

AN EXPERIMENTAL AGENT-BASED CITY SIMULATION: PERSONALITY-DRIVEN ECONOMIC BEHAVIOR AND STABILITY OUTCOMES

Bogdan-Gabriel GHEORGHE¹

Abstract

This paper presents an agent-based economic simulation in a city-builder environment in which citizens act as autonomous agents driven by personality traits rather than direct player control. Each agent makes decisions regarding work, consumption, and recreation based on internal needs and trait-dependent functions. Workplaces consume and produce resources, while a market regulates prices dynamically through supply-demand interactions. To investigate how behavioral profiles shape economic outcomes, two contrasting population scenarios were evaluated: a Greedy City, dominated by agents with greedy personalities who prioritize personal wealth, and a Diligent City, where agents prioritize filling positions that are in demand even if they have lower salaries. Results show that personality distributions have significant effects on economic stability, production efficiency, and price volatility. The Greedy City produced erratic output patterns, recurrent input shortages, and unstable market prices, whereas the Diligent City maintained consistent production chains, higher overall output, and stable economic conditions after an initial period of job sorting. These findings indicate that variations in agent personality can influence macro-level behavior in the simulated environment, highlighting the potential value of incorporating behavioral diversity in agent-based economic and game simulations.

Keywords: Agent-Based Modeling, Behavioral Simulation, Personality-Driven Decision Making, City-Building Simulation, Market Simulation, Resource Economics

JEL Classification: C63, D91, C7

1. Introduction

Simulating economic behavior in games and virtual environments has evolved from simple production chains to complex systems involving autonomous agents with motivations and personalities. Classical city-building games such as *The Settlers*² and *Banished*³ provide resource management and production chains, but they do not explicitly model individual agent personalities that influence macro-level trends.

¹ Engineer, UNSTPB, Romania, bogdan.gheorghe0711@stud.fils.upb.ro

² Blue Byte Software, *The Settlers*, Ubisoft, 1993, <https://www.ubisoft.com/en-us/company/about-us/our-brands/the-settlers>

³ Shining Rock Software, *Banished*, 2014, <https://shiningrocksoftware.com/game/>

The present work introduces an experimental economic simulation in which citizens behave according to personality traits such as greed, diligence, or laziness. These traits determine preferences for work, consumption, recreation, housing and job switching. By coupling personality-based agent models with resource-dependent workplaces and a dynamic market, the simulation examines how individual decisions can aggregate into higher-level economic trends.

The main question is “how do different personality distributions within the population affect production, economic stability, and welfare in a city simulation ?” To answer this question, two controlled scenarios were executed: A highly greedy population and a highly diligent population.

2. Related Work

Agent-based modelling (ABM) has become a central methodology for studying complex socio-economic and ecological systems where global behavior emerges from the interaction of autonomous individuals. Early reviews highlighted that ABM can capture differences between agents, how they interact in space, and their various behaviors, making it especially useful for simulation, where individual decisions shape overall outcomes. Bousquet and Le Page (2004) provide a foundational overview of multi-agent simulations in ecosystem management, showing how decentralized agents interacting with resource flows can produce emergent patterns at the system level [1]. Their analysis argues that ABM can be useful for problems with social and spatial aspects.

A significant portion of ABM research concerns the representation of human decisions. An's (2012) review of human decision modeling in coupled human–natural systems highlights that different ABM models have their own strengths and weaknesses, but real humans will change their thinking method and adapt to the environment therefore a system that can replicate that decision making is far away but it can still be useful if the model it's kept simple[2].

Beyond ecological systems, multi-agent simulation has increasingly been applied to socio-economic behavior. Roozmand et al. (2011) demonstrate that incorporating psychological factors such as personality traits and cultural dimensions leads to more realistic consumer decision models and market behavior [3]. Their findings support the use of personality traits in agent-based environments but also say that even after incorporating them, the data were not sufficiently accurate, further continuing the idea that a personality-based ABM can simulate real-world practices, albeit to a lesser degree of accuracy.

At the methodological level, Müller et al. (2013) introduced the ODD + D protocol as an extension of the widely used ODD (Overview, Design concepts, Details) standard for ABM

descriptions [4]. ODD + D explicitly incorporates decision-making processes, mental states, and behavioral rules.

Land-use and economic ABM research has further emphasized the importance of taking into account social interactions and human decisions Matthews et al. (2007) provide a rigorous analysis of agent-based land-use models, noting that heterogeneity is essential in influencing the dynamics of such systems [5].

Recent work also highlights the challenges inherent in analyzing the outputs of complex ABMs. Lee et al. (2015) argue that ABM results are more challenging and require more time and attention than the ABM itself [6].

Steinbacher et al. (2021) state that ABMs are very flexible and can be adapted to very different problems with different conditions and that ABMs as a whole are a promising avenue for research [7].

Overall, the literature supports the core hypothesis of this paper: that micro-level behavioral heterogeneity, especially personality-driven labor and consumption choices, can systematically shape macro-level outcomes.

2.1. Similar games

“The Settlers” is a game that focuses on production flow optimization and efficient transportation. Its citizens do not have internal states or personalities; they function as fixed units that follow predefined roles within supply chains.

In “Banished”, on the other hand, the emphasis is put on survival, resource hardship, and dynamic population needs, but still treats citizens as interchangeable workers without complex decision-making.

Unlike traditional agent-based city-building simulations, this project investigates how incorporating personality-driven decision-making into an agent-based city simulation influences production dynamics, economic stability and citizen welfare. By encoding personality traits as parameters within all the functions and behavior-tree decision logic, the resource flows and economic dynamics emerge from interactions between predetermined production processes and dynamic agent decision-making. This approach provides a structured representation of agent decision-making that allows individual personality variations to influence economic behavior.

3. System Architecture and Methodology

3.1. Overview

The simulation framework is composed of several interacting subsystems that collectively attempt to reproduce the dynamics of an agent-based urban economy. The citizen subsystem models autonomous agents with personality traits, physiological needs (hunger, fatigue),

financial resources, and job preferences, all of which influence their decisions. The workplace system represents productive buildings that transform input resources into output goods and serve as employment nodes within the economic network. A centralized market subsystem controls the flow of all goods and determines prices dynamically through supply–demand interactions.

The time structure is introduced through a daily cycle mechanism that regulates work schedules, consumption routines, and opportunities for job transitions. Agent behavior is further governed by a behavior tree, enabling agents to evaluate and choose among actions such as working, eating, sleeping, or engaging in non-essential activities. Additionally, a housing subsystem models residential mobility, allowing agents to relocate based on income, proximity to workplaces, and personal satisfaction.

All components are implemented in Unity using C#, employing a modular architecture built around node-based behavior trees and specialized scripts.

3.2. Agents

Each citizen agent is characterized by a set of internal attributes and conditions. These include personality traits (e.g., greedy, diligent, lazy, social), which influence decision-making, basic physiological and social needs (such as hunger, fatigue, recreation, and clothing requirements), which generate periodic demands for consumption, personal money from their salary, used to purchase goods and pay for housing and individualized work preferences, including varying degrees of willingness to switch jobs in response to economic situations.

The current implementation makes use of personality traits through modifiers that affect how workplace or needs calculation occurs for the agent. Greedy agents prioritize personal income and therefore disproportionately favor workplaces offering higher salaries, even when such choices undermine overall production-chain efficiency. In the job-switching evaluation, these agents apply an increased weight of 10% of their greedy stat to the salary component of the utility calculation. In contrast, diligent agents are designed to support systemic stability. They preferentially seek employment in workplaces experiencing input shortages and, independently of external conditions, have a 50% probability each day of evaluating alternative positions with the explicit goal of addressing the largest production bottleneck in the city. This mechanism enables diligent agents to act as stabilizing forces within the simulated economy.

3.3. Workplaces and Production Chains

Each workplace in the simulation is defined by a structured set of parameters. These include the required input resources for production, output goods generated through processing activities, the number of workers needed to achieve full operational capacity, and the salary

offered to potential employees. Workplaces also specify operational time windows defined by start and end hours during which production activities and service provision occur. For social or recreational establishments, such as inns, an additional parameter is the maximum number of customers that can be accommodated simultaneously. Furthermore, each workplace maintains a productivity coefficient that evolves according to the cumulative experience of its workforce, enabling more efficient production as employees gain skill over time.

Within the economic system, workplaces function simultaneously as production nodes, transforming inputs into outputs, and as market actors who engage in the buying of required resources and selling of produced goods. This dual role situates workplaces at the core of both the supply chain and market exchange dynamics.

3.4. Central Market and Price Regulation

All goods produced or consumed within the simulation flow through a centralized market, which functions as the primary exchange mechanism between workplaces and agents. The market tracks, for each resource type, the daily supply, demand and shortage accumulated throughout the simulation cycle. At the end of each day, prices are updated using a supply-demand driven adjustment algorithm designed to reflect scarcity, prevent extreme price shocks, and ensure temporal smoothness.

The pricing function operates in these steps:

The first step is calculating the shortage score of the resources, which is calculated as resource demand divided by supply: $resource.shortage = \frac{resource.demand}{resource.supply}$.

After which the function checks to see if it has to apply the upper bounds, in this case, the upper bounds are 20 times the base price of the resource, it does so by comparing the shortage score of that resource with 20, which results in: $resource.shortage < 20$.

If the above is true and the shortage score is less than 20 then the function calculates the new target price for the resource as the base price multiplied with shortage score: $resource.targetPrice = resource.basePrice * resource.shortage$, if the above it's not true and the shortage is more than 20 then the target price become base price multiplied with 20: $resource.targetPrice = resource.basePrice * 20$ and if both of those are untrue and the demand and supply are both equal to 0 then the target price become the base price: $resource.targetPrice = resource.basePrice$.

Lastly we interpolate and calculate the current price which will be the interpolation between the old price of the resource and the target price with the rate of adjustment controlled by a smoothing factor pre-decided: $resource.price = Mathf.Lerp(resource.price, resource.targetPrice, smoothing)$,

After the update, daily supply and demand values are reset for the next simulation cycle.

This mechanism ensures that rare goods become expensive, abundant goods become inexpensive, and price evolution remains stable and continuous rather than oscillatory. Consequently, dynamic prices influence both production behaviors as workplaces adjust to input scarcity and consumption behavior, since agents evaluate affordability when fulfilling their needs.

3.5. Decision System (Behavior Trees)

Each citizen agent employs a behavior-tree architecture to evaluate and execute actions according to internal needs, personality, and environmental conditions. The decision process follows a priority-based evaluation model:

1. Work participation: Agents determine whether to attend their assigned workplace, conditional on current work hours, energy levels (food and sleep), and personal traits influencing diligence or laziness.
2. Food acquisition: If hunger exceeds a personality-adjusted threshold, the agent initiates a food search. Lazy agents tolerate higher hunger levels before acting, whereas more disciplined personalities intervene earlier.
3. Sleep behavior: Agents decide to rest when energy drops below a trait-dependent threshold. Lazy personalities exhibit increased sleep duration and earlier withdrawal from productive activities.
4. Recreation: If the mood falls below a defined threshold, the agent seeks recreational venues, such as inns to restore it.
5. Job switching: Agents periodically evaluate alternative employment options based on a utility calculation influenced by personality and workplace characteristics

The job-switching mechanism is personality-dependent. Standard agents compare the score of their current workplace with alternatives. The standard score is calculated as follows:

First, the function calculates a weighted dot product between 2 vectors, 1 vector is the citizens traits while the other is the workplace's traits, if C is the vector of citizen traits and W is the vector for the workplace than the sum so far would be : $S = \sum_{i=1}^8 C_i W_i$.

Then it calculates the salary component which is the citizens greed trait value multiplied with salary of the workplace multiplied with 0.01 which results in : $SalaryScore = Citizen.greed * Workplace.salary * 0.01$.

At the end the function adds those two together and then subtracts the distance between the workplace and the citizens house which make the final equation : $Score = S + SalaryScore - DistanceFromHome$. After this is the new score is better than the old score the citizen will change its workplace at the next available time.

Greedy agents assign disproportionately high weight to the salary component, effectively diminishing the relevance of distance or personal affinity. This leads them to cluster around high-paying workplaces, even when doing so destabilizes production chains.

In contrast, diligent agents prioritize economic stability. They mainly move toward workplaces experiencing a significant production bottleneck, that is calculated through a ShortageScore. When this score becomes sufficiently low, indicating an unmet demand for essential inputs, diligent agents have a chance to voluntarily relocate to mitigate the shortage, independent of salary considerations.

4. Experimental Design

4.1. Scenarios

Two experimental scenarios were simulated, each comprising a population of 66 citizen agents interacting within an identical economic and infrastructural environment. The production system consisted of the following workplaces: two farms, one lumber mill, one mine, two toolmakers, one jeweler, one clothmaker, and one textile maker. Each workplace transforms specific input resources into output goods at rates determined by its 1 characteristics. Input consumption and output production differ across workplaces, reflecting processing efficiencies.

Workplaces also incorporate temporal constraints, operating only during predefined hours, and impose capacity limits on the number of employees that can be assigned simultaneously. In addition, the simulation includes a skill-accumulation mechanism: for every in-game day an agent works at a given workplace, their proficiency in that occupation increases, thereby enhancing the productivity of the workplace through accumulated employee experience. The two scenarios differ exclusively in their population personality composition:

- Scenario A — “Greedy City”: 80% of agents possess greedy traits, 10% are diligent, and the remaining 10% are assigned other personality types.
- Scenario B — “Diligent City”: 80% of agents are diligent, 10% are greedy, and 10% exhibit other behaviors.

4.2. Evaluation metrics

The evaluation framework monitored several quantitative indicators designed to capture both micro-level agent behavior and macro-level economic performance. Specifically, the following metrics were recorded:

- Economic output, measured as the total quantity of goods produced across all workplaces.
- Production stability, measured through the frequency and severity of input shortages within production chains.
- Price volatility, reflecting fluctuations in market prices arising from supply–demand imbalances.

- Citizen welfare, assessed through indicators of food and clothing availability, agent mood states, and sleep adequacy.
- Job switching frequency represents the rate at which agents make transitions between workplaces in response to score evaluations and personality-driven tendencies.

All metrics were logged at the granularity of one in-game day. Data collection spans a 14-day simulation period for each scenario, covering all workplaces and the entire agent population.

5. Results

5.1. Output and Stability

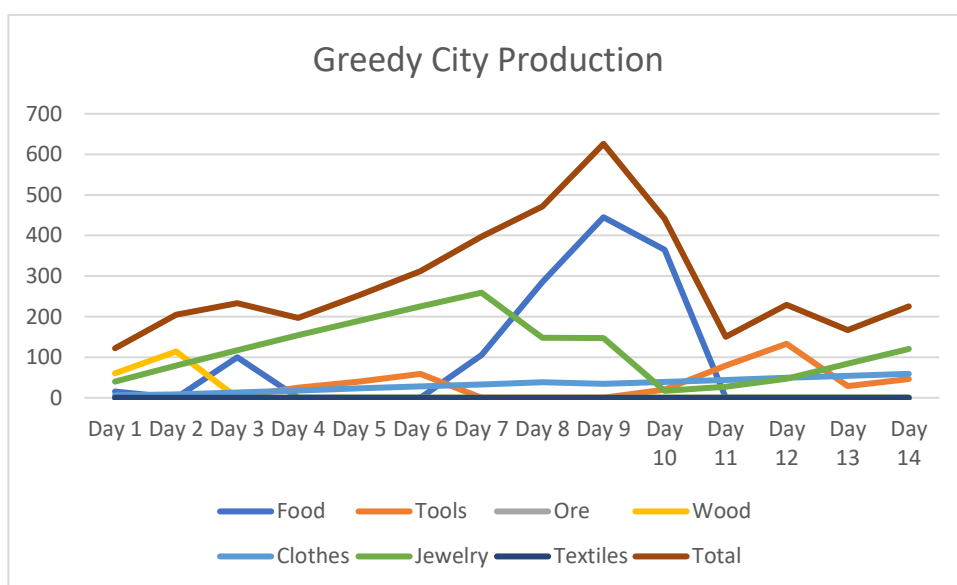


Chart 1. Greedy City Production Chart

Production in the Greedy City exhibited substantial instability, characterized by recurrent input shortages and frequent disruptions in output continuity. As prices fluctuated due to the agents' collective behavior, greedy workers tended to abandon their current positions whenever the market value of another good became more attractive. This led to rapid switching toward workplaces associated with temporarily higher-priced outputs. Such behavior created labor imbalances, amplifying shortages further destabilizing the production chain.

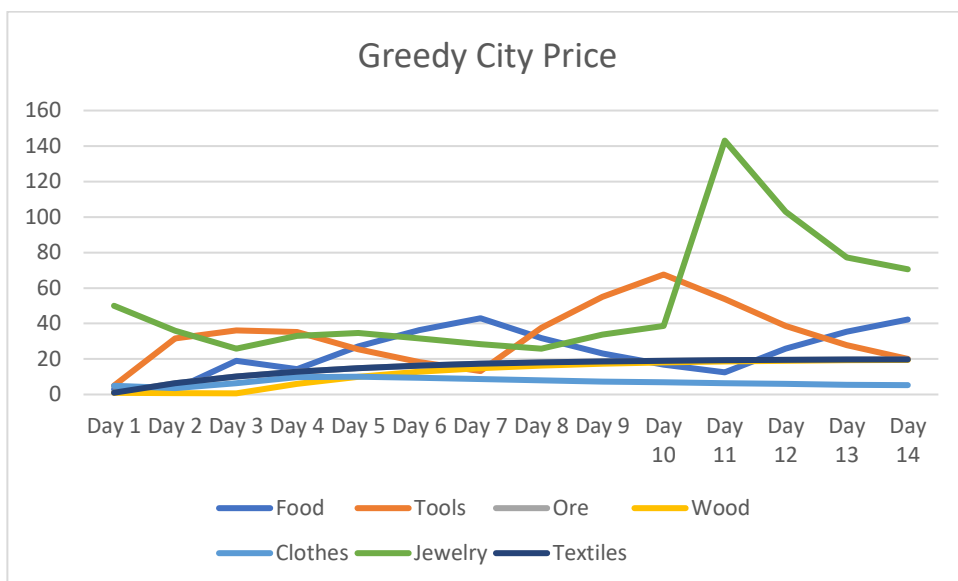


Chart 2. Greedy City Price Chart

Price dynamics in the Greedy City were similarly unstable, largely as a consequence of the irregular labor allocation patterns observed across workplaces. Places that failed to generate high wages suffered from understaffing, which in turn limited their production capacity. Workers employed in these low-income workplaces had reduced purchasing power and were therefore unable to meet even basic consumption needs. This reduction in effective demand further decreased the market value of the goods produced in those places. The resulting feedback loop, low wages leading to low demand, which then leads to even lower incentives for workers to join or remain in those industries, was especially important for essential goods such as clothing, textiles, and wood. These goods, while fundamental for agent survival, experienced reduced production and declining prices because greedy agents consistently moved towards more profitable sectors. This dynamic significantly amplified economic instability and weakened the overall production system.

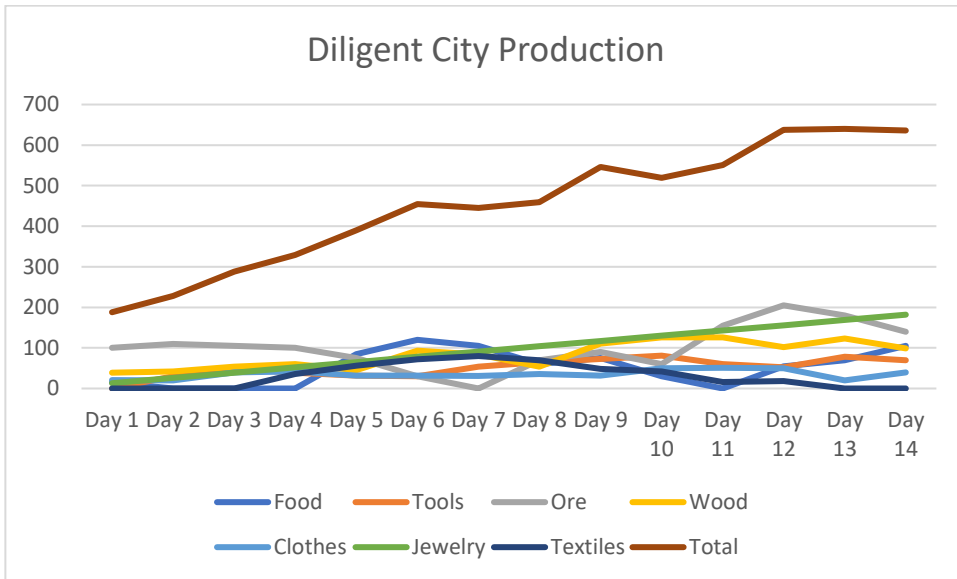


Chart 3. Diligent City Production Chart

In contrast to the Greedy City, the Diligent City demonstrated a steady and consistently increasing level of production across all goods, accompanied by only minimal shortages as the simulation progressed. The stable labor allocation characteristic of diligent agents, who reliably occupy essential positions within the production chain, enabled workplaces to maintain continuous inputs and sustain good output levels. This resulted in a more resilient and efficient economic system compared to the volatile dynamics observed in the Greedy scenario.

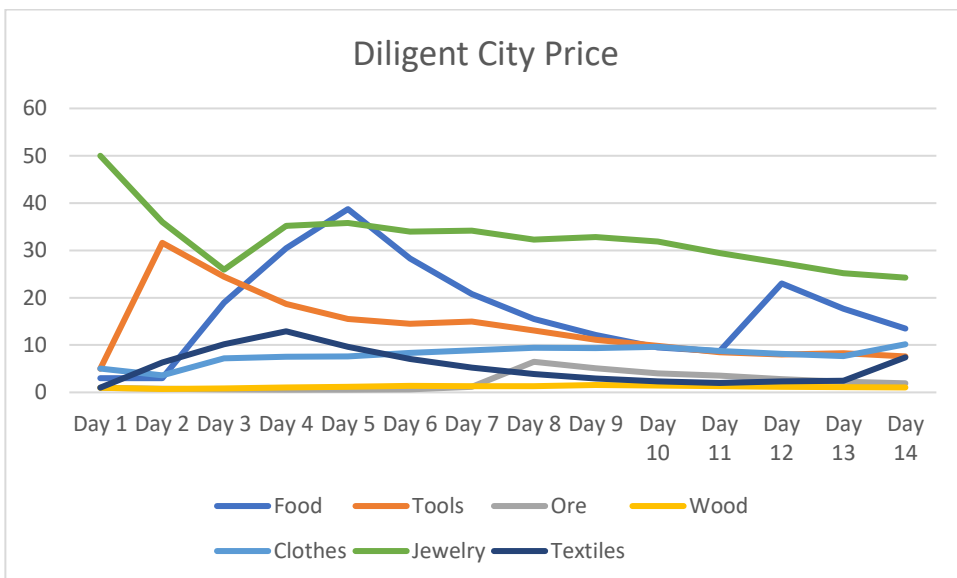


Chart 4. Diligent City Price Chart

In the Diligent City, during the initial days the price levels exhibited a temporary instability, reflecting the supply fluctuations caused by erratic labor distribution. However, as certain shortages were gradually alleviated and production stabilized in workplaces, market prices began to converge toward their respective base values. This downward adjustment improved the affordability of essential goods and increased accessibility for the agent population, partially mitigating the economic disruption observed at the start of the scenario.

5.2. Welfare and Consumption

The two scenarios also produced different patterns in citizen welfare and daily living conditions. Greedy agents exhibited several indicators of reduced and unstable well-being. Their consumption behavior was irregular, resulting in:

- Lower and highly inconsistent food intake, driven by fluctuating income and frequent job instability
- Irregular access to clothing, reflecting reduced purchasing power in low-wage periods
- Elevated purchases of jewelry, a consequence of high production output and strong demand, which temporarily increased disposable income
- Frequent relocation between houses, arising from constant job changes and shifting economic circumstances.

In contrast, diligent agents maintained significantly more stable life patterns due to their consistent employment and income. This manifested in:

- More regular and reliable eating and sleeping routines.
- Higher overall mood, driven by reduced unmet needs.
- Fewer days without access to food or clothing reflecting better alignment between income and consumption requirements.
- Greater productivity, as agents remained in the same workplace for longer periods and accumulated experience, thereby enhancing workplace output.

5.3. Job Switching Frequency

In the Greedy City, persistent shortages caused sharp fluctuations in both market prices and workplace salaries. As wages in shortage-affected industries increased, greedy agents whose decision-making heavily prioritizes income frequently abandoned their current jobs in favor of newly profitable opportunities. This behavior produced a highly volatile labor market, with an average of approximately 23 job switches per in-game day. The continual

reallocation of labor further amplified production instability, creating a self-reinforcing cycle of shortages, wage spikes, and additional job switching.

In contrast, the Diligent City exhibited a more stable labor environment. As diligent agents consistently filled essential positions, production bottlenecks were gradually resolved, leading to more balanced supply levels across resource types. With shortages alleviated, workplace salaries and prices tended to converge toward stable values, reducing the economic incentive for workers to relocate. As a result, the simulation recorded approximately 11 job transitions per day, roughly half the rate observed in the Greedy City. This stability further contributed to sustained productivity and more reliable economic performance.

6. Discussion

The results support the main hypothesis: the distribution of personality traits in the population significantly affects the overall economic behavior observed in the simulation.

The Greedy scenario displayed a pattern of agents individually optimizing for short-term salary gains but collectively undermining the broader economy. Specifically, greedy agents:

- Overstaffing high-salary workplaces (e.g., Jeweler, Toolmaker)
- Ignoring essential basic inputs (farms, mines, textiles)
- Causing price surges and production collapse

Conversely, the Diligent population exhibited behavior aligned with collective welfare and long-term system stability. These agents:

- Self-organized into efficient production chains
- Maintained stable resource flow
- Achieved higher aggregate welfare metrics, including food availability, clothing access, and mood stability.

Together, these findings suggest that differences in agents' personality traits can meaningfully influence overall economic behavior.

7. Limitations

The current data represents a single 14-day cycle simulation, while multiple simulations were run to ensure similar and consistent results across, the current data was recorded from just one of them. Which means that the conclusions are only orientational and are dependent on the initial conditions of each simulation.

The current implementation presents several limitations that constrain the generalizability and long-term applicability of the findings. First, the simulation does not yet incorporate demographic dynamics such as birth, death, aging, or migration, limiting its ability to represent population evolution over extended periods. Second, the experimental design evaluates only two primary personality distributions, which restricts the exploration of more diverse behavioral or mixed-trait societies.

Although prices adjust through an internal market mechanism, the system does not currently model taxation, government policy, or external trade, all of which play critical roles in real-world economic environments. In addition, workplaces operate with fixed production rules and do not yet adapt outputs in response to market conditions, preventing the observation of more realistic firm-level optimization behaviors.

Practical constraints also influenced system complexity. Due to development time limitations and the experimental nature of the application, several advanced features were excluded from the current version. Furthermore, the simulation engine is not yet optimized for large-scale, long-duration scenarios, making it computationally challenging to run simulations with very large populations or extended time horizons.

These limitations highlight areas for future refinement and expansion in order to support more robust and realistic economic modeling.

8. Conclusions

This project demonstrates that integrating personality traits into an agent-based economic simulations can produce measurable, interpretable variations in macro-level behavior within a controlled experimental setting. In the presented scenarios, populations dominated by greedy agents behave similarly to unstable boom–bust economies, characterized by labor volatility, production bottlenecks, and highly fluctuating prices. In contrast, populations dominated by diligent agents show greater self-organization, more stable production chains, and higher general welfare.

While the model is not intended as a predictive economic tool, these results suggest that psychological diversity at the agent level can meaningfully shape economic structures in simulation-based environments. This has potential implications for both game development and exploratory research in agent-based economic modeling.

Future work will expand the model's scope by improving support for large-scale, long-duration simulations and introducing additional personality types with more depth. Planned improvements include a more complex behavior tree that will enable more nuanced decision-making and allow agents and workplaces to sell surplus goods such as jewelry into broader markets.

References

- [1] Bousquet, F. and Le Page, C., 2004. Multi-agent simulations and ecosystem management: a review. *Ecological modelling*, 176(3-4), pp.313-332.
- [2] An, L., 2012. Modeling human decisions in coupled human and natural systems: Review of agent-based models. *Ecological modelling*, 229, pp.25-36.
- [3] Roozmand, O., Ghasem-Aghaee, N., Hofstede, G.J., Nematbakhsh, M.A., Baraani, A. and Verwaart, T., 2011. Agent-based modeling of consumer decision making process based on power distance and personality. *Knowledge-Based Systems*, 24(7), pp.1075-1095.
- [4] Müller, B., Bohn, F., Dreßler, G., Groeneveld, J., Klassert, C., Martin, R., Schlüter, M., Schulze, J., Weise, H. and Schwarz, N., 2013. Describing human decisions in agent-based models—ODD+ D, an extension of the ODD protocol. *Environmental Modelling & Software*, 48, pp.37-48.
- [5] Matthews, R.B., Gilbert, N.G., Roach, A., Polhill, J.G. and Gotts, N.M., 2007. Agent-based land-use models: a review of applications. *Landscape Ecology*, 22(10), pp.1447-1459.
- [6] Lee, J.S., Filatova, T., Ligmann-Zielinska, A., Hassani-Mahmooei, B., Stonedahl, F., Lorscheid, I., Voinov, A., Polhill, J.G., Sun, Z. and Parker, D.C., 2015. The complexities of agent-based modeling output analysis. *Journal of Artificial Societies and Social Simulation*, 18(4).
- [7] Steinbacher, M., Raddant, M., Karimi, F., Camacho Cuenca, E., Alfarano, S., Iori, G. and Lux, T., Advances in the agent-based modeling of economic and social behavior. *SN Bus Econ* 1, 99 (2021) [online]

Bibliography

- An, L., 2012. Modeling human decisions in coupled human and natural systems: Review of agent-based models. *Ecological modelling*, 229, pp.25-36.
- Bonabeau, E., 2002. Agent-based modeling: Methods and techniques for simulating human systems. *Proceedings of the National Academy of Sciences*, 99(suppl_3), pp.7280-7287.
- Bousquet, F. and Le Page, C., 2004. Multi-agent simulations and ecosystem management: a review. *Ecological modelling*, 176(3-4), pp.313-332.
- Chang, X., Liu, L., Liu, Z. and Chen, W., 2013. Method of multi-agent system for simulating land-use decision-making behavior of farmer households. *Transactions of the Chinese Society of Agricultural Engineering*, 29(14), pp.227-237.
- Dumitrescu, C., Radu, V., Gheorghe, R., Tăbîrcă, A.I., Ștefan, M.C. and Manea, L., 2024. Crowd panic behavior simulation using multi-agent modeling. *Electronics*, 13(18), p.3622.

- Lee, J.S., Filatova, T., Ligmann-Zielinska, A., Hassani-Mahmooei, B., Stonedahl, F., Lorscheid, I., Voinov, A., Polhill, J.G., Sun, Z. and Parker, D.C., 2015. The complexities of agent-based modeling output analysis. *Journal of Artificial Societies and Social Simulation*, 18(4).
- Leoneti, A.B., Bañares-Alcántara, R., Pires, E.C. and de Oliveira, S.V.W.B., 2022. A multi-criteria and multi-agent framework for supporting complex decision-making processes. *Group Decision and Negotiation*, 31(5), pp.1025-1050.
- Matthews, R.B., Gilbert, N.G., Roach, A., Polhill, J.G. and Gotts, N.M., 2007. Agent-based land-use models: a review of applications. *Landscape Ecology*, 22(10), pp.1447-1459.
- Müller, B., Bohn, F., Dreßler, G., Groeneveld, J., Klassert, C., Martin, R., Schlüter, M., Schulze, J., Weise, H. and Schwarz, N., 2013. Describing human decisions in agent-based models—ODD+ D, an extension of the ODD protocol. *Environmental Modelling & Software*, 48, pp.37-48.
- Pilla, V., Patel, N.V. and Khan, T., 2012. Multi-agent simulation of business processes: a theoretical model to manage and report carbon footprint in an emergent organisation. *International Journal of Business Information Systems*, 9(4), pp.435-450.
- Roosmand, O., Ghasem-Aghaee, N., Hofstede, G.J., Nematbakhsh, M.A., Baraani, A. and Verwaart, T., 2011. Agent-based modeling of consumer decision making process based on power distance and personality. *Knowledge-Based Systems*, 24(7), pp.1075-1095.
- Steinbacher, M., Raddant, M., Karimi, F., Camacho Cuena, E., Alfarano, S., Iori, G. and Lux, T., Advances in the agent-based modeling of economic and social behavior. *SN Bus Econ* 1, 99 (2021) [online]