Proceedings of the International Conference on Industrial Engineering and Operations Management

Publisher: IEOM Society International, USA DOI: 10.46254/GC02.20240139
Published: December 01, 2024

Reimagining Economic Opportunity: Preliminary Agent-based Model of Economic Stratification

Ichraq Ouhmidou
Department of Mechanical and Industrial Engineering
Sultan Qaboos University
Muscat, Oman
s117436@student.squ.edu.om

Khalid AL Zebdeh
Department of Mechanical and Industrial Engineering
Sultan Qaboos University
Muscat, Sultanate of Oman
alzebdeh@squ.edu.om

Emad Summad
Department of Mechanical and Industrial Engineering
Sultan Qaboos University
Muscat, Sultanate of Oman
esummad@squ.edu.om

Abstract

This paper explores the application of simulation modeling of an economic system using the aspects of Agent-based modeling. The developed model relies on the aggregated behavior of the agents and provides a what-if analysis tool that can be used by a policy maker to tackle economic phenomenon such as economic stratification. The model uses both macroeconomic and microeconomic measures in diagnosing the economic situation. The economical level of each agent is taken into consideration which discriminates the contribution of this model in addressing the phenomenon in an integrated way.

Keywords
Agent-based Modelling, Economic environment simulation, policymaking, Economic Stratification.

1. Introduction
For studying and forecasting economic results in the modern world, simulation has always been a crucial tool. Economic models are used to extensively rely on historical data and statistical analysis to forecast future trends, with the accuracy varying with the magnitude of the data. Yet, by simulating the intricate relationships between economic entities and their surroundings, simulation offers a more dynamic method of doing economic research. Simulating real-world economic situations entails creating a virtual environment. This setting may be used to examine the effects of different policy choices, market circumstances, and economic shocks. Researchers may experiment with economic systems via simulation, which can reveal important details about how these systems function. Simulation models are used in the economic environment because they allow for the testing of policy decisions' effects prior to their

implementation. This is crucial when discussing macroeconomic policy since choices made in this area might have a significant impact on whole economies. For instance, a government organization may utilize simulation to examine the effects of a new tax law or interest rate change before putting them into practice.

The effects of changing market circumstances on specific companies or industries may also be studied via simulation. Simulation modeling has the capability to shed light on how shifts in supply or demand may affect prices, output levels, and profits by simulating the interactions between buyers and sellers. Businesses may utilize this data to better guide their pricing, production, and investment choices. Risk management is a key area where simulation is used in the business world; with which may assist investors and financial institutions in evaluating the possible effects of various economic events, such as a recession or a rapid change in market circumstances, by simulating various scenarios. They may be able to handle risk more effectively and make wiser investing choices as a result. The study of behavioral economics, which aims to comprehend how human behavior affects economic results, is likewise promoting the usage of simulation more frequently. Simulation models can give insights into how individuals and organizations make economic decisions by mimicking the decision-making processes of economic actors. This knowledge may be utilized to create more effective policies and treatments that account for the behavioral biases and heuristics that influence economic decision-making.

Thereby, an effective tool for assessing and forecasting economic results is definitely a need, which offers important insights into how economic systems function by enabling researchers to evaluate the effects of policy choices, market conditions, and economic shocks in a controlled setting. However, simulation is being applied more often in a variety of economic domains, such as risk management, behavioral economics, and the study of macroeconomic policy; leading to the anticipation of future economic policy and decision-making to be increasingly influenced by simulation as the discipline develops.

Consequently, this study attempts to emphasize and demonstrate the use of simulation models in the economic areas and attempt to develop an empirical model of an economic environment to validate its applicability and highlight the manifestation of unequal distribution of economic resources, and social groups are separated and classified according to relative status, leading to economic inequality (Davis 2015). This is referred as economic stratification which is tackled as a phenomenon by means of the developed Agent-based model.

1.1 Objectives

The economic environment is full of sophisticated outcomes that are caused by interrelationships of many factors that contribute into the formulation of policies with which an economic system is governed. This study attempts to develop an agent-based simulation model that would assist in the design of relevant policies that would ensure economic growth while monitoring socio-economic impacts. This goal is based on the dilemma of whether inequality has one one-type of impact other than trading-off between promoting intergroup equality or widening stratification for the sake of societal well-being as well as economic growth.

2. Literature review

Economic systems fall under the category of complex systems because they encounter multiple interrelations with other types of factors and many parties contribute to the formation of the associated complexities. Therefore, the study of Mylek et al. (2020) attempted to examine the degree to which public actors exhibit some cognitive complexity as ‘integrated complexity’ when comprehending the socio-economic trade-offs, where policy interventions aim to reduce magnified risks. Similarly, Kim et al. (2014) emphasized the importance of considering legal governance mechanisms within a global economic system. Whilst Matutinovic and Igor (2001) argue that socio-economic diversity drives both social and ecological stability as many other factors such as the available physical resources, climate dynamics and population demographics are affecting the economic system. Research attempted to use Socio-economic position (SEP) measures which encompass various facets of the stratification hierarchy (Mood, 2017). For instance, income and wealth denote disparities in economic resources, socio-economic indices integrate indicators of cultural assets such as education, prestige scales reflect differences in the subjective assessment of occupational social standing, whilst class analysis emphasizes occupational assets (Lambert and Bihagen, 2014, Lambert et al., 2008). Consequently, most economic research on labor market inequalities tends to focus narrowly on material aspects, whereas sociologists often adopt a broader perspective that tackles employment relations as well as cultural and symbolic resources. These measures are inherently or explicitly part of the stratification theory, and thus, the choice of measurement tends to be formulated by different causal explanations of social inequalities. For example, economists typically interpret income inequalities as a result of individual-level differences in productivity driven by market mechanisms, while class analysis favors structural explanations related to control over power resources associated with different occupations, thereby positioning the occupational structure as the core of the stratification system (Wright, 2015). As a result, the sociological emphasis on occupation-based measures reflects the shared belief that occupations significantly determine individuals' life chances (Tilly, 1998). Furthermore, according to Richard et al. (2011), it is stated that economic complexity needs to be addressed comprehensively rather than considering only classicism as heterodoxy. Mueller and Bernardo (2020) emphasize the impact of policy failure in macroeconomic intervention and that it can contribute to complex global and national systems. Likewise, Tamborini et al. (2011) claim that it is very challenging to manage and control macroeconomic finance during globalization era and open capital markets. Thus, they suggest the application of network theory and approaches to tackle regulatory policy interventions. Furthermore, Milne and Alistair (2009) conclude that the most critical managing mechanism with the economic system is to maintain the flow of finance. Whereas Brunk et al. (2008) criticizes the traditional macroeconomic policies and proposes an ecological approach to address economic stagnation. However, on the micro-level, Kijazi and Martin (2013) introduce an approach to represent complex agent behavior as 'socially rational' agents. This approach forces complex agents to act independently and eliminates the economic perspectives related to the concept of rational economic agents which assume that all agents behave similarly. whereas, economic agents are affected by different complex patterns of behavior, and often resemble cross cutting social networks. Therefore, macroeconomic policies: like monetary policy, fiscal spending, exchange rate and industrial policies, and trade and investment strategies have contributed to intergroup inequality. The degree of this inequality and the effect of this kind of stratification on a country's economy is determined by its economic structure (Seguino 2021). So, this simulation model aims to assist in balancing off the two-faced effect; where it can possibly drive economic growth, or harm societal well-being. But hopefully, nations can still opt for growth driven by equity.

3. Research Methodology

As a way of tackling economic stratification phenomenon, Agent-based modeling (ABM) becomes one of the foremost approaches and a powerful holistic tool to study complex phenomena in the sense of capturing the interactions between agents that populate the economic environment. It mainly relies on deriving the aggregate patterns by combining all the agent's individual behavior. It is a bottom-up approach where the contributing factors are aggregated to form the big picture of the economic system. Therefore, agents-based modelling is selected to emphasize the single impact of a policy or a factor on a tremendous population of agents that are participating in the rise of this phenomenon. Furthermore, ABM exhibits the dynamics of the economic system which can inform the decision and policy makers with insightful outcomes that can be used to achieve a sustainable economic system.

3.1 Data Collection

The foremost step to build an agent-based modeling is to develop a conceptual model by collecting theoretical data which defines the mechanisms in order to extract the simple rules of agents. This model highlights a simple framework of the actual model. It demonstrates the main elements of the economic stratification phenomenon in terms of the type of agents and their characteristics, as it is shown in Figure.1. The conceptual model captures both the macroeconomic and the microeconomic elements to provide a comprehensive picture of the addressed phenomenon. With the aid of this model and the simple rules of the agents with which potential interactions (behaviors) towards each other are captured, a promising agent-based model is to be developed.

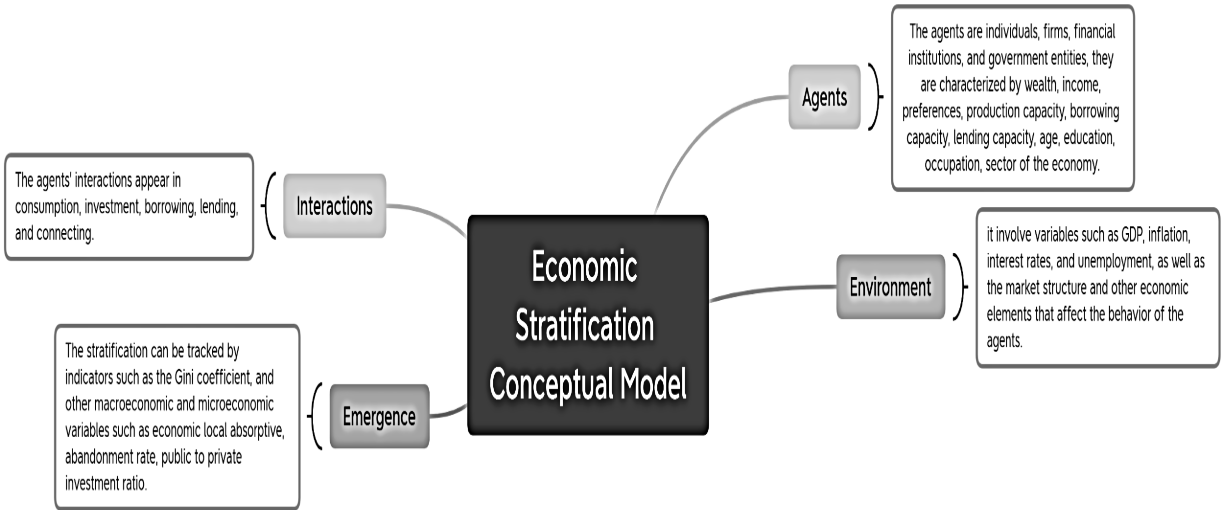

Figure 1. Conceptual Model of Economic Stratification

3.2 Agents' Interactions

As an important step to develop an ABM, the simple rules of the main agents are generated, and they represent the dynamics of the ABM where interactions take place. Agents in this model possess various attributes such as initial wealth, income generation rate, consumption rate, investment rate, and networking. These attributes influence their behaviors, which include working to earn income, consuming goods and services, saving and investing in wealth, making financial decisions (e.g., borrowing, lending), and interacting with other agents through trade, cooperation, or competition. The economy within this model is characterized by a dynamic market and robust institutions. The market operates through a price mechanism, driven by supply and demand dynamics, and is subject to fluctuations. Institutions play a crucial role, encompassing government policies (taxes, subsidies, regulations), the financial system (banks, credit markets), and social safety nets (welfare, unemployment benefits). These elements collectively shape the economic environment in which agents operate. Time is represented in discrete steps, with each step corresponding to a specific period (e.g., a day). The simulation process begins with initialization, where a population of agents is created with initial attributes, and the initial economic conditions (market prices, interest rates, etc.) are set up. During each time step, agents generate income based on their income rate, consume goods and services according to their consumption rate, save and invest a portion of their income, and make financial decisions based on their risk tolerance and market conditions. They also interact with other agents through trade, cooperation, or competition. The market prices and quantities are updated based on supply and demand, and government policies and institutional rules are applied. The simulation advances to the next time-step, continuing this process until a specified number of time steps is reached or a certain condition. The simple rules are identified for agents and tabulated in Tables 1,2,3,4,5 and 6.

Table 1. High income households' simple rules

High income households
earning a high initial level of income
Have a high probability of having high paying jobs
Have a high probability of having access to investment opportunities
Have a high probability of having access to high quality educational institutions
Have a higher probability of accumulating wealth as time elapses

Table 2. Low-income Households' Simple Rules

Low-income households
earning a low level of initial income
Subjected to unemployment or having a high probability of being employed in low paying jobs
Having rare access to investment opportunities.
Having a low probability of gaining higher level of education.
Having lower probability of accumulating wealth over time.

Table 3. Firms' Simple Rules

Firms
Each firm has a specific product or service to offer in a certain sector.
Firms hire workers who are unemployed in case of labor shortages.
firm can invest in a new sector or in existing one based on its capabilities in terms available resources and potential future returns.
Firms are linked to financial institutions to borrow loans.
Firms interact with governmental entities through legislations.

Table 4. Financial institutions' Simple Rules

Financial institutions
Financial institutions lend money to both individuals and firms.
Financial institutions invest in different types of sectors, depending on the internal rate of the return.
Financial institutions follow the regulations of the government, and provide some grants.

Table 5. Governmental entities' Simple Rules

Governmental entities
The government supports public goods and services.
The government makes policies and regulations that affect the behavior of all other agents(dominant).
The government sets programs to sponsor low-income households

Table 6. Educational institutions' Simple Rules

Educational institutions
Educational institutions enhance households' educational level and connect with firms for research and development purposes.
Educational institutions receive funding from the government and may request tuition fees.
Educational institutions may follow regulations made by the government.

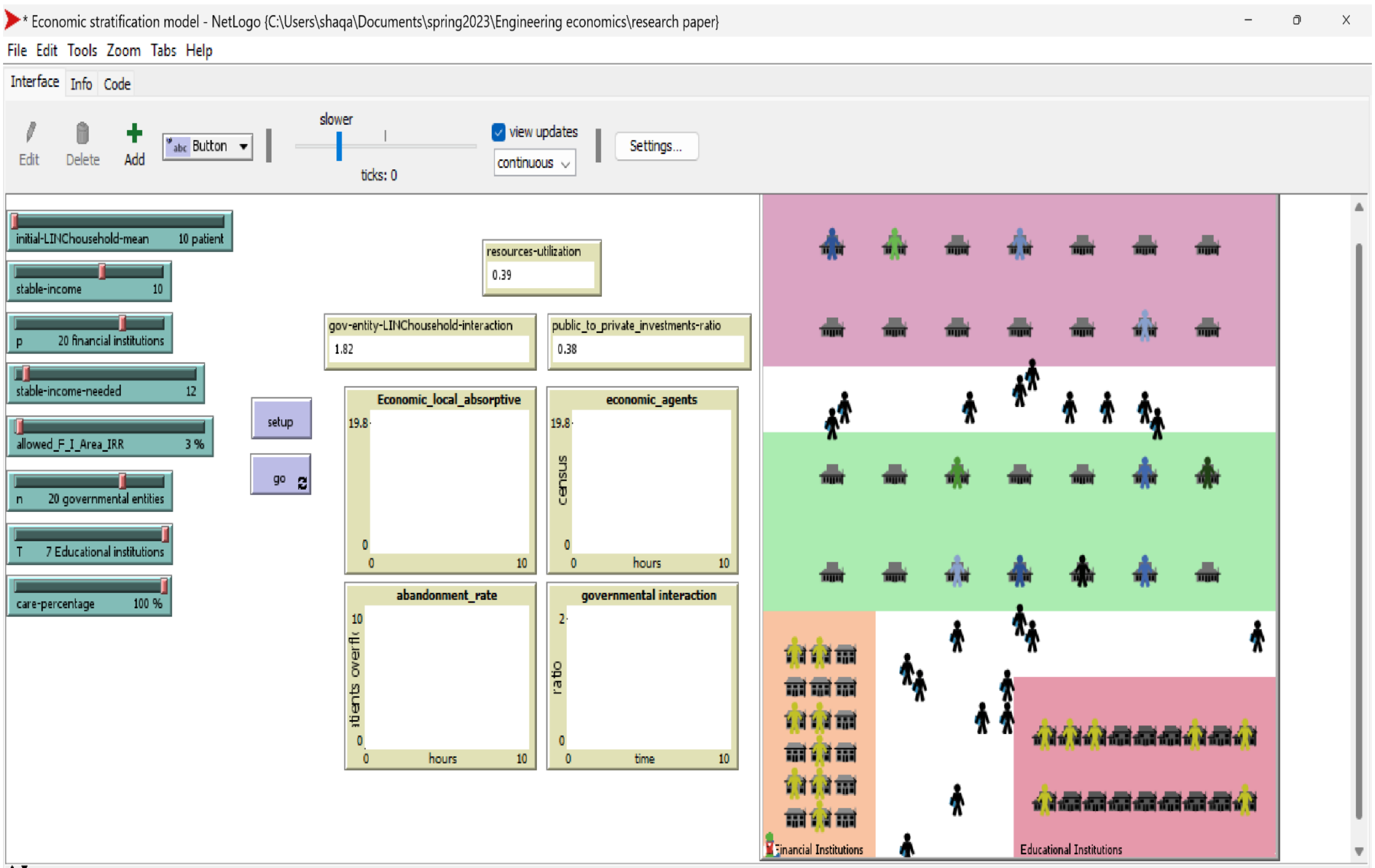

Figure 2. The User Interface Window of Netlogo

3.3 The Simulation Experiment

After transforming both conceptual model and simple rules into an ABM. Three elements of the simulation model will be displayed on the interface window of the Netlogo software as shown in Figure.2. The interaction environment and the agents participating in the economic system, the input parameters, and finally the output plots and monitors. for instance, the sliding buttons that are located on the left hand of the window, are assigned to indicate the different values of the input parameters. The user can select amongst a wide range of input values with which multiple scenarios can be generated to study the outputs. Furthermore, the user will first press the setup button and then adjust the input values either collectively or individually according to his/her viewpoints and press the go button to observe the behavior of agents and extract the effect through the illustrated plots and monitors. This simulation model addresses an economic complex system that involves many agents that are interacting with each other. Therefore, several factors are considered and presented as input variables as tabulated and explained in Table.7. The following section is dedicated to showing some of the scenarios that could be Contemplated and discussed afterwards.

Table 7. The simulation Model Input Parameters and their interpretations

Factors/input parameters	**indication**
Number of governmental entities	Indicates how many governmental entities there are in the economic system.
Number of financial institutions	Indicates how many financial institutions are there in IE
Number of educational institutions	Indicates how many educational institutions are there in IE
initial-LINChousehold-mean	Mean value of low-income households' arrival distribution to governmental entities
Stable- income	Indicates the value of the minimum stable income as set by the government
Stable-income-needed	Indicates the value the minimum stable income required by the financial institutions
allowed_F_I_Area_IRR	Indicates the minimum value the IRR set by financial institution
care-percentage	Indicates the degree of care paid to entities by the governments

4. Results

This section is designed to illustrate some of the generated scenarios from the ABM simulation. The simulation model accumulated 204 runs to generate the following outputs for a timeline of 231 consecutive days (Figure 3, Figure 4 and Figure 5).

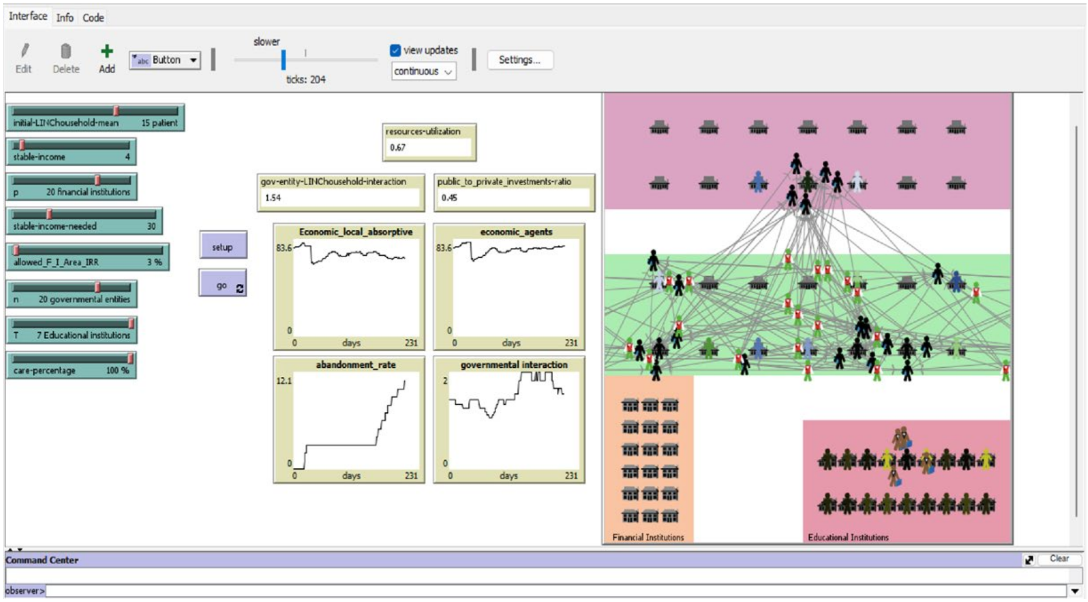

Figure 3. First scenario's input parameters and outputs

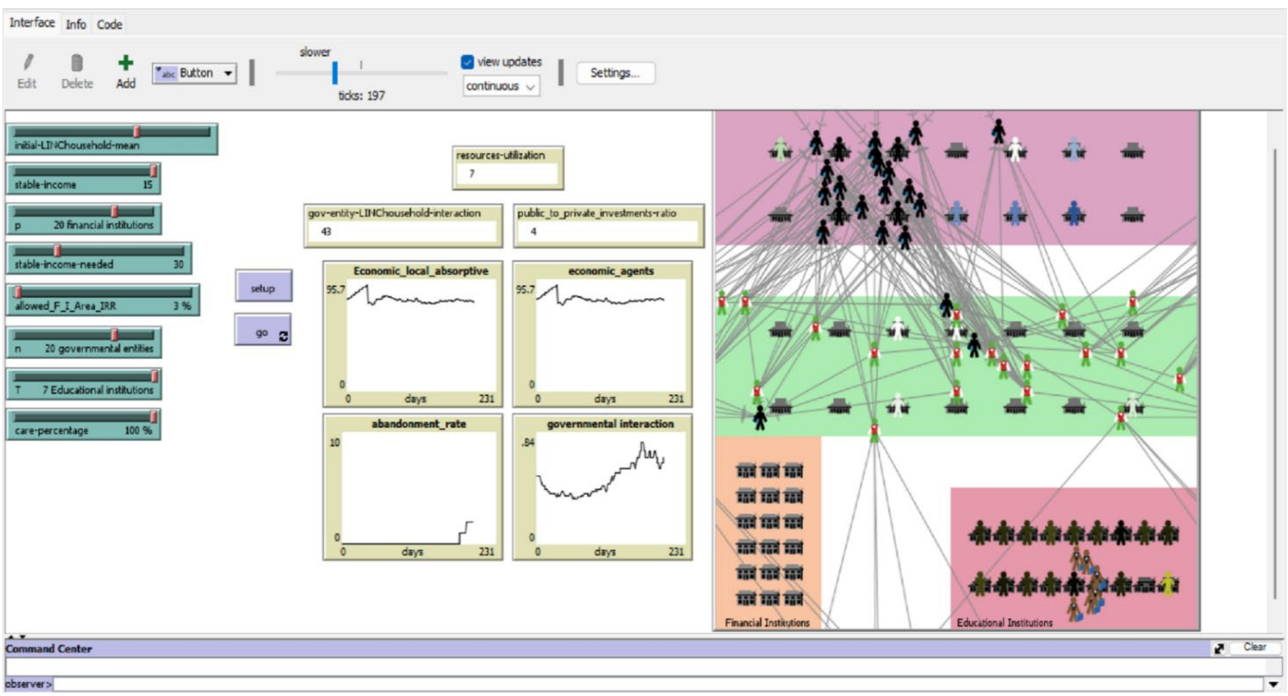

Figure 4. Second scenario's input parameters and outputs

5. Discussion of results

For the first scenario, since the average stable income multiplier of 100 RO for low-income households is specified to be low as 4. More governmental attention is paid to the low-income households, and this is illustrated by the high percentage of governmental interactions reaching a value of 200%. Which indicates that each single low-income household is interacting with two governmental entities. Furthermore, 67% of the governmental resources are utilized to address low income-level economic burdens. This explains the decreased liability of the economic system to absorb and meet the local needs and only 83% at maximum were met and only 45% of the total investments are made by the governmental entities compared to private investments. This is also coupled with high rates of financial abandonment in which it reaches 12% and keeps rising dramatically as time elapses. However, 83% of the agents were contributing to the economy. This can be a sign indicating that some individuals lack access to opportunities and resources that are being offered to the more affluent groups in society who are the high-income class.

For the second scenario, the average stable income multiplier of 100 RO for low-income households is increased to 15. less governmental attention is paid to the low-income households in this case, and it accounts for 43% of the total governmental interactions. Furthermore, 70% of the governmental resources are utilized to sustain the economy and this is coupled with the increase of collective contribution to the economy reaching a high percentage of 95.7%. This also explains the decreased abandonment rate of financial institutions reaching a rate of less than 3%. The economic system is able to absorb and meet the local needs reaching a level of 95.7%. However, only 40% of the total investment are made by the governmental entities comparing to private investments. Thus, in this particular case less economic stratification is to be witnessed and raising the stable income threshold of low-income households can be a successful policy to tackle unequal distribution of wealth, income and opportunities.

For the last scenario, the needed stable income multiplier of 100 RO for individuals and firms is set to be at 60 and the average stable income is kept at 10. Similar to the first scenario, governmental attention is paid to the low-income households, and this is illustrated by the governmental interactions between the two agents, it reaches a maximum value of 244%. Furthermore, 85% of the governmental resources are being utilized to address this concern. This also explains the decreased percentages of economic absorptive with which it reaches a peak value 86.9%. Only 40% of the total investments are made by the governmental entities compared to private investments. This is also coupled with high rates of financial abandonment in which it reaches 16.5% and keeps rising dramatically as time passes; this occurs due to the fact that both medium-income individual and medium-profit firms have not been able to acquire loans and financial institution stressed on the tight criterion of having 60000 as a net present value. This may imply that economic resources and opportunities are concentrated in the hands of a small, affluent group of agents (with high-income), and this can limit the ability of the wider population to access knowledge, technologies, and investments. However almost 96% of the agents were contributing positively to the economy, especially the high-income agents who are taking the lead of the economy.

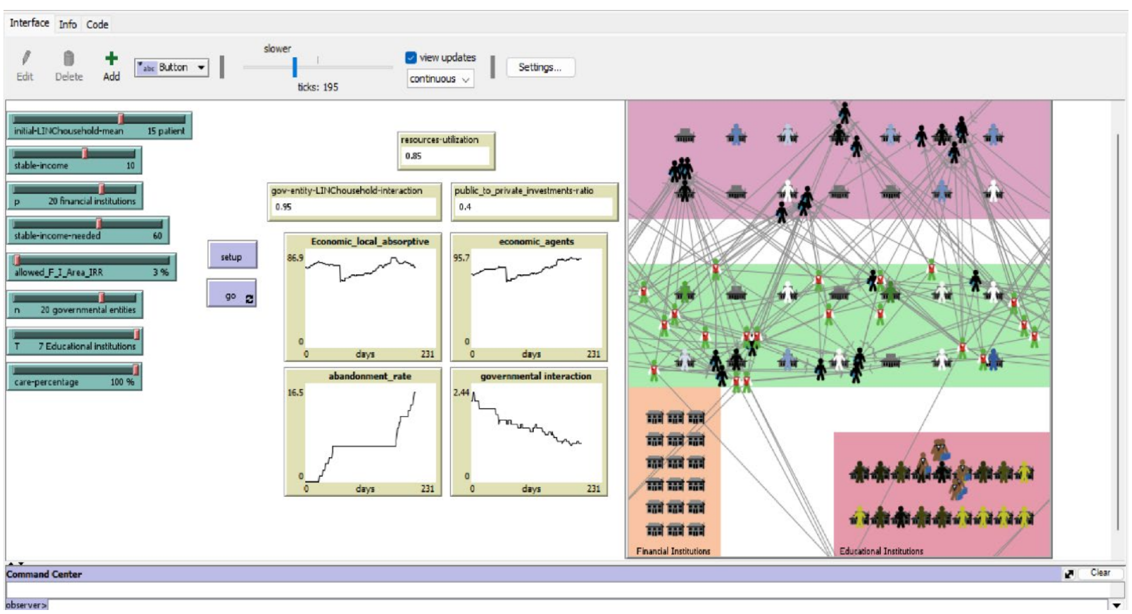

Figure 5. Third scenario's input parameters and outputs

6. Conclusion

To conclude, the aim of this paper was to develop an empirical simulation tool using agent-based modelling to tackle the phenomenon of economic stratification. The Simulation model can demonstrate insightful outputs that represent measures of economic stratification with which a policy maker can test his/her policies and their impacts. The complexity of the addressed phenomenon is dissolved by selecting appropriate measures and indicators that any user can relate to them. However, the developed simulation model can be further extended to include more agents and economic aspects. Moreover, the model has the potential in investigating the impact of politics in such an economic situation, with the present of realistic parameters that would assist in the validating the simulation model. As was previously mentioned, the intricate realities of economic systems can be captured by incorporating agent heterogeneity, which involves integrating diverse agent characteristics to reflect real-world complexity. Modeling realistic market dynamics, including price fluctuations and competition, is crucial for understanding the behavior of markets, also experimenting with different policy interventions allows for the assessment of their impact on economic outcomes, providing valuable insights into potential policy effects. Introducing the element of randomness into the model simulates uncertainty and stochastic events, would add a layer of realism to the analysis, with which researchers can gain profound insights into the dynamics of economic stratification and the potential effects of various policies and interventions.

References

Brunk, Gregory & Hunter, Kennith., An ecological perspective on interest groups and economic stagnation. *Journal of Socio-Economics*. 37. 194-212., 2008. 10.1016/j.socec.2007.01.014.

Davis, J., Stratification Economics and Identity Economics. *Cambridge Journal of Economics*, 39, 1215-1229., 2015. https://doi.org/10.1093/CJE/BEU071.

Kijazi, Martin., Complexity Theory and Forest Resource Economics, *Post-Faustmann Forest Resource Economics*, 41-70., 2013. 10.1007/978-94-007-5778-3_3.

Kim, Rakhyun & Mackey, Brendan., International Environmental Law as a Complex Adaptive System. *International Environmental Agreements: Politics, Law and Economics*. 14., 2014. 10.1007/s10784-013-9225-2.

Lambert, P. S., & Bihagen, E., Using occupation-based social classifications. *Work, employment and society*, *28*(3), 481-494. 2014

Lambert, P.S., Leai Larry Tan, K., Prandy, K., Gayle, V. and Max Bergman, M. , The importance of specificity in occupation-based social classifications", *International Journal of Sociology and Social Policy*, Vol. 28 No. 5/6, pp. 179-192. 2008.

Matutinovic, Igor., The aspects and the role of diversity in socioeconomic systems: An evolutionary perspective. *Ecological Economics*. 39. 239-256., 2001. 10.1016/S0921-8009(01)00205-1.

Milne, Alistair., Macroprudential policy: What can it achieve?. *Oxford Review of Economic Policy - OXFORD REV ECON POLICY*. 25. 608-629., 2009. 10.1093/oxrep/grp036.

Mood, C., More than Money: Social Class, Income, and the Intergenerational Persistence of Advantage. *Sociological Science*, *4*. 2017

Mueller, Bernardo., Why public policies fail: Policymaking under complexity. *EconomiA*. 21. 311-323., 2020. 10.1016/j.econ.2019.11.002.

Mylek, Melinda & Schirmer, Jacki., Understanding acceptability of fuel management to reduce wildfire risk: Informing communication through understanding complexity of thinking. *Forest Policy and Economics*. 113. 102-120.,2020. 10.1016/j.forpol.2020.102120.

Richard P.F. Holt, J. Barkley Rosser Jr. & David Colander., The Complexity Era in Economics, *Review of Political Economy*, 23:3, 357-369, 2011. DOI: 10.1080/09538259.2011.583820

Seguino, S., The Macroeconomics of Stratification. *Oxford Research Encyclopedia of Economics and Finance*., 2021. https://doi.org/10.1093/acrefore/9780190625979.013.747.

Tamborini, Roberto & Gaffeo, Edoardo., If the Financial System Is Complex, How Can We Regulate It?. *International Journal of Political Economy*. 40. 79-97., 2011. 10.2753/IJP0891-1916400205.

Tilly, C., *Durable inequality*. University of California Press, 1998.

Wright, E. O., *Understanding class*. verso books, 2015.

Biographies

Ichraq Ouhmidou is an industrial engineer and postgraduate student in Sultan Qaboos University. She is passionate about creating simulation models of real work systems and studying them as well. Ichraq is very enthusiastic when it comes to anything that is related to enhancing a current system regardless of its type. “There is always room for improvement no matter what” is her favorite quote.

Dr. Khalid Alzebdeh has completed his PhD from Michigan State University, USA and postdoctoral studies from Michigan State University and Georgia Institute of Technology, USA. He is currently an Associate Professor at the

Department of Mechanical and Industrial Engineering, Sultan Qaboos University, Sultanate of Oman. He has published more than 35 papers in reputed journals and has been serving as an editorial board member of several journals. Dr. Alzebdeh is a registered Professional Engineer in the state of Minnesota, USA. His current research interests include technology innovation, processing of advanced materials, which include, bio-composites, nano-structured and cellular materials.

Emad Summad serves as an Assistant Professor in the Department of Mechanical and Industrial Engineering at Sultan Qaboos University in Muscat, Oman. He holds a BSc, MSc, and Ph.D. in Industrial Engineering and specializes in policy matters related to innovation and entrepreneurship within a knowledge-based economy. Dr. Summad's research focuses on the orchestration mechanisms of innovation ecosystems and the strategic selection of partners for open innovation. He is also a proponent of technology-driven lean startups.