**CCT College Dublin**

**Assessment Cover Page**

|  |  |
| --- | --- |
| **Module Title:** | Statistics for Data Analytics  Programming for Data Analytics  Data Preparation and Visualisation  Machine Learning for Data Analytics |
| **Assessment Title:** | [CA2 50%](https://moodle.cct.ie/mod/assign/view.php?id=115129) Integrated Assessment |
| **Lecturer Name:** | John O'Sullivan, Sam Weiss, David McQuaid, Muhammad Iqbal |
| **Student Full Name:** | Zhongjie Fei |
| **Student Number:** | 2022173 |
| **Assessment Due Date:** | 06/01/2023(11/01/2023 after PMC) |
| **Date of Submission:** | 11/01/2023 |

**Declaration**

|  |
| --- |
| By submitting this assessment, I confirm that I have read the CCT policy on Academic Misconduct and understand the implications of submitting work that is not my own or does not appropriately reference material taken from a third party or other source. I declare it to be my own work and that all material from third parties has been appropriately referenced. I further confirm that this work has not previously been submitted for assessment by myself or someone else in CCT College Dublin or any other higher education institution. |

Icon

Description automatically generated Author: Zhongjie Fei

Student ID: 2022173

**Report for Beef Price Analysis in Ireland**

**and**

**a quick comparison to Spain**

MSc in Data Analytics

*e-mail:* [*2022173@student.cct.ie*](mailto:2022173@student.cct.ie)

***Abstract***

*Agriculture has played a significant role in human progress, providing food and income for the majority of the global population. Among the various forms of animal production, beef production has remained popular throughout history. The complexity of the beef production industry has resulted in fluctuations in beef prices over time. In this study, the author aimed to analyse and visualise the changes in beef prices from 2017 to 2021 in Ireland and conduct a brief comparison with Spain. Two machine learning models were built to train and predict, and a sentiment analysis was created lastly to gain insight into people's opinions on recent beef prices worldwide. By examining these factors and their possible impacts, the study aims to provide a better understanding of the beef production industry and its potential future trends.*

*Keywords: agriculture, beef prices, data analysis, statistics, visualisation, machine learning, sentimental analysis*

**0. Introduction**

Agriculture has long been an essential part of human history and with the advent of data science, modern agriculture has seen significant improvements in production efficiency. As people become increasingly concerned with environmental sustainability and health, there is a growing focus on organic and environmentally friendly agricultural practices. The beef production industry, particularly in Ireland, remains popular, leading the author to investigate the fluctuations in beef prices over time and their relation to other factors such as beef production, beef feeding prices and more. Corresponding data was collected and processed for analysing statistical aspects and creating interactive visualisations to provide a more direct understanding. Machine learning models, including linear regression and random forest, were applied to train models and make predictions, and a sentiment analysis was conducted to understand people's perspectives on recent beef prices at last.

**1. Agriculture and beef production**

The emergence of agriculture, dating back thousands of years ago, marked a significant milestone in the historical development of human civilisation. It is the major source of food and income for majority of people around the world (Branco, 2020).

According to Branco (2020), food production in agriculture is a complex and multi-faceted process that involves a range of factors including farming size, soil management, water and electricity usage, pest and disease control, food security monitoring etc. Data science, for example artificial intelligence, now plays an important role in modern agriculture management, which have led to significant increases in food production, allowing for the feeding of growing global populations. However, the fast development of modern agriculture consequently raises concerns about the environmental and the potential loss of biodiversity (ibid.). Additionally, the use of chemicals for fertilising and pest control can have negative effects on soil and water quality but also on food safety. Therefore, organic farming and organic food production are being promoted in order to maintain sustainability.

Animal production is one of the two major branches in agriculture, alongside crop production. Within animal production, there are various sub-sectors, including beef production, dairy production, pig production, and poultry production, to name a few. Despite the increasing demand for chicken and other meats, beef production continues to play a crucial role in meeting the protein needs of the global population, providing essential nutrients and energy for human health and development (Kahn and Cottle, 2014).

The price of beef is determined by a variety of factors, including supply and demand, production costs, and government policies. To elaborate, the demand for beef is affected by consumer preferences, population growth, and income levels, and the supply of beef is influenced by factors such as weather conditions, disease outbreaks, and production costs as well as government policies (Croxton, 1905). An increase in demand will lead to a higher price, however, an increase in supply will lead to a lower price. The production costs of beef encompass a wide range of expenses, e.g. equipment and facilities, veterinary care, feeding and labour.

**1.1 Common Agriculture Policy (CAP)**

The European Union's Common Agriculture Policy (CAP), first established in 1962 and regularly amended, plays a significant role in shaping the agricultural industry in Europe. It was proposed to, according to official website of European Commission:

1. Ensure the continuity of food production and distribution;
2. Ensure a supply of safe and affordable food;
3. Encourage younger generations to take up farming and promote environmentally friendly farming;
4. Practice LEADER method to thrive remote and mountainous areas with disadvantages;
5. Reduce power imbalance and help small farms etc.

The latest publication of the CAP places a stronger emphasis on environmental protection and organic farming, while also promoting fairness and innovation within the industry (European Commission, 2022).

As reported by the European Commission (2021), in Ireland in 2020, the allocation of CAP expenditure was 76.4% for direct payments, 19.9% for rural development, and 3.8% for market measures. Additionally, the beef (cattle) sector accounted for 29% of the output component, making it the second largest sector behind dairy. Feedingstuffs represented the highest percentage of intermediate consumption, at 47.2%.

**1.2 EU Beef Carcass Classification Scheme**

There are various beef carcass classification schemes used around the world, with a common scheme adopted by European countries. According to the Department of Agriculture, Food, and the Marine (2022) in Ireland, the European scheme categorises beef carcass from three perspectives:

* Sex: denoted by the letters A (young bull), B (bull), C (steer), D (cow), E (heifer);
* Conformation (Quality): E, U, R, O, P with E being the best and P the poorest;
* Fatness: the degree of fat is denoted by the numbers 1, 2, 3, 4, 5 in order of increasing fatness.

**2. Study objective**

The main purpose of this study was to investigate and visualise the dynamic changes in beef prices in Ireland and to analyse the relationship with other potential influencing factors such as feedingstuffs and beef production. Moreover, the study aimed to compare the beef prices and production in Ireland to that of Spain, another major beef-producing country in Europe. Given the assumption that beef prices in Ireland may differ significantly from those in Spain due to its high consumption level, several hypothesis tests were used to test this assumption. To further understand the data, two machine learning models were applied and compared. Finally, a sentiment analysis was implemented using Twitter API to observe people’s recent (past 7 days) comments on beef prices worldwide.

Jupyter notebook version 6.4.8 and Python version 3.9.12 were used for exploratory data analysis (EDA), visualisation and machine learning in our report.

**3. Data collection and preparation**

Due to the complexity of beef prices and the limitations of this study, we chose to focus on the R3 level of beef carcass, including all sexes, from 2017 to 2021 for our analysis. Furthermore, we selected three potential factors that could affect beef prices for examination: beef production, beef feedingstuff prices, and pigmeat prices. However, during our research, we were unable to obtain reliable data on beef feedingstuff prices in Spain. As a result, this factor had to be omitted when comparing the two countries. We later also discovered that Spain was missing data for the bull and steer on R3 level. As a result, we had to drop these elements when comparing.

During the data collection period, datasets related to beef prices, beef production, and pigmeat prices were collected from the European Commission's agri-food data portal (<https://agridata.ec.europa.eu/extensions/DataPortal/home.html>). The data explorer function on the website allowed us to download the desired data for beef prices and beef production directly through filtering. However, for the pigmeat prices, we had to use the open API function to collect the data as the filtering function was not working properly within the data explorer mode (see Jupyter notebook). This thus avoided complication for preparation.

Data related to beef feedingstuff prices in Ireland was downloaded from Central Statistics Office website ([https://data.cso.ie/#](https://data.cso.ie/%23)). While there are several types of beef feedingstuffs, we only selected two types for our analysis. At this stage, four datasets were ready for processing. Through examination the structure of the original datasets (Table 1-4), few insights were gained to process the four datasets for later merging:

* For datasets that contains weekly information, groupby function based on date (and country) was used to transform the weekly price into average monthly price, i.e. beef prices and pigmeat prices, since the other two data only contains monthly information;
* Due to the inconsistency of time/date format, a new column was added in each dataset with the same format of year and month (%Y-%m).

**3.1 Processing of beef price dataset**

**Table 1: Details of features in beef price dataset**

|  |  |  |
| --- | --- | --- |
| FN | Attribute name | Description |
| 1 | Year | year |
| 2 | Week | week number |
| 3 | Begin Date | begin date of the week |
| 4 | End Date | end date of the week |
| 5 | Member State | country name |
| 6 | Category | beef sex |
| 7 | Product | classification code |
| 8 | Price | price in euro per 100 kg |

The main modification applied to this dataset was to calculate the mean beef price based on the date and country. This was done in order to have a monthly beef prices representation rather than weekly. Subsequently, duplicate rows and some unnecessary columns were removed, and columns name and their order were reorganised to simplify the dataframe and prepare it for further processing (Figure 1).

Table

Description automatically generated

**Figure 1: Beef price dataset after preparation**

**3.2 Processing of beef production dataset**

**Table 2: Details of features in beef production dataset**

|  |  |  |
| --- | --- | --- |
| FN | Attribute name | Description |
| 1 | Member State | country name |
| 2 | Member State Code | country code |
| 3 | Category | beef sex |
| 4 | Year | year |
| 5 | Month | month |
| 6 | 1000 Heads | measure unit |
| 7 | kg/head | measure unit |

The main modification applied in this dataset was to combine the Year and Month columns and format the date to match the previously used date format. The unique values in the Category feature were also modified to match the names used in the beef price dataset. Finally, the columns were reorganised to make the dataframe more succinct (Figure2).

Table

Description automatically generated

**Figure 2: beef production dataset after preparation**

**3.3 Processing of beef feeding price dataset**

**Table 3: Details of features in beef feeding price dataset**

|  |  |  |
| --- | --- | --- |
| FN | Attribute name | Description |
| 1 | STATISTIC Label | label |
| 2 | Month | date (year and month) |
| 3 | Type of Feedstuff | feedstuff type |
| 4 | UNIT | measure unit |
| 5 | VALUE | price |

In this dataset, the main change applied was the Month column to match the date format above (Figure 2). Also, the dataset was split into two parts according to its feedstuff type (see attached).

Text

Description automatically generated

**Figure 3: beef feeding price dataset after preparation**

**3.4 Processing of pigmeat price dataset**

**Table 4: Details of features in pigmeat price dataset**

|  |  |  |
| --- | --- | --- |
| FN | Attribute name | Description |
| 1 | memberStateCode | country code |
| 2 | memberStateName | country name |
| 3 | beginDate | begin date of the week |
| 4 | endDate | end date of the week |
| 5 | weekNumber | week number |
| 6 | price | price in euro |
| 7 | unit | measure unit |
| 8 | pigClass | pig classification (E) |

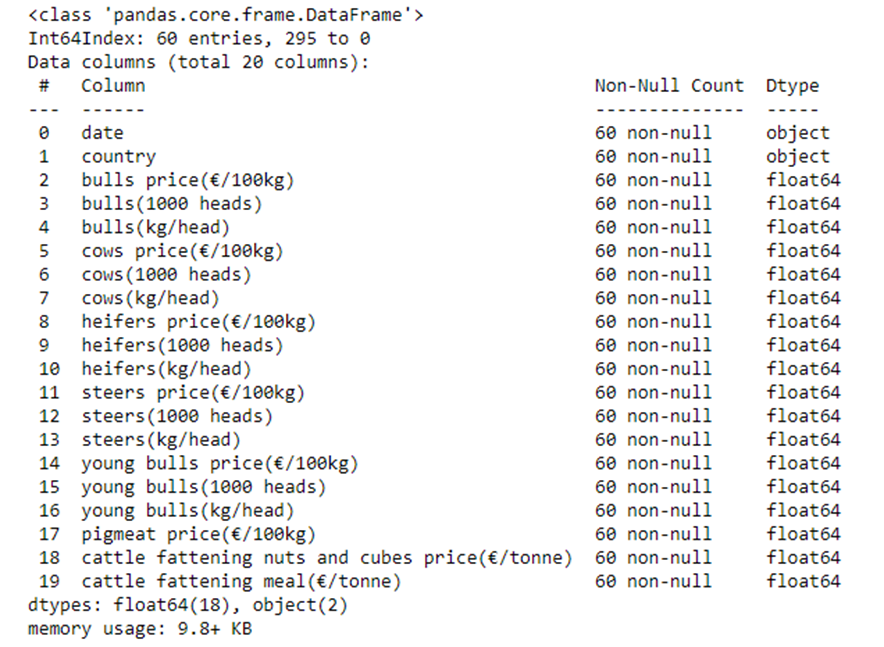
Similar to the processing methods used for the beef price dataset, the pigmeat prices were also converted to average monthly prices (Figure 4). It is worth noting that the values of pigmeat prices were in string format with euro signs after requesting from API. Thus, a conversion function was applied to change it to the appropriate numerical format (see attached).

Table

Description automatically generated

**Figure 4: pigmeat price dataset after preparation**

**3.5 Data merging**

****

**Figure 5: Information of ireland\_beef**

**Text

Description automatically generated**

**Figure 6: information of ie\_es\_beef**

After the preparation of the original datasets, we applied the merge and pivot function in pandas to convert the original datasets into two final datasets for analysis, in addition to some essential reorganising. The first dataset, “ireland\_beef” contains the data for analysing beef prices in Ireland alone, while the second dataset, “ie\_es\_beef” includes the data for comparing the beef prices between Ireland and Spain (Figure 5-6, see attached also).

Finally, the datasets were checked for missing values and duplicates before proceeding to the analysis. Missing values were not addressed in this study.

**4. Statistics**

In this section, we first provided a brief overview of the basic statistics in our two final datasets. We then used the "ie\_es\_beef" dataset to test our hypothesis. The hypothesis tests were used to determine if there is a statistically significant difference in beef prices between Ireland and Spain.

**4.1 Basic statistics**

Table

Description automatically generated

**Figure 7: First half** **of the basic statistics related to Ireland**

Table

Description automatically generated

**Figure 8: Second half of the basic statistics related to Ireland**

*Overview of beef statistics in Ireland from 2017 to 2021:*

* The average bull price is 294.58€/100kg, with the highest being 347.19€/100kg and the lowest being 243.17€/100kg
* The average cow price is 325.90€/100kg, with the highest being 378.21€/100kg and the lowest being 271.66€/100kg
* The average heifer price is 388.19€/100kg, with the highest being 431.59€/100kg and the lowest being 347.29€/100kg
* The average steer price is 379.57€/100kg, with the highest being 427.84€/100kg and the lowest being 342.27€/100kg
* The average young bull price is 366.84€/100kg, with the highest being 413.59€/100kg and the lowest being 320.64€/100kg
* The average pigmeat price is 157.53€/100kg, with the highest being 190.76€/100kg and the lowest being 136.73€/100kg
* The average cattle fattening nuts and cubes price is 285.49€/tonne, with the highest being 345.13€/tonne and the lowest being 262.44€/tonne
* The average cattle fattening meal price is 278.65€/tonne, with the highest being 339.30€/tonne and the lowest being 248.93€/tonne, etc

Graphical user interface

Description automatically generated with low confidence

**Figure 9: Basic statistics related to Spain**

*Overview of beef statistics in Spain from 2017 to 2021:*

* The average cow price is 263.16€/100kg, with the highest being 304.84€/100kg and the lowest being 233.51€/100kg
* The average heifer price is 380.47€/100kg, with the highest being 426.52€/100kg and the lowest being 343.90€/100kg
* The average young bull price is 370.95€/100kg, with the highest being 436.44€/100kg and the lowest being 333.14€/100kg
* The average pigmeat price is 155.51€/100kg, with the highest being 189.09€/100kg and the lowest being 123.39€/100kg, etc

**4.2 Hypothesis test**

A hypothesis test is a procedure for making a decision about the value of a population parameter on the basis of sample data (Reif, 2008). The goal is to determine whether there is enough evidence to support the alternative hypothesis, or whether the data is more likely to have occurred if the null hypothesis is true.

There are two type of hypothesis tests. Parametric statistical tests are based on assumptions about the distribution of data and the parameters of the population from which the sample is drawn, usually assuming normality in the distribution. These tests are more powerful when the assumptions are met but can be unreliable if the assumptions are not met. Non-parametric statistical tests, on the other hand, make fewer or no assumptions about the population distribution, and instead rely on the order or rank of the data. These tests are considered robust and can be used when the assumptions of parametric tests are not met but are generally less powerful than parametric tests.

Since there are three types of beef prices, i.e. cow, heifer, and young bull, in Ireland and Spain, we therefore separated the null hypothesis into three distinct parts. Normality tests using the Shapiro-Wilk test with a significance level of 0.05 were performed to check whether the data was normally distributed. The results of the normality test indicated that, with the exception of cow prices in Spain, the prices for all other categories of beef were normally distributed.

To test the null hypotheses, we used both parametric and non-parametric hypothesis testing methods. After analysing the data, we found that:

* Reject the null hypothesis that cow prices in Ireland were significantly different from those in Spain;
* Reject the null hypothesis that heifer prices in Ireland were significantly different from those in Spain (since the sample for heifer prices were more normally distributed, we had more trust in the results of parametric testing);
* Failed to reject the null hypothesis that young bull prices in Ireland were significantly different from those in Spain.

**5. Visualisation**

In this section, some of the interactive graphs were discussed. It is worth mentioning that the basic style of the visualisation was based on the average age of farmers and their gender distribution, as reported by the Central Statistics Office (2021). According to this report, in 2020, the average age of a farmer in Ireland was 54 years old, and more than 86% were male. Thus, the target audience for visualisations is older individuals. To effectively communicate information to this demographic, we highlighted a few key design considerations:

First, we suggested using high contrast colours for the graphs, to make them easier for older individuals to read. Additionally, the font size of the title should be large to improve readability.

Second, we recommended using simple graph styles that are easy to understand, such as line charts and bar charts. This will help older individuals to quickly grasp the information being presented.

Lastly, we noted that research shows that the top five colours that older men prefer are blue, red, green, black and pink. Therefore, it is important to take into consideration these colour preferences when designing the visualisations (Eldertech, 2017).

**Figure 10: Beef prices in Ireland from 2017 to 2021**

Chart, histogram

Description automatically generated

*Overview:*

* Heifer price > Steer price > Young bull price > Cow price > Bull price
* The prices of all five categories of beef tend to display similar patterns of fluctuation, with the top three categories showing the most correlation
* A trend of rising prices between March and May was observed each year
* Critical thinking: though weather condition was not considered in this study, the trend above may be the result of harsh winter conditions, as the largest price increase in the dataset occurred in March 2018, which coincided with a heavy snowstorm in Ireland. Similarly, the increase of beef prices after 2021 could also be attributed to impact of Covid pandemic

**Figure 11: Beef production in Ireland from 2017 to 2021**

Graphical user interface, chart, line chart

Description automatically generated

*Overview:*

* Steer production > Heifer production > Cow production > Bull production > Young bull production
* September every year has the highest production of steers, however, March every year has the highest production of young bulls

**Figure 12: Weight of the beef per head in Ireland from 2017 to 2021**

Chart, histogram

Description automatically generated

*Overview:*

* Bull weight > Steer weight > Heifer weight ≈ Cow weight > Young bull weight
* Bulls get a weight increase around March and September every year

**Figure 13: Beef feeding price in Ireland from 2017 to 2021**

Chart, histogram

Description automatically generated

*Overview:*

* The beef feeding prices show a constant rising tendency, especially after September 2020
* The prices of two beef feedstuffs show high positive correlation

**Figure 14: Relation between steer prices and steer production in Ireland from 2017 to 2021**

Chart, bar chart, histogram

Description automatically generated

*Overview:*

* This graph was present since it shows the “best” negative correlation between prices and production, e.g. September 2017, September 2019
* Generally speaking, the correlation between prices and production is not obvious (see Jupyter notebook)

**Figure 15: Scatterplot showing correlation between cow prices and cattle fattening nuts and cubes prices**

Chart, scatter chart

Description automatically generated

*Overview:*

* The correlation tends to be more obvious when the cow price gets really high
* Possibly the recent constant increasing in feeding prices is causing the cow prices to reach its highest
* The tendency mentioned above is also displaying in other beef categories (see attached)

**Figure 16:** **Cow price in Ireland and Spain from 2017 to 2021**

Chart, line chart

Description automatically generated

*Overview:*

* Cow prices in Ireland are higher than Spain
* The price difference is more obvious from January 2017 to May 2018 and from November 2020 to December 2021
* Similar tendency of fluctuation is showing

**Figure 17: Heifer price in Ireland and Spain from 2017 to 2021**

Chart, histogram

Description automatically generated

**Figure 18: Young bull price in Ireland and Spain from 2017 to 2021**

Chart, histogram

Description automatically generated

*Overview:*

* Figure 17 and Figure 18 demonstrate that the price differences of heifer and young bull between Ireland and Spain are insignificant

**Figure 19: Cow production in Ireland and Spain from 2017 to 2021**

Chart, bar chart, line chart, histogram

Description automatically generated

*Overview:*

* Cow production in Ireland is higher than Spain in general
* Both countries show increasing in production around July each year

**Figure 20: Heifer production in Ireland and Spain from 2017 to 2021**

Chart, line chart, histogram

Description automatically generated

*Overview:*

* Heifer production in Ireland is much higher than Spain

**Figure 21: Young bull production in Ireland and Spain from 2017 to 2021**

Chart, bar chart

Description automatically generated

*Overview:*

* There is way more young bull production in Spain than Ireland
* Spain has high young bull production across the whole years

**Figure 22: Weight of cow per head in Ireland and Spain from 2017 to 2021**

Chart, bar chart

Description automatically generated

**Figure 23: Weight of heifer per head in Ireland and Spain from 2017 to 2021**

Chart, bar chart

Description automatically generated

**Figure 24: Weight of young bull per head in Ireland and Spain from 2017 to 2021**

Chart, bar chart, histogram

Description automatically generated

*Overview:*

* Figure 22-24 demonstrate that the weight of cow and heifer in Ireland is higher than Spain, however, the weight of young bull in Spain is higher than Ireland

**6. Machine Learning**

In our study, we employed two supervised machine learning techniques to train and test our data in order to make predictions on bull beef prices. The data utilized for training was sourced from the dataset "ireland\_beef" and our goal was to predict bull prices based on the other features within the dataset, with the exception of the date and country variables

**6.1 Linear Regression**

In the Linear Regression model, we used the StandardScaler function to normalise our data. The dataset was then split into a 75% training and 25% testing partition. In order to optimise the model, we practiced GridSearchCV and tuned the hyperparameters to find the best combination that maximised the accuracy. Our final model achieved an accuracy of approximately 60% using 12 optimal features, as detailed in the Jupyter notebook.

**6.2 Random Forest**

The Random Forest model performed extremely poorly, reaching at most an accuracy of 6%, even after practicing GridSearchCV to tune the hyperparameters. As a result, this model is not recommended for training on this dataset, as demonstrated in the accompanying Jupyter notebook.

**7. Sentimental analysis**

Sentiment analysis, also known as opinion mining, is a field of natural language processing that aims to identify and extract subjective information from source materials, such as text or speech (Liu, 2012). The primary goal of sentiment analysis is to determine the attitude, sentiment, or emotional state of the text's author or speaker with respect to a particular topic or subject.

The goal of the sentimental analysis was to gather and analyse recent public opinions on beef prices using the Twitter API. To accomplish this, we requested and collected over 80 tweets through the API. We then applied various text processing techniques, such as converting all words to lowercase, removing punctuation, and removing stopwords and so on.

Finally, we applied a logistic regression model to fit the processed data, utilising either the TfidfVectorizer or CountVectorizer function, and achieved an accuracy of approximately 94%. This suggests that the logistic regression model was able to effectively classify the sentiment of the tweets.

**8. Conclusion**

In summary, through our study, we found that hypothetically there was no significant difference in cow and heifer prices between Ireland and Spain. However, there was a possibly significant difference in young bull prices between the two countries. Additionally, we observed an annual increase in beef prices around March for all beef categories, and noted that beef feeding prices have been on the rise since 2017, with a particularly steep increase after 2020. Our study also revealed that Ireland had higher beef production for cow and heifer compared to Spain, but that young bull production was rare in Ireland. Finally, we found that Linear and Logistic Regression models were effective for machine learning and sentiment analysis, achieving good accuracy, whereas the Random Forest model was not suitable for our data.

* **Version control link:**<https://github.com/alecfei/beef-price-analysis>

**References**

Einar Martin, A. (2021) *Parametric versus nonparametric tests*. Available at: <https://ledidi.com/academy/parametric-versus-nonparametric-tests> (Accessed: 8 January 2023).

Branco, P.A.B. (2020) *Food Production and Agriculture*. Canada: Delve Publishing.

Central Statistics Office (no date) Databases - CSO - Central Statistics Office. CSO. Available at: [https://www.cso.ie/en/databases/](https://www.cso.ie/en/databases/%20) (Accessed: 8 December 2022).

Central Statistics Office (2021) *Demographic Profile of Farm Holders - CSO - Central Statistics Office*. CSO. Available at: <https://www.cso.ie/en/releasesandpublications/ep/p-coa/censusofagriculture2020-preliminaryresults/demographicprofileoffarmholders/> (Accessed: 5 January 2023).

Croxton, F.C. (1905) ‘Beef Prices’, *Journal of Political Economy*, 13(2), pp. 201–216.

Department of Agriculture, Food and the Marine (2022) *EU Beef Carcase Classification Scheme*. Available at: <https://www.gov.ie/en/collection/bc95b-eu-beef-carcase-classification-scheme/> (Accessed: 17 December 2022).

Eldertech, M. (2017) ‘Designing Technology for Seniors - Color in User Interfaces for Elderly People’, *User Interfaces for Seniors*, 25 March. Available at: <https://eldertech.org/color-in-designing-technology-for-seniors/> (Accessed: 4 January 2023).

European Commission (2022) *CAP overview*. Available at: <https://agriculture.ec.europa.eu/common-agricultural-policy/cap-overview_en> (Accessed: 10 December 2022).

European Commission (2021) *EU country factsheets*. Available at: [https://agriculture.ec.europa.eu/system/files/2022-04/agri-statistical-factsheet-ie\_en\_0.pdf](https://agriculture.ec.europa.eu/system/files/2022-04/agri-statistical-factsheet-ie_en_0.pdf%20%20)  (Accessed: 15 December 2022).

Liu, B. (2012) *Sentiment Analysis and Opinion Mining*. Cham: Springer International Publishing (Synthesis Lectures on Human Language Technologies). Available at: <https://doi.org/10.1007/978-3-031-02145-9>.

Kahn, L. and Cottle, D. (2014) *Beef Cattle Production and Trade*. Collingwood, Vic: CSIRO PUBLISHING.

Reif, F. (2008) *Fundamentals of Statistical and Thermal Physics*. 56946th edition. Long Grove, Ill: Waveland Pr Inc.