

SIMCITY: MULTI-AGENT URBAN DEVELOPMENT SIMULATION WITH RICH INTERACTIONS

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ABSTRACT

Large Language Models (LLMs) open new possibilities for constructing realistic and interpretable macroeconomic simulations. We present **SimCity**, a multi-agent framework that leverages LLMs to model an interpretable macroeconomic system with heterogeneous agents and rich interactions. Unlike classical equilibrium models that limit heterogeneity for tractability, or traditional agent-based models (ABMs) that rely on hand-crafted decision rules, SimCity enables flexible, adaptive behavior with transparent natural-language reasoning. Within SimCity, four core agent types (households, firms, a central bank, and a government) deliberate and participate in a frictional labor market, a heterogeneous goods market, and a financial market. Furthermore, a Vision-Language Model (VLM) determines the geographic placement of new firms and renders a mapped virtual city, allowing us to study both macroeconomic regularities and urban expansion dynamics within a unified environment. To evaluate the framework, we compile a checklist of canonical macroeconomic phenomena, including price elasticity of demand, Engel’s Law, Okun’s Law, the Phillips Curve, and the Beveridge Curve, and show that SimCity naturally reproduces these empirical patterns while remaining robust across simulation runs.

1 INTRODUCTION

The rapid development of Large Language Models (LLMs), has enabled multi-agent simulations of human societal activities across diverse scales and domains (Gao et al., 2024a). In these settings, autonomous LLM-powered agents interact with each other and with their environment. Existing work has examined not only general social simulacra (Park et al., 2023; Huang et al., 2025; Piao et al., 2025), but also domain-specific applications such as public administration crisis (Xiao et al., 2023), health policy (Hou et al., 2025) or deduction game (Xu et al., 2025). While these work demonstrate the social simulation capabilities of LLM-driven agents, we focus on their application to the **simulation and evaluation of urban-style economic activities**.

For the past two decades, the Dynamic Stochastic General Equilibrium (DSGE) framework has been the predominant paradigm for studying aggregate economic behavior (Blanchard, 2009; Gandon et al., 2023). While mathematically elegant, DSGE models the economy with fully rational agents solving explicit optimization problems in equilibrium, which restricts heterogeneity and richer behavioral dynamics (Sergi, 2018; Vines & Wills, 2020; Storm, 2021). agent-based models (ABMs) offer a bottom-up alternative that accommodates heterogeneity but typically rely on hand-crafted decision rules (Dilaver et al., 2018). Advancing the ABM tradition with recent developments in LLMs, we propose **SimCity**, a multi-agent macroeconomic simulation framework that enables flexible, adaptive behavior with transparent natural language reasoning, and a virtual city environment that provides spatial context.

SimCity models the economy as the interaction of four types of agents: households, firms, a central bank, and a government. To incorporate realistic heterogeneity, households and firms are instantiated as families of agents with rich variation in preferences, abilities and other background, whereas the central bank and government are modeled as single institutional agents, in line with the economic literature (Blanchard, 2025). Agents are implemented through an LLM-based module that integrates environmental observations, agent-specific traits, and structured memory to generate reasoning, planning, and decision-making. Following the classic agent–interaction–environment

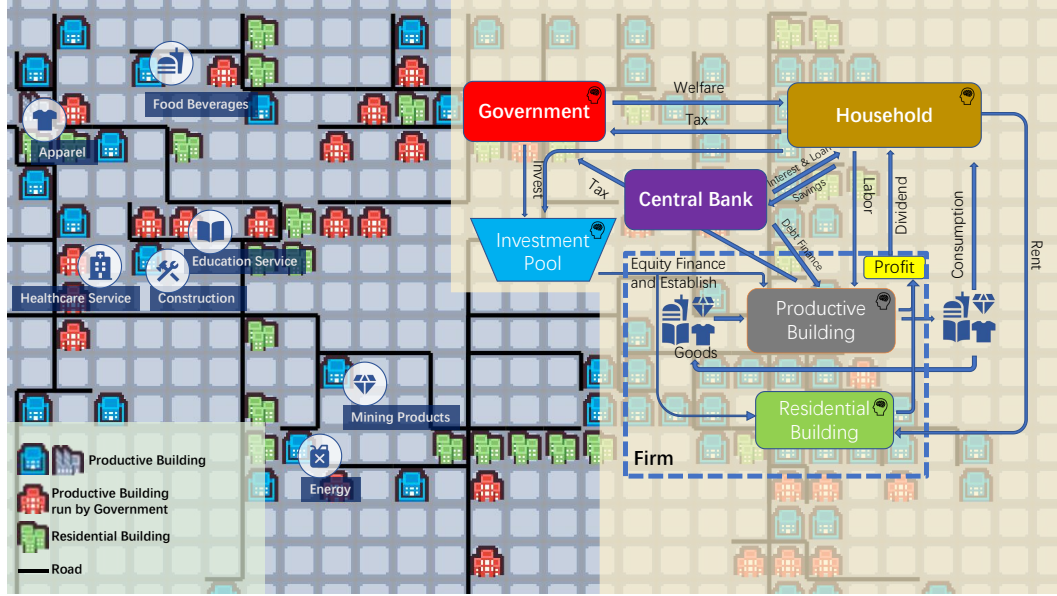


Figure 1: The framework of SimCity. Left: A visualized map with three types of buildings. Right: The rich interactions between various agent modules.

paradigm of multi-agent system design (Wooldridge, 2009), we construct a simulation environment that features a frictional labor market, heterogeneous goods markets, and core financial interactions. To provide spatial context for both agents and researchers, the environment is augmented with a visualized map.

Experimental results show that SimCity successfully exhibits a range of classic macroeconomic phenomena, such as Okun’s law, the Phillips curve, the Beveridge curve, price elasticity of demand and Engel’s curve. It also simulate the dynamic expansion of a city, and facilitates the simulation of novel economic shocks that were difficult to study in previous frameworks.

In summary, our work makes the following contributions:

1. **LLM-driven macroeconomic simulation with rich interactions.** We integrate LLMs into economic simulation by modeling four distinct economic roles, households, firms, a central bank, and a government, as LLM-driven agents, enabling realistic agent heterogeneity and rich economic interactions.
2. **Visualized urban-style simulation environment.** We provide LLM-based agents with a mapped virtual city that provides spatial context and renders the dynamics of urban expansion, supporting decision-making in a realistic urban setting.
3. **Systematic evaluation.** We compile a comprehensive checklist of canonical macroeconomic phenomena and regularities and use it to demonstrate that our framework exhibits established macroeconomic patterns and generates plausible responses to exogenous shocks.

2 RELATED WORK

LLMs for Social Simulation The application of LLMs to social simulation represents an emerging and promising research frontier. LLMs are capable of exhibiting human-like behaviors (Xie et al., 2024) and can be endowed with diverse personas (Chen et al., 2024), offering a basis for interpretable agentic reasoning. Structurally, these simulation frameworks typically contain agents, an environment they interact with, and the interfaces that mediate their interactions (Gao, 2024). Existing work in this domain can be broadly divided into two categories. The first category encompasses general-purpose social simulation frameworks such as Park et al. (2023), Tian et al. (2025), Tang et al. (2024), Piao et al. (2025), and Huang et al. (2025), which aim to model general societal

Table 1: A comparison of agent-driven macroeconomic simulators.

Simulator	AI Economist	LEN	CATS	EconAgent	Simcity
Households	10	100	100	200	200
Tax Schedule	Non-linear	×	×	Non-Linear	Non-linear
Tax Type	Labor	×	×	Labor	Labor& Value-Added
Agents' Types ^a	HG	HB	HFB	HBG	HFBG
Markets ^b	×	L	LGF	×	LGF
Visualized Map	✓	×	×	×	✓
Goods Type	2	1	1	1	10+
Interpretability	×	×	×	✓	✓

^aH: Household, F: Firm, B: Bank, G: Government

^bL: Labor Market, G: Goods Market, F: Financial Market

patterns. The second category investigates specific social phenomena, such as public administration crises (Xiao et al., 2023), health policy (Hou et al., 2025), political manipulations (Touzel et al., 2024), financial market (Gao et al., 2024b), and deduction games (Xu et al., 2025).

Traditional Macroeconomic Modeling DSGE and ABM represent two leading, and in many respects, contrasting approaches to macroeconomic modeling. DSGE features highly idealized decision-makers characterized by precise mathematical objective functions, rational expectations about future variables, and strict market-clearing equilibrium conditions (Stokey et al., 1989; Ljungqvist & Sargent, 2018). In contrast, ABM follows a bottom-up, simulation-driven methodology, where agents are endowed with rule-of-thumb behavior patterns and, in some cases, learning heuristics (Tesfatsion & Judd, 2006; Axtell & Farmer, 2025). Although DSGE remains the dominant approach in economics departments and policy institutions (Woodford, 2009; Negro et al., 2013; Chen et al., 2023), there has been a renewal of interests in ABMs, particularly following the Global Financial Crisis of 2008 and again after the COVID-19 crisis, as mainstream DSGE models struggled to account for these unprecedented shocks (Gatti et al., 2008; Stiglitz, 2018; Borsos et al., 2024). Our work is closer to the ABM tradition. However, we depart from conventional ABMs by replacing predetermined behavioral rules with LLM-powered agents capable of flexible reasoning and information processing in natural languages.

Comparison to EconAgent Li et al. (2024) introduces EconAgent as an early attempt at LLM-driven macroeconomic simulation. Its framework restricts agent-environment interactions to two simplified variables: consumption share and work propensity, which constrains the range of economic activities that can be simulated. Our work extends this approach by incorporating other key economic elements, including firms as LLM-driven agents, heterogeneous goods markets, enriched financial activities and taxation system. Thus, our framework allows the exploration of a wider range of macroeconomic phenomena.

3 ENVIRONMENT AND INTERACTION

Our framework consists of three core layers: environment, interaction protocol, and agents. This section describes environment and interaction of our system architecture.

3.1 ENVIRONMENT

Each simulation step represents one month. The order of events within each step is detailed in Appendix D.2. By design, agents can only access information from previous steps.

The simulation proceeds in two phases. In phase 1 (*the move-in phase*), new households with synthetic profiles, representing immigrants or newborns, are introduced into the SimCity environment until a predetermined maximum population is reached. Unlike the typical burn-in period used purely for model stabilization in ABMs (Lengnick, 2013), this phase is explicitly designed to study urban expansion, capturing how economic activity and spatial development evolve as the city grows.

In phase 2 (*the development phase*), the population is fixed. However urban developments such as firm creation, investment, and spatial reallocation, continue to take place. We focus on this phase to study macroeconomic regularities, as the system operates in a quasi-steady state that is less susceptible to the transient noise present during the expansion period.

There are three markets in the environment. Firms sell goods to each other and to households in a *goods market*. Notably, goods are qualitatively differentiated (e.g., food, clothing). Firms post jobs and are matched with households in a *labor market*. The central bank accepts deposits and provides loans in a *financial market*. Details of environment setup can be found at Appendix D.1.

We develop a web-based render module to visualize the urban expansion as shown in Figure 1 shown. All buildings are displayed on the rendered map. Geographic placement of new firms are decided by a Visual-Language Model (VLM). For technical details of the module please refer to Appendix D.3.

3.2 INTERACTION PROTOCOL

We leverage the common-sense reasoning capabilities of LLMs to act as human-like, heterogeneous agents. Details about the prompts used are provided in Appendix E.1. Agents interact with the environment by means of *function calling*. The framework loads all the operations that the agent can execute and appends formatted function names along with their descriptions to the prompt. The LLMs will return the actions to be taken and their parameters in JSON format. Framework will execute after a verification. For detailed examples, see the Appendix E.3.

4 AGENTS

This section presents an overview of the agents in SimCity. As illustrated in Figure 1, there are four agent types: households, firms, a government, and a central bank, each simulated by an LLM. Building on prior work (Gatti et al., 2011; Wolf et al., 2013; Dawid & Gatti, 2018; Li et al., 2024), our enriched framework expands the decision space considerably.

- Households make four key decisions each period: consumption bundle, labor market action, housing, and financial activity.
- Firms set production levels and prices, decide on hiring and capital investment, and acquire financing when needed.
- The government collects taxes and stimulates the economy through public spending and transfer payments to support consumption and improve social welfare.
- The central bank adjusts the interest rate in response to market conditions.

4.1 HOUSEHOLDS

Households are the fundamental units in our simulation and interact with all other agent types and markets. Each household is initialized with a **heterogeneous profile**, including age, education, consumption preference, skill endowment. Details about these characteristics and initialization process can be found in Appendix D.4.

Each month, households receive two types of information: a **personal report** summarizing income, expenditures, and other status changes during the current period, and a **citywide update** containing goods prices, labor market conditions, housing availability, returns on investment and interest rates. Additionally, households are matched with job vacancies created by firms probabilistically.

Based on this information, each household decides on (i) its **consumption bundle**, which requires a minimum expenditure on certain essential goods (Ravn et al., 2008); (ii) its **labor market action** (accepting or rejecting a new job if offered, or resigning from its current job); (iii) its **housing choice**, and (iv) its **financial decisions** (saving, borrowing, or investing in the common investment pool, which is discussed below).

4.2 INVESTMENT POOL AND FIRMS

Investment Pool An investment pool is implemented as an intermediary module that leverages a VLM for investment decisions. Funds from households’ investment actions are temporarily de-

posited into this pool and returned if unused for a month. When the pool accumulates sufficient capital and the VLM deems conditions favorable, a new firm is established.

The pool chooses from a library of 44 **synthetic firm templates**, each of which produces a unique type of good, and selects a geographic placement for the firm. The construction of these templates from real-world data is detailed in Appendix D.5. After a firm is established, all contributing households receive shares of the firm in proportion to their investment.

Firms Each *firm* in SimCity produces a single good. It hires households as workers, invests in capital to improve productivity, and transforms input goods to its specialized output, which is then sold in the market. Firms are instantiated from templates that specify skills requirements of job positions in the firm and the input-output relations governing its production process, where a firm may take possibly more than one input good for its production. The effectiveness of resource utilization (i.e. the ratio at which input goods are transformed into the output good) is determined by a firm-specific Cobb-Douglas production function (Cobb & Douglas, 1928):

$$Y_i = A L_i^{1-\alpha} K_i^\alpha, \quad (1)$$

where A is total factor productivity, K the firm’s capital stock, L the effective labor supply, defined as the amount of labor input adjusted for the match between job skill requirements and employees’ actual skills.

Similar to households, firms receive **individual reports** summarizing their internal operation (e.g., expenditure composition, employee skill profiles), and **citywide updates** on external conditions such as unemployment rate, interest rates, supply/demand conditions in the goods market.

After deliberating on these information, each firm chooses (i) the **quantity and price** of its outputs, taking into consideration the prices of relevant input goods, as well as the geometric distance to their respective suppliers; (ii) its **labor market actions**, which may include posting job vacancies, laying off employees, or modifying wages; and (iii) its **investment decision**, including whether to borrow from the bank, and whether to purchase fixed assets to increase its capital.

More detailed description of firms can be found at Appendix C.3.

4.3 GOVERNMENT

Macroeconomic Indicators The *government* monitors key indicators about the state of the economy, and adjusts taxation and fiscal policies to enhance social welfare, as measured by these indicators. The most important macroeconomic indicators include total consumption, total investment, nominal GDP, and real GDP, where nominal GDP is calculated using current prices, and real GDP uses constant base-year prices. Inflation is tracked in two forms: wage inflation, defined as the rate of change in average wages, and GDP inflation, measured by the rate of change in the GDP deflator. The GDP deflator itself is the ratio of nominal GDP to real GDP.

Tax and Welfare The government collects bracketed income tax from households and value-added tax (VAT) from firms. Let $\mathcal{B} = \{(b_k, r_k)\}_{k=1}^K$ denote a tax schedule, where b_k is the lower threshold of bracket k , with $b_{K+1} = \infty$, and r_k the corresponding marginal tax rate. The tax liability from agent i with tax base z_i (income for households, or profit for firms) is:

$$t_i = \sum_{k=1}^K r_k [\min\{z_i, b_{k+1}\} - b_k]_+, \quad (2)$$

where $[\cdot]_+ \equiv \max\{\cdot, 0\}$. The total tax revenue collected by the government is the summation of taxes from all agents. The government uses this tax revenue in three ways: investing in the construction of public service buildings, which are modeled as government-owned firms, distributing it to households as a universal basic income (UBI), or reserving it.

Mathematical definitions of indicators and other details can be found in Appendix C.4.

4.4 CENTRAL BANK AND FINANCIAL SYSTEM

The *central bank* accepts deposits, provides loans, and implements monetary policy. In the first month of each year, it sets the policy interest rate according to a modified Taylor rule, which is a

Table 2: Macroeconomic agent-based modeling checklist.

Regularity	AI-economist	EconAgent	LEN	CATS	Simcity(Ours)
Phillips Curve ^a	/	✓	×	×	✓
Okun’s Law ^b	/	✓	✓	✓	✓
Beveridge Curve ^c	/	/	× ^d	/	✓
Price Elasticity of Demand ^e	/	/	/	/	✓
Engel’s Law ^f	/	/	/	/	✓
Investment Volatility ^g	/	/	/	/	✓
Price Stickiness ^h	/	/	/	/	✓

Legend: ✓: Verified; ×: Verified but inconsistent; /: Mechanism not available in the model.

^aShort-run inverse relationship between the inflation rate and the unemployment rate.

^bInverse relationship between the change in the unemployment rate and the change in real GDP growth.

^cJob vacancy rate tends to fall when unemployment rises.

^dThe LEN paper claims verified Beveridge Curve, but we are unable to reproduce with <https://github.com/newwayland/baseline-economy>.

^eQuantity demanded is downward sloping in price, though the magnitude depends on the type of goods.

^fAs household income rises, food’s spending share declines while the absolute amount increases.

^gConsumption is less volatile than GDP, while investment is more volatile than GDP over the business cycle.

^hPrice has stickiness, i.e., firms don’t update price frequently. This is also often called “menu cost”.

widely used monetary policy targeting rule (Galí & Gertler, 2007; Dawid & Gatti, 2018). Formally:

$$\hat{r} = \max(r^n + \pi^t + \alpha(\pi - \pi^t) + \beta(Y - Y^n), 0), \quad (3)$$

where \hat{r} is the policy rate set by the central bank, r^n the long-run natural interest rate, π^t the target inflation rate, π the GDP inflation in the last period, Y the actual output (GDP), and Y^n the potential output as measured by a linear trend. Parameters α and β capture the central bank’s responsiveness to inflation and output gap, respectively.

Intuitively, when inflation is high or output exceeds its long-term trend (signals of an overheated economy), the central bank raises interest rate to cool the economy and maintain monetary stability, and vice versa (Galí, 2015). To reflect the gradual adjustment observed in real-world monetary policy, we incorporate a smoothing term consistent with empirical evidence on persistent rate changes (Coibion & Gorodnichenko, 2012).

At each time step, deposits and loans accrue interest: deposit rate equals the policy interest rate, while loan rate equals the policy rate plus a fixed markup. Further details about the financial system are in Appendix C.5.

5 EXPERIMENTS

We conduct experiments to evaluate SimCity’s ability to perform macroeconomic simulations and to display urban development dynamics. A key limitation of existing frameworks (Lengnick, 2013; Li et al., 2024) is the lack of a common basis for comparison. Prior studies often highlight a relatively small set of selected macroeconomic phenomena, making it difficult to gauge and compare the capacities of different simulation frameworks. To address this gap, we compile a checklist of canonical macroeconomic “stylized facts” from the broad economics literature (Blanchard & Fischer, 1989; Williamson, 2014; Óscar Jordà et al., 2017; Axtell & Farmer, 2025), many of which have previously been used to evaluate other ABM models. We then use this checklist to assess SimCity’s ability to reproduce established patterns and to simulate new ones under novel economic shocks. Taking advantage of SimCity’s rich framework, we aim to answer the following research questions:

- **RQ1:** What phenomena emerge in SimCity, compared with prior simulation environments?
- **RQ2:** Are emergent regularities robust across multiple simulations?
- **RQ3:** How does SimCity grow during the move-in phase?
- **RQ4:** To what extent can SimCity reflect against external shock?

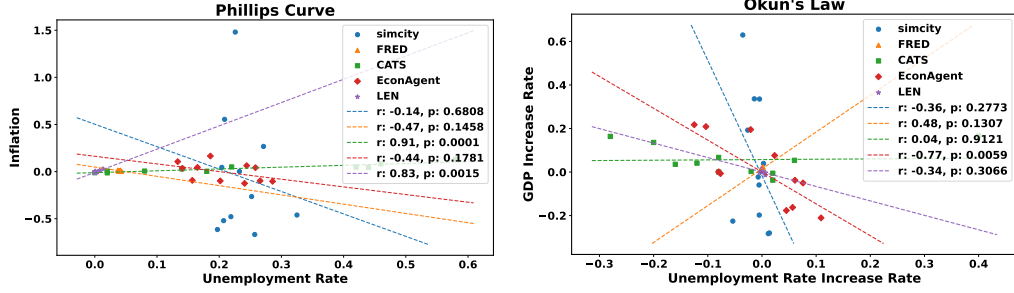


Figure 2: Emergence of the Phillips Curve and Okun’s Law in SimCity simulations. r -value is the Pearson correlation coefficient and p -value indicates the statistical significance of it.

5.0.1 EXPERIMENT SETUP

We simulate an economy with a maximum of 200 households. Simulation proceeds in two phases. During the initial phase, which lasts 36 steps (3 years), new households continue to enter. During the second phase, which lasts 144 steps (12 years), the population remains fixed and we observe the simulation under steady-state conditions. We use `gpt-4o-mini` for regular reasoning and `gpt-4` as the vision language model for establishment decision-making. Both are provided by Azure OpenAI API¹ with default sampling parameter. We provide detailed examples of prompts and responses in Appendix E.3.

For comparison, we select two traditional ABMs with predetermined rules LEN (Lengnick, 2013) and CATS (Gatti et al., 2011), a deep multiagent reinforcement learning model AI-economist (Zheng et al., 2022), a LLM-based system EconAgent (Li et al., 2024) and real world data FRED from 1970 Q1 (Federal Reserve Economic Data)².

5.1 EMERGENCE OF MACROECONOMIC PHENOMENA (RQ1)

A central test of macroeconomic simulations is its ability to exhibit well-documented empirical regularities (“stylized facts”) observed in real economies. Leveraging the strong role-play capabilities of LLM agents, SimCity captures many of these regularities that traditional agent-based models have historically struggled to generate. Table 2 summarizes the key phenomena and compares SimCity’s performance with baseline models.

Phillips Curve and Okun’s Law The Phillips Curve (Phelps, 1967) describes the inverse relationship between unemployment and inflation, while Okun’s Law (Okun, 1963) depicts the negative relationship between changes in the unemployment rate and real GDP growth. Following prior work (Li et al., 2024), we use these well-known empirical regularities as major tests of the plausibility of macroeconomic dynamics in our simulation. Recent economic studies using more modern methodologies and granular data document that the Phillips Curve slope is small and has flattened in recent decades (Hazell et al., 2022; Furlanetto & Lepetit, 2024). Consequently, a steeper or more negative slope does not necessarily indicate a more faithful reproduction of the Phillips Curve. As shown in Figure 2, SimCity successfully demonstrates these relationships.³ We acknowledge that the SimCity points have a large p -value (this could be improved by a larger sample size), but we empirically verify that the negative slope can be reproduced with different random seeds in Section 5.2.

Beveridge Curve The Beveridge Curve captures the negative relationship between the job vacancy rate, which is the number of unfilled job openings as a proportion of total job postings, and the unemployment rate (Blanchard & Diamond, 1989; Lengnick, 2013). SimCity successfully exhibits this relationship too, whereas other frameworks in comparison lack the firm module needed to explicitly model job vacancies.

¹<https://portal.azure.com/>

²<https://fred.stlouisfed.org/>

³We omit AI-Economist from this comparison because unemployment is not incorporated in its framework.

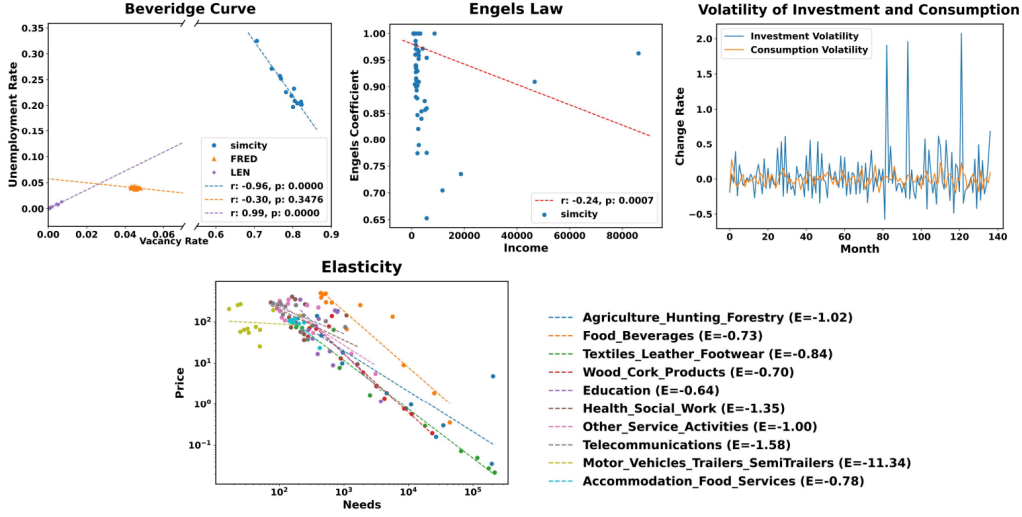


Figure 3: Beveridge Curve and other macroeconomic emergences from SimCity.

Further Tests We further validate our model by examining Engel’s Law, a foundational empirical regularity, and the Law of Demand, a fundamental economic principle. Engel’s Law states that the proportion of income spent on food (the Engel coefficient) decreases as income rises (Chai & Moneta, 2010). Simulations from SimCity correctly exhibit this pattern, reflecting that LLM-driven agents display human-like preferences. Notably, validating Engel’s Law requires a heterogeneous goods market, which previous frameworks lacked and therefore could not support.

To test the Law of Demand, we estimate the Price Elasticity of Demand (PED) for each good, defined as $E = \frac{\Delta \log Q}{\Delta \log P}$, which measures how quantity demand responds to changes in price. Standard economic theory predicts a negative elasticity for normal goods, but the magnitude depends on the importance of the good to consumers (Mas-Colell et al., 1995). As shown in Figure 3, SimCity not only exhibits the general negative association predicted by the Law of Demand but also captures the variation in elasticity across goods. For example, necessities like “food/beverages” are more inelastic ($-1 < E < 0$), whereas goods such as “motor/vehicles/trailers/semitrailers” are more elastic ($E < -1$), which is a pattern confirmed by numerous empirical studies (Perloff, 2009; Nelson et al., 2014). Last but not least, as shown in Figure 3 (top-right), our volatility of investment is larger than that of consumption, which matches common-sense.

5.2 ROBUSTNESS (RQ2)

An important question for LLM-driven simulations is whether the observed economic phenomena remain stable and reproducible across runs. To address this, we run three sets of experiments with the same hyper-parameters but different random seeds, and the results demonstrate that the observed regularities are robust. Experiment results can be found at Figure 6 in Appendix B.1.

5.3 URBAN EXPANSION DURING THE MOVE-IN PHASE (RQ3)

As mentioned in Section 3.1, our simulation involves a phase in which households move in. Figure 4 illustrates the developments during this stage. As shown in the figure, in the first 15 months, GDP steadily increases with the influx of residents. Then, as the influx ceases, the city transitions from a period of expansion to one of stable development after more than ten months of fluctuations. Meanwhile, we note that the VLM, without additional prompts, forms a clustered structure with residential areas near the center and production buildings on the periphery.

5.4 CASE STUDY: EXOGENOUS PRICE IMPULSE (RQ4)

We separately apply a price-down and a price-up impact on the city. In the beginning of year 15, we randomly select 7 of 44 goods in two different simulations and apply a 50% price-down and a price-up impulse separately. We then let the simulation run for 6 years. Price-down impulse response is

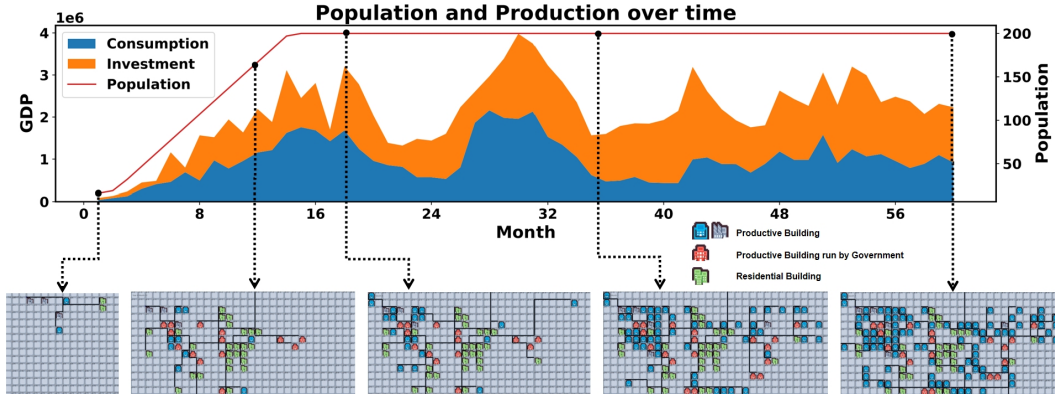


Figure 4: GDP & population curves, and map changes during the move-in phase.

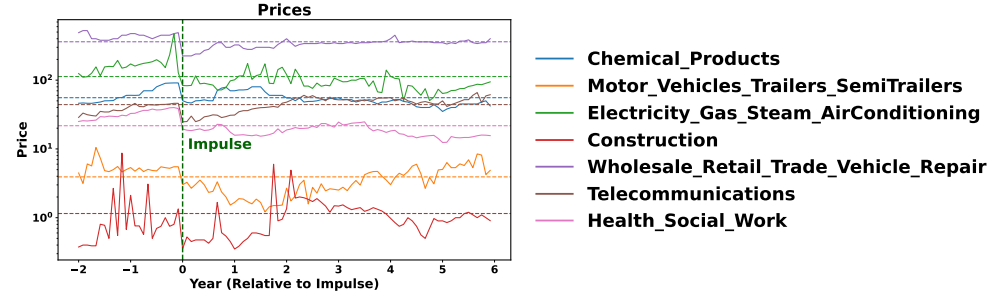


Figure 5: External impulse (at year 15) does not significantly affect tendency of prices of goods.

shown as Figure 5 and price-up at Figure 7 (Appendix B.2). The experiment shows that the good’s price level gradually returns to equilibrium after an exogenous shock. Due to the effect of price stickiness, the response to the exogenous shock will take some time. Note that dotted lines in the figure represent long-run average prices of goods. Since the shock is one time and the fundamentals of the economy did not change, prices revert close to their original levels in the long-run.

6 LIMITATIONS

Abnormal Behavior from Agents. Our agent’s decision-making is powered by a LLM. A significant challenge arises from the inherent difficulty in imposing robust constraints on the LLMs’ decisions. Furthermore, there exists a non-trivial probability that the LLM may generate highly aberrant or unexpected decisions, such as altering a price by several orders of magnitude. While the likelihood of any single such event is small, its probability becomes non-negligible over hundreds of iterations. In this work we apply simple heuristic-based checks prevent those egregious behavior.

Lack of Complex Financial Activities Our current simulation framework does not incorporate real-world financial markets, such as those for bonds, stocks, or their derivatives. Moreover, the simulated agents do not employ mathematical optimization techniques in their investing strategies. These simplifications may limit the model’s ability to accurately simulate complex market dynamics.

7 CONCLUSION

With SimCity, we conduct complex simulations that incorporates four distinct LLM-driven economic roles (households, firms, the central bank and the government), with a visualized map and markets with heterogeneous goods. Experiments show that SimCity robustly matches a checklist of established macroeconomic phenomena and exhibit plausible responses to exogenous shocks. We hope SimCity could serve as a solid base platform towards more a realistic economic simulation.

8 ETHICS STATEMENT

This work utilize LLM-driven agents to simulate. No sensitive or private data is used. Names of agents are generated by LLMs and are not intended to represent any real individuals or entities. Our simulation has not been quantitatively calibrated with real-world data and does not constitute a prediction of reality.

9 REPRODUCIBILITY STATEMENT

To help with the reproducibility of our work, we provide all LLMs prompts in Appendix E.1. We call LLMs API with default sampling parameters. We repeat experiments with different random seeds (Appendix B.1) to ensure that our main results are robust. We plan to release code in near future.

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A STATEMENT ON LLM USAGE

This work utilize LLM-driven agents to simulate. In addition, we use LLMs to improve the grammar and readability of this manuscript. The LLM was not used for any other scientific aspects of this work, and all intellectual content is solely the product of the authors.

B EXPERIMENT DETAIL AND ADDITIONAL RESULTS

LLMs Costs Our simulation costs about 800,000 tokens, which is roughly \$0.25 per step. For a standard 180 steps simulation, the total cost is around \$180.

B.1 ROBUSTNESS

We run three sets of experiments with the same hyper-parameters but different random seeds, and the results demonstrate that the observed regularity is reproducible.

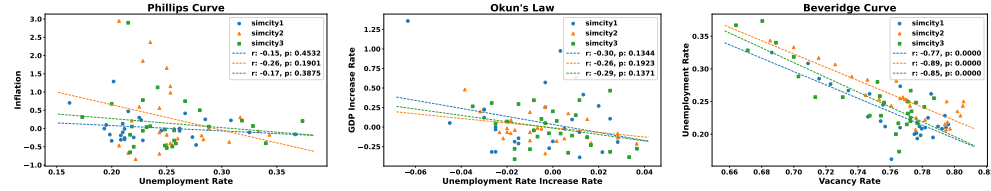


Figure 6: The results from different random seeds demonstrate that the observed regularity is robust.

B.2 PRICE IMPULSE

The price-up impulse response, Figure 7, is shown here due to space limitation.

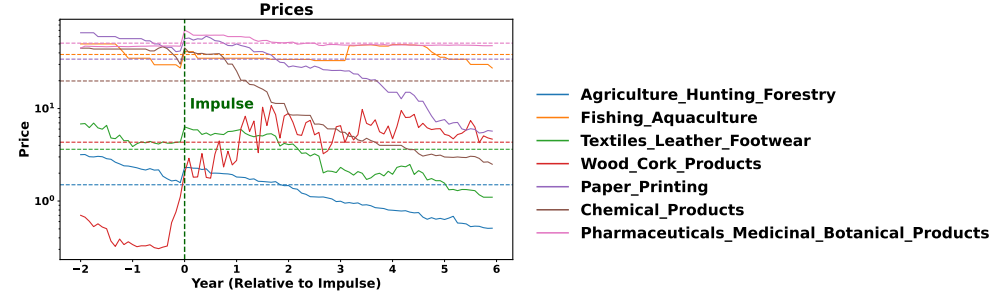


Figure 7: External impulse does not significantly affect long-run prices.

C AGENTS DETAILS

C.1 NOTATIONS

We define the following notations:

- The goods set, \mathcal{G} , where $|\mathcal{G}|$ denotes the number of heterogeneous goods present in our simulation. Certain subsets of \mathcal{G} have a specific meaning, such as \mathcal{G}_E for essential goods, \mathcal{G}_T for transportation goods and \mathcal{G}_D for durable capital.
- Each step in our simulation represents a month. For clarity, time subscripts are suppressed unless needed for exposition. For example, the labor choice at time t for household i is written as l_i instead of $l_{i,t}$.

C.2 HOUSEHOLDS

A household i is characterized by the following attributes:

- **Cash Holdings m_i :** The amount of money held by the household.
- **Labor Participation:** An indicator $l_i \in \{0, 1\}$, where 1 means the household is employed to work in a position denoted by position $_j$ and receives a salary S_j , and 0 means the household is unemployed. Note we are modeling the extensive margin of labor, instead of the intensive margin (hours worked).
- **Innate Skills:** Each household is endowed with heterogeneous skills. Please see Table 3 for the full list of skills. For each skill j , the innate skill level $s_{i,j} \sim U(s_{\min}, s_{\max})$ means that when the household works in a job requiring skill j , it supplies $l_i \times s_{i,j}$ effective units of labor. Additionally, the probability that a household is matched with a vacancy requiring skill j is an increasing function of $s_{i,j}$. This is in line with the directed search literature in economics (Wright et al., 2021).
- **Heterogeneous Consumption Preferences:** The household has needs denoted by n_i . For each good $g \in \mathcal{G}$, $n_{i,g}$ represents the desired number of units of good g to be purchased. n_i may split to essential needs $n_{e,i}$ which is fixed denoting immutable demands and additional needs $n_{a,i}$. The modeling of essential goods has a long history in economics. See for example, the Stone-Geary Utility function (Stone, 1954).
- **Housing:** Each household resides in a house \mathcal{H}_i . Consequently, the household must pay rent r_i to the owner of the property⁴.

C.3 FIRMS

Each firm i is characterized by the following attributes:

- **Cash Holdings m_i :** The monetary resources currently available to the firm.
- **Output Good:** Each firm specifies a specific type of good $g_i \in \mathcal{G}$.
- **Shareholders:** A collection of households and/or government entities, each holding a share denoted by $\text{share}_{i,j}$.
- **Dividend Rate d_i :** A parameter $d_i \in [0, 1]$ representing the fraction of the firm’s profits that are distributed as dividends to shareholders. Specifically, a shareholder holding $\text{share}_{i,j}$ receives a dividend computed as:

$$D_j = \frac{\text{share}_{i,j} d_i m_i}{\sum \text{share}_i}.$$

- **Job Positions \mathcal{J}_i :** A list of job vacancies within the firm. Each position j requires a specific skill and offers a salary $S_{i,j}$.
- **Durable Capital \mathcal{K}_i :** The stock of durable capital assets that the firm has invested in to support production.
- **Estimated Value \mathcal{V}_i :** The firm’s estimated value, calculated as:

$$\mathcal{V}_i = \frac{\sum_{j=t-12}^{t-1} \text{profit}_j}{12 \cdot \max(\mathcal{I}_{d,t}, \epsilon_d)} + m_i - L_i + \mathcal{K}_i.$$

where $\mathcal{I}_{d,t}$ denotes the GDP deflator, and $\epsilon_d = 0.02$ is a lower bound introduced to prevent division by zero.

- **Loans:** The amount of loan the firm owes to the financial system.

If a firm experiences zero income for a year and its assets are insufficient to cover its overdue debts, the firm is declared bankrupt. In that case, all employees are terminated, and the land it occupied is released.

A rentable apartment (residential building) is also formally modeled as a firm, though its decision-making is limited to adjusting its rental price based on conditions in the housing market.

⁴In this model, we assume that everyone rents their housing. In reality, if a household owns its home, one can think of it as renting a property in which it holds full ownership.

C.4 GOVERNMENT

The government records a series of indicators:

- **nominalGDP_t**: the sum of consumption, investment, and government spending, and **realGDP_t**, computed things above using the base year's prices.
- **eq_t**, **giniW_t**, **giniI_t**: measures of equality, wealth inequality (Gini coefficient), and income inequality (Gini coefficient), defined as follows. Suppose there are n households, and let $\{x_{(i)}\}_{i=1}^n$ denote the sorted (in increasing order) wealth (or income) of households. Then,

$$\mathbf{giniW}_t = \frac{\sum_i \text{sorted_wealth}_i \cdot 2i}{n \cdot \text{sum_wealth} - \frac{n+1}{n}}, \quad (4)$$

$$\mathbf{giniI}_t = \frac{\sum_i \text{sorted_income}_i \cdot 2i}{n \cdot \text{sum_income} - \frac{n+1}{n}}, \quad (5)$$

$$\mathbf{eq}_t = 1 - \frac{n}{n-1} \mathbf{giniI}_t. \quad (6)$$

- Unemployment rate u_t , along with broad monetary aggregates M0 and M1⁵.
- Goods production Y_t , and average production $\bar{Y} = \frac{\sum_t Y_t}{T}$.
- Inflation: including wage inflation \mathcal{I}_w and GDP inflation \mathcal{I}_d , each defined by:

$$\mathcal{I}_{w,t} = \frac{\sum_{\text{household}} S_{i,t}}{\sum_{\text{household}} S_{i,t-1}} - 1, \quad (7)$$

$$\mathbf{GDPdeflator}_t = \frac{\mathbf{nominalGDP}_t}{\mathbf{realGDP}_t}, \quad (8)$$

$$\mathcal{I}_{d,t} = \frac{\mathbf{GDPdeflator}_t}{\mathbf{GDPdeflator}_{t-1}} - 1. \quad (9)$$

C.5 CENTRAL BANK AND FINANCIAL SYSTEM

We implement a Taylor rule with interest rate smoothing in the policy behavior of our simulated central bank agent. Without smoothing, simulated interest rates exhibit implausibly high volatility in response to small shocks.

Interest rate smoothing refers to the empirical regularity that central banks adjust policy rates gradually over time, rather than immediately to the level implied by contemporaneous macroeconomic conditions. This behavior is often interpreted as reflecting forward-looking policy preferences, model uncertainty, or an aversion to financial market instability. In practice, this means that the actual interest rate set by the central bank is

$$r_t = \rho r_{t-1} + (1 - \rho) \hat{r}_t, \quad (10)$$

where \hat{r} is the policy rate computed from the unmodified Taylor rule 3, r_{t-1} the interest rate set last period, and ρ is the smoothing factor.

Empirically, interest rate smoothing is a well-documented phenomenon. For example, Coibion & Gorodnichenko (2012) estimate a Taylor rule with smoothing and find that the smoothing coefficient typically ranges between 0.7 and 0.9 in developed economies. We choose $\rho = 0.8$ as our parameterization.

D FRAMEWORK DETAILS

D.1 ENVIRONMENT SETUP

There are 44 types of goods in SimCity. Each of them represents of an economic industry in the real world as categorized by Organization for Economic Co-operation and Development (OCED).

⁵M2 is not included since fixed deposits have not been defined.

Initial prices of all goods are set at 50. However, the specific choice of initial prices do not matter for our simulation. We experimented with various initial prices but in all cases, as we mention in 5.4, prices reach steady-state in a small number of steps. Similarly, wages of positions and rents of residential buildings are set arbitrarily.

D.2 STAGES WITHIN EACH STEP

As aforementioned, each simulation step represents one month, and each step includes the following four stages:

- **Production and Trading Stage:** Firms produce goods, after which households and firms purchase goods for consumption and materials as planned.
- **Taxation and Dividend Stage:** Firms pay dividends, while the government collects taxes and disburses welfare.
- **Metabolic Stage:** New companies are established through equity financing from the investment pool, bankrupted companies are removed, and the population grows according to set rules.
- **Revision Stage:** Households, firms, the government, and the central bank agents review their situations and decide on their actions. Only the revision stage involves LLM agents.

D.3 RENDER MODULE

We utilize `flask-socketio` to build a web-server and `Vue.js` to build a website.

The assets are from the open-source `tiny-battle` package created by Kenney⁶.

D.4 PROFILE SETUP

Age distribution is from the Demographic and Housing Characteristics (DHC) table from U.S. Census Bureau⁷.

To assign realistic initial cash holding to households, we estimate the income distribution using U.S. microdata. We use the 2023 American Community Survey (ACS) IPUMS microdata, which contains detailed household-level income information. We assume a lognormal distribution for household income, a standard approximation in the economics literature due to its simplicity and its ability to capture the right-skewed nature of income data.⁸ Formally, the initial cash holding is drawn from

$$\ln m_{i,0} \sim \mathcal{N}(\mu, \sigma^2) \quad (11)$$

where $\mu = 11.1496$, $\sigma^2 = 1.1455$, which are estimated via maximum likelihood estimation (MLE).

D.5 SYNTHESIS

We assume that each category of goods is produced by a representative type of firm. Therefore, we generate a firm template for each category, which specifies the firm’s name, the skill requirements for its positions, and an input-output ”recipe” derived from the Input-Output Tables (IOTable) provided by the OECD.⁹

We process the IOTable to determine the inputs for each firm. For each category of goods, we normalize the input requirements from all other categories needed to produce one unit of output. We then select the top input categories that cumulatively account for more than 75% of the total input value, defining these as the necessary inputs for the corresponding firm’s production process.

⁶www.kenney.nl

⁷<https://data.census.gov/table?q=PCT12&d=DEC+Demographic+and+Housing+Characteristics>

⁸While some heavier-tailed distributions (e.g. Pareto) better approximate top incomes, our simulation does not focus on the super-rich. Hence, the lognormal distribution is a reasonable choice. See Hlasny (2021) for a recent summary of related work.

⁹<https://www.oecd.org/en/data/datasets/input-output-tables.html>

Then, we use the prompt introduced in Listing 1 to call a LLM to generate the processed input-output into a firm template.

Observing that the positions required skills in the generated firm templates contain many semantically similar skills, we use the prompt introduced in Listing 2 to call an LLM to merge these similar skills. Skills after merge is shown at Table 3.

Listing 1: Prompt for firm template generation.

```
I am currently developing a game. One of the tasks I need to do now is:
    Given a recipe, please help me design a building to produce this
    recipe.
First, I will give you a recipe, which is composed of some raw materials.
    Then, you need to design a suitable building to produce it. Noticing
    that the employees' core skill should be as abstract as possible.

``type`` must either "BusinessBuilding" or "ServiceBuilding". If you
    consider a type of product is mainly provided by government, you
    should set it as ServiceBuilding, else BusinessBuilding.
Here is an example:

```
Recipe

{
 "input": {
 "RawFood": 1000
 },
 "output": {
 "Food": 1000
 }
}

Your Response:

{
 "template_name": "Restaurant",
 "width": 1,
 "height": 1,
 "description": "A restaurant that uses raw food to serve food.",
 "type": "BusinessBuilding",
 "building_cost": 500000,
 "provide_radius": 10,
 "employees": [
 {
 "position_type": "Manager",
 "salary": 3000.0,
 "core_skills": [
 "Management"
],
 "importance": 1.0
 },
 {
 "position_type": "Cook",
 "salary": 1000.0,
 "core_skills": [
 "Cooking"
],
 "importance": 0.5
 },
 {
 "position_type": "Waiter",
 "salary": 1000.0,
 "core_skills": [
```

```

972 "Service"
973],
974 "importance": 0.5
975 },
976 {
977 "position_type": "Waiter",
978 "salary": 1000.0,
979 "core_skills": [
980 "Service"
981],
982 "importance": 0.5
983 }
984],
985 "recipes": [
986 {
987 "input": {
988 "RawFood": 1000
989 },
990 "output": {
991 "Food": 1000
992 }
993 }
994]
995 }
996 ```
997
998 Now the recipe I provide will listed follow "### Recipe ###"
999 You should respond with a factory design in the same format as the
1000 examples above.

```

Listing 2: Prompt for merging skills

```

1000 ```
1001 [Skills]
1002 ```
1003 The content above is a list of several skills from my economic simulation
1004 environment, SimCity. A job posting might require several of these
1005 skills. I now feel that there are too many of them and they need to
1006 be simplified. Please merge the skills that have the same meaning
1007 into a single skill (note: only merge two skills if and only if they
1008 are very similar; for example, Geology and Mining should not be
1009 merged because they are different specialties), and provide the merge
1010 relationships: a JSON object { "A": "B" } indicates that skill A is
1011 essentially skill B.
1012
1013 If several skills are to be merged into one category, choose the most
1014 representative one as B. Then, return this JSON object.
1015
1016
1017
1018
1019
1020
1021
1022
1023
1024
1025

```

Table 3: List of skills.

|                     |                       |                         |                        |
|---------------------|-----------------------|-------------------------|------------------------|
| Management          | Quality Control       | Operations Management   | Logistics Management   |
| Physical Labor      | Aquaculture           | Environmental Science   | Engineering            |
| Monitoring          | Maintenance           | Geology                 | Mining                 |
| Chemistry           | Surveying             | Technical Skills        | Food Science           |
| Machinery Operation | Safety Management     | Supply Chain Management | Pharmaceutical Science |
| Laboratory Skills   | Metalworking          | Assembly                | Energy Management      |
| Water Management    | Equipment Maintenance | Project Management      | Design                 |
| Building            | Sales                 | Customer Service        | Vehicle Maintenance    |
| Data Analysis       | Regulations           | Equipment Operation     | Driving                |
| Transportation      | Communication         | Culinary                | Cleaning               |
| Media Production    | Equipment Handling    | Logistics               | Information Technology |
| Finance             | Technical Support     | Real Estate             | Insurance              |
| Market Analysis     | Office Management     | Administrative Support  | Building Maintenance   |
| Research            | Consulting            | Facility Maintenance    | Basic Repairs          |
| Support             | Teaching              | Marketing               | Legal Knowledge        |
| Human Resources     | Sanitation            |                         |                        |

## E PROMPTING AND EXAMPLES

### Structure of Prompt

#### System Prompt:

You are a citizen of SimCity and you are taking action improve your life . Basically speaking, your goal is to be consuming a greater variety of products, acquiring more money and assets, and having a stable job and residence .

There are some information about you and the city which may affect your life ...

#### User Prompt:

User Prompt:

### Profile

Your name is [name], and you are [age] years old..... You current have [money] money. You are working at [place] as [ position ] with salary [ salary ]...

### Report

...During the past 12 months, your average income is [average\_income]. This month, your income is [ total\_income ] , which consists of the following parts :

- Salary : ...
- Benefit : ...

...

This month, your outcome is [ total\_outcome ]

...

### Observation

Here are opening positions in the city :

-[ position\_id ]: ...

...

The social average return on investment is [roi], and the interest rate of the bank is [ interest\_rate ] .

Figure 8: Structure of Prompt

### E.1 PROMPTING STRUCTURE

We aim to leverage the common-sense capabilities of large language models to act as human-like, heterogeneous agents. Figure 8 provides the structure of the prompt for a household agent.

As mentioned in 4, the Agent will receive necessary information to make its decisions. The Profile includes some basic personal information about the Agent, such as current income, age, skills, job, and residence. The Report includes some of the Agent’s recent experiences and information. The Observation presents information about the overall environment that the Agent should be aware of,

Table 4: Example Listings

| Agent Type                 | System Prompt | User Prompt | Response   |
|----------------------------|---------------|-------------|------------|
| Household                  | Listing 3     | Listing 4   | Listing 5  |
| Government                 | Listing 6     | Listing 7   | Listing 8  |
| Investment Pool            | Listing 9     | Listing 10  | Listing 11 |
| Firm(Productive Building)  | Listing 12    | Listing 13  | Listing 14 |
| Firm(Residential Building) | Listing 15    | Listing 16  | Listing 17 |

such as vacant positions, the unemployment rate, prices of goods and the Return on Investment (ROI).

Prompts for other agents are structured in a similar manner. Detailed examples are provided in Appendix E.3.

## E.2 FUNCTION CALLING

The model interacts with the environment by means of Function Calling. The framework loads all the operations that the Agent can execute and appends formatted function names along with their descriptions to the prompt. The LLMs will return the actions to be taken and their parameters in JSON format. Framework will execute after a verification.

## E.3 FULL EXAMPLES

Full examples of all types of agents can be found at Table 4.

Listing 3: System prompt example of household agent

```
You are a citizen of SimCity and you are taking action improve your life.
Basically speaking, your goal is to be consuming a greater variety
of products, acquiring more money and assets, and having a stable job
and residence.
There are some information about you and the city which may affect your
life. The information including four parts: "### Profile", "###
Report", "### Observation", and "### Actions".
You will be provided your personality traits and skills, and some
personal information, which will be listed after "### Profile".
You have also provided your last month's living status, which will be
listed after "### Report".
Any information about the city which may affect your life will be listed
after "### Observation".
Based on this information, you may take some actions to improve your life
. These actions you may take will be listed after "### Actions".
You should only respond in JSON format as described below:
{
 "reasoning": "reasoning"
 [
 "action1(para1, para1, ...)",
 "action2(para1, para1, ...)",
 ...
]
}
Ensure the response can be parsed by Python 'json.loads', e.g.: no
trailing commas, no single quotes, etc.
```

Listing 4: User prompt example of household agent

```
Profile
```

1134  
 1135 Your name is Donald, and you are 61 years old. You current have 2667.408  
 1136 money in your account.  
 1137 You are a Active, Unadventurous man  
 1138 You are working at Mining Facility as Engineer with salary 2200. This  
 1139 work requires skills: Engineering.  
 1140  
 1141 You are living in Residential Building at (12, 11) with rent 900. Your  
 1142 work place is at (15, 19). The distance between your home and your  
 1143 work place is 11.  
 1144  
 1145 You have experienced the following education:  
 1146 - K-12  
 1147 - Bachelor  
 1148 - Master  
 1149  
 1150 You plan to spend a percentage of your income on the following items:  
 1151 - Agriculture\_Hunting\_Forestry: 0.1  
 1152 - Fishing\_Aquaculture: 2.0  
 1153 [... and other needs.]  
 1154 - Household\_Employer\_Activities: 0.0  
 1155 - Motor\_Vehicles\_Trailers\_SemiTrailers: 0.0  
 1156  
 1157 Bank Account Donald:  
 1158 You have no savings  
 1159 You have no loans.  
 1160 Demand deposit interest rate is 56.0464%, and loan rate is 58.0693%.  
 1161 Your loanable amount is 677334.81606351.  
 1162  
 1163 ### Report  
 1164  
 1165 This month, your income is 5467.408, which consists of the following  
 1166 parts:  
 1167 - Salary: 2800.000 (51.2126%)  
 1168 - Welfare: 2667.408 (48.7874%)  
 1169  
 1170 This month, your outcome is 3753.360, which consists of the following  
 1171 parts:  
 1172 - Consumption: 2878.360 (76.6876%)  
 1173 - Agriculture\_Hunting\_Forestry: 290.547 (10.0942%)  
 1174 - Wood\_Cork\_Products: 560.000 (19.4555%)  
 1175 - Education: 280.000 (9.7278%)  
 1176 - Other\_Service\_Activities: 1400.000 (48.6388%)  
 1177 - Electricity\_Gas\_Steam\_AirConditioning: 280.000 (9.7278%)  
 1178 - Food\_Beverages: 67.813 (2.3560%)  
 1179 - Tax: 0.000 (0.0000%)  
 1180 - Rent: 875.000 (23.3124%)  
 1181  
 1182 ### Observation  
 1183  
 1184 Here are opening positions in the city:  
 1185 - position\_id: 2000149, Warehouse Worker requires skills Physical Labor,  
 1186 Logistics Management, with salary 350  
 1187 - position\_id: 2000330, Maintenance Worker requires skills Maintenance,  
 1188 Physical Labor, with salary 500  
 1189 [... and other available positions.]  
 1190 You expect the work should cover your spending of 3753.360.  
 1191  
 1192 Here are available residential buildings in the city:  
 1193 - residential id: 200006 at (11, 1) with rent 875  
 1194 - residential id: 200051 at (7, 14) with rent 875  
 1195 [... and other residential buildings' position and rent]  
 1196 - residential id: 200036 at (12, 5) with rent 900  
 1197 - residential id: 200052 at (21, 7) with rent 875

1188 The social average return on investment is 13.1554%, and the interest  
 1189 rate of the bank is 56.0464%.  
 1190 If roi is higher than the interest rate of the bank, you can invest your  
 1191 money in the investment market to get a higher return on investment  
 1192 and you may borrow money from the bank to invest if you need.  
 1193 Otherwise, you may simply save your money in the bank.  
 1194 The prices of goods on the market are as follows:  
 1195 - Agriculture\_Hunting\_Forestry: 121.652, 35.9921%  
 1196 - Fishing\_Aquaculture: inf, 0.0000%  
 1197 - Food\_Beverages: 137.423, 35.5278%  
 1198 [... and other prices and their tendency. ]  
 1199 - Household\_Employer\_Activities: inf, 0.0000%  
 1200 - Motor\_Vehicles\_Trailers\_SemiTrailers: 75.000, 130.7692%  
 1201 When adjusting your needs for goods, please keep the following points in  
 1202 mind:  
 1203 1. You can adjust your needs for goods based on the price change rate.  
 1204 All change rates are derived from the average prices of the past 12  
 1205 months.  
 1206 2. Your demand for goods should also reflect your income. If your income  
 1207 increases, you should allocate a higher percentage of your income to  
 1208 luxury items and a lower percentage to food.  
 1209 3. If your income decreases, you should allocate a lower percentage of  
 1210 your income to luxury items and a higher percentage to food.  
 1211 During the past 12 months, your average income is 733.333:  
 1212 - 12 months ago, you were unemployed, and your income was 0.000.  
 1213 - 11 months ago, you were working at Maintenance Worker, and your income  
 1214 was 0.000.  
 1215 - 10 months ago, you were unemployed, and your income was 0.000.  
 1216 - 9 months ago, you were working at Laborer, and your income was  
 1217 1500.000.  
 1218 - 8 months ago, you were working at Laborer, and your income was  
 1219 1300.000.  
 1220 - 7 months ago, you were working at Laborer, and your income was 0.000.  
 1221 - 6 months ago, you were working at Production Worker, and your income  
 1222 was 2000.000.  
 1223 - 5 months ago, you were working at Warehouse Worker, and your income was  
 1224 0.000.  
 1225 - 4 months ago, you were working at Production Worker, and your income  
 1226 was 1200.000.  
 1227 - 3 months ago, you were working at Warehouse Worker, and your income was  
 1228 0.000.  
 1229 - 2 months ago, you were working at Engineer, and your income was 0.000.  
 1230 - 1 months ago, you were working at Engineer, and your income was  
 1231 2800.000.  
 1232 ### Interfaces  
 1233 Here are the actions you may take:  
 1234 - resign(): If you are currently employed, you will be fired from your  
 1235 current job.  
 1236 - find\_job(position\_id: int): Choose a job. If you are already employed,  
 1237 you will be fired from the current job. You may choose not to work  
 1238 even if you are unemployed to wait for a better opportunity.  
 1239 - modify\_needs\_percentage(name: str, percentage: float): Set your needs  
 1240 of a specific item to a certain percentage of your income. 1 means  
 1241 100% of your income, 0.5 means 50% of your income. Higher and more  
 varied needs may lead to higher happiness, while lower needs may  
 save your money.  
 - set\_invest\_rate(rate: float): Set the investment rate. The investment  
 rate is the percentage of your money that you will invest into the  
 investment market each month. It should be between 0 and 1.

```

- borrow(amount: float): Borrow money from the bank, those money will be
 paid back with interest. You may borrow money from the bank for
 investment or to purchase necessary consumable goods.
- payback(loan_id: int): Pay back the loan with the given loan_id.
- save_money(amount: float): Save money to the bank to get interest.
- withdraw(amount: float): Withdraw money from the bank.
- move_to_home(building_id: int): Move your home to a specific building.
 If your are currently homeless, you will move into the building.
- wait(): Your life is pretty good now. What you want is to keep the
 status quo.

```

Listing 5: Response example of household agent

```

{
 'reasoning': "At 61 years old, it's crucial to manage your finances and
 job stability. Given your current job as an Engineer at a Mining
 Facility with an income of 2800, your expenses are relatively high
 at 3753.360 monthly. You need to either adjust your spending habits,
 take a second job with potentially lower salary but manageable
 workload, or invest wisely. Your current plan shows significant
 consumption in various sectors. Considering the job market, there's
 an opportunity as a Metallurgist, which aligns with your Engineering
 skills and offers a higher salary. Resigning from your current job
 to pursue this position could help improve your finances
 significantly. Additionally, to prepare for a potential career
 transition, you might consider modifying your spending to save more
 .",
 'actions':
 [
 'resign()',
 'find_job(1000008)', # 1000008 here is a job id
 "modify_needs_percentage('Food_Beverages', 0.15)",
 "modify_needs_percentage('Other_Service_Activities', 0.3)",
 "modify_needs_percentage('Electricity_Gas_Steam_AirConditioning', 0.1)
]
}

```

Listing 6: System prompt example of government agent

```

You are the governing body of SimCity, entrusted with the task of making
 strategic decisions to improve the city's overall standard of living.
 There are four primary categories of information available to you that
 will affect your decision-making process: "### City Profile", "###
 City Statistics", "### Citizen Feedback", and "### Potential
 Initiatives".

The "### Report" section contains data regarding the city's current
 economic, social, and environmental status..

You should respond in JSON format as described below:
```
{
  "strategies": "strategies",
  [
    "initiative1(paral, paral, ...)",
    "initiative2(paral, paral, ...)",
    ...
  ]
}
```
Ensure the response can be parsed by Python `json.loads`, e.g.: no
 trailing commas, no single quotes, etc.

An example output might look like this:

```



```

1296 ...
1297 {
1298 "strategies": "Given the city's high unemployment rate and the
1299 citizens' feedback about lack of job opportunities, it would be
1300 beneficial to invest in job creation programs. Furthermore, the
1301 high levels of pollution suggest a need for environmental
1302 initiatives.",
1303 "actions": [
1304 "LaunchJobCreationProgram('Technology Sector')",
1305 "ImplementEnvironmentalPolicy('Recycling Initiative')",
1306]
1307 }

```

Listing 7: User prompt example of government agent

```

1309 ### Report
1310
1311 Here is the government report:
1312 The government has a balance of 1.102307578548789e-09.
1313
1314 Bank Account Government:
1315 You have no savings
1316 Loans:
1317 - id: 369, loan amount: 13924261.356747806, should be paid back at
1318 1973-01
1319
1320 Demand deposit interest rate is 56.0464%, and loan rate is 58.0693%.
1321 Your loanable amount is 10000000.000000002.
1322
1323 The government of the city has the following tax policy:
1324 - Tax Building by following brackets:
1325 - Up to 10000 get 3.0% tax
1326 - Up to 50000 get 8.0% tax
1327 - Up to 100000 get 13.0% tax
1328 - Tax Citizen by following brackets:
1329 - Up to 10000 get 5.0% tax
1330 - Up to 20000 get 10.0% tax
1331 - Up to 50000 get 15.0% tax
1332 - Up to 100000 get 20.0% tax
1333
1334 The government has collected 124774.65254701707 as tax.
1335 - Tax Citizen are from:
1336 - 55701.10070718494 are from up to 0
1337 - 0.0 are from up to 100000
1338 - Tax Building are from:
1339 - 0.0 are from up to 100000
1340 - 69073.55183983216 are from up to 0
1341
1342 The government has distributed 50000 to every citizen as UBI.
1343
1344 There're 200 citizens in the city, and working or living in 122 buildings
1345 .
1346 During the last month, the city has:
1347 - Consumption: 489137.5517
1348 - Investment: 1299054.2543
1349 and total nominal GDP is 1788191.8059999999.
1350 The real GDP, calculated by the base year's price, is 1810789.8210999998.
1351 The GDP deflator is 0.9875203544681556.
1352
1353 The social equality defined as Gini coefficient of income is 0.8564, and
1354 the wealth inequality is 0.8576.
1355 The unemployment rate is 0.235.
1356 During the past 12 months, the city has:

```

```

- 1972-02-01 00:00:00: Consumption: 803850.0466, Investment:
 1430793.5346, Government Expense: 50000.0, GDP: 2284643.5812, Wealth
 Gini Coefficient: 0.8619, Income Gini Coefficient: 0.7464,
 Unemployment Rate: 0.335, Homeless Rate: 0.095, Average Happiness:
 0.9475, Average Wage: 1234.325, Average Position Salary: 1755.1287,
 Broad Money Supply: M0 22620930.0, M1 22620930.0, Deposit Rate:
 0.4203, Loan Rate: 0.4421, Reserve Rate: 0.05
[... and other historic information.]

Interfaces
Here are the actions you may take:
- adjust_bracket(type: str, brackets: list[tuple[float, float]]): Adjust
 the tax bracket for a given type.
 type: 'Building' or 'Citizen'
 bracket: list of tuples, each tuple contains a threshold and a tax
 rate. 1 means tax 100% and 0.1 means tax 10%.
 e.g. adjust_bracket('Building', [(10000, 0.05), (50000, 0.1),
 (100000, 0.15), (500000, 0.2)])
- adjust_UBI(amount: float): Adjust the amount of UBI(Universal Basic
 Income) welfare. Noting that if the government has no money, it will
 not distribute UBI.
- invest(amount: float): Invest government's money into the investment
 market. This action may stimulate the economy.
- borrow(amount: float): Borrow money from the bank, those money will be
 paid back with interest.
- payback(loan_id: int): Pay back the loan with the given loan_id.
- save_money(amount: float): Save money to the bank to get interest.
- withdraw(amount: float): Withdraw money from the bank.

```

Listing 8: Response example of government agent

```

{
 'strategies': "The city's current balance indicates a significant amount
 of debt with no savings, suggesting that financial management needs
 immediate attention. The high unemployment rate points to economic
 distress, indicating a need for initiatives that stimulate job
 creation and investment. Adjusting tax brackets, especially for
 buildings, could also enhance government revenue, which is crucial
 given the existing loans. Additionally, reviewing the Universal
 Basic Income (UBI) distribution may free up resources for essential
 services.",
 'actions': [
 "adjust_bracket('Building', [(10000, 0.04), (50000, 0.07), (100000,
 0.12)])",
 'invest(10000000)',
 'borrow(10000000)',
 'adjust_UBI(40000)'
]
}

```

Listing 9: System prompt example of investment pool

```

You are a city planner in SimCity and you are tasked with planning the
position and type of a new building.

You must follow the following criteria:
1) The plan should be based on the current city layout and economic
 situation.
2) Act as a city planner and provide a detailed development plan. You may
 construct various buildings and can build multiple instances of the
 same type if deemed suitable.
3) Always refer to the city report, which outlines the current status of
 the city.
4) Determine the type and location of new buildings based on the
 information provided in the city report.

```

```

1404 5) Formulate a step-by-step plan for the construction of the buildings.
1405 6) Factories should be built together and placed away from residential
1406 areas, while service and commercial buildings should be located near
1407 residential areas.
1408
1409 There is some information about the city which may affect your plan. The
1410 information includes two parts: "### Report" and "### Layout"
1411
1412 You should then respond to me with
1413 Reasoning: Are there any steps missing in your plan? What is the purpose
1414 of each step in the plan? What does the city layout imply? What does
1415 the city report imply?
1416 x: x_position of the topleft corner
1417 y: y_position of the topleft corner
1418 type: which type of building you'd choose. if you decide not to build,
1419 type should be "None"
1420
1421 You should only respond in JSON format as described below:
1422 {
1423 "reasoning": str
1424 "investments": [
1425 {
1426 "x": int,
1427 "y": int,
1428 "type": str
1429 },
1430 ...
1431]
1432 }
1433 Ensure the response can be parsed by Python `json.loads`, e.g.: no
1434 trailing commas, no single quotes, etc.
1435
1436 Here are some examples:
1437
1438 INPUT:
1439 ### Report
1440 There are several building templates available for construction:
1441 - Residential Building: Houses 100 people, costs 500 money to build.
1442 - Factory: Employs 50 people, costs 1000 money to build.
1443 - Shop: Employs 10 people, generates 200 money per month, costs 500
1444 money to build.
1445
1446 ### Layout
1447 [An Image]
1448
1449 OUTPUT:
1450 {
1451 "reasoning": "Based on the city layout and report, the city cannot
1452 produce enough foods. The solution may be build a Restaurant.
1453 According to the layout, the (25, 25) is a good place.",
1454 "investments": [
1455 {
1456 "x": 25,
1457 "y": 25,
1458 "type": "Factory"
1459 }, {
1460 "x": 23,
1461 "y": 17,
1462 "type": "Factory"
1463 },
1464 {
1465 "x": 55,
1466 "y": 23,
1467 "type": "Residential Building"
1468 }
1469]
1470 }

```

```

]
}

```

#### Listing 10: User prompt example of investment pool

```

Report

Here is the average local price of goods in the city:
- Agriculture_Hunting_Forestry: 121.652
- Nonenergy_Mining_Products: 35.766
[... and other prices]
- Health_Social_Work: 168.629
- Other_Service_Activities: 65.000

If one of the goods is not produced, the price will not be displayed.

There're 200 citizens in the city, and 28 residential buildings have
capacity, and provide 139 empty houses.
The homeless rate is 0.045, which means 9 citizens are homeless.
and the average rent is 878.4848484848485

Here is the list of buildings that can be built in the city:
- Agro-Processing Plant(Produces Agriculture_Hunting_Forestry): An agro-
processing plant that transforms food beverages and agricultural
products into refined agricultural goods. Cost 50000 to build, needs
4 employees to run
- Aquaculture Facility(Produces Fishing_Aquaculture): A facility
dedicated to aquaculture, producing sustainable seafood and fishery
products. Cost 50000 to build, needs 5 employees to run
[... and all other templates available]
- Service Center(Produces Other_Service_Activities): A service center
that coordinates a variety of professional services and
administrative support to fulfill community needs. Cost 50000 to
build, needs 7 employees to run
- Residential Building: A place where people live. Cost 50000 to build,
may contain up to 10 people

The size of investment pool is: 3558921.7446145327

Those goods that citizens failed or partially satisfied because of the
lack of supply or high price:
- Professional_Scientific_Technical_Activities: Lack 3210.8557714909352
- Electricity_Gas_Steam_AirConditioning: Lack 1111.6091447969354
[... and all other templates available]
- Transport_Warehousing_Support: Lack 0.0
- Household_Employer_Activities: Lack 0.0

Layout

[An image encoded by base64]

```

#### Listing 11: Response example of investment pool

```

{
 'reasoning': 'The city report indicates certain deficits in goods and
services that are not being met, leading to rises in particular
goods prices and shortages. Several critical sectors are highlighted
for development: Electricity and Gas, Real Estate,
Telecommunications, and Food Beverages. Given the current investment
pool available, it is viable to invest in facilities producing
these significant needs to reduce shortages and stabilize prices.
The layout shows ample space available for construction and already
has a basic infrastructure setup, with residential and other

```

```

buildings positioned in various grid locations. Key sectors
identified for investment would benefit from proximity to existing
buildings for utilities and staff access. Positions (2, 2), (10, 3),
and (-2, -2) appear to be vacant plots suitable for building based
on the provided layout image.', 'investments': [
 {'x': 2, 'y': 2, 'type': 'Energy Production Facility'},
 {'x': -2, 'y': -2, 'type': 'Telecommunication Hub'},
 {'x': 10, 'y': 3, 'type': 'RealEstateDevelopmentOffice'},
 {'x': 4, 'y': 2, 'type': 'Food Processing Plant'}
]
}

```

#### Listing 12: System prompt example of firm(Productive Building) agent

```

You are a helpful assistant that utilize the information provided below
to adjust strategy for my company.

The information of the building will report below "### Report", and
actions you may do to the building will be listed after "### Actions
".

You must follow the following criteria:
1) You should analyze the report and utilize the actions to adjust the
strategy for the building.
2) You may engage in appropriate equity financing or loan and enhance
your output by purchasing capital.

You should only respond in JSON format as described below:
{
 "reasoning": "reasoning"
 [
 "action1(para1, para1, ...)",
 "action2(para1, para1, ...)",
 ...
]
}

Ensure the response can be parsed by Python 'json.loads', e.g.: no
trailing commas, no single quotes, etc.

One of the example outputs is as follows:
{
 "reasoning": "The building is in a good condition and the rent is low.
 You should consider increasing the rent to maximize profit.",
 "actions": [
 "IncreaseRent(1000)"
]
}

```

#### Listing 13: User prompt example of firm(Productive Building) agent

```

Report

Here is the monthly report for Food Processing Plant:
Overall, during this month, the building gross profit is -9028.45, with
rest cash 0.00. It has 16199.2565 durable investments for promoting
production.
The building has 2 employees, 2 vacant positions, and run with efficiency
109.6429%.
The building aims to maximize its profit, and the following is the
detailed income and expense:

This month, the building income is 17474.907, which consists of the
following parts:
- Local trading income: 17474.907(100.0000%)

```

1566 This month, the building outcome is 26503.355, which consists of the  
 1567 following parts:  
 1568 - Other outcome list as follows:  
 1569  
 1570 The efficiency of this building is 109.6429%, which consists of the  
 1571 following parts:  
 1572 - Production Manager has 35.7143% importance, and Kevin is working here.  
 1573 Because of Kevin's skills: Management\*1.15 Quality Control\*1.17 ,  
 1574 the efficiency addition is 82.8571%. 1000.0 salary is paid to Kevin.  
 1575 [... and other employees]  
 1576  
 1577 The building has 4 positions, and here are the details:  
 1578 - position\_id: 2000011, Kevin(Production Manager), salary: 1000.0  
 1579 [... and other positions]  
 1580 The unemployment rate in the city is 29.3333%, and the average  
 1581 unemployment rate in the past 12 months is 29.3333%.  
 1582 You may adjust the salary of the position according to the unemployment  
 1583 rate.  
 1584 If the unemployment rate is high, you could open more job positions (in  
 1585 practice, converting positions with zero wages into paid positions)  
 1586 while reducing the salaries of existing roles to save money.  
 1587 Alternatively, if the unemployment rate is low, you may adjust the salary  
 1588 of the position to a higher level to attract more candidates.  
 1589 Additionally, you may want to close certain vacancies that  
 1590 consistently fail to attract applicants.  
 1591  
 1592 The building run with loss: -9028.4482. And there will be no dividend for  
 1593 shareholders.  
 1594  
 1595 The social average return on investment is 12.8436%, and the interest  
 1596 rate of the bank is 56.0464%.  
 1597 If roi is higher than the interest rate of the bank, you can invest your  
 1598 money in the investment market to get a higher return on investment  
 1599 and you may borrow money from the bank to invest if you need.  
 1600 Otherwise, you may simply save your money in the bank.  
 1601  
 1602 The building has the following goods in storage:  
 1603 - Food\_Beverages: 90356.9299  
 1604 - Accommodation\_Food\_Services: 265.0336  
 1605  
 1606 Bank Account Food Processing Plant:  
 1607 You have no savings  
 1608 Loans:  
 1609 - id: 330, loan amount: 69237.53829366148, should be paid back at  
 1610 1972-12 <- DUE!! MUST PAYBACK AS SOON AS POSSIBLE!!!  
 1611 [... and other loans.]  
 1612  
 1613 Demand deposit interest rate is 56.0464%, and loan rate is 58.0693%.  
 1614 Your loanable amount is 0.  
 1615  
 1616 The building has the following price setting for selling goods:  
 1617 - Food\_Beverages: The average price in the city is 137.4227, changed  
 1618 (35.5278%) compared to last year. And the building's price is 200.  
 1619 [... and other goods.]  
 1620  
 1621 There are some items that you may produce more to sell because of  
 1622 shortage currently on the market:  
 1623 - Food\_Beverages: short of 1259.5254643790224 units goods on the market  
 1624 [... and other goods.]  
 1625  
 1626 During the past 12 months, the building has generated 511752.528 profit,  
 1627 running at an average efficiency of 0.588. Capital of the building  
 1628 has changed from 7757.525 -> 16199.256 (8441.732).

```

1620 Last year, the building produced 57466.231 goods, and sold
1621 5929.863(10.3189%) goods. The storage has changed from {'
1622 Food_Beverages': 50231.5365, '
1623 Public_Administration_Defence_SocialSecurity': 136.1209, '
1624 Agriculture_Hunting_Forestry': 109.142} to {'Food_Beverages':
1625 90356.9299, 'Accommodation_Food_Services': 265.0336}
1626
1627 ### Interfaces
1628 Here are the actions you may do to the building:
1629 - fire(position_id): Terminate the employment of an employee associated
1630 with a given position_id. This action will result in a one-month
1631 salary compensation, potentially reducing efficiency but also
1632 decreasing monthly expenditures
1633 - adjust_salary(position_id, new_salary): Modify the salary of a
1634 specific position using its position_id. Increase the salary to
1635 retain/attract skilled employees, or decrease it to reduce expenses.
1636 - close_vacancy(position_id): Close a vacancy for a specific position.
1637 This action will set the salary of the position to 0, effectively
1638 closing the position temporarily.
1639 - set_max_running_efficiency(efficiency): Set the maximum running
1640 efficiency of the building. An efficiency lower than 1 indicates
1641 that the firm operates below its full capacity (i.e., "idles") to
1642 reduce production output and material costs.
1643 - capital_invest(amount): Buying durable goods with [amount] money to
1644 increase the capital amount of the building. This action will
1645 improve productivity of the building.
1646 - equity_finance(amount): Issue shares to raise money. This action will
1647 increase the current cash of the building.
1648 - borrow(amount): Borrow money from the bank, those money will be paid
1649 back with interest. You may borrow money from the bank to invest in
1650 the building or to cover the cost of the building.
1651 - payback(loan_id): Pay back the loan with the given loan_id.
1652 - adjust_price(name, new_price): Alter the price of a particular product
1653 . If your productivity is in surplus, you may decrease the price to
1654 sell more goods, and if the product in market is in shortage, you
1655 may increase the price to boost profit.
1656 - set_dividend_rate(rate): Modify the dividend rate of the building.
1657 This rate determines the proportion of profits that will be
1658 distributed to shareholders. e.g. set_dividend_rate(0.5) will
1659 distribute 50% of profits to shareholders.
1660

```

Listing 14: Response example of firm(Productive Building) agent

```

1658 {
1659 'reasoning': 'The building is currently running at a loss and has no
1660 cash reserves, making it essential to minimize expenses while
1661 addressing vacancies that could enhance productivity. By reducing
1662 salaries due to the high unemployment rate and hiring for critical
1663 roles, particularly the Food Scientist and the vacant Production
1664 Worker position, profitability can improve. Additionally, immediate
1665 loan repayments are crucial to avoid further financial penalties.',
1666 'actions': [
1667 'close_vacancy(2000012)',
1668 'close_vacancy(2000014)',
1669 'adjust_salary(2000011, 800)',
1670 'adjust_salary(2000013, 500)',
1671 'borrow(10000)',
1672 'payback(330)'
1673]
1674 }

```

Listing 15: System prompt example of firm(Residential Building) agent

```

1674 You are a helpful assistant that utilize the information provided below
1675 to adjust strategy for a residential
1676
1677 The information of the building will report below "### Report", and
1678 actions you may do to the building will be listed after "### Actions
1679 ".
1680 You should analyze the report and utilize the actions to adjust the
1681 strategy for the building.
1682
1683 You should only respond in JSON format as described below:
1684 {
1685 "reasoning": "reasoning"
1686 [
1687 "action1(para1, para1, ...)",
1688 "action2(para1, para1, ...)",
1689 ...
1690]
1691 }
1692 Ensure the response can be parsed by Python 'json.loads', e.g.: no
1693 trailing commas, no single quotes, etc.
1694
1695 One of the example outputs is as follows:
1696 {
1697 "reasoning": "The building is in a good condition and the rent is low.
1698 You should consider increasing the rent to maximize profit.",
1699 "actions": [
1700 "set_rent(1000)"
1701]
1702 }

```

Listing 16: User prompt example of firm(Residential Building) agent

```

1701 ### Report
1702
1703 Here is the monthly report for Residence:
1704 The residential building lives 1 citizens, and its capacity is 10.
1705 The rent per month is 925, and here're other building's rent per month:
1706 - Residential Building at (14, 5): 900
1707 - Residential Building at (11, 2): 900
1708 [... and other residential buildings' position and rent]
1709
1710 ### Interfaces
1711 Here are the actions you may do to the building:
1712 - set_rent(new_rent): Alter the rent per month for the residential
1713 building. This action will directly affect the monthly income of the
1714 building.

```

Listing 17: Response example of firm(Residential Building) agent

```

1716 {
1717 'reasoning': 'The building has a low occupancy rate with only 1 out of
1718 10 units filled. The current rent is at the higher end compared to
1719 other similar residences nearby. To attract more residents, we
1720 should consider lowering the rent slightly to improve occupancy.',
1721 'actions': ['set_rent(900)']
1722 }

```