FINAL PROJECT

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Title: Availability heuristic in the Real Business Cycle Model

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ABSTRACT

This research proposes a macroeconomic model that extends the Real Business Cycle framework by incorporating the availability heuristic, a cognitive bias in human decision-making. This model recognizes that agents may be subject to attentional bias, which can result in suboptimal consumption and investment choices. Specifically, it examines how the availability heuristic, whereby individuals place greater weight on easily and recent retrievable information, can lead to inefficient allocation of resources. The model proposed assumes that agents use current productivity to predict future aggregate productivity, following an AR(1) process, despite the actual aggregate productivity following an AR(2) process.

However, given the complexity inherent in solving these models, numerical simulations are not attempted. Instead, the focus is on developing a theoretical framework to explain how attentional bias may affect economic outcomes within the RBC model. The difficulty in solving these types of models arises from their nonlinear and dynamic nature, as well as the intricate interplay of behavioural factors.

Consequently, the contribution is limited to proposing a theoretical model and providing a nuanced understanding of the potential implications of incorporating behavioural factors into macroeconomic analysis. This work adds to the growing body of literature in behavioural macroeconomics, highlighting the need to consider human behaviour when examining economic outcomes.

Keywords: Real Business Cycle model, Behavioural economics, Attentional bias, Availability heuristic, Economic efficiency, Autoregressive Model.

RESUMEN

Esta investigación propone un modelo macroeconómico que amplía el marco del Ciclo de Negocios Reales al incorporar la heurística de disponibilidad, un sesgo cognitivo en la toma de decisiones humanas. Este modelo reconoce que los agentes pueden estar sujetos a sesgos de atención, lo que puede resultar en elecciones subóptimas de consumo e inversión. Específicamente, examina cómo la heurística de disponibilidad, mediante la cual los individuos otorgan mayor peso a la información fácilmente disponible y reciente, puede llevar a una asignación ineficiente de recursos. El modelo propuesto asume que los agentes utilizan la productividad actual para predecir la productividad agregada futura, siguiendo un proceso AR(1), a pesar de que la productividad agregada real sigue un proceso AR(2).

Sin embargo, dada la complejidad inherente en la resolución de estos modelos, no se intentan simulaciones numéricas. En su lugar, el enfoque se centra en desarrollar un marco teórico para explicar cómo el sesgo de atención puede afectar los resultados económicos dentro del modelo del Ciclo de Negocios Reales. La dificultad en resolver este tipo de modelos surge de su naturaleza no lineal y dinámica, así como de la intrincada interacción de los factores conductuales.

En consecuencia, la contribución se limita a proponer un modelo teórico y proporcionar una comprensión matizada de las posibles implicaciones de incorporar factores conductuales en el análisis macroeconómico. Este trabajo se suma al creciente cuerpo de literatura en macroeconomía conductual, resaltando la necesidad de considerar el comportamiento humano al examinar los resultados económicos.

Palabras claves: Modelo de Ciclo Económico Real, Economía Conductual, Sesgo de atención, Heurística de disponibilidad, Eficiencia económica, Modelo Autorregresivo.

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I. INTRODUCTION

Behavioural economics has been an area of growing interest in recent years and economists have sought to develop new models that more accurately capture the complexity of real-world decision-making. One of the key insights of this field is that individuals do not always behave in perfectly rational ways when making economic decisions as we have been assuming when solving macroeconomic models. Instead, they are often subject to a range of cognitive biases that can lead to suboptimal choices and outcomes.

One important attentional bias is the availability heuristic, which is the tendency for individuals to place greater weight on easily accessible information, often derived from recent or vivid events, when making judgments or decisions. This bias can lead individuals to overestimate the possibility of rare and recent events and to underestimate the likelihood of more common and long-term events, which can result in inefficient allocation of resources.

In this paper I propose a new macroeconomic model that extends the Real Business Cycle (RBC) framework by incorporating the availability heuristic. The RBC model is a commonly used tool in macroeconomics that seeks to explain fluctuations in output and employment over the business cycle. However, this model does not account for the role of psychological factors in economic decision-making assuming perfectly rational behaviour.

The aim of this study is to investigate the impact of the availability heuristic on consumption and investment choices within the RBC model. I will investigate the impact of this bias and present a theoretical framework that accounts for the influence of attentional bias in economic decision-making and its potential consequences for resource allocation efficiency. Given the complexity of the models involved, we focus on constructing a theoretical model, rather than conducting numerical results.

To provide a more detailed overview of our paper, we begin with a detailed literature review of the historical development of the Real Business Cycle (RBC) model and behavioural economics. I then dig into the concepts of behavioural economics and the RBC model, outlining and discussing their limitations. Highlight the model and its assumptions, including the representative agent assumption, the rational expectations hypothesis, and the efficient market hypothesis. We also explore the critiques of the model and how they have motivated the development of alternative frameworks that incorporate behavioural factors., despite its success

in explaining business cycle fluctuations, fails to account for important aspects of human behaviour, such as the influence of psychological biases.

Furthermore, I will attempt to suggest a possible model that capture the effect of attentional bias in the context of the RBC framework. Beginning by introducing the concept of attentional bias and its impact on decision-making, focusing on the availability heuristic and its implications for resource allocation. We then propose a theoretical extension to the RBC model that incorporates attentional bias, emphasizing the importance of integrating behavioural factors into macroeconomic analysis.

Finally, we explore the implications of attentional bias on wealth, consumption and investment, illustrating how this bias may lead to suboptimal resource allocation and macroeconomic outcomes. I will examine how attentional bias may result in the overvaluation of recent events and the undervaluation of long-term trends, leading to inefficient investment and consumption decisions.

In this way, this study aims to contribute to the growing body of literature on behavioural economics and emphasizes the importance of considering cognitive biases in macroeconomic analysis. By proposing a theoretical framework that integrates attentional bias into the RBC model, we provide a more realistic representation of human decision-making and its impact on macroeconomic outcomes. We hope our findings will stimulate further research in this area and provide insights for policymakers and economists seeking to improve the understanding of economic behaviour.

II. Literature Review

The study of economics has always been interested in how individuals make decisions in order to allocate resources. However, the traditional assumption of rational behaviour has been challenged in recent years, leading to the emergence of a new field of study: behavioural economics. Behavioural economics is concerned with how psychological factors can influence economic decision-making, providing new understandings into the behaviour of economic agents and the implications of these behaviours for macroeconomic outcomes.

In this literature review, I will examine the Real Business Cycle (RBC) model and the historical development of behavioural economics, two areas of study that have had a significant impact on modern macroeconomics. Beginning by tracing the historical development of the RBC model, examining its theoretical foundations and key insights. I will then move on to the historical development of behavioural economics, exploring its roots in psychology and its evolution into a distinct field of study within economics.

2.1 Historical development of the Real Business Cycle model

The Real Business Cycle (RBC) model is a macroeconomic model that aims to explain the fluctuations in real economic activity over time based on neoclassical growth theory. The model emerged in the late 1970s as a response to the limitations of traditional Keynesian and monetarist models, which were unable to account for the observed volatility and persistence of macroeconomic variables.

Kydland and Prescott (1982) were the first to introduce the RBC model in a per titled "Time to Build and Aggregate Fluctuations." Their model emphasized the role of technology and capital accumulation in driving long-run economic growth. In the RBC model, fluctuations in economic activity are caused by exogenous shocks to technology that affect the productivity of firms and the incentives of households to work and save.

The RBC model gained significant attention and was further developed and improved by following economists, including Long and Plosser (1983), King and Rebelo (1993), and Uhlig (1997). One of the key contributions of the RBC model was to show that fluctuations in real

economic activity are driven by real factors, such as technology shocks and changes in labour supply, rather than nominal factors, such as monetary policy and inflation.

2.2 Historical development of behavioural economics

Behavioural economics on the other side, is a field that has gained significant attention and popularity over the past few decades, with researchers increasingly recognizing the limitations of traditional neoclassical economics in explaining real-world phenomena. Traditional economics assumes that individuals are rational, self-interested actors who make decisions based on complete and consistent information. However, this assumption has been criticized as being unrealistic and not accounting for the cognitive and emotional biases that influence decision-making.

The origins of behavioural economics can be traced back to the 20th century when the concept of bounded rationality was introduced by economist Herbert Simon. He argued that individuals have limited cognitive abilities and are not capable of processing all the information available to them, which leads to suboptimal decision-making. However, it wasn't until the 1970s that behavioural economics began to emerge as a distinct field of study.

One of the pioneers of behavioural economics was Daniel Kahneman, who, along with Amos Tversky, developed prospect theory in the 1970s. Prospect theory challenged the traditional assumption of rationality by showing that individuals make decisions based on the potential for gains and losses rather than the final outcome. The theory was revolutionary and cleared the path for the advancement of behavioural economics as a discipline.

In the 1980s and 1990s, behavioural economics continued to grow, with researchers exploring various cognitive and emotional biases that affect decision-making. One such bias is the endowment effect, which was first introduced by Richard Thaler. The endowment effect refers to the tendency for individuals to value objects they own more than identical objects they do not own, which again, can lead to suboptimal decision-making in markets. Another important development in behavioural economics was the introduction of the concept of mental accounting by Thaler in the 1980s. Mental accounting refers to the tendency for individuals to categorize and evaluate economic outcomes based on subjective criteria rather than objective criteria.

In the 2000s, behavioural economics gained even more attention, with the awarding of the Nobel Prize in Economics to Kahneman in 2002. This recognition helped to legitimize the field and attract even more researchers to the study of behavioural economics. Since then, research in behavioural economics has expanded to cover a wide range of topics, including consumer behaviour, decision-making in financial markets, and public policy.

III. Theorical Framework

The primary objective of this paper is to propose an extension to the Real Business Cycle (RBC) model by incorporating the availability heuristic. To achieve this goal, the first step will be to provide an in-depth explanation of the concept of behavioural economics, highlighting its differences from traditional economics. This will help establish a strong foundation for understanding the potential implications of incorporating cognitive biases into economic models.

I will then solve the simplified version of the RBC model to lay the groundwork for comprehending the more complex model that will be developed later. This will enable us to understand the fundamental principles of the RBC model and the ways in which it can be enhanced by integrating behavioural economics.

3.1Behavioural economics

Behavioural economics revolutionizes traditional economic theory by incorporating psychological and sociological factors that influence human behaviour. It acknowledges that individuals are not always rational decision-makers, and their actions are shaped by cognitive biases, emotions, and social norms. This interdisciplinary approach recognizes the importance of understanding these specific behaviours to develop models that quantitatively capture their impact on the economy. By integrating insights from psychology and sociology into economic analysis, behavioural economics enhances our understanding of economic behaviour and offers a more realistic depiction of how individuals make choices in economic contexts.

One of the most relevant models of behavioural economics is Prospect Theory, which was already introduced in the literature review section of this paper. This model of decision-making explains how individuals evaluate and choose between different options, suggesting that individuals are risk-averse when it comes to gains, but risk-seeking when it comes to losses. Another important concept is Loss Aversion, which is the tendency for individuals to experience a greater psychological impact from losses than from gains, leading them to be more willing to take risks to avoid losses than to achieve gains.

Nudge Theory is another concept that suggests that individuals can be encouraged to make better decisions by modifying the way options are presented to them. By changing the default option in a certain way, policymakers can "manipulate" individuals towards making more

beneficial decisions, without restricting their freedom of choice. A common place to find this effect is at groceries stores where they place products that have a higher interest of selling at eye-level, this can encourage individuals to make choices without forcing them to do so.

Additionally, Availability Heuristic is a cognitive bias where individuals judge the likelihood of an event based on how easily they can recall similar events from memory. This means that individuals may overestimate the probability of rare or recent events, simply because they are more memorable. We can acknowledge this in individuals that may be more afraid of flying than driving, even though driving is statistically more dangerous, because plane crashes are more widely publicized and memorable.

This are just a few of all the different types of human behaviour that have a direct or indirect effect to consumption and investment choices. In this study, I will focus on the availability heuristic, as there are not many studies relating this effect to economics.

While behavioural economics has gained popularity in recent years, it is not without its critics. Some economists argue that it is not a coherent as it relies too heavily on anecdotal evidence and lacks clear theoretical foundations. Others argue that it overemphasizes the role of irrational behaviour and reduces the importance of rational decision-making and market efficiency. Despite these criticisms, behavioural economics has contributed to a richer and more diverse set of economic models. By acknowledging the limitations of traditional models and incorporating insights from other disciplines and has opened new possibilities for research and policy analysis in macroeconomics.

3.2 Business Cycle and the RBC model*

* This section follows Chapter 3 “Business cycles” in Macroeconomics III lecture notes (2020) by Vahagn Jerbashina and Chapter 9 in Doepke et al. (1999) and King and Rebelo (1999).

For a better understanding of the basic Real Business Cycle model, it essential to first understand what business cycles are so, with that said, business cycles are the fluctuations in aggregate output and other economic activity, such as unemployment and trade, over the medium term. In an economy, medium-term is typically associated with a period of several months or years. These fluctuations can be both upward and downward, with upward changes in output referred to as economic booms and downward changes as economic busts or recessions. When recessions are relatively long-lasting, they become the feared economic recessions. Fluctuations are measured relative to the long-term growth trend of output and are very unpredictable.

The study of business cycles is a major topic in macroeconomics. Economists have been researching business cycles for a long time, dating back to Adam Smith and David Ricardo. However, there is a lot of disagreement among economists about what causes business cycles and how to fix them. This topic is so important that economists even have different schools of thought about it. The classical and neo-classical schools of thought attribute business cycle fluctuations to exogenous processes that affect aggregate output.

The economy can experience fluctuations in output and other aggregate variables due to different types of shocks. One such shock is the technology shock, which can happen when there are technological changes that affect the production process and increase productivity. Weather shocks can also affect output, particularly in agriculture and tourism industries that rely heavily on weather conditions. Monetary shocks are another type of shock that can affect output when changes in money supply and inflation occur. Political shocks can also influence the economy through changes in public expenditure and regulations.

The Real Business Cycle model

The Real Business Cycle (RBC) model is a macroeconomic model that explains fluctuations in output and employment in terms of changes in productivity, as well as changes in the supply and demand for labour. It is a dynamic general equilibrium model that views the economy as a complex system of interacting agents, where markets clear and prices adjust to ensure that all resources are optimally allocated.

The RBC model suggests that changes in productivity, which reflect changes in technology or the efficiency with which resources are used in production, are the primary source of economic fluctuations. These productivity shocks are modelled as stochastic processes that are assumed to be the only source of fluctuations in the economy. The other sources of economic fluctuations that we just saw, such as monetary policy or fiscal policy, are assumed to have little or no effect on the real economy. The model is based on several key assumptions that are essential for its analysis and empirical relevance:

1. Rational expectations: It assumes that economic agents have rational expectations, meaning that they form their expectations about future economic variables based on all available information, including past and current economic data. This implies that agents do not make forecasting errors, and that they adjust their expectations immediately when new information becomes available.

2. Competitive markets: Assumes that all markets in the economy are perfectly competitive, meaning that no single agent can influence prices or quantities in any market. This assumption implies that agents are price takers and that market outcomes are determined by the intersection of supply and demand.

3. Complete markets: The RBC model assumes that all markets are complete, meaning that all possible assets can be traded in all possible states of the world. This assumption implies that there are no restrictions on trading, and that agents can hedge against all possible risks by buying and selling appropriate assets.

4. Imperfections: Which assumes that there are no frictions in the economy, such as transaction costs, imperfect information, or imperfect competition. It implies that agents can participate in economic activities without any costs, that they have perfect information about economic variables, and that they have no barriers to entry or exit in any market.

5. Representative agent: The RBC model assumes that there is a single representative agent who maximizes his or her lifetime utility by choosing consumption, labour supply, and investment decisions. This assumption implies that all agents in the economy have identical preferences and face identical economic constraints.

6. Cobb-Douglas production function: The RBC model assumes that the economy produces a single final good using labour and capital as inputs, and that the production function has a constant returns to scale Cobb-Douglas form. This assumption implies that output is proportional to the product of labour and capital, raised to a constant power.

7. Flexible prices: The RBC model assumes that all prices in the economy are flexible, meaning that they can adjust immediately to changes in supply and demand conditions. This assumption implies that changes in economic conditions, such as changes in technology or productivity, are reflected immediately in market prices.

8. Efficient market clearing: The RBC model assumes that all markets clear efficiently, meaning that all agents who are willing and able to engage in economic activities can do so. This assumption implies that there are no shortages or surpluses in any market, and that all resources are allocated efficiently across the economy.

The RBC model is typically expressed as a system of nonlinear, dynamic equations that describe the behaviour of agents and markets over time. These equations capture the interdependent relationships between key macroeconomic variables, such as output, consumption, investment, and labour supply. The model is often solved using numerical methods, which involve simulating the behaviour of the system over time under different parameter values and initial conditions which we are going to solve further in this section.

The RBC model has been subject to extensive empirical testing, with mixed results. Some studies have found that the model is able to explain a significant portion of the observed variability in economic activity, while others have found that it is too simplistic to capture the complexity of real-world economic phenomena. One criticism of the RBC model is that it assumes away many important features of the real world.

In recent years, there has been growing interest in extending the RBC model to incorporate insights from behavioural economics. Behavioural economics challenges the assumptions of traditional economics by acknowledging that individuals are not perfectly rational decision-makers, and that their behaviour is influenced by a variety of cognitive biases, emotions, and social norms. By incorporating these insights into the RBC model, researchers hope to develop a more nuanced understanding of economic behaviour, and to better account for the complex interplay between economic variables and human behaviour.

IV. **Model Proposed**

4.1 The Real Business Cycle mode: Recursive competitive equilibrium

For a better understanding of the model that I will propose, there is the need to develop the basic RBC model but, in its traditional form, is often presented from the point of view of a planner who optimally allocates resources across sectors and agents to maximize social utility. This centralized decision-making approach simplifies the analysis by abstracting away from the complexities of decentralized decision-making and market interactions. However, when incorporating behavioural agents into the model, it becomes more appropriate to describe the RBC model in terms of a competitive equilibrium, with that being said, I am now going to explain he Basic Real Business Cycle model but not from the point of view of a planner, as is usually taught, though, I will adapt the explanation of the model so we can understand the basics of this model and also so that it is more useful to understand my proposed model later on where I introduce the availability heuristic.

A competitive equilibrium framework represents a decentralized market setting where agents act independently, making decisions based on their individual optimization problems while considering their own utility subject to other constraints (like the budget of the household). Prices and quantities adjust in response to market forces, ensuring that aggregate demand equals aggregate supply in each period.

I am first going to solve the firm's problem as it is like the planer problem, considering the Cobb-Douglas production function:

$$F(K, L) = zK^{\alpha}L^{1-\alpha}$$

Where F(K,L) represents the production level (or total output), *K* and *L* represents the quantity of capital and labour input used in the production process, *z* is the total factor productivity or the efficiency of converting inputs (in this case, capital and labour) into outputs and α being the elasticity of labour ($0 \leq \alpha \leq 1$).

The aggregate productivity (*z*) moves according to an autoregressive process of order 1 (AR(1)), this is what make the model dynamic over time as the current value of *z* is related to the previous value of this variable (as it has order 1).

$$log\,(z_{t+1}) = \rho log\,(z_t) + \varepsilon_t,\ \ \varepsilon_t \overset{i.i.d.}{\sim} (\mu, \sigma^2)$$

Where $z_t$and z_{t+1} are the aggregate productivity at time *t* and *t+1* respectively, ε_t is a random variable that is independent and identically distributed (i.i.d.) called error term and follows a normal distribution with μ and σ^2 representing the average and the variance.

The parameter ρ is the autoregressive coefficient, which determines the strength and direction of the relationship between $z_t$and z_{t+1} .It represents the persistence or memory of the AR process, in other words, it represents the importance or the impact of the current level of productivity (z_t) does to the future one (z_{t+1}).

Logs are employed in this case to transform the variables in the autoregressive process into a logarithmic form, enabling the analysis of relative changes and facilitating the interpretation of the coefficients as elasticities.

Now we maximize the profit of the firm by subtracting from the production function, the total cost that it would have to pay in other to produce:

$$\max_{K,L} zK^{\alpha}L^{1-\alpha} - wL - RK$$

Where *w* is the wage that the firms pays to every unit of labour and *R* is the rental rate for every unit of capital. To maximize the profit (π), we do the firs other condition (FOC) by deriving it with respect the capital and labour:

$$[K]:\ R = \alpha z\left(\frac{K}{L}\right)^{1-\alpha}$$

$$[L]: w = (1-\alpha)z\left(\frac{K}{L}\right)^{\alpha}$$

For simplicity, we assume that populations size is 1 and households supply labour inelastically. Therefore, labour will be constant and exactly 1 for all time periods. We now can rewrite the equations form the firm's FOC:

$$R(K,z) = \alpha z K^{1-\alpha}, \quad (1)$$

$$w(K,z) = (1-\alpha) z K^{\alpha}, \quad (2)$$

These functions determine the prices in each time period of the return to capital and the wage, meaning that, when we know the capital of the firms and their factor of production, we could know what would the prices be.

There is a connection between the capital rental rate (R) and the interest rate received by the household (r). This equation shows that the capital rental rate (R) is equal to the interest rate received to the household (r) plus the capital depreciation rate (δ). This depreciation represents the rate at which capital depreciate over time so $\delta \in (0,1)$.

$$R(K,z) = r(K,z) + \delta, \quad (3)$$

To summarize this first part of the RBC model, the aggregate state of the economy is represented by the variables K and z. These two variables completely summarize the aggregate state of the economy.

The fact that the aggregate state of the economy is given by (K, z) implies that, any two time periods in which the aggregate state (K, z) is the same will exhibit identical behaviour in terms of production and factor prices. This is because changes in K and z directly impact the rental rate of capital, the wage rate, and subsequently influence the decisions of firms and households in the economy.

In this competitive equilibrium formulation of the RBC model, households play a crucial role as they act as suppliers of labour and capital . They make consumption decisions to maximize their utility, subject to their intertemporal budget constraint.

To represent the household's problem, I will use the Bellman equation (named after Richard Bellman) as it is a fundamental concept for dynamic models. So, this equation will represent

the optimization problem faced by the household as it provides a recursive relationship that allows the household to make decisions regarding consumption and savings over time to maximize its lifetime utility.

$$V(a, K, z) = \max_{c, a'} \{u(c) + \beta E_{z'}[V(a', K', z')|z]\}$$

To understand more deeply what these equations is telling us, let's look at it by sections:

- *V(a,K,z)* is called the household's value function which measures the discounted lifetime utility of a household. It depends on the household's current assets (*a*), aggregate capital (*K*).

- The function *u(c)* is the utility function, which quantifies the satisfaction (or utility) the household gets form consuming a giving amount of consumption *(c)* so, in this case, the only source of satisfaction that the household can get is by consuming, because we expect to have a positive relation between the level of consumption and utility (if consumption increases, the utility will also increase).

- The variable *a* is the amount of current assets (time t) and *a'* represents the level of assets in the next period (time t+1).

- The parameter β is the discount factor, it reflects the household's preferences for current versus future consumption. It quantifies how much weight the household places on future utility compared to present utility. A higher value of β implies that the household values future utility and is more patient or forward-looking in its decision-making. This discounting reflects the time value of money and captures the household's willingness to trade off current consumption for higher future consumption. Therefore, as the beta increases, agents place a greater weight on future utility compared to situations with a lower beta.

- The value function *V(a', K', z')* represents the discounted lifetime utility of the household in the next period, given its choices of consumption (c) and assets (a') in the current period. It depends on the state variables in the next period, which are the assets (a'), aggregate capital (K'), and production factors (z').

- The term $E_{z'}[V(a', K', z')|z]$ represents the expected value function of the household in the next period ($V(a', K', z')$) given the amount of the production factors of the current

state (z). In other words, this expectation represents the household's best estimation about what the future will look like if they just know today's production factor.

By solving the Bellman equation, the household aims to maximize the sum of its current utility ($u(c)$) and the discounted future utility $V(a', K', z')$. This maximization is obtained over the possible choices of consumption (c) and assets (a').

Uncertainty is an important aspect of the representative household's decision-making process. Specifically, the household lacks complete knowledge about the future aggregate productivity level (z'). However, it does possess information about the distribution of z', which is influenced by the current value of the productivity level (z) of the economy as we have seen in the previous AR (1) function previously. To express this uncertainty, the household adopts a strategy based on the expected value of its lifetime utility in the next time period ($E_{z'}[V(a', K', z')|z]$).

Therefore, the value function makes a relationship that connects the present and future periods. By solving the equation iteratively, starting from a given initial condition, the household can determine the optimal decisions at each point in time by considering the uncertainty in future values functions with a goal of maximizing lifetime utility.

As we have seen the concept of aggregate state of the economy when solving the firm's problem for the household side, the state of the household refers to its current situation at a particular point in time. It is described by two variables: the household's current level of assets (a) and the economy's aggregate state, which includes the level of capital (K) and the production factors (z). These variables together capture all the relevant information about the household's circumstances.

The important thing to note is that if the state of the household is the same at two different points in time, the household will make the same decisions and have the same level of satisfaction in both periods. In other words, the state variables completely summarize the household's situation, and knowing them allows us to understand the household's choices.

Once we have the value function of the household, we cannot yet solve the maximization optimisation problem as household's are subject to a budget constraint and other functions and laws which I will now explain.

When talking about a budget constraint we define it as the restriction in allocation of its available resources (or income) between consumption and savings. In this case, expenditures are given by consumption and assets taken to the next time period, and income is given by wage payments and assets. The budget constraint also reflects the idea that the household's does not consume or save more than total available resources that they own.

We can first define the income of a certain period as:

$$Y = c + I, \tag{4}$$

This equation matches the amount of income (*Y*) that the household is going to have (at a certain period of time) to the amount of expenditures it is going to charge at that same period. We assume that the total income is going to be the sum of the wage (*w*) times the amount of hours work (*L*) plus the returns of the assets at the last period ($a+ar(k,z)$).

$$w(K,z) + [1 + r(K,z)]a = c + a', \tag{5}$$

As we did with equations (1) and (2), we normalize the amount of labour to 1 meaning that the total wage earned is going to be the same as the actual wag rate. Moreover, and for clarification, there is no need to do the expectation of the returns of the assets ($E[1 + r(K,z)]a$) as the amount gained from the assets is known because the household know the amount of capital that firms need (*K*), the productivity (*z*) and the depreciation rat (δ) so, following equations (1) and (3), we conclude that the interest rate that received the household is known because is determined by the aggregate state of the economy.

$$E\{[1 + r(K,z)]a|r,a\} = [1 + r(K,z)]a$$

Realize that the budget constrain also has into consideration the option of having savings, meaning that households doesn't have to consume all their income necessarily, they also have the option of saving. Considering the definition of saving (*s*) as the difference between the amount of assets that you will have in the future minus the amount of assets you currently own and the rate in which these assets are depreciated (δ).

$$s = a' - (1 - \delta)a$$

So, in the budget constraint (equation 4), savings are taking implicitly as the difference among assets that the household own and, as all the saving have a return rate of *r*, this means that all saving are invested so, in this economy that I am proposing, savings equals investments (*I*).

$$I = s$$

I will now describe how does the capital change over time defining the law of motion for the aggregate capital as a new function *h*, where the exogenous variables will be the level of capital and productivity at the previous time period:

$$K' = h(K, z)$$

In this case, as household know the law of motion, they have knowledge of how the aggregate capital will evolve over time. That's why, they can make a precise expectation about the future level of capital (so it will no longer be an expectation as they know exactly the value of the variable) and they will now, thanks to the law of motion, have into consideration the impact of their decisions on the evolution of the aggregate capital when they optimally chose the level that they want to consume or invest.

Notice that, as this basic RBC model uses a first order autoregression (AR(1)), households, in order to know the future level of capital, they only need the current value of aggregate productivity (*z*) and current level of capital (*k*). We will see later on that the law of motion is going to change if we add more orders to the autoregression function.

Finally, in order to ensure the long-term sustainability of the economic model, it is crucial to incorporate a no-Ponzi condition. This concept refers to the avoidance of unsustainable borrowing or debt accumulation by the economy, whereby it does not rely on continually accumulating debt to finance its present consumption or investment.

An option to incorporate the no-Ponzi condition into the model is to enforce the constraint that future asset values must be higher or at least equal to zero.

$$a' \geq 0$$

This condition acts as a safeguard, ensuring that households make prudent choices regarding asset accumulation, consumption, and investment, thereby maintaining sustainability in the long run.

By adhering to the no-Ponzi condition, the model ensures that the economy does not fall into a situation of excessive debt and financial instability. Instead, it promotes responsible decision-making, encouraging households to prioritize saving and investment over unsustainable borrowing. This constraint serves as a crucial safeguard, contributing to the overall stability and viability of the economic system.

As I already mentioned at the introduction, the inclusion of iterations and AR(1) functions introduces significant complications, which makes it challenging to obtaining a closed-form solution. These complexities appear due to the interdependencies between variables and the sequential nature of the decision-making process.

That's why I will define two new functions, called the policy function, that represents the solution of the optimization problem obtained by solving the household maximization problem:

$$V(a, K, z) = \max_{c, a'} \{u(c) + \beta E_{z'}[V(a', K', z')|z]\}$$

Subject to:

The budget constraint: $w(K, z) + [1 + r(K, z)]a = c + a'$

The No-Ponzi condition: $a' \geq 0$

Law of motion of capital: $K' = h(K, z)$

And the AR(1): $log\,(z_{t+1}) = \rho log\,(z_t) + \varepsilon_t,\ \varepsilon_t \overset{i.i.d.}{\sim} (\mu, \sigma^2)$

These functions, denoted as $g_c(a, K, z)$ and $g_{a'}(a, K, z)$, represent the optimal choices made by a household in terms of consumption and assets, respectively, when the household is in a particular state (a, K, z).

The policy function $g_c(a, K, z)$ represents the optimal consumption choice of a household in state (*a, K, z).* It tells us the amount of consumption that the household should choose to maximize its current utility plus the discounted lifetime utility in the future, considering its current level of assets, the aggregate capital, and the productivity factor.

Similarly, the policy function $g_{a'}(a, K, z)$, represents the optimal choice of assets to be taken to the next time period by a household in a specific state (*a, K, z*). It indicates the amount of assets that the household should hold or accumulate for the future, given its current assets, the aggregate capital, and the productivity factor. The function $g_{a'}(a, K, z)$, tells the household how much of its available resources should be for future periods.

Once we obtain the optimal solutions from both firms and household's sides of the economy, we can proceed to solve the model and identify the competitive equilibrium. This equilibrium represents a set of conditions that guarantee a state of balance in the economy, where all agents make optimal decisions based on the current prices, resource allocations and the capital and labour market clear. To establish a competitive equilibrium, the model must satisfy the following conditions:

- Price functions: The prices, denoted as *w(K, z)* and *R(K, z),* are determined based on the firm's first-order conditions (equations 1 and 2). These conditions represent the optimization problem faced by the firm, where it maximizes its profit by choosing the optimal levels of capital (*K*) and production factor (*z*).

- Interest rate: The interest rate, denoted as *r(K, z)*, is determined by equation (3). It represents the return received by the household on its savings or investments. It includes the capital rental rate *R(K, z)* and a constant depreciation term δ, which represents a risk-free return.

- Value function and policy functions: The value function *V(a, K, z)* and policy functions $g_c(a, K, z)$ and $g_{a'}(a, K, z)$, are solutions to the household's problem. The household aims to maximize its discounted lifetime utility by choosing the optimal consumption (*c*) and assets taken to the next period (a') given its current level of assets (*a*), the aggregate state (*K, z*), and the distribution of future productivity levels (z'). The value function represents the maximum utility achievable, while the policy functions specify the optimal choices of consumption and assets.

- Capital market clearing: The equilibrium condition $g_{a'}(K, K, z) = h(K, z)$, implies that, when the aggregate state of the economy is (K, z) and the household's asset level is a, the level of assets chosen by the household to be taken to the next period (a') is equal to the aggregate capital level in the next period, as determined by the law of motion function *h(K, z).* This condition ensures that the household's asset decisions align with the economy's aggregate capital, maintaining balance in the capital market.

To better understand this last point (the capital market clearing) we can check what should happen if we suppose that $g_{a'}(K, K, z) \neq h(K, z)$. In this scenario it would imply that that the individual household decisions regarding asset accumulation are not aligned with the overall capital accumulation process of the economy.

We can detect two possible scenarios: Total assets exceed the actual capital stock $g_{a'}(K, K, z) > h(K, z)$, this implies that households, have chosen to accumulate more assets than what the economy's aggregate capital would permit resulting in an excess supply of assets in the economy. It can lead to inefficiencies, as there would be unutilized capital. This mismatch may also lead to downward pressure on asset prices, potentially affecting investment decisions and overall economic performance.

In the other hand, if total assets fall short compared to the actual capital stock $g_{a'}(K, K, z) < h(K, z)$ it indicates that households have not accumulated enough assets to match the required level of aggregate capital in the next period. In this situation it would result in an undersupply of assets in the economy. It could also lead to upward pressure on asset prices, affecting the cost of capital and potentially distorting investment decisions.

In both cases, a mismatch between the household's asset choices and the aggregate capital level can disrupt the efficient functioning of the economy. It can impact investment, production, and resource allocation, leading to suboptimal outcomes.

To ensure a well-functioning economy, the equilibrium condition $g_{a'}(K, K, z) = h(K, z)$ is necessary. It ensures that the asset decisions made by households collectively align with the overall capital accumulation process, maintaining consistency between individual choices and the economy's aggregate dynamics.

In the competitive equilibrium, each individual household takes the law of motion of capital as a predetermined relationship. The household recognizes that the aggregate level of capital in the next time period depends on the collective choices of all households in the economy. While

each household considers its own state variables (a, K, z) in optimizing its consumption and asset decisions, it understands that the law of motion of capital is influenced by the behaviour of all households acting simultaneously. Thus, while making its optimal choices, each household accounts for the interdependence and coordination with other households that collectively determine the law of motion of capital.

Overall, a competitive equilibrium is achieved when price functions, interest rate determination, household's problem and capital market clearing are satisfied. It implies that prices, interest rates, value and policy functions, and capital market clearing are consistent and mutually reinforcing, leading to an optimal allocation of resources, and maximizing welfare for households and firms in the economy.

4.2 Availability heuristic

In this section, I will attempt to capture the concept of attentional bias by injecting the idea of availability heuristic to the RBC model with recursive competitive equilibrium previously shown in the earlier section. Before creating this model it is important to have a clear understanding of these two concepts;

Attentional bias is the tendency to focus more on certain stimuli or information based on our pre-existing beliefs, expectations, or emotional states. It influences decision-making processes and can lead to deviations from rational behaviour. By incorporating attentional bias into economic models, we can gain insights into how individuals prioritize and allocate attention, which in turn affects their economic choices and outcomes.

One specific type of attentional bias is the availability heuristic in which influences our decision-making process by conducting us to rely on easily accessible or memorable information. It is important to note that this heuristic tends to prioritize short-term information when forming judgments or making decisions.

This cognitive shortcut often causes us to overestimate the likelihood of rare or unusual events because they leave a more intense impression in our memory. Consequently, we may allocate more attention and importance to these events, even if they are statistically unlikely to occur again in the future. For example, upon hearing news of a plane crash, individuals may become more fearful of flying, despite the fact that flying is statistically much safer than driving a car.

Understanding the influence of the availability heuristic on decision-making provides valuable insights into the biases that shape our economic choices. In the subsequent sections, I will examine deeper into the implications of the availability heuristic within the context of economic decision-making, remarking its effects on consumption and investment.

4.2.1 RBC with availability heuristic

In other to capture the effects of this human behaviour into the economy, I will use the Real Business Cycle model explained in section 4.1 in which the economy followed an autoregressive process of order one and the agents of the economy knew it and they chose the optimal resources allocation according to it. Now, I will assume that the economy follows an AR(2) process and I will define two possible situations; one where the agents are rational and know the true distribution of the economy, so they will also have an autoregressive function of order two, and another situation where they don't know how the economy is behaving as they act wrongly assuming an AR(1) process.

The logic about doing this differentiation is that, the agents thinks that the level of productivity on this period only depend on the last period productivity capturing the idea of availability heuristic that agents only take into consideration recent information. Whereas the actual economy takes into consideration long term information or events as the true aggregate productivity include, not just the level of productivity in the last period, but also in the last two ones.

Realise that in this model, the difference between the order of the autoregression function of the agents and the economy is just of one however, it could be higher. Actually, the higher the order of the autoregression function the better it is going to reflect the availability heuristic as it is going to emphasise more the difference of long and short term. However, in this case and for simplicity, the difference of orders of the AR it is just going to be by one.

I will first explain the case in which agents are rational and know that the economy follows an AR(2).

First of all, let's develop the firm's optimization problem in which they maximize their profits choosing the optimal level of capital (*K*) and labour (*L*):

$$\max_{K,L} zK^{\alpha}L^{1-\alpha} - wL - RK$$

Notice that the firm's optimization problem is the same as we previously did, this is because the firms doesn't have to do any prediction of what the level of the productivity factor (z) would be as we take the productivity as given.

Once more, we assume that population size is 1 and households supply labour inelastically. Solving the problem by doing the first order condition, we get functions 1 and 2 which expresses the optimal allocation of the capital rental rate (*R*) and the wage rate (*w*):

$$R(K,z) = \alpha z K^{1-\alpha}, \quad (1)$$

$$w(K,z) = (1-\alpha) z K^{\alpha}, \quad (2)$$

The relation between the capital rental rate (R) and the interest rate received by the household (r) is denotated by equation (3) in which $\delta \in (0,1)$:

$$R(K,z) = r(K,z) + \delta, \quad (3)$$

The household problem in the other side, it has significant changes now that we introduce an autoregression of different order than before. This is because households do care about the level of future productivity (*z'*) as their value function depends on the utility function of the current time period plus discounted lifetime utility of the household in the next period. Thus, the value function makes a relationship that connects the present and future periods.

$$V(a,K,z,z_{-1}) = \max_{c,a'} \{u(c) + \beta E_{z'}[V(a',K',z',z)|z,z_{-1}]\}$$

Observe that now, the value function it depends not only the state variable of the household, that is the current levels of aggregate productivity (*z*), assets (*a*), and capital (*K*) but also on the level of the aggregate productivity of the last time period (z_{-1}). This is due to the fact that now it follows a distribution of an autoregressive function of order 2.

$$log\,(z_{t+1}) = \rho_1 log\,(z_t) + \rho_2 \log(z_{t-1}) + \varepsilon_t, \quad \varepsilon_t \overset{i.i.d.}{\sim} (\mu, \sigma^2)$$

It is important to punctuate that, the key point of this new AR(2) process is the $\rho_2$autoregressive coefficient which differs form the AR(1) by simply being $\rho_2 \neq 0$. This new relationship tell us that, we are also taking into account more periods or, in other words, we are now taking into account further information about the state of the economy

Furthermore, the budget constraint is still the balance between amount of income and expenditure, (equation 5) where in this economy, the only way household can generate income is by working or by the returns of the assets that they chose to have in the last period (at a rate *r(K,z)*).

$$w(K,z) + [1 + r(K,z)]a = c + a', \tag{5}$$

As we already mentioned, for keeping the economy balanced and sustainable, we are going to implement a no-Ponzi condition that it is also going to be:

$$a' \geq 0$$

And the last but certainly not least function that we need for being able to complete the household problem is the law of motion for the aggregate capital where, in this case, in other to predict the future level of capital (*K'*), households not only need the aggregate state of the economy (that is the current level of capital and aggregate production) but also, the past level of *z*.

$$K' = h_2(K, z, z_{-1})$$

It is important to highlight that z_{-1} now plays a role because we are now in the case where agents know how the economy behaves and that is by taking into account both z and z_{-1} as well as the level of capital *K*.

To sum up the household optimization problem we have that:

$$V(a, K, z, z_{-1}) = \max_{c,\, a'} \{u(c) + \beta\, E_{z'}[V(a', K', z', z)|z, z_{-1}]\}$$

Subject to:

The budget constraint: $w(K,z) + [1 + r(K,z)]a = c + a'$

The No-Ponzi condition:	$a' \geq 0$
Law of motion of capital:	$K' = h_2(K, z, z_{-1})$
And the AR(2):	$log\ (z_{t+1}) = \rho_1 log\ (z_t) + \rho_2 \log(z_{t-1}) + \varepsilon_t$

Let's denotate the optimal choices of consumption and assets as $g2_c(a, K, z, z_{-1})$ and $g2_{a'}(a, K, z, z_{-1})$, when the household is in a particular state (a, K, z, z_{-1}).

Once we obtain the optimal solutions from both firms and households sides of the economy, we can find the equilibrium that balances the economy, to do so the model must satisfy the price function and interest rate, *w(K, z)* , *R(K, z)* and *r(K, z)*; the optimal consumption and assets chosen form household's ($g2_c(a, K, z, z_{-1})$ and $g2_{a'}(a, K, z, z_{-1})$), and the capital market clearing where, similarly to what we have already seen, $g2_{a'}(K, K, z, z_{-1}) = h_2(K, z, z_{-1})$.

It is now time to talk about the second scenario where the economy stills follows an autoregression function of order two but now, the agents don't know it and as a consequence, they act as it was an AR (1) that's why, the optimization problem is exactly the same as the one I already developed at section 4.1.

4.2.2 Benchmarking

Once we have defined the two possible behaviours that agents could have, to represent the effect of availability heuristic, we are going to assume that in this economy, there are infinite number of rational agents that knows that the economy follows an autoregression function of order two and, on the other hand, there are just a finite number of agents that doesn't know it and therefore, follow an AR (1) function.

This implies that the economy aggregates are affected by the behaviour of the rational agents, but not by the behavioural agents. However, it is important to note that this model can be extended to consider scenarios where all agents exhibit behavioural tendencies or where there is a mixture of both rational and behavioural agents in the economy. By allowing for a strictly positive measure of behavioural agents, we can explore the dynamic interactions between different types of agents and their impact on macroeconomic outcomes.

In a more comprehensive framework that includes both rational and behavioural agents, the dynamics of the economy would be influenced by the decision-making processes of all agents. The presence of behavioural agents would introduce additional complexities and dynamics into the model, as their choices and biases would interact with the decisions of rational agents. This extension would provide a richer understanding of how the interplay between different types of agents shapes resource allocation and macroeconomic outcomes.

Lets sum up what we know about these two types of agents:

<table>
<tr><th colspan="2">Economy following an AR (2)</th></tr>
<tr><th>Agents following an AR (2)</th><th>Agents following an AR (1)</th></tr>
<tr><td>$V(a,K,z,z_{-1}) = \max_{c,a'}\{u(c) + \beta E_{z'}[V(a',K',z',z)|z,z_{-1}]\}$
Subject to:

The budget constraint: $w(K,z) + [1 + r(K,z)]a = c + a'$

The No-Ponzi condition: $a' \geq 0$
Law of motion of capital: $K' = h_2(K,z,z_{-1})$

And the AR(2): $log\,(z_{t+1}) = \rho_1 log\,(z_t) + \rho_2 \log(z_{t-1}) + \varepsilon_t$</td><td>$V(a,K,z) = \max_{c,a'}\{u(c) + \beta E_{z'}[V(a',K',z')|z]\}$
Subject to:

The budget constraint:$w(K,z) + [1 + r(K,z)]a = c + a'$

The No-Ponzi condition: $a' \geq 0$
Law of motion of capital: $K' = h(K,z)$

And the AR(1): $log\,(z_{t+1}) = \rho log\,(z_t) + \varepsilon_t$,</td></tr>
<tr><th colspan="2">In a competitive equilibrium</th></tr>
<tr><td>$w(K,z) = (1-\alpha)zK^{\alpha}$</td><td>$w(K,z) = (1-\alpha)zK^{\alpha}$</td></tr>
</table>

$R(K,z) = r(K,z) + \delta$ $g2_c(a,K,z,z_{-1})$ $g2_{a'}(K,K,z,z_{-1}) = h_2(K,z,z_{-1}).$	$R(K,z) = r(K,z) + \delta$ $g_c(a,K,z)$ $g_{a'}(K,K,z) = h(K,z)$

So, in this case, the agents who follow an AR (2) process demonstrate a remarkable accuracy when it comes to making optimal choices regarding their consumption and future assets. This is primarily due to the fact that in a competitive equilibrium, the level of future capital is directly influenced by the agents' decisions, and their law of motion of capital takes into account both the present and past levels of aggregate productivity. Consequently, these agents are able to determine the appropriate level of consumption and future assets with precision.

On the other hand, the situation is quite different for agents who follow an AR (1) process. These agents consistently find themselves making incorrect choices regarding their optimal levels of consumption and future assets. Unlike the agents in the AR (2) process, their decision-making framework lacks the comprehensive consideration of past levels of aggregate productivity. As a result, their ability to accurately assess and determine the appropriate levels of consumption and future assets is compromised.

The disparity in accuracy between the two groups of agents stems from the fundamental differences in their underlying processes. While the AR (2) process incorporates a broader scope of information, accounting for both present and past factors, the AR (1) process solely relies on the current state of the system. Consequently, agents following the AR (1) process tend to overlook vital historical patterns and fail to anticipate the future state of the economy accurately.

By contrasting these two types of agents, it becomes evident that the AR (2) process offers a significant advantage in terms of decision-making accuracy. The incorporation of past information provides a more comprehensive understanding of the economic dynamics, enabling agents to make more informed choices. On the other hand, agents following the AR (1) process are left with a limited perspective, leading to consistently erroneous determinations of optimal consumption and future assets.

V. Conclusions

In conclusion, this research paper has presented a macroeconomic model that extends the Real Business Cycle (RBC) framework by incorporating the availability heuristic, a cognitive bias in human decision-making. The primary objective was to investigate the impact of attentional bias on consumption and investment choices within the RBC model, and to provide a theoretical framework that captures the influence of this bias on macroeconomic outcomes.

By recognizing that individuals are subject to attentional bias and often rely on easily accessible information, derived from recent or vivid events, this model offers a more realistic representation of decision-making processes. The availability heuristic, a specific attentional bias, leads individuals to overestimate the likelihood of rare and recent events, while underestimating the probability of more common and long-term events. As a result, resource allocation becomes inefficient.

The proposed model assumes that agents use current productivity to predict future aggregate productivity, following an autoregressive process of order one (AR(1)), despite the actual aggregate productivity following an autoregressive process of order two (AR(2)). This distinction captures the essence of the availability heuristic, where agents prioritize short-term information and neglect the long-term trends that influence true aggregate productivity.

The theoretical analysis reveals the implications of attentional bias on economic outcomes within the RBC framework. Agents who correctly assume the AR(2) process demonstrate accuracy in making optimal consumption and investment choices by considering both present and past levels of aggregate productivity. In opposition, agents assuming the incorrect AR(1) process consistently make suboptimal decisions due to their limited perspective, ignoring crucial historical patterns and failing to anticipate future economic states accurately.

The model's findings emphasize the importance of integrating behavioural factors into macroeconomic analysis. It highlights that attentional bias, specifically the availability heuristic, can lead to inefficient resource allocation, affecting wealth, consumption, and investment decisions. The overvaluation of recent events and the undervaluation of long-term trends hinder optimal economic outcomes.

This research contributes to the growing body of literature on behavioural economics by proposing a theoretical framework that integrates attentional bias into the RBC model. It underscores the significance of considering cognitive biases in macroeconomic analysis to provide a more accurate understanding of economic behaviour. By incorporating the availability heuristic, the model offers insights into how human decision-making processes can shape macroeconomic outcomes.

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