Assignment 2

Submitting Instructions

For this coursework, you will be asked to develop an agent-based model (ABM) in Python to simulate Bitcoin trading dynamics against GBP. You may use a notebook or an IDE of your choice, but all code must be submitted in a **single zip file** on **Learn**. A **PDF report** documenting your analysis and results is also required.

Introduction

This assignment involves developing agents with various trading strategies to analyze behavior in a simulated Bitcoin vs. GBP market. You may refer to an article by Cocco, Tonelli, and Marchesi[1] and other academic resources to support your understanding of agent-based models (ABM) in financial Bitcoin simulations. The main goal of this coursework is to make sure you know how to develop an ABM for a real-world financial scenario.

Goal: Build a functional ABM to explore different trading strategies and examine their impact on agent behavior and market dynamics. You will follow defined agent rules, implement market response functions, and evaluate trading performance across various agent types.

Additionally, keep in mind that you can use any research result or dataset (Google Scholar is your friend!) to model the agents, estimate parameters, and to validate your model.

Important: Everyone approaches ABM differently and creates different models. Therefore, you are expected to justify and explain all the assumptions you make and the reason for them in your report.

Task 1 – Agent Construction

Agents in this model hold both GBP and Bitcoin. Allocate an amount of b Bitcoin and g GBP to every agent at the start; all agents should start with the same amount of GBP and Bitcoin . To represent real-life scenarios, every 90 days additional Bitcoin amounting to 10% of the Bitcoin currently in circulation enter the market and those are assigned to agents, giving them an amount of Bitcoin proportional to those already owned following the Gibrat principle of preferential attachment (rich get richer).

Agents can only open a new position if they have closed their previous position (except for the initial position which can be initiated before previous close). To close a position in the model an agent needs to sell all the Bitcoin they obtained when they opened the position.

Task 1.1 – Define Chartists

Chartists seek profit in GBP through Bitcoin trades, following specific rules for opening and closing positions with specific weightings. Build the chartists following the rules and the

[1] Cocco, L., Tonelli, R., & Marchesi, M. (2019). An agent-based artificial market model for studying Bitcoin trading. *IEEE Access, 7*, 42908-42920.

weightings specified below:

1. Apply Opening & Closing Position Rules (5 marks)

- **Momentum-Based Rule**: Open a position if the Bitcoin price trend is upward for the last n days (i.e., prices increased consecutively). Close the position when the closing price shows a single downward movement after the series of increases. You can reopen a position again only if the trend is upward for the last n days.
- **Relative Strength Index (RSI) Rule**: Use the 14-day RSI, which signals buying (opening) when below 30 and selling (closing) when above 70:

$$\text{RSI} = 100 - \frac{100}{1 + \frac{\text{Average Gain}}{\text{Average Loss}}},$$

where Average Gain $= \frac{\sum \text{Gains}}{\text{Period Length}}$ and Average Loss $= \frac{\sum \text{Losses}}{\text{Period Length}}$. The $\sum$ Gains is the total of all positive price changes over the specified period (14 days), while $\sum$ Losses is the total of all negative price changes.

2. Apply Decision Weightings (5 marks)

Define 4 subtypes of Chartists with distinct rule priorities:

- High importance, 80% of an agent's decisions are based on the Momentum rule and low importance, 20% on the Relative Strength Index (RSI) rule
- High importance (80% of decisions) on RSI, low importance (20% of decisions) on Momentum.
- Balanced (50/50) weighting of decision making for both rules.
- Alternating rule usage depending on weekly market conditions; use Momentum strategy (100% of the time) and switch to the 14-day RSI strategy if the weekly volatility, defined as the standard deviation of 30-day daily returns, exceeds 2.5%. Once the weekly volatility falls back below 2.5%, return to using the Momentum strategy.

Discuss Expectations (5 marks)

Discuss the expected behavior and performance for each subtype, and justify any additional modifications. Which subtype do you anticipate will perform best under market volatility? Why? Which agents do you expect would accumulate the most wealth? Which agents will open and close the most positions?

Task 1.2 – Define Random Traders (5 marks)

Random traders operate without profit motivation and open or close positions randomly within their available Bitcoin and GBP holdings. They represent investors with no market analysis in their decision-making.

Describe the expected behavior of Random Traders. How does their activity differ from Chartists in this model? What market effect might result from such trades?

Task 1.3 – Implement Market Environment (10 marks)

Develop the market environment where agents can trade. Explain any assumption you make. For price updates, use Petrov's price response function[2]:

$$r_n(\Delta N_n) = S_n - S_{n-1} = \lfloor \alpha \cdot \text{sgn}(\Delta N_n) \sqrt{|\Delta N_n|} \rfloor,$$

where $r_n(\Delta N_n)$ is the price change at the step n, $\alpha = \frac{\sqrt{2}}{2}$ is the parameter limiting the minimum price shift, sgn(.) is the sign function, and $\lfloor . \rfloor$ is the floor function.

Task 2 – Running and Analyzing the Model

Task 2.1 – Model Execution and Parameter Tuning (7 marks)

Run your model from January 1, 2020, to November 1, 2024, varying parameter n (justify your choice of range). Analyze the behavior of the agents as n changes. Do agents with higher values of n exhibit fewer or more trades? What other conclusions can you draw form this analysis?

Task 2.2 – Performance Comparison (15 marks)

- **Ratio of GBP to Bitcoin Held**: Evaluate the proportion of wealth held in GBP versus Bitcoin for each agent type to understand their asset allocation strategies. Consider how this ratio changes over time and how that compares to the final ratio at the end of the simulation.
- **Total Wealth (GBP + Bitcoin)**: Asess the overall wealth of each agent type, combining both GBP and Bitcoin holdings to observe their financial performance.
- **Exposure Time**: Measure the percentage of time the agents have an open position in the market over the simulation period.
- **Win Rate**: Calculate the percentage of profitable trades for each agent type to understand their trading effectiveness and consistency in generating positive returns.
- **Maximum Drawdown**: Measure the maximum drawdown (the largest peak-to-trough decline) experienced by each agent type.

Interpret the differences in these 5 performance metrics across the four types of chartists. How do they compare with each other? How do the random traders compare with each subtype of chartists? Were the outcomes as you predicted? Why or why not?

Task 3 – Model Validation

Task 3.1 – Market Dynamics Validation (8 marks)

[2]Petrov, Vladimir. Essays on Directional-Change Intrinsic Time. Diss. University of Zurich, 2019.

Compare your model results with findings from Cocco, Tonelli, and Marchesi or other sources. Focus on agent wealth distribution, Bitcoin price movements, and trading volume trends. Discuss any differences in metrics and and how they might be affected based on model assumptions.

Task 3.2 – Comparison to Real-World Data (10 marks)

Discuss the changes in Bitcoin prices over the period by analyzing the log-returns. Compare the log-returns obtained from your model with those in the article and real-world values. Why do you think the prices in your model do (or do not) match published findings? How does the volatility (the degree of price variation) in your model compare to real Bitcoin price changes? Does your model show similar patterns of price jumps or drops as seen in actual Bitcoin data? Give examples.

Task 3.3 – Agent Behavioral Impact (5 marks)

Evaluate how differences in agent behavior (e.g., frequency of trades, risk tolerance) could affect market volatility in your model. How realistic do you find these behaviors, and what adjustments might improve accuracy?

Task 4 – Propose a New Agent Class

Task 4.1 – New Agent Design (5 marks)

Design a new agent class, citing relevant literature or online resources. Define their entry/exit rules and their decision logic. To fully define this new agent class take into account the four steps for agent design we have seen in class.

Task 4.2 – Market Impact Analysis (7 marks)

Analyze the impact of your new agent class on the market. Describe how the addition of this agent type changes overall market trends, volatility, or price stability. How does it affect the monthly earnings and wealth accumulation of the other agents?

Task 4.3 – Performance Discussion (8 marks)

Compare the new agent class with chartists and random traders across the different performance metrics. Discuss the advantages and disadvantages of your agent and evaluate their effectiveness in volatile conditions. Could this agent type reflect real trading behaviors? Why or why not?

Task 5 – Summary Report (5 marks)

Write a brief report (approx. 250 words) summarizing the results, performance of each agent type, model limitations, and possible improvements. This report should include any limitations of the ABM you created (anything you think affected your results), performance of different agents, any improvements you can think of, etc.

This report should be the last part (Task 5) of your PDF file. You still need to answer and discuss all the tasks above independently from the summary report. The 250-word limit is only for Task 5.