**Creating Models to Forecast Protein Demand**

Kevin Lim

7815073

University of Manitoba

ECON 4822

Gregory Mason

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1. **Introduction**

Retailers and businesses provide consumers with necessities for their everyday lives such as food. It is useful for businesses to provide consumers with the right products by forecasting demand, as it allows them to make informed business strategies (Beattie, 2020). We are especially interested in creating a protein demand forecast model. In this paper, we will develop a model to forecast protein demand within Canada. Creating a forecast model is important because it is useful for retailers and businesses to understand what protein demand will be like in the future. So, by predicting protein demand, they will have a better sense of how many meat products they want to purchase to supply consumers. One thing to note is that there are various kinds of proteins that we can observe. To narrow this down, we focus specifically on four specific proteins, being chicken, pork, beef, and fish.

We divide the paper into three additional sections. Section 2 will be the literature review where we explore a method of forecasting and factors that affect demand. There are two parts to Section 3, the exploratory analysisand the statistical analysis. In the exploratory analysis, we come up with hypotheses and in the statistical analysis, we run regressions to determine models to forecast protein demand and the results of our regressions. Section 4 is the conclusion where we state limitations and future research.

1. **Literature Review**

**Part 1: A Basic Method of Forecasting**

Forecasting allows us to predict demand for products over a short horizon. Factors that can affect demand for products can be driven from everything to holidays, weather, seasons, promotions, special events, and prices. These multiple factors can make forecasting difficult to perform. Some basic forecasting models include qualitative techniques, time series analysis, and casual methods. Though we should keep in mind that while forecasts can predict future sales, it is far from a perfectly accurate model as sudden changes can always occur that may affect demand. Also, long-term forecasts decrease in accuracy the longer the time period, due to uncertainty. Regardless, forecasting is quite useful, and we will briefly discuss one forecasting method of interest, being time series analysis(Ma & Fildes, 2021; Putra, n.d.).

              A time-series analysis uses several years of data for available products to pinpoint relationships and trends. It also helps to explain any systemic variation within the data because of seasonality and identifies reoccurring cyclical patterns. The analysis can be used to predict future demand once the analysis is finished.We can use the models to predict future demand after finishing the analysis. Time series analysis requires time series data where we use data from different points in time. That is where it differs from cross-sectional data where we observe different variables at a single point in time. Since the data is from adjacent time periods, there is a chance that the observations may be correlated with each other. The challenge with using time series analysis is that we need to filter out data from other factors such as seasonal variations or sales from a promotion campaign. (Chambers et al., 1971; Erica, 2021).

**Part 2: Factors affecting retail sales**

COVID-19 will be a major factor affecting sales in the coming years. Many consumers have lost their jobs, meaning they have less income to spend. As a result, consumers will make more economical food choices, such as buying ground beef over steak and regular over organic meats. Consumers in different income brackets respond to price differently, as high-income consumers are less responsive to price, and low-income consumers are more responsive to price. Middle-income consumers fall somewhere in the middle. So, demand patterns vary between different levels of income (Lusk & Tonsor, 2016; Schaer, 2020). Additionally, a large proportion of North America consumes food outside of homes. According to Boston Consulting Group, 50% of meat consumption is outside of homes in the US. But with the pandemic limiting food services, consumers are cooking at home more often. As a result, they still consume the same number of calories, but the percentage of meat consumed is lower (Ontario Farmer, 2020). Tying into income, price is also affects demand depending on the amount of income.

Protein demand is also affected by price. There are multiple factors that can affect the price. The feed for the livestock, packaging, and energy are just a few factors. A study in Turkey also noted that the price of red meat reflects the price in chicken meat. Income elasticities of red meat such as beef (0.32), goat (0.53), andmutton (0.48) are higher than the price elasticity of chicken (0.08) or fish (0.11). Additionally, substitute goods can also affect the demand for a protein like chicken. Increases in the price of red meat result in higher consumption of chicken meat as in Turkey, the price of chicken is preferable for consumers compared to other meats. They also noted that the price of beef could be high because the marketing opportunities are higher (AKIN et al., 2020).

Population is a factor that could affect demand. While food production has kept up with demand, it is theoretically possible that food production could fall behind a growing population. In Kravdal’s study,they measure food in terms of calories available. They find that democratic countries import more cereals as a result of population growth.Growth in calorie availability is positively correlated with literacy levels and purchasing power. Countries that have large cereal yields are generally the countries with high population growth rates. The calorie availability is negatively influenced by population growth in regions such as North Africa and the Middle East (Kravdal, 2001). According to Gouel and Guimbard, food demand in developed countries with low population growth rates doe not see high food demand. Additionally, population increase will result in an increase in animal-based foods (Gouel & Guimbard, 2019).

These are some factors that may affect demand. We want to keep in mind how population, income, and prices can all affect the demand for different proteins.Additionally, we will be using time series analysis to conduct our analysis to create a forecast model.

1. **Data Analysis**

**Part One: Exploratory Analysis**

The exploratory analysis will explore trends between the demands for different meat proteins throughout 2000 – 2019. The objective of the analysis is to examine the variations of proteins and how the demand has changed over time. We narrow down the data into a few specific variables that we want to explore. We use chicken, beef, pork, and fish demand obtained from the Government of Canada’s agriculture section (Government of Canada, 2020). Additionally, we obtained population, prices of protein products, and quarterly wages from Statistics Canada. These datasets are not uniform in terms of time, so we made transformations to turn them into quarterly datasets.

**Protein Demand and Prices**

**Figure 1**

Figure 1 indicates that demand for beef was generally the highest during the early 2000s, with chicken right behind. However, around 2004 – 2005, chicken demand has overtaken beef. The demand for pork was at its highest during the year 2000 but has declined since. The summary statistics also suggest that the demand for fish has continuously fallen buthas seen growing demand post-recession as seen in Table 1. These trends suggest that chicken.

Additionally, the prices for each protein product have increased overtime except for canned salmon. The price of canned salmon decreased by the time the Great Recession occurred but has seen an increase afterward. The demand for chicken as well as its price sees a positive relationship where both demand and price have increased over the years, suggesting that chicken is a preferred protein. The beef and pork demand has an inverse relationship with their respective products, with sirloin steak and pork chops as their price has increased over time. Demand for fish and the price of canned salmon share a somewhat similar trend with both declining until the Great Recession, followed by rising demand and prices afterward.

**Table 1**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Summary Statistics of protein demand (in kilograms) before the Great Recession (Q1 2000 – Q4 2007)** | | | | |
| **Statistic** | **DCHIC** | **DBEEF** | **DPORK** | **DFISH** |
| **Mean** | 30.50 | 30.86 | 25.87 | 9.15 |
| **Median** | 30.69 | 30.69 | 25.62 | 9.22 |
| **Standard Deviation** | 0.44 | 0.69 | 1.96 | 0.58 |
| **Minimum** | 29.12 | 29.94 | 23.06 | 7.50 |
| **Maximum** | 30.99 | 32.40 | 28.94 | 9.81 |
| **Summary Statistics of protein demand (in kilograms) during the Great Recession (Q1 2008 – Q3 2009)** | | | | |
| **Mean** | 30.93 | 28.76 | 23.52 | 7.70 |
| **Median** | 30.95 | 28.65 | 23.65 | 7.78 |
| **Standard Deviation** | 0.12 | 0.59 | 0.36 | 0.27 |
| **Minimum** | 30.77 | 27.08 | 22.81 | 7.22 |
| **Maximum** | 31.12 | 29.75 | 23.89 | 8.05 |
| **Summary Statistics of protein demand (in kilograms) after the Great Recession (Q4 2009 – Q1 2019)** | | | | |
| **Mean** | 30.79 | 26.29 | 21.59 | 8.37 |
| **Median** | 31.42 | 25.73 | 21.67 | 8.37 |
| **Standard Deviation** | 1.76 | 1.11 | 0.64 | 0.42 |
| **Minimum** | 29.73 | 24.42 | 20.58 | 7.51 |
| **Maximum** | 35.06 | 27.98 | 23.23 | 9.14 |

*Note: The Great Recession is used as a halfway benchmark for comparison*

**Table 2**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Summary Statistics of prices (per kilogram) before the Great Recession (Q1 2000 – Q4 2007)** | | | | |
| **Statistic** | **ARPCHIC** | **ARPSIRLOIN** | **ARPCHOPS** | **ARPCANNED** |
| **Mean** | $ 5.05 | $ 14.24 | $ 9.58 | $ 3.56 |
| **Median** | $ 5.11 | $ 14.33 | $ 9.47 | $ 3.43 |
| **Standard Deviation** | $ 0.41 | $ 1.14 | $ 0.46 | $ 0.35 |
| **Minimum** | $ 4.34 | $ 11.16 | $ 8.25 | $ 3.20 |
| **Maximum** | $ 5.73 | $ 16.31 | $ 10.65 | $ 4.37 |
| **Summary Statistics of prices (per kilogram) before the Great Recession (Q1 2008 – Q3 2009)** | | | | |
| **Mean** | $6.18 | $15.62 | $9.93 | $3.30 |
| **Median** | $6.27 | $15.52 | $9.44 | $3.30 |
| **Standard Deviation** | $0.22 | $0.52 | $0.23 | $0.03 |
| **Minimum** | $5.85 | $14.94 | $9.09 | $3.27 |
| **Maximum** | $6.41 | $16.41 | $9.76 | $3.34 |
| **Summary Statistics of prices (per kilogram) after the Great Recession (Q4 2009 – Q1 2019)** | | | | |
| **Mean** | $7.13 | $19.93 | $11.45 | $4.07 |
| **Median** | $7.18 | $20.36 | $12.01 | $4.34 |
| **Standard Deviation** | $0.40 | $3.27 | $1.22 | $0.61 |
| **Minimum** | $6.33 | $15.16 | $9.18 | $3.04 |
| **Maximum** | $7.76 | $24.94 | $13.08 | $5.42 |

*Note: The Great Recession is used as a halfway benchmark for comparison*

**Population and Wages**

**Figure 2**

**Table 3**

|  |  |  |
| --- | --- | --- |
| **Slope Coefficients for Quarterly Wages** | | |
| **Period** | **Q1 2000 - Q4 2009** | **Q1 2010 – Q1 2019** |
| **Coefficients** | 0.368602 | 0.738104 |

Quarterly wages from the years 2000 – 2009 is growing at a steadier, higher rate than 2010 – 2019 with a coefficient of 0.368602. This suggests that demand was higher for beef for a brief amount of time because consumers have more income to spend during 2000 – 2009. However, from 2010 – 2019, wages are growing at a slower rate compared to 2000 – 2009 with a coefficient of 0.738104. Income is possibly unable to keep up with the rising prices of steak during 2010 – 2019, contributing to the declining demand for beef. Additionally, chicken demand continues to rise despite the rising prices, perhaps due to a more affordable price. For pork, the demand for this protein is less than chicken and beef. The price of pork chops lies between chicken and sirloin steak, so pork could be a substitute in place of beef. Finally, for fish, demand dropped up until 2007, possibly because increasing incomes allow consumers to buy other desirable meat proteins to consume. After 2007, the demand for fish saw an increase possibly because income was growing at a slower rate, and prices were lower compared to other meat proteins as seen with canned salmon.

**Figure 3**

**Table 4**

|  |  |  |
| --- | --- | --- |
| **Slope Coefficients for Quarterly Wages** | | |
| **Period** | **Q1 2002 - Q4 2009** | **Q1 2015 – Q1 2019** |
| **Coefficients** | 884.42113 | 1234.0398 |

By comparing the slope coefficient from Q1 2002 – Q4 2009 with the coefficient from period Q1 2015 – Q1 2019 in Table 4, we can see that during Q1 2015 – Q1 2019, the population was growing at a quicker rate. It suggests that with a faster rate of population growth, there will be more demand for meat as families may want to purchase more meat for the household. Additionally, their preferences for meat may depend on the amount of income a family has.

The hypotheses to take away from the exploratory analysis is that price and demand for chicken and fish have a positive relationship with each other, while pork and beef have a negative relationship. Quarterly wages do not have an effect on proteins except for beef.Additionally, an increasing population growth rate will result in an increasing demand for protein. We will take a further look at the hypotheses in the statistical analysis.

**Part Two: Statistical Analysis**

In the statistical analysis, we will develop a forecast using an economic model to predict protein demand. The hypothesis for protein demand is that wages have no effect on protein demand except for beef. Population will have a positive relationship with protein demand as the population continues to increase. The price of proteins will have a negative relationship with their respective proteins. We will explore different types of regression models to determine the best fit for our study.

One of the issues of using time series data is autocorrelation, where there is a correlation error in the error terms from different time periods. This is observed by plotting the residuals and conducting the Durbin-Watson test.

**Figure 4**



*Note: Residual plot of regressing demand for chicken (top left), beef (top right), pork (bottom left), fish (bottom right).*

Looking at *Figure 4,* we see positive autocorrelation in our plots. By using the Durbin-Watson test, we can also test for autocorrelation. The test results in values between 0 and 4, where the closer the value is to 0, the more likely it is that we have a case of positive autocorrelation. If the value is closer to 4, it is a case of negative autocorrelation. We list the resulting d-statistics in *Table 5*. All values are close to 0, confirming that there are cases of positive autocorrelation.

**Table 5**

|  |  |
| --- | --- |
| **Durbin-Watson Test Results** | |
| **Protein** | **D-statistic** |
| **DCHIC** | 0.5569601 |
| **DBEEF** | 0.3737459 |
| **DPORK** | 0.463584 |
| **DFISH** | 0.4113023 |

To avoid autocorrelation, we use a robust regression to account for this error. Using a robust regression helps in reducing errors in the regression. It does not change the coefficients of the variables, but it improves the t-values.

Seasonality is the yearly, reoccurring patterns within the data. We want to run a regression to observe how our regression models compare with and without seasonality. To do this, we generate quarterly seasonal dummy variablesand add them to the regression model. In Table 6 and 7, we estimate the regressions with and without the dummy variables.

**Table 6**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Linear Regression Without Dummies** | | | | |
| **Variable** | **DCHIC** | **DBEEF** | **DPORK** | **DFISH** |
| **QW** | .00002862  0.00046  0.06 | -.00139634\*\*\*  0.00044  -3.21 | -.00028158  0.00072  -0.39 | -.00042556  0.00026  -1.64 |
| **ARPCHIC** | -2.797066\*\*\*  0.27364  -10.22 | -.9355548\*\*\*  0.28819  -3.25 | -.93115733  0.47429  -1.96 | -1.1869417\*\*\*  0.17077  -6.95 |
| **ARPSIRLOIN** | .37174683\*\*\*  0.05902  6.30 | .08457264  0.05563  1.52 | .16468307  0.10896  1.51 | -.05951998  0.05152  -1.16 |
| **ARPCHOPS** | -.08000099  0.15146  -0.53 | -.50995762\*\*\*  0.14308  -3.56 | -.51325725  0.32060  -1.60 | .44743775\*\*\*  0.13081  3.42 |
| **ARPCANNED** | -.10907411  0.15929  -0.68 | -.2299257  0.14454  -1.59 | 2.002348\*\*\*  0.32235  6.21 | .30794731\*\*\*  0.06840  4.50 |
| **POP** | 1.423e-06\*\*\*  0.00000  3.81 | 6.608e-07\*\*\*  0.00000  2.15 | -6.860e-07  0.00000  -1.21 | 6.335e-07\*\*\*  0.00000  3.60 |
| **\_cons** | -4.9235176  7.80565  -0.63 | 32.012386  6.12536  5.23 | 50.471764  11.28474  4.47 | -5.5502355  3.55033  -1.56 |
| **R2** | .89540379 | .95989719 | .90514804 | .7838323 |
| **F** | 91.630822 | 341.09088 | 141.65777 | 82.922615 |
| **N** | 77 | 77 | 77 | 77 |

*Note:* The results in each cell are the coefficients, standard errors, and t-values in descending order *(b/se/t)*.

\*\*\*p< 0.05

**Table 7**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Linear Regressions with Dummies** | | | | |
| **Variable** | **DCHIC** | **DBEEF** | **DPORK** | **DFISH** |
| **QW** | .00007842 | -.00137979\*\*\* | -.00022471 | -.00043881 |
|  | 0.00049 | 0.00045 | 0.00071 | 0.00027 |
|  | 0.16 | -3.06 | -0.32 | -1.62 |
| **ARPCHIC** | -2.8517839\*\*\* | -.95117216\*\*\* | -1.0028965\*\*\* | -1.1803287\*\*\* |
|  | 0.26541 | 0.29620 | 0.45650 | 0.16572 |
|  | -10.74 | -3.21 | -2.20 | -7.12 |
| **ARPSIRLOIN** | .37752987\*\*\* | .08465554 | .17056221 | -.05867913 |
|  | 0.05460 | 0.05656 | 0.10364 | 0.05309 |
|  | 6.91 | 1.50 | 1.65 | -1.11 |
| **ARPCHOPS** | -.0935278 | -.51179807\*\*\* | -.53362844 | .44490732\*\*\* |
|  | 0.14936 | 0.14610 | 0.31462 | 0.13532 |
|  | -0.63 | -3.50 | -1.70 | 3.29 |
| **ARPCANNED** | -.10400499 | -.22768293 | 2.0152243\*\*\* | .3089751\*\*\* |
|  | 0.16505 | 0.14985 | 0.32150 | 0.06856 |
|  | -0.63 | -1.52 | 6.27 | 4.51 |
| **POP** | 1.408e-06\*\*\* | 6.560e-07\*\*\* | -6.952e-07 | 6.407e-07\*\*\* |
|  | 0.00000 | 0.00000 | 0.00000 | 0.00000 |
|  | 3.6 | 2.07 | -1.26 | 3.50 |
| **Q1** | -.10480253 | -.05595779 | -.2394369 | .00495896 |
|  | 0.14972 | 0.17043 | 0.26026 | 0.12540 |
|  | -0.70 | -0.33 | -0.92 | 0.04 |
| **Q2** | -.2273976 | -.04963114 | -.3227638 | -.00612405 |
|  | 0.15021 | 0.17192 | 0.24395 | 0.12368 |
|  | -1.51 | -0.29 | -1.32 | -0.05 |
| **Q3** | -.13856494 | -.04136328 | -.29829246 | -.03322831 |
|  | 0.15277 | 0.16124 | 0.23789 | 0.11780 |
|  | -0.91 | -0.26 | -1.25 | -0.28 |
| **\_cons** | -4.4878476 | 32.138082 | 50.896958 | -5.6707849 |
|  | 8.13154 | 6.33993 | 10.94364 | 3.70548 |
|  | -0.55 | 5.07 | 4.65 | -1.53 |
| **R2** | .89834729 | .95996732 | .90740831 | .78431533 |
| **F** | 69.15542 | 218.46346 | 95.608791 | 62.9799 |
| **N** | 77 | 77 | 77 | 77 |

*Note:* The results in each cell are the coefficients, standard errors, and t-values in descending order *(b/se/t)*.

\*\*\*p< 0.05

Our dummy variables*Q1, Q2, and Q3* in Table 7 indicate that there is no significance at the five percent level.This means that these variables do not add to the explanatory power of the regression. Seasonality has no major effect on the dependent variables.Our guess is that protein demand is not affected because consumers do not have a preference for when they demand protein. Additionally, it does little to improve the R­­2. So, we can drop the dummies and use the results from Table 6 to construct our regression models by using statistically significant variables. One thing to note from Table 6 is that the price variables *ARPSIRLOIN* in *DBEEF* and *ARPCHOPS* in *DPORK* are not significant. This suggests a result of mismatched price variables as sirloin steak and pork chops are more expensive products and a more common product from these proteins would be a better fit. Our basic regression models would look like this:

The sign for our models makes sense, given our literature review. Wage only affects the demand for beefand no other proteins. Furthermore, wage has an inverse relationship with beef demand, where decreases in quarterly wages decrease the demand for beef. Most of the price variables in the models make sense. However, the increase in the price of canned salmon increases the demand for fish as seen in Model 4. We would expect something similar to Model 1 where the increase in the price of chicken results in a decrease in the demand for chicken, but it is not the case. Additionally, in Model 3,only an increase in the price of canned salmon explains the demand for pork. It is difficult to say this a good model given only one variable explains the variation in pork demand. Lastly, population is significant in every model, barring the demand for pork. We verify that an increase in population increases demand.

Another model that could be used to regress protein demand was by using seemingly unrelated regressions. This model shares the error term among the dependent variables. However, as we add more variables, the difference between ordinary least squares and seemingly unrelated regressions becomes smaller, making it difficult to justify using this method over the other. In Table 8, we have the results from using seemly unrelated regressions, and compared to our results in Table 6, the coefficients are relatively the same.

**Table 8**

|  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Seemingly Unrelated Regressions** | | | | | | | | | | | | |
| **Equation** | **Obs** | | **Parms** | | **RMSE** | | **"R-sq"** | | **chi2** | | **P** | |
| **DCHIC** | 77 | | 6 | | .45593 | | 0.8954 | | 659.16 | | 0.0000 | |
| **DBEEF** | 77 | | 6 | | .4724211 | | 0.9599 | | 1843.07 | | 0.0000 | |
| **DPORK** | 77 | | 6 | | .7520334 | | 0.9051 | | 734.79 | | 0.0000 | |
| **DFISH** | 77 | | 6 | | .3140529 | | 0.7838 | | 279.20 | | 0.0000 | |
| **DCHIC** | | | | | | | | | | | | |
|  | | **Coef.** | | **Std. Err.** | | **z** | | **P>z** | | **[95% Conf. Interval]** | | |
| **QW** | | .0000286 | | .0004126 | | 0.07 | | 0.945 | | -.00078 | | .0008372 |
| **ARPCHIC** | | -2.797066 | | .2940496 | | -9.51 | | 0.000 | | -3.373393 | | -2.220739 |
| **ARPSIRLOIN** | | .3717468 | | .0619598 | | 6.00 | | 0.000 | | .2503079 | | .4931858 |
| **ARPCHOPS** | | -.080001 | | .1592231 | | -0.50 | | 0.615 | | -.3920726 | | .2320706 |
| **ARPCANNED** | | -.1090741 | | .1682157 | | -0.65 | | 0.517 | | -.4387707 | | .2206225 |
| **POP** | | 1.42e-06 | | 3.00e-07 | | 4.75 | | 0.000 | | 8.36e-07 | | 2.01e-06 |
| **\_cons** | | -4.923518 | | 6.10945 | | -0.81 | | 0.420 | | -16.89782 | | 7.050783 |
| **DBEEF** | | | | | | | | | | | | |
|  | | **Coef.** | | **Std. Err.** | | **z** | | **P>z** | | **[95% Conf. Interval]** | | |
| **QW** | | -.0013963 | | .0004275 | | -3.27 | | 0.001 | | -.0022342 | | -.0005585 |
| **ARPCHIC** | | -.9355548 | | .3046854 | | -3.07 | | 0.002 | | -1.532727 | | -.3383824 |
| **ARPSIRLOIN** | | .0845726 | | .0642009 | | 1.32 | | 0.188 | | -.0412588 | | .210404 |
| **ARPCHOPS** | | -.5099576 | | .1649823 | | -3.09 | | 0.002 | | -.8333169 | | -.1865983 |
| **ARPCANNED** | | -.2299257 | | .1743 | | -1.32 | | 0.187 | | -.5715475 | | .1116961 |
| **POP** | | 6.61e-07 | | 3.10e-07 | | 2.13 | | 0.033 | | 5.26e-08 | | 1.27e-06 |
| **\_cons** | | 32.01239 | | 6.330429 | | 5.06 | | 0.000 | | 19.60497 | | 44.4198 |
| **DPORK** | | | | | | | | | | | | |
|  | | **Coef.** | | **Std. Err.** | | **z** | | **P>z** | | **[95% Conf. Interval]** | | |
| **QW** | | -.0002816 | | .0006805 | | -0.41 | | 0.679 | | -.0016153 | | .0010521 |
| **ARPCHIC** | | -.9311573 | | .4850198 | | -1.92 | | 0.055 | | -1.881779 | | .0194639 |
| **ARPSIRLOIN** | | .1646831 | | .1021995 | | 1.61 | | 0.107 | | -.0356243 | | .3649904 |
| **ARPCHOPS** | | -.5132573 | | .2626304 | | -1.95 | | 0.051 | | -1.028003 | | .0014889 |
| **ARPCANNED** | | 2.002348 | | .2774632 | | 7.22 | | 0.000 | | 1.45853 | | 2.546166 |
| **POP** | | -6.86e-07 | | 4.94e-07 | | -1.39 | | 0.165 | | -1.65e-06 | | 2.82e-07 |
| **\_cons** | | 50.47176 | | 10.07723 | | 5.01 | | 0.000 | | 30.72076 | | 70.22276 |
| **DFISH** | | | | | | | | | | | | |
|  | | **Coef.** | | **Std. Err.** | | **z** | | **P>z** | | **[95% Conf. Interval]** | | |
| **QW** | | -.0004256 | | .0002842 | | -1.50 | | 0.134 | | -.0009825 | | .0001314 |
| **ARPCHIC** | | -1.186942 | | .2025467 | | -5.86 | | 0.000 | | -1.583926 | | -.7899575 |
| **ARPSIRLOIN** | | -.05952 | | .042679 | | -1.39 | | 0.163 | | -.1431693 | | .0241294 |
| **ARPCHOPS** | | .4474378 | | .1096758 | | 4.08 | | 0.000 | | .2324772 | | .6623984 |
| **ARPCANNED** | | .3079473 | | .11587 | | 2.66 | | 0.008 | | .0808463 | | .5350483 |
| **POP** | | 6.33e-07 | | 2.06e-07 | | 3.07 | | 0.002 | | 2.29e-07 | | 1.04e-06 |
| **\_cons** | | -5.550236 | | 4.2083 | | -1.32 | | 0.187 | | -13.79835 | | 2.697881 |

The two models suffer from multicollinearity, however. Multicollinearity occurs when there is correlation between the independent variables. By creating a matrix of the independent variables, we can determine which variables share correlation. We find that there is a correlation between the money variables such as prices and wage as a result of inflation over time. To solve this, we try running the first difference regression. First differences measure changes over time compared to levels. By transforming the variables using differences, we no longer have an issue of multicollinearity.

**Table 9**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **First Difference Regression** | | | | |
| **Variable** | **DDChicken** | **DDBeef** | **DDPork** | **DDFish** |
| **DQW** | .00008438  0.00012  0.68 | -.0000327  0.00030  -0.11 | -.00021644  0.00017  -1.30 | .00004951  0.00010  0.51 |
| **DARPCHIC** | -.14715039  0.18707  -0.79 | .33705236  0.46180  0.73 | -.27908685  0.25177  -1.11 | -.07893762  0.14630  -0.54 |
| **DARPSIRLOIN** | .02335943  0.03549  0.66 | -.05870785  0.08760  -0.67 | .06922742  0.04776  1.45 | .01733734  0.02775  0.62 |
| **DARPCHOPS** | .10487202  0.07814  1.34 | .16447824  0.19289  0.85 | -.33765647\*\*\*  0.10516  -3.21 | .0462116  0.06111  0.76 |
| **DARPCANNED** | .07302709  0.13758  0.53 | .47728914  0.33964  1.41 | -.00085847  0.18516  -0.00 | -.02290113  0.10759  -0.21 |
| **DPOP** | 3.874e-07  0.00000  0.66 | 9.056e-08  0.00000  0.06 | 1.094e-06  0.00000  1.37 | 4.912e-07  0.00000  1.06 |
| **\_cons** | .03376874  0.05645  0.60 | -.11138255  0.13934  -0.80 | -.15079319  0.07597  -1.98 | -.05369157  0.04414  -1.22 |
| **R2** | .05724304 | .0571014 | .16206752 | .03387679 |
| **F** | .6982658 | .69643338 | 2.2242562 | .40324373 |
| **N** | 76 | 76 | 76 | 76 |

*Note:* The results in each cell are the coefficients, standard errors, and t-values in descending order *(b/se/t)*.

\*\*\*p< 0.05

Table 9 is our results from the first-difference regression where the multicollinearity issue is addressed. However, we now have an issue where most variables are not statistically significant, barring the differenced price of pork chops in the differenced demand for pork. This suggests that there is a complex multicollinearity problem and requires further research to solve. Additionally, the R2 for each protein is unable to explain most of the variation in demand. Out of all the models tested, the linear regression model is the best fit from this analysis.

1. **Conclusion**

To conclude, we find that the wage only affects the demand for beef. We also find that seasonality has no effect on any of the dependent variables. Population affects all proteins except for pork. Additionally, some of the price variables are statistically significant such as the price of chicken and sirloin steak affecting the demand for chicken. However, the price of sirloin steak and pork chops do not affect their respective proteins, suggesting a potential case of mismatched variables. The model for demand in pork may require more verification as only one variable is significant enough to affect demand. There is also the problem of multicollinearity in our models that would require further research to solve. A potential solution could be an instrumental variable approach where a variable affects the dependent variable through the independent variable, but that is beyond the scope of our analysis.

Another thing to note is that we have only constructed a basic model to predict protein. It does not factor in the effects of how COVID-19 will affect the demand. We already know that COVID-19 has caused protein demand to fall (Attwood & Cother, 2020). It is possible that COVID-19 will have an effect on consumer’s wages, potentially limiting their demand for proteins. Beef especially, as in our research, we find that wage affects the demand for beef. Another factor affecting demand that was not explored was the supply of protein. The meat industry is concentrated and not resilient, as a small setback can affect the demand for proteins (Griekspoor, n.d.).

The objective of this study was to create a model to predict protein demand using significant variables. While we do have models, it requires future research to refine the details before we can conclude that we have accurate models to predict protein demand.

**Appendix**

|  |  |  |
| --- | --- | --- |
| **Variable** | **Variable Explanation** | **Source** |
| **DCHICK** | |  | | --- | | Protein demand using protein disappearance of animal protein sources in Canada (food available per person, per year) in kilograms (eviscerated and carcass weights) | |  | |  | |  | | Agriculture Canada. [https://ww](https://www5.agr.gc.ca/eng/canadas-agriculture-sectors/animal-industry/red-meat-and-livestock-market-information/protein-disappearance-and-demand-by-species/?id=1415860000022)  [w5.agr.gc.ca/eng/animal-industr](https://www5.agr.gc.ca/eng/canadas-agriculture-sectors/animal-industry/red-meat-and-livestock-market-information/protein-disappearance-and-demand-by-species/?id=1415860000022)  [y/red-meat-and-livestock-market](https://www5.agr.gc.ca/eng/canadas-agriculture-sectors/animal-industry/red-meat-and-livestock-market-information/protein-disappearance-and-demand-by-species/?id=1415860000022)  [-information/protein-disappeara](https://www5.agr.gc.ca/eng/canadas-agriculture-sectors/animal-industry/red-meat-and-livestock-market-information/protein-disappearance-and-demand-by-species/?id=1415860000022)  [nce-and-demand-by-species/?id](https://www5.agr.gc.ca/eng/canadas-agriculture-sectors/animal-industry/red-meat-and-livestock-market-information/protein-disappearance-and-demand-by-species/?id=1415860000022)  [=1415860000022](https://www5.agr.gc.ca/eng/canadas-agriculture-sectors/animal-industry/red-meat-and-livestock-market-information/protein-disappearance-and-demand-by-species/?id=1415860000022), accessed on  November 28, 2020 |
| **DBEEF** |
| **DPORK** |
| **DFISH** |
| **QW** | Quarterly Employee Wages (Determined by multiplying average weekly wages by the 4 weeks in a month then summing each quarter) | [Statistics Canada. Table 14-10-0306-01  Employee wages by occupation, monthly, unadjusted for seasonality DOI: https://doi.org/10.25318/1410030601-eng](https://doi.org/10.25318/1410030601-eng) |
| **QW%** | Percent change in employee wages | [Statistics Canada. Table 14-10-0306-01  Employee wages by occupation, monthly, unadjusted for seasonality DOI: https://doi.org/10.25318/1410030601-eng](https://doi.org/10.25318/1410030601-eng) |
| **ARPCHIC** | |  | | --- | | Monthly average retail prices for food and other selected products per kilogram. | |  | |  | |  | | "Statistics Canada. Table 18-10-0002-01 Monthly average retail prices for food and other selected products  DOI: https://doi.org/10.25318/1810000201-eng" |
| **ARPSIRLOIN** |
| **ARPCHOPS** |
| **ARPCANNED** |
| **POP** | Population estimates, quarterly. | [Statistics Canada. Table 17-10-0009-01 Population estimates, quarterly DOI: https://doi.org/10.25318/1710000901-eng](file:///C:\Users\Kevin\AppData\Roaming\Microsoft\Word\Statistics%20Canada.%20Table%2017-10-0009-01%20Population%20estimates,%20quarterly%20DOI:%20https:\doi.org\10.25318\1710000901-eng) |
| **POP%** | Percent change of population estimates | [Statistics Canada. Table 17-10-0009-01 Population estimates, quarterly DOI: https://doi.org/10.25318/1710000901-eng](file:///C:\Users\Kevin\AppData\Roaming\Microsoft\Word\Statistics%20Canada.%20Table%2017-10-0009-01%20Population%20estimates,%20quarterly%20DOI:%20https:\doi.org\10.25318\1710000901-eng) |
| **DDCHICK** | Differenced protein demand. | |  | | --- | | Agriculture Canada.  [https://ww](https://www5.agr.gc.ca/eng/animal-industry/red-meat-and-livestock-market-information/protein-disappearance-and-demand-by-species/?id=1415860000022)  [w5.agr.gc.ca/eng/animal-industr](https://www5.agr.gc.ca/eng/animal-industry/red-meat-and-livestock-market-information/protein-disappearance-and-demand-by-species/?id=1415860000022)  [y/red-meat-and-livestock-market](https://www5.agr.gc.ca/eng/animal-industry/red-meat-and-livestock-market-information/protein-disappearance-and-demand-by-species/?id=1415860000022)  [-information/protein-disappeara](https://www5.agr.gc.ca/eng/animal-industry/red-meat-and-livestock-market-information/protein-disappearance-and-demand-by-species/?id=1415860000022)  [nce-and-demand-by-species/?id](https://www5.agr.gc.ca/eng/animal-industry/red-meat-and-livestock-market-information/protein-disappearance-and-demand-by-species/?id=1415860000022)  [=1415860000022](https://www5.agr.gc.ca/eng/animal-industry/red-meat-and-livestock-market-information/protein-disappearance-and-demand-by-species/?id=1415860000022), accessed on  November 28, 2020  November 28, 2020 [28, 2020](file:///C:\Users\Kevin\AppData\Roaming\Microsoft\Word\Agriculture%20Canada.%20https:\www5.agr.gc.ca\eng\animal-industry\red-meat-and-livestock-market-information\protein-disappearance-and-demand-by-species\%3fid=1415860000022,%20accessed%20on%20November%2028,%202020) | |  | |  | |
| **DDBEEF** |
| **DDPORK** |
| **DDFISH** |
| **DQW** | Differenced quarterly wages. | [Statistics Canada. Table 14-10-0306-01  Employee wages by occupation, monthly, unadjusted for seasonality DOI: https://doi.org/10.25318/1410030601-eng](https://doi.org/10.25318/1410030601-eng) |
| **DARPCHIC** | Differenced average retail prices. | "Statistics Canada. Table 18-10-0002-01 Monthly average retail prices for food and other selected products  DOI: https://doi.org/10.25318/1810000201-eng" |
| **DARPSIRLOIN** |
| **DARPCHOPS** |
| **DARPCANNED** |
| **DPOP** | Differenced population. | [Statistics Canada. Table 17-10-0009-01 Population estimates, quarterly DOI: https://doi.org/10.25318/1710000901-eng](file:///C:\Users\Kevin\AppData\Roaming\Microsoft\Word\Statistics%20Canada.%20Table%2017-10-0009-01%20Population%20estimates,%20quarterly%20DOI:%20https:\doi.org\10.25318\1710000901-eng) |

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