

**MS986: Stochastic Modelling for Analytics**

**Agent Based Modelling Assignment**

**Investigating the Scottish Whisky Market**

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# **Introduction**

Scotch Whisky is required by law to be distilled and aged in Scotland using only three ingredients: cereals, water, and yeast; however, it is not a legal requirement for the ingredients to be from Scotland (Scottish Whiskey Association, 2019). This paper will aim to investigate different scenarios in relation to volume of imported cereals in Scotch whiskey production by modelling various scenarios through Agent-Based Modelling (ABM). The ABM enable insights to be derived from three different scenarios of volumes of imported cereals; these are fully imported, half imported, and none imported.

# **Background**

Whisky-making is thought to have started in Scotland as winemaking techniques spread from European monasteries; without grapes, monks utilised grain mash to create an early form of the popular spirit. The name itself, is derived from the Gaelic word uisge beatha, which loosely translates to 'water of life’. Scotch must be manufactured from malted barley, with many scotches using nothing more than barley, water, and yeast. Whole grains and different cereals can be used, as well as caramel colouring, in the recipe. The spirit must also be matured for at least three years in wood casks and have an alcohol by volume (ABV) of less than 94.8 percent. Finally, whiskey may only be called Scotch if it was manufactured entirely in Scotland (The Scotch Advocate, 2018). The reputation of Scotch whiskey is not bult on the origins of the ingredients, but rather on the traditional production methods and that production takes place in Scotland. There has never been a requirement for Scotch to use only Scottish grown cereals. The industry is, however, a strong supporter of Scottish agriculture with 85% of the barley used in production been sourced from Scottish farms. In 2014, the overall volume of cereals used in production at distilleries across Scotland was 64% (The Scotch Whisky Association, 2020).

If the Scottish government was to make it mandatory for distilleries to use only home-grown cereals, the sector could benefit from the unique selling point of provenance and traceability, while reducing carbon miles and enhancing Scotch Whisky's already stellar reputation. Unfortunately, this is not always the case, with Scots farmers frequently struggling to sell locally farmed grain while cereals are imported at cheaper rates from all over the world.

# **Objectives**

This paper presents an agent-based model (ABM) of the Scottish whisky industry market. Buyers and sellers are present within the model, who both aim to secure the best price possible when trading with each other. Through setting different parameters in the ABM, the paper will aim to investigate various scenarios of the Scottish whisky sector. Most notably, how different amounts of imported cereals can affect businesses and consumers. This will allow for an understanding of how following a comparative advantage model and importing 100% of the cereals used in production can influence revenue, profit, and whisky prices. From here, the paper will look to assess how the state of the economy and exchange rates can impact revenue and profit.

# **Model Results**

# **Overview of Results**

The model was simulated over six different scenarios, with the population of agents being set to 75 for both consumers and businesses in all simulations. Firstly, three simulations were run for each category of imported cereals, these are: ‘fully imported’, ‘half imported’, and ‘none imported. The parameter for whisky prices was set to ‘highly priced’ for all three simulations. No further changes were made to the parameters of the model, they were all set to a balanced approach. Consumers have been assigned a set number of whisky they wish to purchase, once the mean number is less than ten the model will stop. Secondly, various simulations will be conducted for the latter part of the analysis. A description of the parameters will be provided for each run.   
The data from the simulations was exported to a CSV file and loaded into Jupyter Notebook for the analysis.

# **4.2.1 Revenue and Profit**

Figure One shows the revenue and profit businesses generated across the three simulations, with all parameters set to a balanced approach in the model. The data plotted is the mean revenue and profit of all businesses. Each tick represents one trading day, with one trade attempted per day for each business and consumer.

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**Fig 1**. Revenue and Profit

The first graph of Figure One presents the revenue and profit of businesses during the simulation when cereals are fully imported. As observed from the graph, the greatest amount of profit is generated when cereals are fully imported from oversees. The following two graphs from Figure One, present simulations of half imported cereals and no imports of cereals, highlighting profits decrease when the volume of imported cereals decrease.

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**Fig 2.** Profits for each Volume of Imports

Figure Two further highlights the difference in profits across the three volumes of imports. Therefore, if whisky manufacturers seek to import cheaper cereals from oversees, they can benefit from cheaper costs of materials and increased profits.

# **4.2.2 Total Cereal Costs**

From the first graph in Figure Three, the mean cereal costs for business in all three scenarios can be observed. Unsurprisingly, the simulation of businesses using only home-grown cereals results in the greatest cost, of £97.3. The lowest cereal costs, of £29.3, were from the simulation where cereals were fully imported. It is important to note these costs were relevant to the amount of whiskey sold over the three simulations, which were extremely similar for all three runs, ranging from 533 to 540 units sold – this is illustrated in second graph from Figure Three.

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**Fig 3.** Total Cereal Costs and Total Sales for each Volume of Imports

# **4.2.3 Whisky and Willing to Spend Prices**

At the beginning of each simulation, both the consumers and businesses are assigned a price they wish to trade at. As expected, both the buyers and sellers come to a price they deem suitable and trade at that price. This suggests the behaviour of the agents is in line with normal market participant behaviour. However, it can be noted from all three graphs in Figure Four, the price is on a gradual downwards slope as the ticks (trading days) increase.

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**Fig 4.** Business and Consumer Trading Prices

**4.3 Further Simulations with Varying Parameters**

# **4.3.1 Economy and Exchange Rate**

For this simulation, parameters have been altered slightly to reflect a poor economic situation and weak exchange rates. Both the parameters ‘state of economy’ and ‘domestic currency state’ have been set to weak. Exchange rates are an important factor when trading internationally, therefore it is beneficial to assess the effect exchange rates can have on the whisky industry. In this run, whisky prices have been set to reflect a whole range of whisky prices you would expect in the market, ranging from the 10-year-old cheaper bottles to the older, more expensive collections. Finally, the volume of imported cereals has been set to fully imported, meaning all cereals are from abroad.

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**Fig 5.** Profit/Revenue and Trading Prices of Weak Economy/Exchange Rate

The first graph from Figure Five echoes the previous findings, with profit and revenue rising steadily over the tick periods. As predicted, profits are extremely high, due to the cheaper production costs with using imported cereals. A range of whisky prices were included in this simulation, meaning expensive bottles were present; this significantly contributed to higher revenue and profit levels, than seen previously. Revenue and profit reached £523,361 and £493,536 respectively.

The second graph from Figure Five follows a similar pattern to what was previously seen, with the price initially starting high and gradually becoming lowering over time. One key difference this time, is the trading prices for both agents spike in opposite direction at the end of the simulation. For the followingsimulation, parameters were changed to reflect a strong economy and healthy exchange rates. Thus meaning, the parameter ‘state of economy’ and ‘domestic currency state’ have been set to strong.

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**Fig 6**. Profit/Revenue and Trading Prices of Strong Economy/Exchange Rate

With a stronger economy and favourable exchange rates, revenue and profit soared in comparison to the previous simulation, when the economy and exchange rates were set to poor. In this round, revenue increased by 81.4% and profits by 76.7%. This suggests when the economy and exchange rates are strong, the Scottish whisky industry can expect to benefit from high revenue and profit. Whisky can be regarded as a luxury item, therefore when the economy and exchange rates are poor, less sales both domestically and internationally can be expected.

Trading prices for a weak economy and exchange rates initially followed a similar pattern as previously seen before, however in this case prices did not spike upwards and downwards at the end of the simulation. Therefore, prices remained more stable throughout.

As previously noted, when the country is facing a period of financial difficulty, revenue and profits remained low in comparison to when the financial outlook was positive; therefore, this reinforces the benefit of following a comparative advantage model, as the sector could keep raw material costs low when facing financial trouble throughout the business.

# **4.3.2 Agent Behaviour**

One final simulation was conducted, with trading behaviour of both agents been set to desperate. The state of the economy and exchange rates were set to weak, and the whisky prices were set to a mix of all. This run reflects a situation when the economy is financial trouble, with consumers desperately trying to get the most for their money, and businesses trying to gain sales. From graph one of Figure Six, profits and revenue were lower than previously seen, due to business offloading whisky at a cheaper price than usual, due to the period of financial difficulty. Trading prices followed an expected pattern, as both agents are acting desperately, the price has drastically decreased over time. Again, this further emphasis the benefit of importing more cereals, especially during a period when the country is in a financial downturn.

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**Fig 7**. Agent Behaviour – Trading Desperately

# **Conclusion**

The purpose of this agent-based model was to simulate the Scottish whisky market, with businesses and consumers trading whisky by exchanging money. The model allowed for insights to be derived from the data, with the intention of studying how different scenarios impacted the buyers and sellers. Overwhelming, the evidence from this study suggests the Scottish whisky sector could benefit from following a comparative advantage approach to importing cereals from oversees. This was evident from the increased revenue and profit for businesses when parameters were set to import 100% of cereals for production. In addition, the ABM allowed for an understanding of how the industry may perform when the economy and exchange rates are strong or poor. As expected, when the economy and exchange rates are strong, businesses generated high levels of revenue and profit, with whisky prices remaining high. On the other hand, when the economy and exchange rates were poor, the benefits of following a comparative advantage model were glaringly obvious, as this allowed for cereal costs to remain low, therefore maximising profits for the business.

Although there are clear benefits in terms of profit for businesses by importing more cereals, the reputation of Scotch whisky should be solemnly considered. If over time, the core ingredient of Scotch is no longer grown in Scotland, the reputation could be damaged as the association of Scotch whisky being Scottish may dwindle. This could have detrimental impacts on not only distilleries, but also farmers and the Scotland’s brand throughout the world.

# **Appendix One: Stochastic ODD Protocol**

# **6.1 Purpose**

The purpose of this model is to explore the possibility of requiring Scotch whisky to be made by only Scottish grown wheats, or alternatively following a comparative advantage model and increasing the import volume of wheats, to be used in the production of Scotch whiskey. The purpose of the agents within the model is to trade at the best possible price. The model will investigate how these different scenarios impact whisky prices and profit of businesses who selling Scotch whisky. Furthermore, the model will assess how different states of the economy and how the strength of exchange rates can influence business revenue and profit.

# **6.2 Entities, state variables and scales**

Entitles and State Variables

The entities within this model are consumers and businesses, both represented by turtles. Each agent has a state variable money, which for the consumers, holds the amount of money they must spend, and for the business, holds the amount of money they have gained from consumers. In addition, both agents have a state variable for their behaviour after a successful or unsuccessful trade. These two state variables are successful trade behaviour and unsuccessful trade behaviour. The purpose of these state variables is to allow for an adjustment in the asking or selling price of the agents.

Scale

For every tick, it represents one trading day, where one trade per agent is made each day.

Landscape

The landscape is a grid of 33x33 patches, coloured cyan. Each consumer is represented by a person figure, coloured purple. The businesses in the grid are represented by yellow houses. In the first tick, both consumers and businesses are placed randomly on the grid. After being placed, businesses will stay situated in that patch for the whole simulation. Consumers will move to the patch of a business to make a trade, if successful in trading they will move to another business and if unsuccessful, they will relocate themselves in the middle of the landscape until they make their next move to a business. Consumers are placed in the middle so those who were unsuccessful are easily identifiable.

# **6.3 Process overview and scheduling**

In each round (tick), the agents do the following:

The consumers will move to a business with the intention of purchasing one unit of whisky. Each consumer will have their ideal price they are willing to pay, and each business will have their ideal asking price for one unit of whisky. So, when a consumer arrives at a business they will assess if the price they are willing to pay is more than the asking price, if this is the case, they will make a purchase; however, if their price they are willing to pay is less than the asking price, they will move to the middle of the grid.

If the consumer was successful in making a purchase, they will decrease the amount they are willing to spend and if they were unsuccessful, they will increase their willing to spend amount. Similarly, businesses carry these actions too. If they are unsuccessful in making a sale, they lower their asking price and if they are successful, they will increase their asking price.

*Willing to Pay.* At the beginning of the simulation, buyers will be assigned a price they are willing to pay. This price will change depending on the success of their trades.

*Whiskey Price.* At the beginning of the simulation, sellers will be assigned an asking price for one unit of whisky. This price will change depending on the success of their trades.

# **6.4 Design concepts**

*Basic principles*

The basic top of this model is to investigate how different volume of imported cereals for Scotch whisky production can influence business profit, whisky prices and volume sold. Consumers within the model wishes to purchase 400 unit of whisky, they do this by finding a business who is selling whisky at a price they deem suitable for them.

*Emergence*

The model’s primary goal is to monitor how business profit and whisky prices are influenced by the volume of imported cereals used in the production of whisky.

*Adaptive Behaviour*

Adaptive behaviour is present within this model for both the consumers and businesses. Consumers decide to purchase one unit of whisky from a particular business or to decline the trade and move on to the next business. The decision to make a purchase or not, is decided by how much the consumer is willing to spend and this amount, is influenced by their previous encounter with a business. If in the previous encounter, the consumer was successful in purchasing one unit of whisky, they will lower the price they are willing to spend for the next business they arrive at. Conversely, if they were unsuccessful in making a purchase, they will increase the amount they are willing to spend.

This behaviour is similar for businesses. If they are successful in making a sale, they will increase their whisky price, and if they are not successful, they will lower their whisky price.

*Objectives*

The objective of each consumer is to purchase 550 units of whisky, while spending the least amount of money possible. On the other hand, businesses will aim maximise their whisky sales and generate high levels of revenue and profit.

*Prediction*

An agent’s price will be predicted depending on if they were successful or unsuccessful in making a trade.

*Interactions*

The interaction within this model takes place when a consumer arrives at a business and observes the asking price for one unit of whisky. From this, they will decide whether to make a trade or not. If the trade is unsuccessful, the consumer will move to the middle of the grid and then interact with another business.

*Stochasticity*

Stochasticity is present for both consumers and businesses. Randomness exists in how much the consumer is willing to spend and, in the business asking price. To avoid extremely low values, an initial value is given then a random number is added. Stochasticity is used in this model to replicate how businesses can have varying prices for similar products, and how consumers can have different amounts they wish to spend.

*Observations*

The view shows businesses, which are represented by yellow houses and consumers, which are represented by purple people. In addition, results can be observed from the plots within the model. These plots show the whisky prices and the profit and revenue the businesses have made. All plots update at every tick.

# **6.5 Initialisation**

The model begins by creating an equal number of consumers and businesses, which is determined by the user. Each business is given a random selling price and each consumer is assigned a random price they are willing to pay, this is influenced by the type of whisky being sold – the type of whisky on sale is decided by the user. In addition, the user determines the volume of imported cereals being used by the businesses in their production process; this volume impacts the overall profit of the business due to there being different cereal costs, depending on the volume of cereals imported. Furthermore, the behaviour of both the consumers and businesses can be set by the user; the two options are normal or desperate.   
Once the simulation begins, consumers will move to businesses and evaluate the asking price. The price the consumer is willing to pay is further influenced by their encounter with a business, if they are successful in purchasing whisky they will decrease their price, in hope of securing a cheaper trade in their next encounter. The opposite is true if they are unsuccessful. The business asking price is also further influenced by their interaction with a consumer, if successful in securing a trade, they will raise their price, if unsuccessful they will decrease their price.

*Input Data*

The model does not facilitate any input of external data.

# **6.6 Sub models**

There are multiple parameters within this model. Firstly, the population of agents is decided by the *n-population* slider - this results in an equal amount of both types of agents. This value is initially set to 75 but ranges from 1 to 150.

Secondly, the volume of imported cereals is determined by the *cereals-imported-quantity* button. There are three values, ‘none imported’, ‘half imported’, and ‘fully imported’. These values influence the profit of the business as the imported volumes have different prices.

Thirdly, whisky prices within the model can be determined by *whisky-prices* button. There are five whisky prices available: ‘Aged 10 Years – Moderately Priced’, ‘Aged 20 Years – Highly priced’, ‘Aged 30 Years – Expensive’, ’40 Years – Very expensive’, and ‘Mix of all prices’. An initial value is provided for each price and then a random value is added, the more expensive bottles of whisky have a higher initial value and random value. An initial value has been provided to avoid an extremely low price. The price set by the user will influence the revenue and profit of each business.

Lastly, the trading behaviour of both consumers and business can be set by the *trading behaviour* button. The two values for their behaviour are ‘normal ‘and ‘desperate’, The agent’s behaviour will influence how much of an adjustment in their asking price/willing to pay price after an interaction.

*Willing To Pay.* The price the consumer is willing to pay is directly influenced by which whisky price category has been set by the user when initialising the model.

*Whisky Price.* The business asking price for one unit of whiskey, which is influenced by the whisky price category that has been set by the user when int initialising the model.

*Revenue.* Businesses within the model calculate their revenue by adding together the whisky prices of the number of units of whisky sold.

*Profit.* Profit of the businesses is calculated by subtracting cereal costs and storage costs from revenue.

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