5-2022

Implicit Cost of Retaliatory Tariffs by Mexico on U.S. Cheese Export

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IMPLICIT COST OF RETALIATORY TARIFFS BY MEXICO ON U.S. CHEESE EXPORT

by

Pengyan Sun

A thesis submitted in the partial fulfillment
of the requirements for the degree

of

MASTER OF SCIENCE

in

Applied Economics

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UTAH STATE UNIVERSITY
Logan, Utah

2022

ABSTRACT

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by

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Utah State University, 2022

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Mexican cheese market plays an important role in U.S. dairy exports. In order to reduce the U.S. trade deficit, the U.S. imposed a series of tariffs. For example, in June 2018, the U.S. imposed tariffs on steel (25%) and aluminum (10%) for Mexico. As a result, in July 2018 Mexico imposed retaliatory tariffs on U.S. cheeses ranging from 20 to 25 percent. Some studies have determined the responses of U.S. exports to retaliatory tariffs. However, the implicit cost of retaliatory tariffs by Mexico on U.S. cheese exports remains unknown. In order to provide valuable information for the government, dairy industry, and farmers, a thorough study about the implicit cost of retaliatory tariffs by Mexico on U.S. cheese exports is necessary. In this research, four different models were used to model the difference between the actual value cheese export to Mexico and the predicted value by month from July 2018 to June 2019. Then, by utilizing the input/output model IMPLAN, the total impact of economies from the losses in retaliatory tariffs was estimated. The results from the four different models indicated that the total changes in industry output related to losses of U.S. cheese exports to Mexico were $419 million, $434 million, $224 million, and $340 million, respectively. The reduced industry output leading to the losses in value-added was estimated to be $132 million, $137 million, $71 million, and $107 million, respectively. Losses in labor income were $80 million, $83 million, $43 million, and $65 million, respectively. The job losses were 1269, 1317, 678, and 1030, respectively. The trade war initiated by the U.S. government led to many countersanctions (e.g. retaliatory tariffs) from other countries. As shown through this work, the trade war had a very negative impact on U.S. companies and farmers. Given the far-reaching implications for industry output, labor income, and job losses, decisions on trade sanctions in the future should be extremely cautious.

(45 pages)

PUBLIC ABSTRACT

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Mexico imposed retaliatory tariffs on U.S. cheeses ranging from 20 to 25 percent in July 2018. In order to provide valuable information for the government and farmers, my research estimated the implicit cost of retaliatory tariffs by Mexico on U.S. cheese exports. In particular, I estimate the difference between the forecasted value of cheese exported to Mexico and the actual value of cheese exported to Mexico using four different models. The total impact to the U.S. economy from the losses due to retaliatory tariffs was assessed by IMPLAN, an input/output model. The results showed that Mexican tariffs decreased U.S. industry output by 354 million, value-added by 112 million, labor income by 68 million, and job by 1074 jobs respectively, on average. Decreasing exports in the long run is expected to decrease labor income and increase job losses in the U.S. which can increase social instability. Therefore, Mexico's retaliatory tariffs triggered by the U.S. trade war have had a great negative impact on the U.S.

ACKNOWLEDGMENTS

I would like to express my gratitude to my supervisor Dr. Man-Keun Kim for all the support and help provided throughout this dissertation. I also want to thank my committee members, Dr. Anastasia Thayer Hassett and Dr. Hernan Tejeda for their help, recommendations, and service. I appreciate all who provided support during my master's program. Thanks to my parents, who are always there for me. Most importantly, I would like to thank my husband, Guopeng Liang, for all his patience, encouragement, and support and especially for bringing up our daughter Sophie Liang.

Pengyan Sun

CONTENTS

Page

ABSTRACT iii

PUBLIC ABSTRACT v

ACKNOWLEDGMENTS vi

LIST OF TABLES viii

LIST OF FIGURES ix

INTRODUCTION 1

1.1 Background 1

1.2 Research Objectives 2

LITERATURE REVIEW 4

DATA AND METHODS 7

2.1. Data source 7

2.2. Statistical analyses 7

2.2.1. Determining the difference 7

2.2.2. Estimating the implicit cost 13

RESULTS 19

CONCLUSION 22

REFERENCES 24

APPENDICES 27

Appendix A. Actual and Forecasting Values of Cheese Export to Mexico 28

Appendix B. Regional Economic Impacts from Loss in Cheese Export 33

LIST OF TABLES

Table Page

Table 1. Summary of Loss in Cheese Export to Mexico 21

Table 2. Summary of Economic Impact 21

Table A-1. Prediction Accuracy of Each Model 28

Table A-2. Forecasted Cheese Export to Mexico by ARIMA Model 28

Table A-3. Forecasted Cheese Export to Mexico by Prophet Model 29

Table A-4. Forecasted Cheese Export to Mexico by Elastic Net Model 30

Table A-5. Forecasted Cheese Export to Mexico by Prophet Boost Model 31

Table A-6. Summary of Loss Between Jul. 2018 and Jun. 2019 32

Table B-1. Regional Economic Impacts from ARIMA 33

Table B-2. Regional Economic Impacts from Prophet 34

Table B-3. Regional Economic Impacts from Elastic Net 35

Table B-4. Regional Economic Impacts from Prophet Boost 36

LIST OF FIGURES

Figure Page

Figure 1. Estimating the Difference Between Actual and Forecasted Cheese Export 8
Figure 2. The Workflow of Training Models 9
Figure 3. The Example of New Date Features 12
Figure 4. Aggregate Input-Output Table for the U.S., 2018 ($million) 15
Figure 5. Actual and Forecasted Cheese Export to Mexico 20

CHAPTER 1
INTRODUCTION

1.1 Background

The profitability of the U.S. dairy products industry depends on international trade because approximately 15% of dairy products production is exported (Ribera et al., 2018). For example, in 2017 $5.4 billion worth of the U.S. dairy was exported to world markets (U.S. Census Trade data, 2019). Mexico is the most important market of U.S. dairy products (International Dairy Food Association, 2018). In 2017, for example, Mexico imported $1.3 billion of dairy products from the U.S. (USDA FAS, 2018). Of the $1.3 billion imported, cheese imports accounted for $391 million, or 30% of Mexico's total dairy imports (U.S. Census Trade data, 2019). Moreover, it is estimated that the $391 million worth of cheese led to a total economic impact in the U.S. of $1.52 billion (Ribera et al., 2018). Therefore, the Mexican cheese market plays a significant role in the U.S. dairy export market.

As a result of the trade war in the late 2010s to reduce the U.S. trade deficit, the U.S. imposed a series of tariffs. In June 2018, the U.S. imposed import tariffs on Mexican steel (25%) and aluminum (10%) (Long, 2018). As a result, Mexico implemented retaliatory tariffs on iron and steel and agricultural products from the U.S. As the trade war escalated, Mexico imposed tariffs on U.S. cheeses ranging from 20% to 25% in July 2018 (International Dairy Food Association, 2018). In addition, the European Union, a major competitor for U.S. cheese exports, ended negotiations for a new free trade agreement with Mexico on April 21, 2018. The retaliatory tariffs and Mexico's new trade agreement with the European Union were suspected to result in negative effects on U.S. cheese exports and the U.S. dairy products industry.

1.2 Research Objectives

While studies exist to determine the response of U.S. exports to retaliatory tariffs (Williams and Hammond, 2020; Flaaen and Pierce, 2019; Grant et al. 2021), no studies to date focus on the implicit cost of retaliatory tariffs by Mexico on U.S. cheese exports. The implicit cost of retaliatory tariffs can be estimated by comparing the actual value of U.S. cheese exported to Mexico with the forecasted value of U.S. cheese exported to Mexico without retaliatory tariffs. Because of the lack of implicit cost information, uncertainties remain in estimating the trade war, the importance of Mexico cheese markets, and the profit of the U.S. dairy industry. This information will also assist the government and farmers to plan future trade policies and production. Therefore, in order to provide valuable information for the government, industries, and farmers, a comprehensive analysis about the implicit cost of retaliatory tariffs by Mexico on U.S. cheese exports is important.

To estimate the implicit cost of retaliatory tariffs from Mexico on U.S. cheese export, we collected data on the value of cheese exports from the U.S. to Mexico from the U.S. Department of Commerce's Census Bureau of Trade (U.S. Census Trade data, 2019). Then, we used four forecasting models to answer the following question: how much did U.S. cheese exports to Mexico decrease due to the retaliatory tariff? For this analysis, we compared the forecasted results from: ARIMA (Autoregressive Integrated Moving Average, which leverages time-series data to forecast future trends), Prophet (a model that forecasts time series data based on an additive model), Elastic Net (a penalized linear regression model), and Prophet Boost (which combines Prophet with XGBoost) models.

Finally, using the input/output model IMPLAN, we answered the second question: what are the economic impacts due to the retaliatory tariffs by Mexico on U.S. cheese exports?

CHAPTER 2
LITERATURE REVIEW

This chapter reviews currently related literature to help us to establish an understanding of the current literature and how our research can contribute to the field.

Generally, a tariff is a tax imposed on the import of a product from a foreign country. Historically, tariffs are utilized to protect domestic companies from competition from products produced in other countries. In 2018, the U.S. took dramatic steps to decrease its trade deficit with several countries (Long, 2018).

Williams and Hammond (2020) analyzed the affected trade due to the escalating U.S. tariffs. The escalating U.S. tariffs war may bring negative economic and policy effects on the U.S. According to the report, escalating U.S. tariffs increased the economic uncertainty. Due to the economic uncertainty, people may decrease business investment and then hinder economic and social development. The Congressional Budget Office determined that the escalating U.S. tariffs would lower the GDP of the U.S. Globally, the global GDP would decrease by 0.8% in 2020 due to the escalating U.S. tariffs. Other countries' retaliatory tariffs also intensified the potential negative effect on the economy of the U.S. Especially for the industries in the U.S. would be harmed by other countries' retaliatory tariffs. The increasing input cost would be bigger than the benefits from the escalating U.S. tariffs. Some U.S. manufacturers may consider shifting manufactories to other countries to avoid the impact of retaliatory tariffs.

Flaaen and Pierce (2019) estimated the responses of manufacturing in the U.S. to tariffs and retaliatory tariffs through three aspects (e.g. protection of domestic industries, increasing imported input costs, and decreasing exported competitiveness). They found that the positive impact of tariffs was counteracted by the negative impact of higher costs from imported protection through retaliatory tariffs. This result also suggests that the tariffs would not increase manufacturing employment or output. Moreover, in the short run, the domestic manufacturer may lose competitiveness due to the retaliatory tariffs. According to this study, tariffs did not play a role in protecting U.S. manufacturing.

Grant et al. 2021 conducted a study to assess the agricultural trade impacts of retaliatory tariffs imposed by foreign countries. They found that retaliatory tariffs led to the U.S. agricultural export losses of tens of billions annually. The losses of export revenue were particularly pronounced for homogeneous goods such as soybean. However, the goods differentiation can restrain the effects of retaliatory tariffs.

Williams and Hammond (2020) give us a better understanding of tariffs, retaliatory tariffs, and trade war. It also brings us some information about the impact of escalating U.S. tariffs on a macro level. For example, retaliatory tariffs may have negative effects on U.S. industries, but we do not know which specific negative effects in industry. Therefore, further studies are needed to be done. The findings of Flaaen and Pierce (2019) are consistent with the report from Williams and Hammond, 2020 in that they found a relatively specific impact of the tariff on manufacturing. But we still do not know the total economic impact (sum of direct effects, indirect effects, and induced effect) of the retaliatory tariffs. The study of lacking total economic impact is incomplete for people to evaluate trade war. Grant et al. 2021 established a new insight for determining the effect of retaliation on U.S. export using a model of bilateral trade to retaliate and non-retaliate markets. The new insight also inspired our research: some models can be used to forecast the value of U.S cheese exports to Mexico without the retaliatory tariffs.

CHAPTER 3
DATA AND METHODS

This section describes how we collected and processed data. First, we detail the data used in this study. Then, we explain the ARIMA, Prophet, Elastic Net, and Prophet Boost models which were used to determine the differences between the forecasted value of cheese exported to Mexico and the actual value of cheese exported to Mexico. Finally, we introduce the IMPLAN model which was utilized to estimate the implicit cost.

2.1. Data source

Time series data of monthly values of U.S. cheese exports to Mexico from January 1996 to June 2019, comprising 282 observations, were collected from the U.S. Department of Commerce's Census Bureau of Trade (U.S. Census Trade data, 2019).

2.2. Statistical analyses

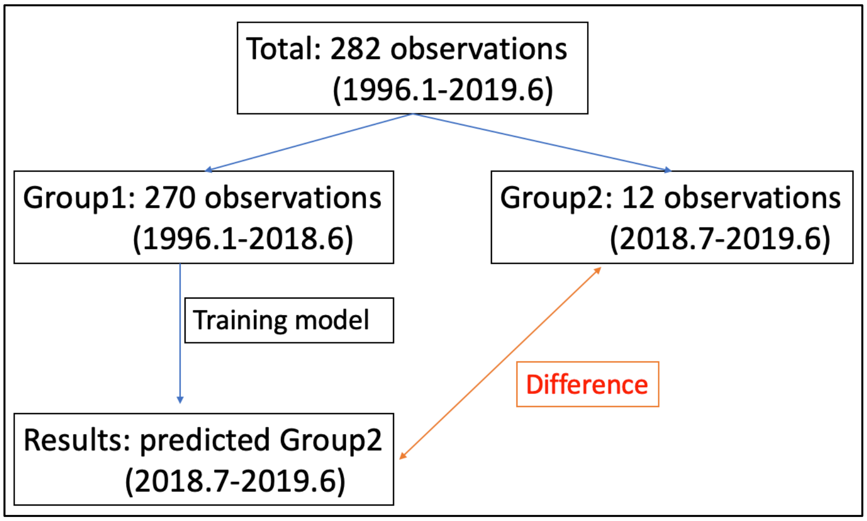
Statistical analyses was conducted in two steps. The first step was to determine the difference between the actual cheese exports to Mexico and the predictive value from July 2018 to June 2019. The second step was to estimate the implicit cost of retaliatory tariffs by Mexico on U.S. cheese exports.

2.2.1. Determining the difference

To forecast the value of U.S cheese exports to Mexico without the retaliatory tariffs, we divided the 282 monthly observations into two groups. Group1 included 270 observations (from January 1996 to June 2018), pre-retaliatory tariff. Group2 consisted of the 12 monthly observations that occurred post-retaliatory tariff (from July 2018 to June 2019). The data observations from Group 1 were utilized to train the models to forecast the

Figure 1

Estimating the Difference Between Actual and Forecasted Cheese Export



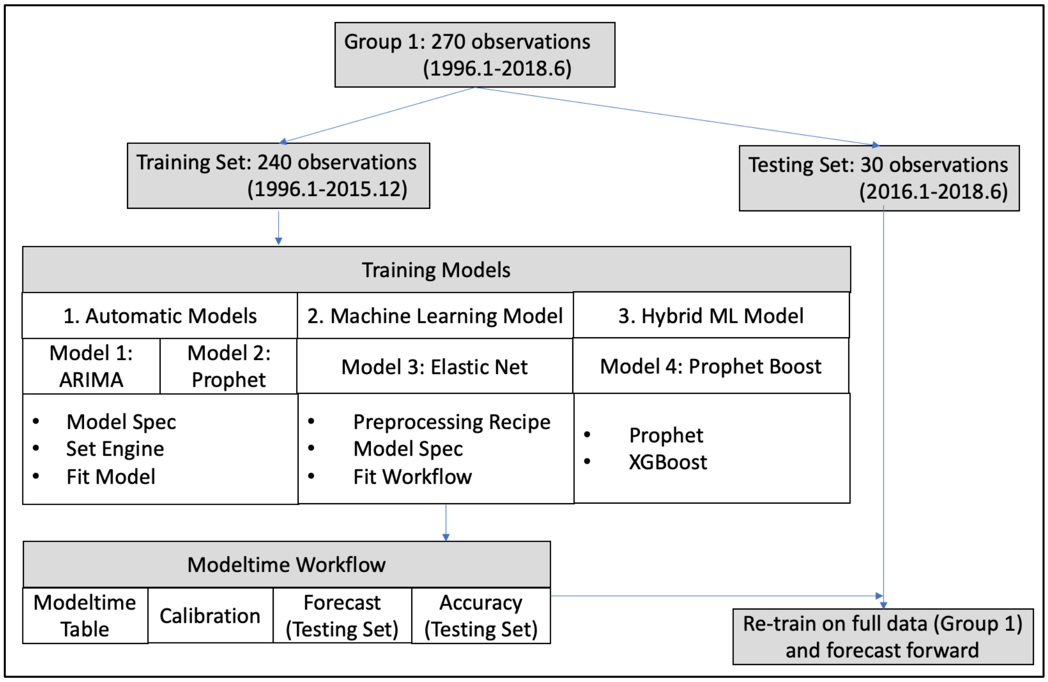
value U.S. cheese export to Mexico from Group 2, the observations recorded after the retaliatory. Then, we determined the difference by comparing the actual and forecasted levels of cheese export to Mexico. Figure 1 shows how we estimated the difference.

Figure 2 shows how we trained the models. The data for Group 1 was split into the training set and testing set. The training set included 240 observations (from January 1996 to December 2015). The testing set consisted of 30 observations (from January 2016 to June 2018).

Each model has its own disadvantages and advantages. Only using one model may cause a biased prediction result. For this reason, three types of models including Automatic models, Machine Learning models, and Hybrid Machine Learning models were utilized. Model 1 (ARIMA) and Model 2 (Prophet) belong to Automatic models. Model 3 (Elastic Net) is a kind of Machine Learning model. Model 4 (Prophet Boost) is a Hybrid Machine learning model.

Figure 2

The Workflow of Training Models



To make sure the results from each model are relatively accurate, models were trained using a two step process. In the first step, the training set was used to train the models. Through the training model, we required models to predict the testing set or subset of observation (forecasting 2016.1-2018.6). By comparing the actual testing set with the predicted testing set, model's predictive abilities were evaluated. The detail about the predictive accuracy of each model was presented in Appendix A (Table A-1). In the second step, the data from Group 1 data were used to train the models a second time and forecasted forward (forecasting Group 2).

Automatic Models follow a defined algorithm. In the present study, two kinds of automatic models (Model 1 ARIMA and Model 2 Prophet) were used. Generally, ARIMA is used for univariate time series data. Prophet model performs well for seasonal effects data. The procedure of Automatic Models was applied using *modeltime* package (Dancho, 2021) in RStudio Version 1.4.1106.

ARIMA is the autoregressive integrated moving average model for time series data. The ARIMA model adding additional seasonal terms is called SARIMA and formed by SARIMA(p,d,q) (P,D,Q)s, where p, q refer to the orders of autoregressive and moving average parts, d is the degree of differencing; s refers to the number of periods in each season. The upper-case P, D, and Q refers to the autoregressive, differencing, and moving average terms for the seasonal part of the model:

(1) $$\phi_s(L^s)\phi(L)\Delta_s^d\Delta^d y_t = \theta_s(L^s)\theta(L)\varepsilon_t$$

where $\phi(L) = 1 - \phi_1 L - \phi_2 L^2 - \cdots - \phi_p L^p$; $\phi_s(L^s) = 1 - \phi_{s1} L^s - \cdots \phi_{sP} L^{sP}$; $\theta(L) = 1 + \theta_1 L + \theta_2 L^2 + \cdots + \theta_q L^q$; and $\theta_s(L^s) = 1 + \theta_{s1} L^s + \cdots + \theta_{sQ} L^{sQ}$.

For Model 1 ARIMA (Hyndman et al., 2008, 2022), we used the default "Auto ARIMA" function to forecast data in R. Auto ARIMA used a combination of unit root tests, minimization of either AIC (Akaike Information Criterion), AICc (corrected Akaike criterion), or BIC (Bayesian Information Criterion) value to obtain the best seasonal ARIMA(SARIMA) model. The Auto ARIMA function searched for a possible applicable model within the default constraints provided. For example, for the seasonal part, the upper-case D (number of seasonal differences) chooses a value based on the seasonal test (e.g. "seas", "ocsb", "hegy", and "ch"). The default maximum value of P, D, and Q are 2, 1, and 2 respectively. Then, the system will return the best ARIMA (SARIMA) model within the providing constraints. In our research, the best ARIMA(SARIMA) model is ARIMA (0,1,1) (0,0,1) [12].

Model 2 Prophet (Taylor, 2021) can be considered as a nonlinear regression model. Prophet works best for highly seasonal data (Taylor and Letham, 2018).

Its simplest form, the model is as follows:

(2) $$y_t = g(t) + s(t) + h(t) + \varepsilon_t$$

where $g(t)$ describes a piecewise-linear trend (or "growth term"), $s(t)$ describes the various seasonal patterns, $h(t)$ captures the holiday effects, and ε_t is a white noise error term.

For model 2 Prophet, we set "seasonality_yearly = TRUE" in the R code which means we toggled on a seasonal component to model year over year seasonality. For all other parameters, we applied the default parameters.

Machine Learning Models can learn and predict data through utilizing various algorithms. Elastic Net was used as a machine learning model in the current study. Model 3 Elastic Net (Friedman, 2010) is an extension of a linear regression that adds regularization penalties to the loss function during training. Regularization is the process to prevent overfitting by adding information. Generally, regularization techniques include L1 Regularization (Lasso Regression) and L2 Regularization (Ridge Regression).

Lasso Regression (Least Absolute Shrinkage and Selection Operator) adds "absolute value of magnitude" of coefficient as penalty term to the loss function and aims at minimizing Equation 3.

(3) $$\underset{\theta}{min} \frac{1}{2m}\left[\sum_{i=1}^{m}(\theta^T x^{(i)} - y^{(i)})^2 + \boldsymbol{\lambda}\sum_{\boldsymbol{j=1}}^{\boldsymbol{n}}\|\boldsymbol{\theta}\|\right]$$

Ridge regression adds "squared magnitude" of coefficient as penalty term to the loss function and aims at minimizing Equation 4.

(4) $$\min_{\theta} \frac{1}{2m}\left[\sum_{i=1}^{m}(\theta^T x^{(i)} - y^{(i)})^2 + \boldsymbol{\lambda}\sum_{j=1}^{n}\|\boldsymbol{\theta}\|_2^2\right]$$

When L1 (Lasso Regression) and L2 (Ridge Regression) regularization combine together, it becomes the elastic net method. Elastic Net aims at minimizing Equation 5.

(5) $$\min_{\theta} \frac{1}{2m}\left[\sum_{i=1}^{m}(\theta^T x^{(i)} - y^{(i)})^2 + \boldsymbol{\lambda_1}\sum_{j=1}^{n}\|\boldsymbol{\theta}\| + \boldsymbol{\lambda_2}\sum_{j=1}^{n}\|\boldsymbol{\theta}\|_2^2\right]$$

For Model 3 Elastic Net, we used the "date" column in the original data to create 43 new features, including time-series signature features and fourier series. Then, the new features would be used to fit the model which would be helpful to deal with the seasonal matter. Figure 3 is an example in which we used the "date" column to create 3 new features.

Figure 3

The Example of New Date Features

Date	Date_half	Date_quarter	Date_month
1996-01-01	1	1	1
1996-02-01	1	1	2
1996-03-01	1	1	3
1996-04-01	1	2	4
1996-05-01	1	2	5
1996-06-01	1	2	6
1996-07-01	2	3	7
1996-08-01	2	3	8
1996-09-01	2	3	9
1996-10-01	2	4	10

Hybrid Machine Learning models combine automated algorithms with machine learning. In the present study, Model 4 Prophet Boost which combines Prophet (Taylor, 2021) with the XGBoost algorithm (Chen, 2021) was used. For the Prophet Boost model, the first step is to model the data using Prophet. Second step regresses the Prophet residuals with the XGBoost algorithm. Prophet has been introduced in Model 2. The following is some information about XGBoost. XGBoost is a scalable tree boosting system (Chen, 2016). In short, it is a faster tool for learning better models. Generally, XGboost is the most widely used algorithm for classification or a regression problem in machine learning. For Model 4, we used the same process as Model 2 and Model 3 to deal with the seasonal matter.

The Modeltime Workflow (Figure 2) can help us speed up the evaluation and selection of models in Rstudio. Four steps were included in Modeltime Workflow.

a. Modeltime Table: organizing the different models with IDs.

b. Calibration: generating fitted values and residuals for the testing set.

c. Forecasting (Testing Set part): generating the forecast data for Testing Set part.

d. Accuracy (Testing Set): calculating the accuracy.

After conducting the Modeltime Workflow, we re-trained models on the full dataset (Group 1) and forecasted forward (forecasting Group 2) for each of the described models. Then, the difference value was calculated by comparing the forecasted value of cheese export to Mexico (assuming no retaliatory tariff) with the actual value of cheese export to Mexico.

2.2.2. Estimating the implicit cost

In the previous analysis, we used four different models to estimate the reduction in the value of U.S. cheese export to Mexico as a result of the retaliatory tariff. Then, we used IMPLAN (French, 2018), an input/output model, to identify the direct, indirect, and induced impacts by sector. In the present study, the direct effects were the losses in U.S. cheese export to Mexico because of the retaliatory tariffs in July 2018 and thereafter. Indirect effects were the changes in transactions of inter-industry due to the reduced cheese export to Mexico (e.g. the losses in dairy sectors). Induced effects were the reduced income of household by the direct and indirect effects. The total economic impact is the sum of direct effects, indirect effects, and induced effects.

Input/output models estimate the economic effects of any changes on the economy using defined inter-industry transactions. Figure 4 was the input/output table using the 2018 IMPLAN database for the U.S. Industries that were aggregated into four sectors: Agriculture, Manufacturing, Cheese manufacturing, and Services. The input/output table specified the relationship between industry and exogenous sectors (e.g. household, import, and export). Section A in Figure 4 showed the inter-industry and intermediate demand relationship. For example, the agriculture industry sold $10450 million in intermediate goods to the Cheese manufacturing industry for production. On the right of section A was the final demand which included household consumers, government expenditure, exports. A row sum was the total output demand from industry. For example, the total output demand for the cheese industry in the U.S. in 2018 was $46759 million. A column sum explained the total payments by industry to other entities. The section V, value added included employment compensation (EC), proprietors' income (PI), other property type income (Oth PI), and indirect business tax (IBT). For example, the cheese industry may

Figure 4

Aggregate Input-Output Table for the U.S., 2018 ($million)

	Industry				Exogenous			
	Agriculture	Manufacturin	Cheese mnfct	Service	HH	Other	Export	Total
Industry		**A**						
Agriculture	75,622	567,213	10,450	24,942	62,032	193,437	110,944	1,044,639
Manufacturing	142,998	2,668,705	4,835	1,158,209	1,643,446	3,049,864	735,958	9,404,015
Cheese mnfct	71	4,793	13,234	9,488	14,966	2,929	1,278	46,759
Service	278,497	1,828,511	7,909	7,635,266	11,484,685	3,589,106	1,365,267	26,189,241
Value added		**V**						
EC	145,165	1,671,067	3,511	9,121,623				
PI	85,446	275,120	67	1,228,142				
Oth PI	205,746	1,305,800	1,349	5,159,795				
IBT	39,209	173,448	314	1,164,422				
Exogenous								
Oth pymt	10,317	74,795	510	227,734				
Import	61,568	834,564	4,581	459,619				
Total	1,044,639	9,404,015	**46,759**	26,189,240				

Agriculture: agriculture, forestry, hunting, and mining; Manufacturing: utilities, construction, and manufacturing; Cheese mnfct: cheese manufacturing; Service: finance, insurance, education, and other services; HH: household consumption; Other: government expenditure, and changes in capital and inventory additions/deletions; EC: employee compensation (wages); PI: proprietors' income; Oth PI: other property type income; IBT: indirect business tax, taxes on production and imports; Oth pymt: federal + state taxes or expenditure, and changes in capital and inventory additions/deletions

purchase $10450 million of agricultural production from the agriculture industry. The total input (column sum) was the same as the total demand (row sum). This is what the input-output table means.

To illustrate how to use this framework as a predictive model, we will look at section A first in Figure 4. Let x_j be the total demand of industry ($j =$Agriculture, Manufacturing, Cheese manufacturing, and Service). Z_{ij} was the sales from row i to column j. y_j was the final demand in industry j. Its form is as follows:

(6) $$x_1 = z_{11} + z_{12} + z_{13} + z_{14} + y_1$$

(7) $$x_2 = z_{21} + z_{22} + z_{23} + z_{24} + y_2$$

(8) $$x_3 = z_{31} + z_{32} + z_{33} + z_{34} + y_3$$

(9) $$x_4 = z_{41} + z_{42} + z_{43} + z_{44} + y_4$$

Then the ratio of each input to total output was calculated, $a_{ij} = z_{ij}/x_j$. For example, $\frac{10450}{46759} = 0.2235$, the cheese industry required \$0.2235 of agriculture products. Calculating a_{ij} for each (i, j) results were shown in Equation 10.

(10) $$A = \begin{bmatrix} 0.0724 & 0.0603 & 0.2235 & 0.0010 \\ 0.1369 & 0.2838 & 0.1034 & 0.0442 \\ 0.0001 & 0.0005 & 0.2830 & 0.0004 \\ 0.2666 & 0.1944 & 0.1691 & 0.2915 \end{bmatrix}$$

Based on $a_{ij} = z_{ij}/x_j$, we derived $z_{ij} = a_{ij}x_j$. Equation (11) to (14) were substituting each z_{ij} in Equation (6) to (9) with $a_{ij}x_j$.

(11) $$x_1 = a_{11}x_1 + a_{12}x_2 + a_{13}x_3 + a_{14}x_4 + y_1$$

(12) $$x_2 = a_{21}x_1 + a_{22}x_2 + a_{23}x_3 + a_{24}x_4 + y_2$$

(13) $$x_3 = a_{31}x_1 + a_{32}x_2 + a_{33}x_3 + a_{34}x_4 + y_3$$

(14) $$x_4 = a_{41}x_1 + a_{42}x_2 + a_{43}x_3 + a_{44}x_4 + y_4$$

Using matrices:

(15) $$\begin{bmatrix} x_1 \\ x_2 \\ x_3 \\ x_4 \end{bmatrix} = \begin{bmatrix} a_{11} & a_{12} & a_{13} & a_{14} \\ a_{21} & a_{22} & a_{23} & a_{24} \\ a_{31} & a_{32} & a_{33} & a_{34} \\ a_{41} & a_{42} & a_{43} & a_{44} \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \\ x_3 \\ x_4 \end{bmatrix} + \begin{bmatrix} y_1 \\ y_2 \\ y_3 \\ y_4 \end{bmatrix}$$

The matrix of input-output was represented $\mathbf{x} = \mathbf{Ax} + \mathbf{y}$, where $A = [a_{ij}]$, $\mathbf{x} = [x_j], and\ \mathbf{y} = [y_j]$. Equivalently, $(\mathbf{I} - \mathbf{A})\mathbf{x} = \mathbf{y}$ or $\mathbf{x} = (\mathbf{I} - \mathbf{A})^{-1}\mathbf{y}$. $(\mathbf{I} - \mathbf{A})^{-1}$ is the Leontief inverse matrix. The forecasted model, $\Delta\mathbf{x} = (\mathbf{I} - \mathbf{A})^{-1}\Delta\mathbf{y}$. Therefore, the column sum of $(\mathbf{I} - \mathbf{A})^{-1}$ was explained as total changes in output due to the changes in final demand.

Cheese manufacturing as an example:

(16) $$(\mathbf{I}-\mathbf{A}) = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} - \begin{bmatrix} 0.0724 & 0.0603 & 0.2235 & 0.0010 \\ 0.1369 & 0.2838 & 0.1034 & 0.0442 \\ 0.0001 & 0.0005 & 0.2830 & 0.0004 \\ 0.2666 & 0.1944 & 0.1691 & 0.2915 \end{bmatrix}$$

$$= \begin{bmatrix} 0.9276 & -0.0603 & -0.2235 & -0.0010 \\ -0.1369 & 0.7162 & -0.1034 & -0.0442 \\ -0.0001 & -0.0005 & 0.7170 & -0.0004 \\ -0.2666 & -0.1944 & -0.1691 & 0.7085 \end{bmatrix}$$

(17) $$(\mathbf{I}-\mathbf{A})^{-1} = \begin{bmatrix} 1.0942 & 0.0944 & 0.3565 & 0.0075 \\ 0.2387 & 1.4411 & 0.3036 & 0.0904 \\ 0.0005 & 0.0013 & 1.3953 & 0.0008 \\ 0.4774 & 0.4314 & 0.5506 & 1.4394 \end{bmatrix}$$

Assuming the final demand (e.g. export) decreased by \$100 (direct effect) for the cheese manufacturing industry. As a result, all industries decreased output. The reduction amount was \$36.65, \$30.36, \$139.53, and \$55.06 from Agriculture, Manufacturing, Cheese manufacturing, and service, respectively (Equation 18). The indirect effect was \$160.6 (=35.65+30.36+139.53+55.06-100). Type I multiplier interprets the inter-industry effects. Type I multiplier was obtained by adding direct effect to indirect effect and dividing by direct effect. Therefore, the Type I multiplier was 2.606 which was the Cheese manufacturing industry column sum of $(\mathbf{I}-\mathbf{A})^{-1}$ in Equation (17).

(18) $$\Delta\mathbf{x} = \begin{bmatrix} 1.0942 & 0.0944 & 0.3565 & 0.0075 \\ 0.2387 & 1.4411 & 0.3036 & 0.0904 \\ 0.0005 & 0.0013 & 1.3953 & 0.0008 \\ 0.4774 & 0.4314 & 0.5506 & 1.4394 \end{bmatrix} \begin{bmatrix} 0 \\ 0 \\ 100 \\ 0 \end{bmatrix} = \begin{bmatrix} 35.65 \\ 30.36 \\ 139.53 \\ 55.06 \end{bmatrix}$$

If the household was treated as an endogenous sector in an input-output table, a Type II multiplier would be calculated. It would account for the direct, indirect, and induced impacts of a change in economic activity. Type II multiplier = (direct effect + indirect effect + induced effect)/direct effect.

As described, multipliers in the IMPLAN model characterize direct, indirect, and induced contributions of the individual sector. In the IMPLAN model, the economic impacts were reported including industry output, value-added, labor income, and employment. Industry output was the production value of an industry in a year. Value-added represented the difference between output and intermediate input costs over a specified period of time. Labor income included employee compensation (e.g. wages) and proprietor income. Employment was the total number of jobs. The total economic impact was determined by multiplying the forecasted cheese losses by the corresponding multiplier.

CHAPTER 4
RESULTS

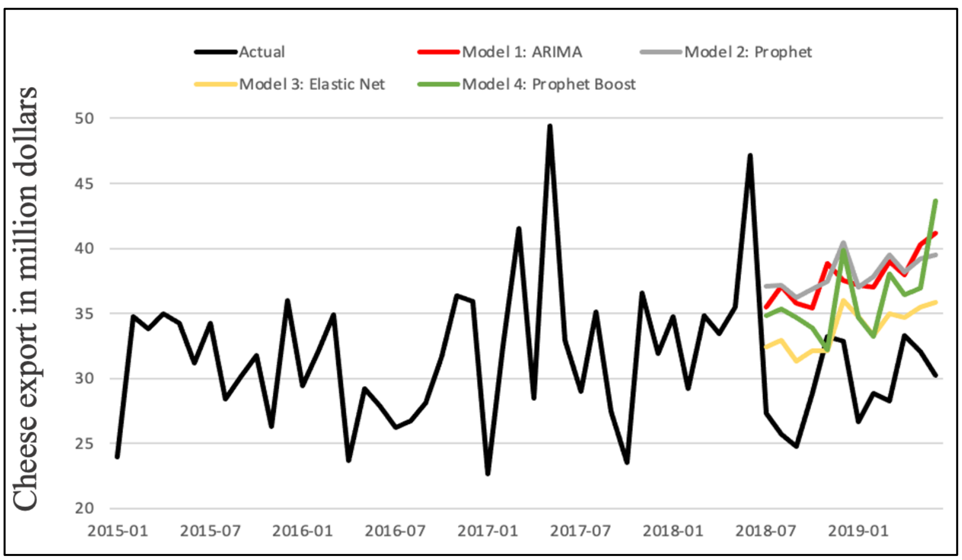
The results section reports the predictions of the 4 different models and the implicit costs that we estimated based on the estimated predictions.

Figure 5 shows the actual value of cheese exported to Mexico (dark line) and forecasted results of different models during July 2018 and June 2019. The value of U.S. cheese exported to Mexico fell sharply in July 2018. The retaliatory tariffs by Mexico significantly affected U.S. cheese export as soon as they were implemented. Due to the retaliatory tariffs from Mexico, Mexico's monthly actual cheese imports were generally lower than the forecasted imports. In other words, U.S. cheese exports to Mexico decreased because of the retaliatory tariffs. By subtracting the value of actual cheese export to Mexico from the forecasted export value (model results), the export loss caused by retaliatory tariffs was assessed. The specific losses predicted based on the forecasted values were \$101 million, \$104 million, \$54 million, and \$82 million (Table 1). Although the specific amount of loss predicted by different models was different, this exercise provided a valuable range for reference. All the details about the difference between actual and forecasted value were reported in additional tables located in Appendix A (Table A-2 - A-6).

Based on the forecasted results about retaliatory tariffs effects on US cheese export from different four models, the economic impacts from loss in cheese export were estimated (Table 2). The total changes of industry output related to losses of U.S. cheese exports to Mexico were \$419 million, \$434 million, \$224 million, and \$340 million, respectively. The losses in value-added caused by the reduced industry output were \$132 million, $137 million, $71 million, and $107 million, respectively. Losses in labor income were $80 million, $83 million, $43 million, and $65 million, respectively. The job losses were 1269, 1317, 678, and 1030, respectively. All the details about regional economic impacts from loss in cheese export were reported in additional tables located in Appendix B (Table B-1- B-4).

Figure 5

Actual and Forecasted Cheese Export to Mexico



Dark line: actual cheese export to Mexico; Red line: forecasted cheese export to Mexico by ARIMA Model; Grey line: forecasted cheese export to Mexico by Prophet Model; Yellow line: forecasted cheese export to Mexico by Elastic Net Model; Green line: forecasted cheese export to Mexico by Prophet Boost Model.

Table 1

Summary of Loss in Cheese Export to Mexico

Model	ARIMA	Prophet	Elastic Net	Prophet Boost
Loss in export ($ million)	101	104	54	82

Table 2

Summary of Economic Impact

Model	ARIMA	Prophet	Elastic Net	Prophet Boost	Average
Industry Output ($ million)	419	434	224	340	354
Value Added ($ million)	132	137	71	107	112
Labor Income ($ million)	80	83	43	65	68
Employment (jobs)	1269	1317	678	1030	1074

Note: economic impact is the sum of direct, indirect and induced impact.

CHAPTER 5
CONCLUSION

This study provided an opportunity to evaluate the impact of retaliatory tariffs by Mexico on U.S. cheese exports. Through the application of various forecasting models, we obtained estimates of the value of cheese exports without retaliatory tariffs. By using different models, our results became less biased. At the same time, our research also provided an example of negative domestic impacts of trade wars. This information can be used to assess the impact of future international trade policy.

This research demonstrates the interconnected nature of various sectors of the economy. Mexico's retaliatory tariffs, even for cheese, did have a significant impact on other sectors of American society (e.g. Wholesale trade). Our results provided a more comprehensive view of retaliatory tariffs by Mexico on U.S. cheese exports since this study included 12 different sectors. The findings from our study are also important for the U.S. to formulate trade policy in the future.

In addition, our research is more specific and more detailed. The dairy farmer can get substantial advice from our results. For example, farmers can adjust their production plans in a timely manner based on our prediction of loss of cheese exports. It also provides reference information for future decisions of industries (e.g. establishing overseas factories).

Due to the limitations of data resources, our research also exists in the limitation. We used the 270 observations (1996.01-2018.06) to train the model. If we could get more data (e.g. data of daily values), the model's predictions may be more accurate. In our research, we determined the total impact, which brings implications for future policy analysis. Future policy analysis should focus on total impacts to avoid underestimating the cost of the policy.

All in all, many sectors of the U.S. have suffered varying degrees of losses under the retaliatory tariffs by Mexico on U.S. cheese export. The U.S. governments, industries, and farmers also would face the challenges of decreasing exports. The decline in labor income and job positions also puts pressure on social stability. Our research is significantly important for assessing these effects. The trade war initiated by the U.S. incurred a set of countersanctions (e.g. retaliatory tariffs) from other countries. Finally, the trade war had a very negative impact on U.S. companies and farmers. Therefore, decisions on trade sanctions in the future should be extremely cautious. Otherwise, all aspects of U.S. society would be affected.

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APPENDICES

Appendix A. Actual and Forecasting Values of Cheese Export to Mexico

Table A-1

Prediction Accuracy of Each Model

Model	type	mae	mape	mase	smape	rmse
ARIMA	Testing set	4.36	14.04	0.68	13.36	5.9
Prophet	Testing set	8.83	30.08	1.37	25.17	9.8
Elastic Net	Testing set	4.58	13.19	0.71	14.09	6.26
Prophet Boost	Testing set	6.53	22.22	1.01	19.27	7.66

mae = mean absolute error; mape = mean absolute percentage error; mase = mean absolute scaled error; smape = symmetric mean absolute percentage error; rmse = Root mean squared error.

Table A-2

Forecasted Cheese Export to Mexico by ARIMA Model

Month/Year	**Actual**	**Forecasts**	**Difference**	**Difference**
		(million dollars)		**(%)**
Jul 2018	27.33	35.49	-8.16	-30
Aug 2018	25.69	37.10	-11.41	-44
Sep 2018	24.74	35.77	-11.03	-45
Oct 2018	28.84	35.42	-6.58	-23
Nov 2018	33.21	38.80	-5.59	-17
Dec 2018	32.82	37.50	-4.67	-14
Jan 2019	26.63	37.17	-10.54	-40
Feb 2019	28.85	36.99	-8.13	-28
Mar 2019	28.28	38.99	-10.72	-38
Apr 2019	33.30	37.98	-4.68	-14
May 2019	32.03	40.30	-8.27	-26
Jun 2019	30.21	41.13	-10.93	-36
Sum	351.93	452.64	-100.71	NA

Table A-3

Forecasted Cheese Export to Mexico by Prophet Model

Month/Year	Actual	Forecasts	Difference	Difference
	(million dollars)			(%)
Jul 2018	27.33	37.08	-9.75	-36
Aug 2018	25.69	37.14	-11.45	-45
Sep 2018	24.74	36.24	-11.50	-47
Oct 2018	28.84	36.89	-8.05	-28
Nov 2018	33.21	37.44	-4.23	-13
Dec 2018	32.82	40.40	-7.58	-23
Jan 2019	26.63	37.03	-10.41	-39
Feb 2019	28.85	37.80	-8.95	-31
Mar 2019	28.28	39.48	-11.20	-40
Apr 2019	33.30	38.20	-4.90	-15
May 2019	32.03	39.18	-7.16	-22
Jun 2019	30.21	39.48	-9.27	-31
Sum	351.93	456.38	-104.45	NA

Table A-4

Forecasted Cheese Export to Mexico by Elastic Net Model

Month/Year	Actual	Forecasts	Difference	Difference
	(million dollars)			(%)
Jul 2018	27.33	32.43	-5.10	-19
Aug 2018	25.69	32.93	-7.23	-28
Sep 2018	24.74	31.31	-6.57	-27
Oct 2018	28.84	32.10	-3.26	-11
Nov 2018	33.21	32.09	1.12	3
Dec 2018	32.82	35.98	-3.15	-10
Jan 2019	26.63	34.75	-8.12	-31
Feb 2019	28.85	33.27	-4.42	-15
Mar 2019	28.28	34.96	-6.69	-24
Apr 2019	33.30	34.65	-1.35	-4
May 2019	32.03	35.49	-3.46	-11
Jun 2019	30.21	35.81	-5.60	-19
Sum	351.93	405.76	-53.83	NA

Table A-5

Forecasted Cheese Export to Mexico by Prophet Boost Model

Month/Year	Actual	Forecasts	Difference	Difference
	(million dollars)			(%)
Jul 2018	27.33	34.82	-7.49	-28
Aug 2018	25.69	35.36	-9.67	-38
Sep 2018	24.74	34.70	-9.97	-40
Oct 2018	28.84	33.84	-5.00	-17
Nov 2018	33.21	32.21	1.00	3
Dec 2018	32.82	39.84	-7.01	-21
Jan 2019	26.63	34.66	-8.03	-30
Feb 2019	28.85	33.22	-4.36	-15
Mar 2019	28.28	38.01	-9.74	-34
Apr 2019	33.30	36.41	-3.11	-9
May 2019	32.03	36.92	-4.89	-15
Jun 2019	30.21	43.69	-13.48	-45
Sum	351.93	433.68	-81.75	NA

Table A-6

Summary of Loss Between Jul. 2018 and Jun. 2019

Month/Year	ARIMA	Prophet	Elastic Net	Prophet Boost
		(million dollars)		
Jul 2018	-8.16	-9.75	-5.10	-7.49
Aug 2018	-11.41	-11.45	-7.23	-9.67
Sep 2018	-11.03	-11.50	-6.57	-9.97
Oct 2018	-6.58	-8.05	-3.26	-5.00
Nov 2018	-5.59	-4.23	1.12	1.00
Dec 2018	-4.67	-7.58	-3.15	-7.01
Jan 2019	-10.54	-10.41	-8.12	-8.03
Feb 2019	-8.13	-8.95	-4.42	-4.36
Mar 2019	-10.72	-11.20	-6.69	-9.74
Apr 2019	-4.68	-4.90	-1.35	-3.11
May 2019	-8.27	-7.16	-3.46	-4.89
Jun 2019	-10.93	-9.27	-5.60	-13.48
Sum	-100.71	-104.45	-53.83	-81.75

Appendix B. Regional Economic Impacts from Loss in Cheese Export

Table B-1

Regional Economic Impacts from ARIMA

Sector	Industry Output	Value Added	Labor Income	Employment
	(million dollars)			(jobs)
Agriculture	12	5	4	97
Dairy cattle & Milk production	44	7	4	96
Mining	2	1	0	5
Utilities	6	3	1	5
Construction	2	1	1	8
Cheese manufacturing	142	16	11	148
Other manufacturing	65	15	7	82
Wholesale trade	33	19	12	139
Retail trade	7	4	3	68
Transportation & Warehousing	16	8	6	95
FIRES[1]	88	53	32	521
Government	2	1	1	7
Total	419	132	80	1269

[1] Finance, Information, Real estate, Education, and Other services

Table B-2

Regional Economic Impacts from Prophet

Sector	Industry Output	Value Added	Labor Income	Employment
	(million dollars)			(jobs)
Agriculture	12	5	4	101
Dairy cattle & Milk production	46	7	4	99
Mining	3	1	0	5
Utilities	6	3	1	6
Construction	2	1	1	8
Cheese manufacturing	147	16	11	153
Other manufacturing	68	15	7	85
Wholesale trade	34	20	12	145
Retail trade	7	4	3	70
Transportation & Warehousing	17	8	7	98
FIRES1	91	55	33	541
Government	2	1	1	7
Total	434	137	83	1317

1 Finance, Information, Real estate, Education, and Other services

Table B-3

Regional Economic Impacts from Elastic Net

Sector	Industry Output	Value Added	Labor Income	Employment
	(million dollars)			(jobs)
Agriculture	6	3	2	52
Dairy cattle & Milk production	24	4	2	51
Mining	1	1	0	3
Utilities	3	1	0	3
Construction	1	0	0	4
Cheese manufacturing	76	8	6	79
Other manufacturing	35	8	4	44
Wholesale trade	18	10	6	74
Retail trade	4	2	1	36
Transportation & Warehousing	9	4	3	51
FIRES[1]	47	28	17	279
Government	1	1	0	4
Total	224	71	43	678

[1] Finance, Information, Real estate, Education, and Other services

Table B-4

Regional Economic Impacts from Prophet Boost

Sector	Industry Output	Value Added	Labor Income	Employment
	(million dollars)			(jobs)
Agriculture	9	4	3	79
Dairy cattle & Milk production	36	6	3	78
Mining	2	1	0	4
Utilities	5	2	1	4
Construction	1	1	0	6
Cheese manufacturing	115	13	9	120
Other manufacturing	53	12	6	67
Wholesale trade	27	15	10	113
Retail trade	5	3	2	55
Transportation & Warehousing	13	7	5	77
FIRES[1]	71	43	26	423
Government	2	1	1	5
Total	340	107	65	1030

[1] Finance, Information, Real estate, Education, and Other services