bound to be omitted variable bias. The variance from the latent variables would be incorrectly grouped with the ε_{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 are 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 to create the synthetic control so that $W(V) = (w_2, \dots, w_I)'$. The following two constrains are placed on the elements of W: $\sum_{i=2}^{I} w_i = 1$ and $0 \leq w_i \leq 1 \quad \forall i$.

Abadie, Diamond, and Hainmueller (2010) suggest finding the optimal W(V), denoted by W*(V), by minimising $\sqrt{(X_1 - X_0 W)' V (X_1 - X_0 W)}$. Here, X_1 is a vector that includes the observed predictors and a collection of simple and weighted averages of the export outcomes in 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. The algorithm for choosing V also indirectly determines which countries will be used as controls, as W* will be a function of V.

After the minimisation, $\sum_{i=2}^{I} w_i^* E_{it} \approx E_{1t}$; $\sum_{i=2}^{I} w_i^* Z_{it} \approx Z_{1t}$; and $\sum_{i=2}^{I} w_i^* S_{it}^P \approx S_{1t}^P$ will hold $\forall t = 1,,,,,T_0$. As μ_i are unobserved, it is not possible to directly choose W such that $\sum_{i=2}^{I} w^*_i \mu_i = \mu_1$. However, Abadie et. al (2010) prove that, 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. In that case,

$$\sum_{i=2}^{I} w_i^* Y_{it} = \hat{Y}_{1t}^N \approx Y_{1t}^N \quad \forall t = 1,,,,,T_0 \tag{4}$$

From here, it follows that the impact of the contamination that we wish to estimate for every export value series is the observed series minus the counterfactual:

$$\hat{\alpha}_{1t} = Y_{1t} - \hat{Y}_{1t}^N \tag{5}$$

There is, naturally, uncertainty regarding the ability of a counterfactual series ($\hat{Y}_{1t}^N$) 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 directly observe the counterfactual scenario. Abadie et al. (2010) propose permutation (placebo) 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 – all countries that did not experience the shock. The placebo tests are carried out using all of the control countries in the data set by estimating:

$$\hat{\alpha}_{it} = Y_{it} - \Sigma_{j=2}^{I} w_j^* Y_{jt} \qquad \forall\, i \neq 1; j \neq i \qquad\qquad (6)$$

The synthetic control method should not predict any gap in the post-intervention period in the placebo cases because the control countries were not embroiled in the botulism scare. When the $\hat{\alpha}_{it}$ are estimated for placebos, the counterfactual will not match true exports perfectly in the post-intervention period as the weights are not perfectly estimated. These discrepancies are then deemed to be the margin of error that allows us to examine whether the actual/counterfactual gap we identified for New Zealand is 'statistically signficant'.[7] We examine the six main categories of New Zealand dairy exports.[8] The methodology is the same in all cases.

In previous works, the synthetic control method has been used with annual data.[9] In a monthly series it is more difficult to develop an accurate control as higher frequency series are often more volatile. This volatility can only be accounted for if other countries had matching patterns of seasonal/monthly volatility.

As the countries observed 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 synthetic placebo results to the actual observations for these countries. This means that the permutation tests are still applicable, because they are

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[7] Strictly speaking, this cannot be a test for statistical significance without making some assumptions about the way the $\hat{\alpha}_{it}$ are distributed. Without such assumptions, we graph the gaps for New Zealand and the placebos, and discuss the differences between them.

[8] Value of exports were simulated for cheese, infant formula, and whey products. For WMP, SMP, and AMF/butter, the year on year growth rate was simulated because New Zealand exports such large quantities of these goods relative to most countries and the synthetic control method does not allow country weightings to exceed one to prevent extrapolation bias (Abadie, Diamond, & Hainmueller, 2010).

[9] Examples include Hinrichs (2012), Cavallo et al. (2013), Barone & Mocetti (2014), Coffman & Noy (2012), duPont & Noy (2015), and duPont et al. (2015).

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 is not plausible 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. Annualising data would not be suitable because it would reduce the number of observations to five, with only one post-treatment observation. Similarly, using moving averages would be problematic because the intervention period would be difficult to pinpoint; both its start and its duration would be difficult to discern. Seasonal adjustment requires strong and consistent seasonal patterns over 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 dairy export data.

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 means that the contamination incident did not have an effect on exports prior to its public announcement (i.e., Fonterra did not change their exporting before they were told of the contaminant by the lab in August).

It is, however, known that Fonterra was aware that there was some issue prior to the announcement of the scare, even though they did not understand its severity (Norris, et al., 2013). If there had indeed been a leakage of information, or if 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. The total estimated impact of the scare would then be biased downward, because some of the downward trend prior to T_0 would be assumed to be normal. However, an incorrect T_0 would bias the counterfactual significantly only if the impact before T_0 is very large or the real onset was much before T_0. Neither of these are likely.[10]

5.   The Data: Source, Description, and Summary Statistics

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 variables. Dairy price data from the Global Dairy Trade (GDT) auction platform include a time series of the Global Dairy Trade Price Index (Figure 1 above).[11] This price information was not used to construct the synthetic controls, as we already include time fixed-effects. Prices were approaching historical highs at the time of the scare. This was partly due to significant supply constraints resulting from a drought that affected Oceania in 2013 (Kamber, McDonald, & Price, 2013). No remarkable price change is observed during or soon after the scare.

The lack of a price response in the case of the WPC contamination incident in August 2013 can be contrasted with the turning point visible in all price series in March 2014. There was a positive supply response from the high prices the previous season, a large surplus of

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[10] In the following section, we observe that the only instance where this is a possible concern is for whey exports. To account for this possibility, we re-estimated the counterfactual with an earlier treatment date. This does not change the estimated impact by much (though the estimated impact does increase).

[11] Prices for the three main export products: WMP, SMP, and AMF, are presented in the appendix. 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.

European products that could no longer be exported to Russia due to sanctions, as well as a slowdown in Chinese imports (OECD/ FAO, 2015).

Dairy export data was collected for New Zealand and the control group. The New Zealand export data was collected from Statistics New Zealand, while the export data for the control group was obtained from the UN Comtrade database. Including New Zealand, the dataset covers 32 countries and accounts for 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 of May 2015.[12]

While New Zealand data was available for all of the products that Statistics New Zealand identifies as containing dairy, many countries in the control group were missing most observations for minor export goods. It is for this reason that we focus 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).[13] Cheese products are also included as they are New Zealand's next largest dairy export. Around 84% of New Zealand dairy exports over the time period are captured in this product group.[14] It is noteworthy that whey products, which include the contaminated WPC80, make up only around 0.5% of total New Zealand

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[12] It was not possible to use quantity data, as the Comtrade database only records export values. Nevertheless, it is applicable to use export values because, as we observed, there was no impact from the WPC contamination incident on dairy prices.

[13] 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.

[14] The exact product classifications and the amounts involved are described in the appendix.

dairy exports.[15] Infant formula, the other potentially affected product, makes up between 2-3% of exports.

Aggregated New Zealand dairy exports are graphed in Figure 3. The vertical black line denotes August 2013, the month in which the scare occurred. 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.

Figure 3: Time series of Total New Zealand Dairy Exports (value)

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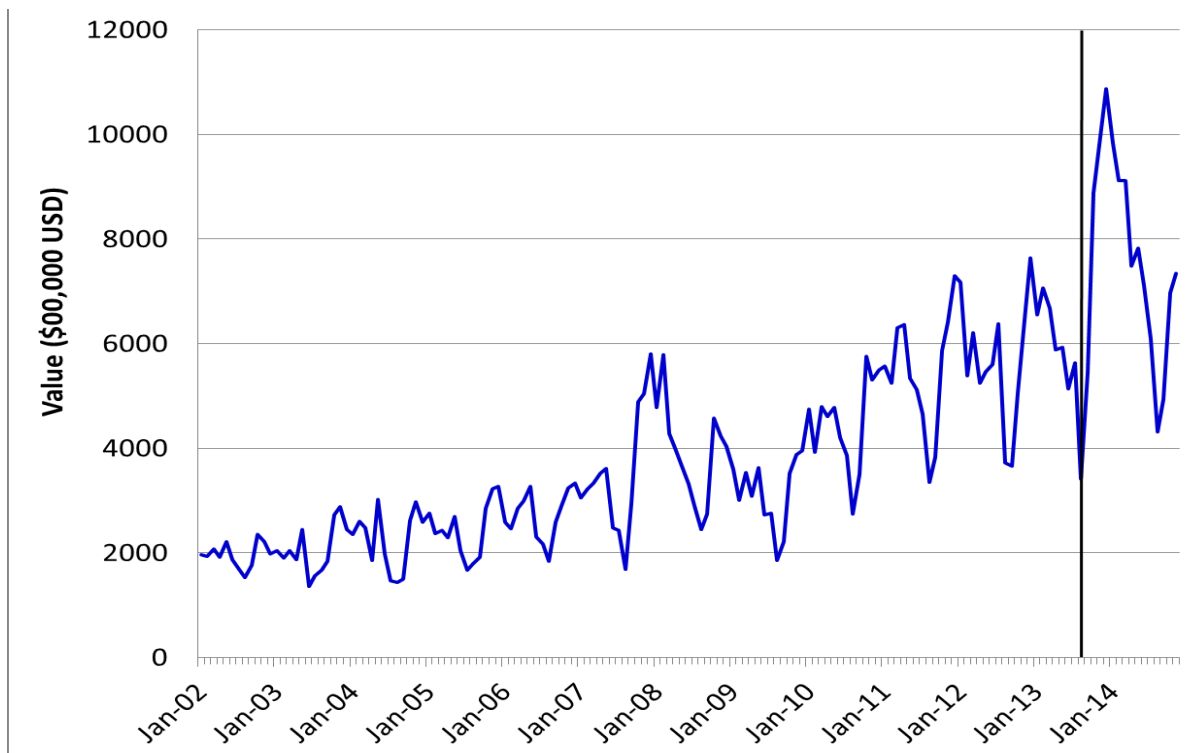
[15] The data in the Comtrade database is recorded at the six digit level using the Harmonised System. It is for this reason that 'the affected product' in this study is taken to be all whey products, rather than whey protein concentrates.

When we examine only consecutive months of August, a potential shock to dairy exports is visible in 2013, but appears very small. Furthermore, there appear to have been larger year to year declines in 2009 and 2007. In the online appendix, we present a comparison of the mean growth rates of exports in the three months before and after the contamination for all the countries included. For all three of the dominant products, WMP, SMP, and AMF/butter, New Zealand exports grew more rapidly 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 positive differences relative to the other countries in the control group. For AMF/butter, New Zealand's change in growth rate is roughly the median of the control group. This is preliminary evidence against a very large impact from the contamination incident for these main products.

In the cases of the affected products, whey products and infant powders, New Zealand's difference in growth rate is negative. New Zealand values are some of the most negative when compared to the control countries. Of the countries that have more negative differences in growth rates, all bar Chile export only very small amounts of whey products and infant formula. This makes it more plausible that the negative values for New Zealand are a result of the contamination incident.

This analysis, however, does not necessarily indicate than there was no impact on goods that were not implicated directly in the scare. Exports maybe 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 exports would have been had the incident not occurred. 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, as dairy commodities are predominantly

traded in USD. The monthly exchange rate changes were sourced from the IMF's International Financial Statistics database.

Climate data was hence introduced into the model, but only for New Zealand and Australia. Kamber et al. (2013) show that droughts in the austral summer months have negative impacts on dairy production, with an increase in price observable in the third quarter. The effects of the 2012-2013 summer drought needed to be accounted for in order to construct an accurate counterfactual using the synthetic control method. Climate data 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 feed. Indirect time variant effects for the other countries, such as those caused by higher feed costs in winter, would be captured in the time fixed effects included in the model.

We use the Global Drought Monitor Index (GDMI), accumulated at the six month level (Vicente-Serrano & Begueria, 2015). The GDMI takes into account precipitation levels and temperature, as well as potential evapotranspiration.[16] The severity and persistence of the drought would suggest that it accounts for at least some of the lower exports observed in 2013.[17] As the GDMI values are available regionally, we weighted the observation for each region by the percentage of dairy production that came from that region in each country. This

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[16] Evapotranspiration 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). More details about this index and its construction are available in Stojkov (2016).

[17] The drought was officially declared to be over in October 2013 (New Zealand Veterinary Association, 2013).

weighting was particularly necessary in the case of Australia, where only a small proportion of the land is used for dairy farming. This resulted in national GDMI time series.

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.

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 exports were recorded, a simple linear interpolation was done to balance the panel. In all cases, except for the two described below, countries were excluded from the control group for the products for which sufficient data was not available. The last few data points for Argentina and Singapore were missing, so we used the Holt-Winters forecasting method to forecast these.

6. Results: The Impact on Dairy Exports

The following figures plot the actual values of the export series for New Zealand, the estimated counterfactual series (i.e., the synthetic New Zealand exports without the contamination), and the estimated impacts for NZ and for the placebos (the gaps between the actual and counterfactual), for each of the six dairy product groups . The weights that were assigned to the control countries in each case are recorded in the online appendix. This

is also where a list of the placebos used for the permutation tests can be found. [18] 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.

First, we analyse the directly implicated products: whey products and infant powders. We follow that with the analysis for WMP, by far New Zealand's largest export product, and then the remaining products: SMP, AMF/butter, and cheese.

Figure 4: Actual and counterfactual New Zealand whey product exports
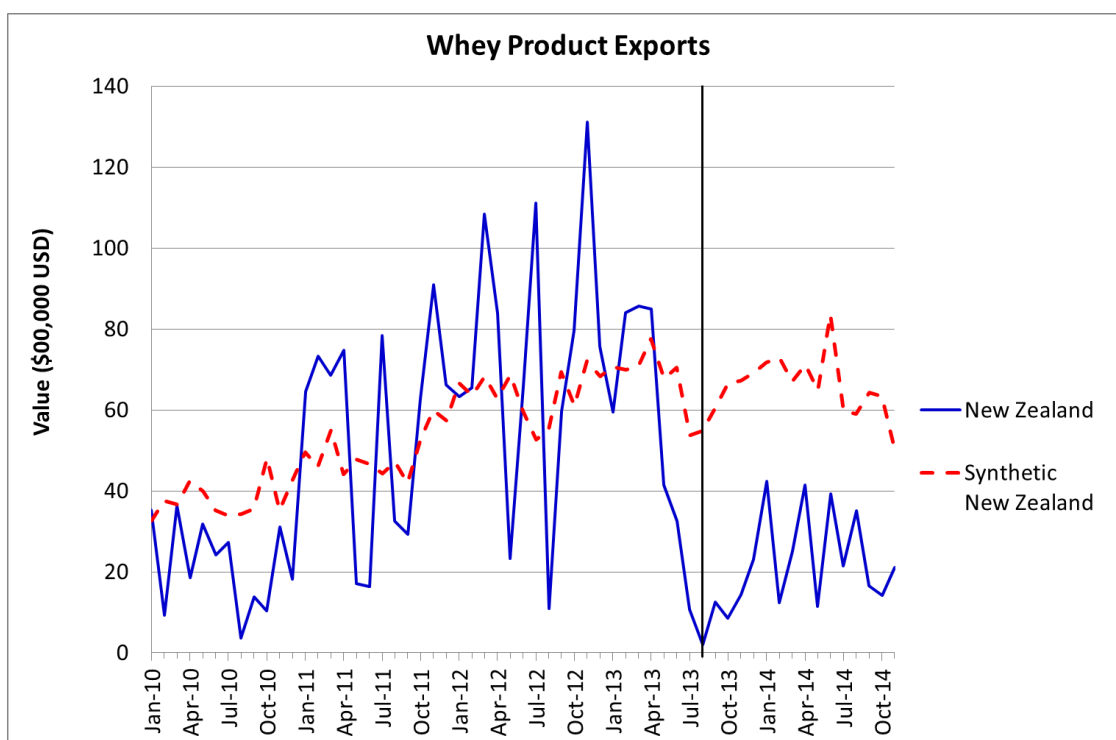
Figure 4 compares the estimated counterfactual whey exports to the actual exports of whey products, the contaminated product. Perhaps unsurprisingly, there appears to be a significant unexpected (unpredicted) drop in exports after August 2013. The gap between the true series and the counterfactual is persistent throughout the post treatment period. The synthetic

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[18] The online appendix is available at: https://sites.google.com/site/noyeconomics/research/natural-disasters.

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, though the actual series is much more volatile. 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, New Zealand's Ministry of Primary Industries was also actively withholding product from export due to the perceived serious nature of the safety threat (Ministry for Primary Industries, 2015). The fact that lower exports persisted for over a year, well after the all-clear, suggests that New Zealand's reputation as a provider of quality whey goods may have been 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 found to have been a false alarm. China's complete ban was lifted in October 2013, but Russia's bans were only lifted in August 2015, and even then only partially (Reuters, 2015).

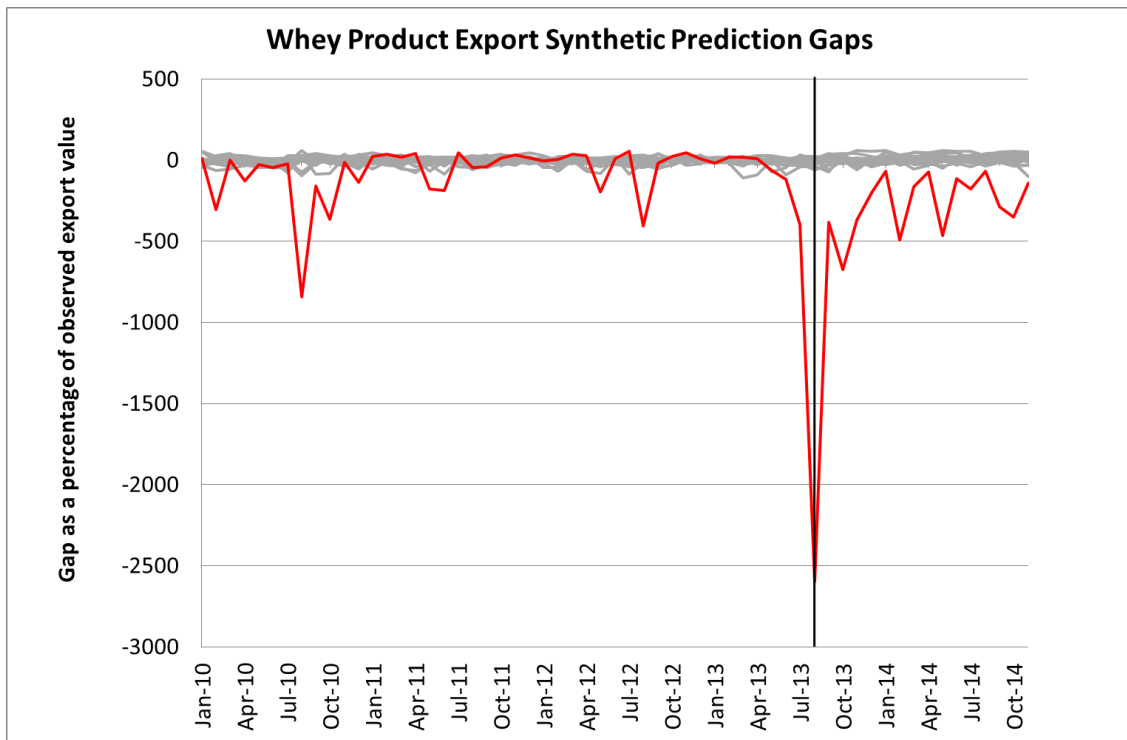**Figure 5: Gaps between actual and counterfactual whey exports for New Zealand and the placebo countries**

Figure 5 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. It is clear that the gap following the WPC contamination incident in the case of New Zealand is significantly and persistently larger compared to both other countries and the variation from New Zealand exports in the pre-treatment period. 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 as well. Acknowledging there is significant noise in the data, we calculated the total loss of New Zealand exports from whey products. 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 4 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: First, the original pattern may be a statistical anomaly; it features less than three years 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.

In the online appendix, a synthetic control is constructed where the treatment period is assumed to be May 2013 (instead of August). 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 is relatively poor in the pre-treatment period, year on year growth rates of whey products are also analysed. Figure 6 shows the growth rate gap of New Zealand whey exports and the corresponding placebo countries.

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. After May 2013, there is a level shift downward in the growth rate, after which the growth rate continues to be lower. This would

suggest that the drop in the growth rate – the lower exports observed between May 2013 and early 2014 – is not seasonal, but rather due to the shock.

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 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 within the margin of error.

Figure 6: Gaps between actual and counterfactual whey product export growth rates for New Zealand and the placebo countries
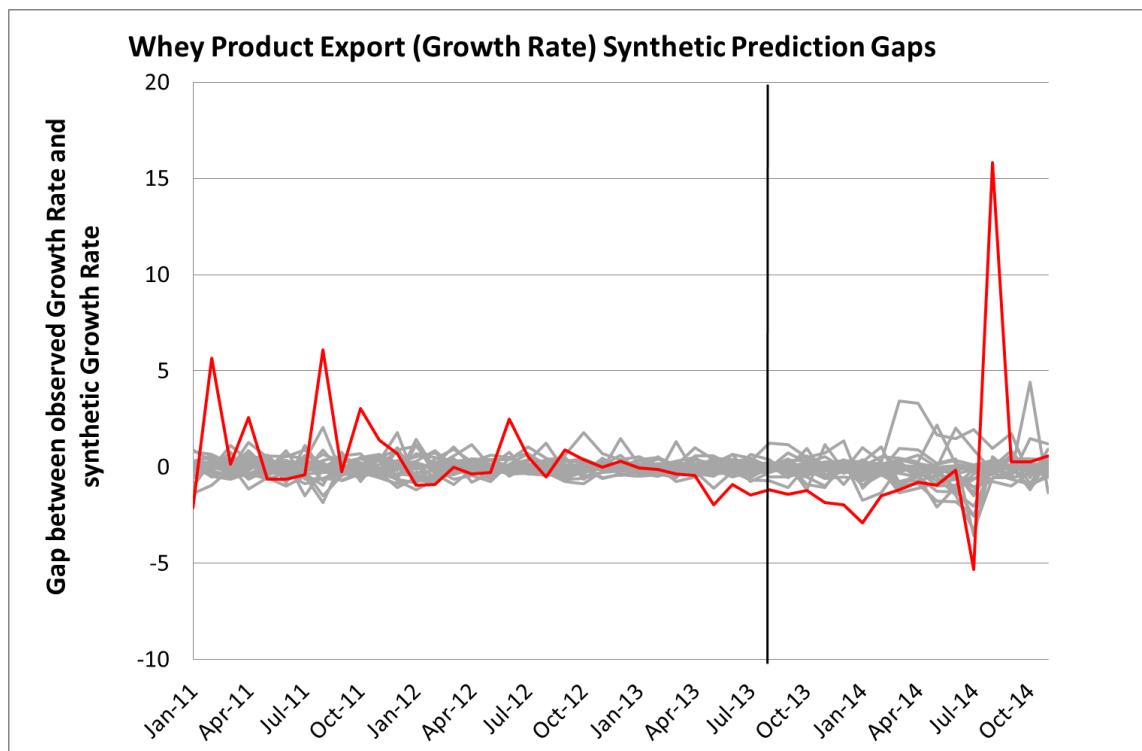
From Figure 6 it is visible that between May 2013 and early 2014, the gap between the New Zealand counterfactual growth rate of whey exports and actual exports is significantly greater (and negative) relative to the gaps for the placebos. All this suggests that the WPC contamination incident has had a significant and persistent impact on both the level and

growth rate of New Zealand whey exports. It is important to emphasise, however, 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.

Another product that was directly entangled in the scare was infant formula (WPC is an ingredient in infant formula). As in the case with whey products, Figure 7 shows that that the contamination incident had a significant impact on New Zealand exports of infant powders in August 2013 that has persisted over time. It is likely that the effect was large because infant formula is a consumer product where safety concerns are of paramount importance.

It is noteworthy that infant formula exports appear to rebound in December 2013, and then fell 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.

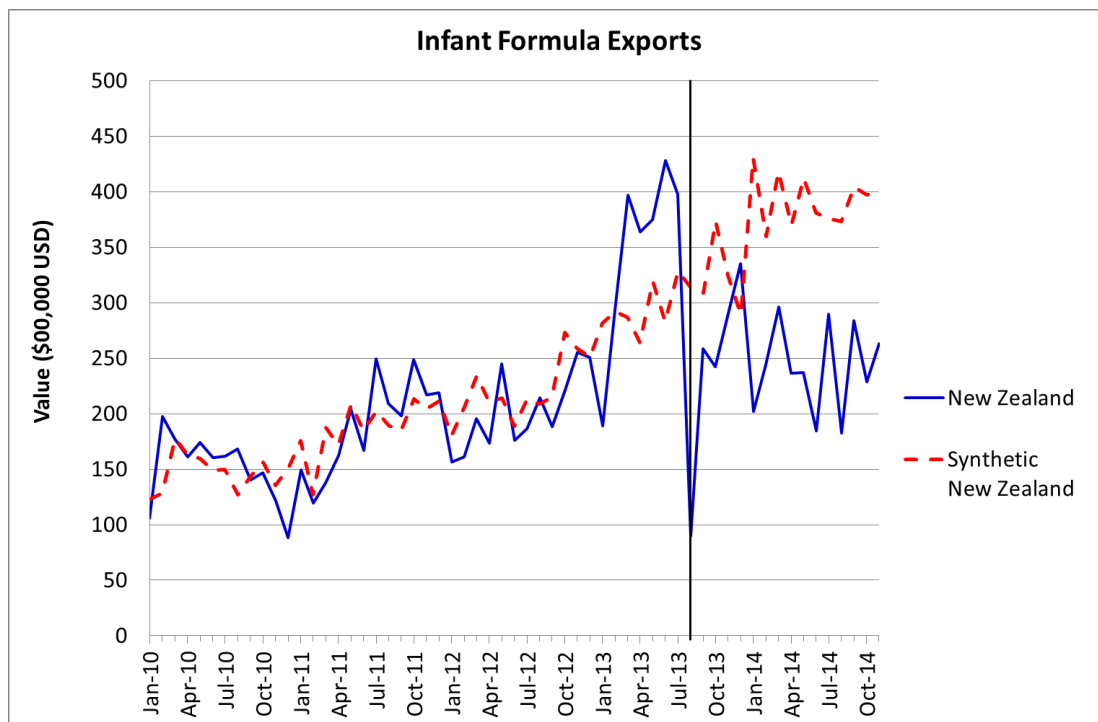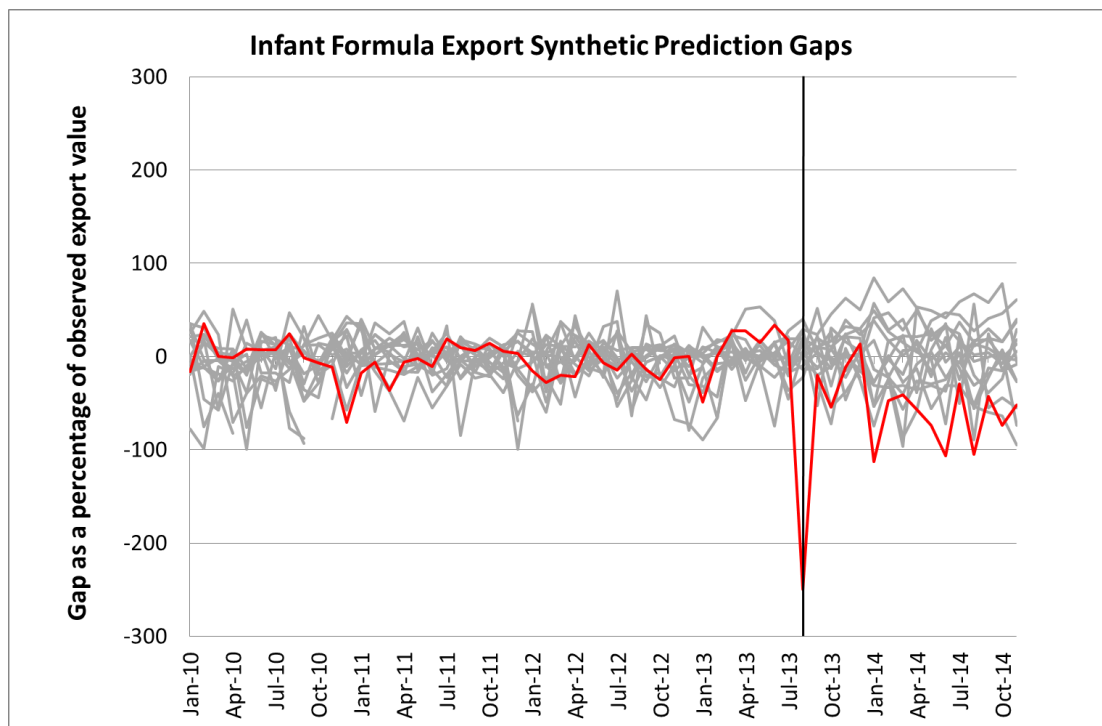**Figure 7: Actual and counterfactual New Zealand infant formula exports**

Figure 8: Gaps between actual and counterfactual infant formula exports for New Zealand and the placebo countries

The placebo significance tests are presented in Figure 8. The discrepancy in the New Zealand case between actual infant formula exports and the predictions of the synthetic control is roughly average relative to those of the placebo countries in the pre intervention period. 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; though the recurrence of the negative gaps after 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. 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.[19]

Figure 9: Actual and counterfactual growth rates of New Zealand WMP exports

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[19] The infant formula industry was one of New Zealand's fastest growing industries prior to the contamination incident and was expanding globally (Fonterra, 2014). Fonterra staff we consulted 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 the appendix, 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.

Growth Rate of WMP Exports
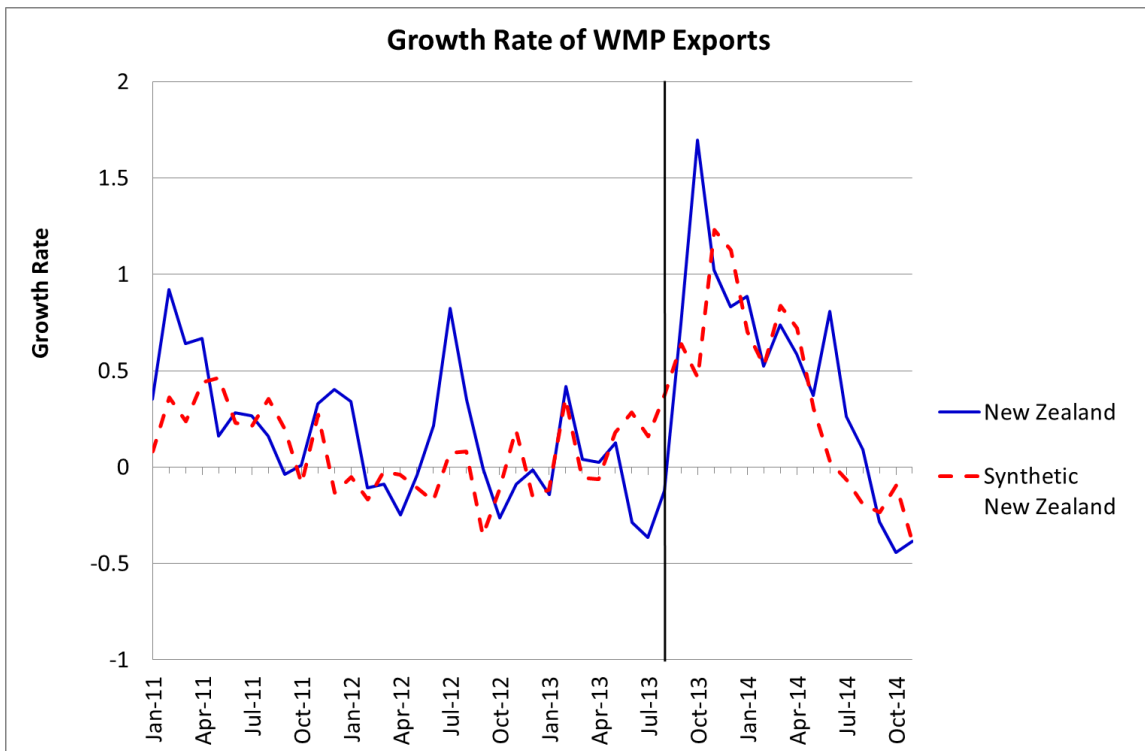
The synthetic counterfactual does not predict the decline in WMP exports that was seen in the months from May 2013 (figure 9). This could be because the effects of the drought which peaked around this time have not been fully accounted for, and therefore the controls were not able to accurately emulate New Zealand conditions. It is also notable that while they are negative, the growth rate declines were at their lowest in July, and already began a recovery in August when the contamination was identified.

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 can be attributed to the contamination incident, or if the discrepancy is merely within the margin of error. 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 on

WMP was very short lived; New Zealand's reputation or share in the market of WMP was not affected.

Figure 10: Gaps between actual and counterfactual WMP export growth rates for New Zealand and the placebo countries
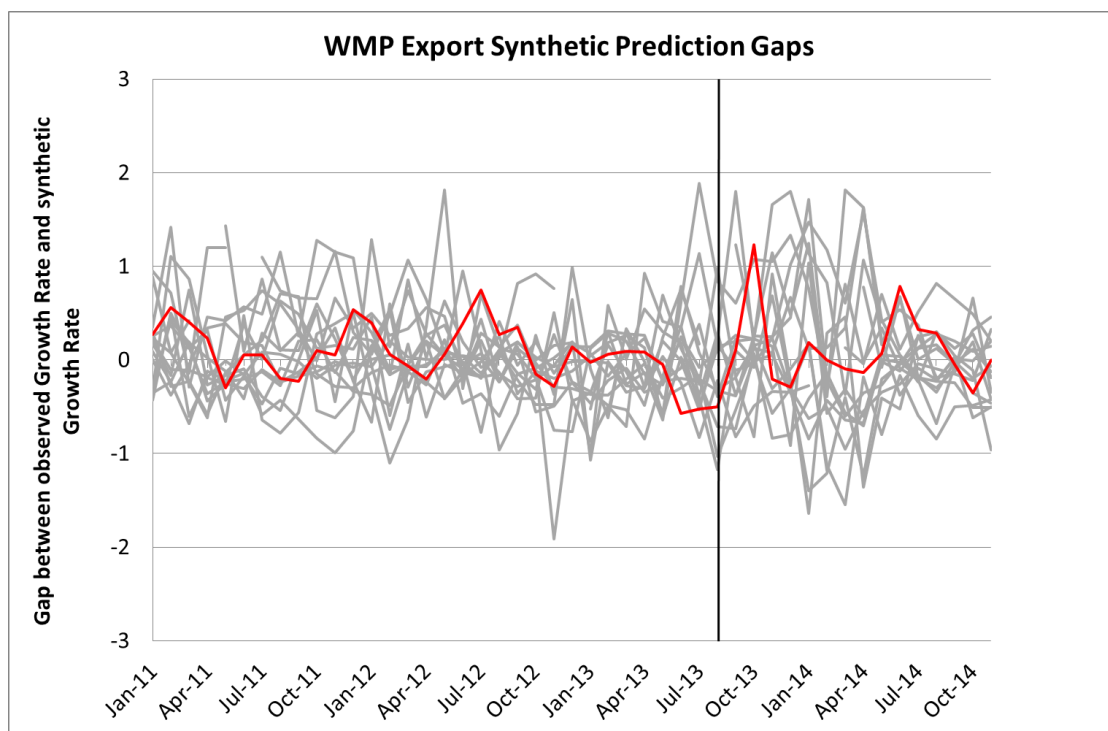

Figure 10 shows that the magnitude of the gap in the prediction for New Zealand WMP growth rates is roughly in the middle of the distribution of the gaps in the control countries for the duration of the series. This indicates that the discrepancy between the actual growth in WMP exports in August 2013 and the synthetically predicted growth rate is not significant. It appears sensible to conclude that the WPC contamination incident did not affect WMP, which alone accounts for around 40% of New Zealand dairy exports.

We finish by presenting similar analysis for the last three groups of dairy products - SMP, butter, and cheese – in Figures 11-13, respectively. For all three products, we only present the factual-counterfactual gaps (the impact) as calculated for New Zealand and the placebos.

When we examine the growth rate of SMP exports, in Figure 11, it is not possible to conclude that there was any change to the growth rate that can be attributed to the WPC contamination incident. We do observe a dip in growth that started in early 2014 (long after the contamination fear was found out to be unfounded) – but this dip is identified within a large volatility observed also for the placebos.

Figure 11: Gaps between actual SMP export growth rates and the synthetic counterfactual predictions for New Zealand and the control group
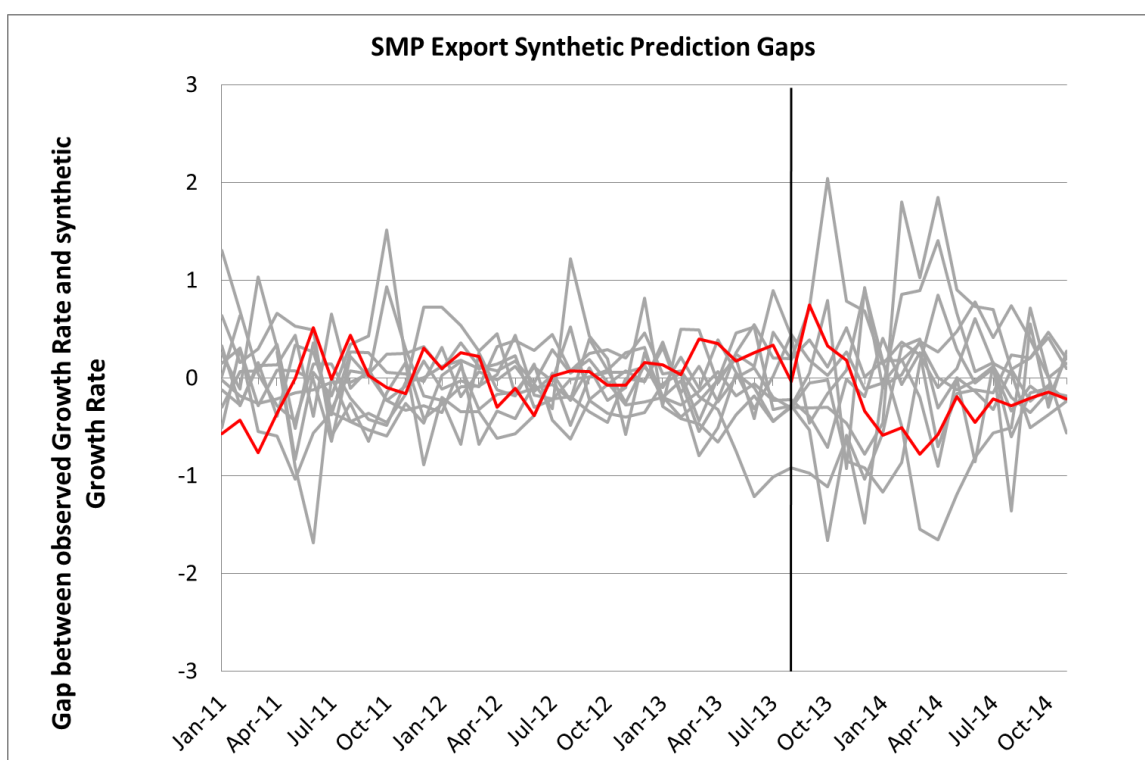
For AMF/butter (Figure 12), it appears that there was a large unexpected drop in the growth rate of exports in August 2013 relative to the previous year. The drop was not predicted by the synthetic counterfactual, which otherwise maps export growth rates quite well in the pre-treatment period. Still, the placebo trials depicted in the figure 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 as overwhelmingly greater as it is 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 may have been a small, transient negative impact from the WPC contamination incident on to the growth rate of New Zealand AMF and butter exports. It is interesting that there may have been a very short-term effect on AMF/butter exports, but not on WMP and SMP exports. [20]

Figure 12: Gaps between actual AMF/butter export growth rates and the synthetic counterfactual predictions for New Zealand and the control group
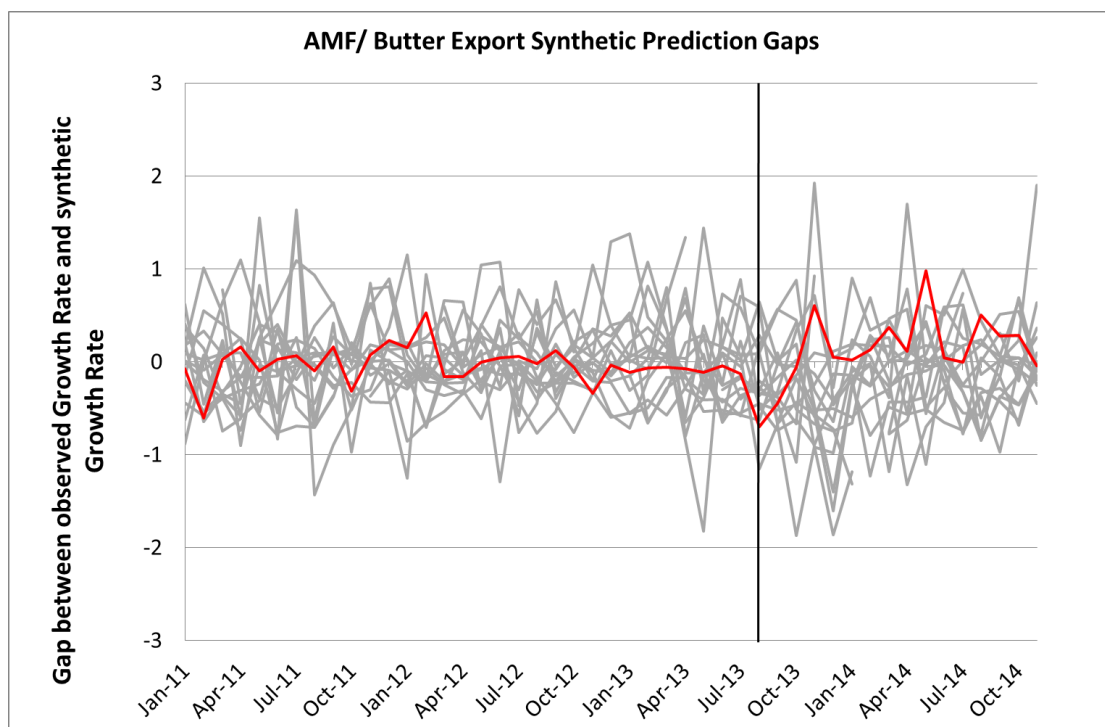

Figure 13 presents actual New Zealand cheese exports and the counterfactual of New Zealand cheese exports had the contamination not occurred. Cheese exports are New Zealand's next

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[20] It is possible that the smaller market for AMF/butter gives buyers relatively more bargaining power and ability to affect market-clearing prices and quantities. 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).

largest dairy export after WMP, SMP, and AMF; in value, they are greater than the values of both infant powders and whey products combined. For cheese, a very large dip is observed in September 2012, followed by a sharp recovery, almost a year before the incident. 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.[21]

As in the case of AMF/butter, the placebo tests shown in Figure 13 are inconclusive. In August 2013 the New Zealand gap (decline in Cheese exports) 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. The seasonal dips in 2010 and 2011 are not as large, and 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 the decline may be attributed to the WPC contamination incident.

The possible impact is short-lived. Given there is no sharp drop in August, again it is possible that cheese exports were more sensitive to the scare because globally as there are many

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[21] As these observations are outliers, when the synthetic counterfactual was constructed for Figure 13, 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. Following discussions with both the Ministry for Primary Industries and Fonterra, there is no reason to believe that there were multiple short-lived shocks. The results of the analysis of cheese exports when the outliers were not removed can be found in the online appendix.

substitues to New Zealand cheese, and 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 all the other products that were not

directly implicated in the scare, we observe no long run impact.

**Figure 13: Gaps between actual cheese exports and the synthetic counterfactual
predictions for New Zealand and the control group**
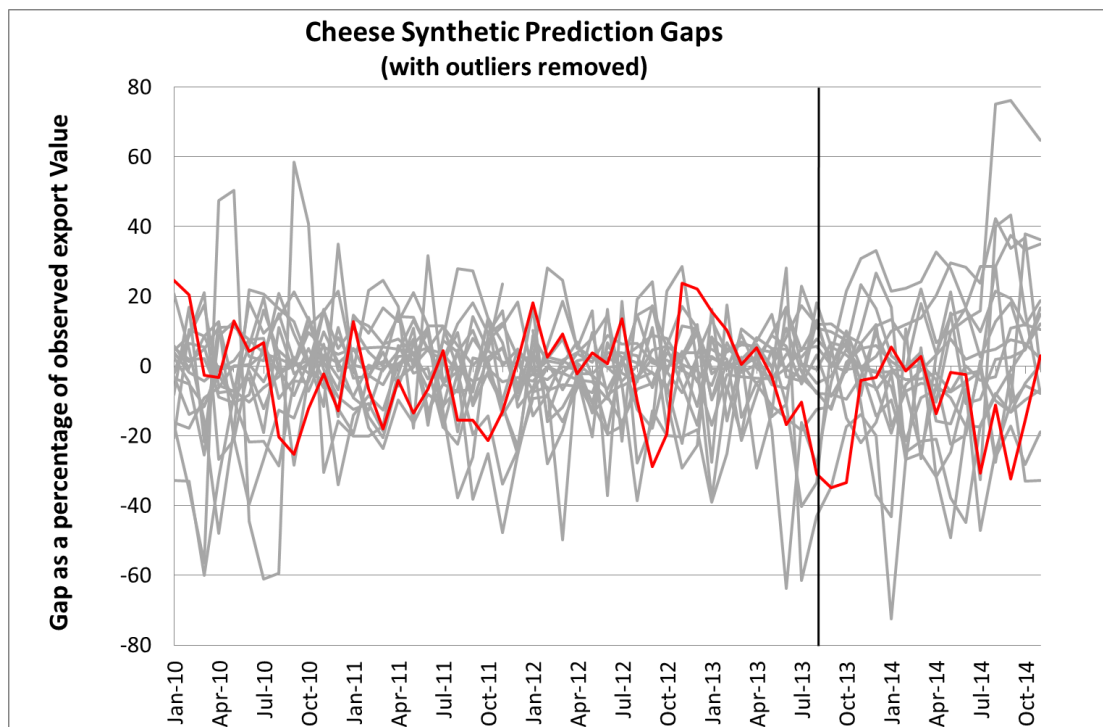
In private discussions, Fonterra employees have suggested that cheese exports were lower

in the months immediately following the scare because delivery of cheese products had

slowed as it was not perceived as a priority at the time of mounting needs to deal with other

products (Fonterra, 2015). The contamination fears apparently created a backlog of

operational and logistic challenges even after it had been confirmed that the contamination was a false alarm.

7. Conclusion: The Good, the Bad, and the Dairy

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 28th of August, the contamination was confirmed to have been benign. We set out to evaluate whether the contamination incident, which implicated the world's largest dairy exporter, could have affected the New Zealand's dairy exports.

Analyses of export patterns, which would have been the most direct impact of the scare, show that the incident had no long term significant impact on the total 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 for AMF/butter and cheese export values were inconclusive, with the possibility of a small short term (2-3 months) decline in export values, but nothing beyond that.

However, there has been a large, statistically significant, and persistent negative impact on whey products and infant formula. 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, and the absence of any substantial impact on other dairy products, it is likely that the relatively weak performance of these products is the result of missed business opportunities and lost market share, rather than remaining fears regarding the safety of New Zealand dairy goods. On the other hand, these results also

indicate that though New Zealand's reputation may be less robust than before the scare, New Zealand is still viewed as a safe source of dairy goods.

This research has estimated that the impact of the Whey Protein Concentrate contamination incident on New Zealand dairy exports was a reduction of between $105 million and $347 million from the start of the scare to November 2014.[22] It is $105 million if it is assumed that Fonterra did not change their whey product export patterns prior to the public 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 (when Fonterrra became initially aware of a possible problem) and the entire impact to infant formula is considered, including lower exports after the temporary recovery in December 2013. 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.

This investigation considered the impact of a false alarm. Overall, our interpretation of the evidence that the majority of the impact from this scandal that we observe 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. It is undoubtedly true, however, that

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[22] The figures are in United States dollars.

the impacts of this incident and the implications for Fonterra's reputation would have been

much greater had the contaminant been confirmed as Clostridium Botulinum.

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