Journal of Japan Association for Earthquake Engineering, Vol. 25, No. 4
(Special issue), 2025

DEVELOPMENT OF A LARGE-SCALE AGENT-BASED ECONOMIC SIMULATOR FOR HIGH-RESOLUTION SIMULATION OF POST-DISASTER ECONOMIES

Joshua PANGANIBAN[1], Amit GILL[2], Lalith MADDEGEDARA[3], Muneo HORI[4], Tsuyoshi ICHIMURA[5] and Kohei FUJITA[6]

[1] M. Eng. Graduate, Department of Civil Engineering, The University of Tokyo, Tokyo, Japan, jlpanganiban.ce@gmail.com
[2] Ph.D., Researcher, Sumitomo Mitsui Construction Company, Ltd., Tokyo, Japan, amitgill@smcon.co.jp
[3] Ph.D., Associate Professor, Earthquake Research Institute, The University of Tokyo, Tokyo, Japan, lalith@eri.u-tokyo.ac.jp
[4] Ph.D., Director-General, Research Institute for Value-Added-Information Generation, JAMSTEC, Yokohama, Japan, horimune@jamstec.go.jp
[5] Ph.D., Professor, Earthquake Research Institute, The University of Tokyo, Tokyo, Japan, ichimura@eri.u-tokyo.ac.jp
[6] Ph.D., Associate Professor, Earthquake Research Institute, The University of Tokyo, Tokyo, Japan, fujita@eri.u-tokyo.ac.jp

ABSTRACT: Although most natural disasters such as major earthquakes are spatially localized, the strong interdependencies among economic entities can make their impacts ripple through the nation for several years, producing substantial economic losses. Enhancing disaster resilience necessitates a comprehensive assessment of the long-term economic impacts of candidate recovery plans considering the complex interrelationships of economic entities, and other real-world constraints such as lifeline access, transportation, and government policies. This requires fine-grained modeling of the economy and infrastructure as an integrated system. To attain this objective, we developed a high-performance computing (HPC) extension for an agent-based economic model, making it possible to efficiently simulate large-scale economies consisting of hundreds of millions of agents at a 1:1 scale. This paper presents the validation of the developed system for the Japanese economy by reproducing the past observations at the national and sectoral levels. As a demonstrative application, we present a simulation of a post-disaster economy considering hypothetical disaster scenarios.

Keywords: *Agent-based economic models, Post-disaster economic simulations, High-performance computing*

1. INTRODUCTION

The strong interrelationship of economic entities, such as firms and households, and their dependence on infrastructures make the impacts of major disasters propagate through the economy of the entire country, causing major economic losses, even if the disaster is geographically localized. These indirect economic impacts are often perceived to produce lesser damages compared to the direct damages caused by the disaster, which is not necessarily true. As an example, the impending Nankai-trough Earthquake is estimated to cause 170 trillion JPY in direct damages but over 1.2 quadrillion JPY in economic losses over a 20-year period[1]. To enhance disaster resilience, it is crucial to be able to comprehensively assess the economic impacts of candidate recovery plans considering the complex interdependencies of the economic entities.

Studying the economic impacts of disasters has been an area of interest over the past few decades. Disasters create highly heterogeneous conditions on different economic entities, even if those entities belong to the same industry or are located in the same region. To accurately capture the economic impacts of disasters considering these conditions, each individual economic entity and their interactions with each other must be considered in the economic model at fine resolution. However, the traditional approaches to estimating the economic impacts of disasters, such as computable general equilibrium models and input-output models, are highly coarse-grained as they lump a large number of economic entities with common characteristics into a single representative entity, rendering these models incapable of considering the highly heterogeneous conditions experienced by different economic entities.

Agent-based economic models (ABEMs) address the above-mentioned limitations of traditional models by simulating economies at a high resolution as a time-step driven system of interacting heterogeneous agents. Therefore, we chose an ABEM for simulating post-disaster economies. Several studies have used agent-based models to study various economic problems, such as assessing the effects of capital and credit available to consumer goods producing firms[2], investigating the impacts of credit networks on growth rate[3], and estimating the economic damages caused by a flood disaster[4]. While the ABEM developed by Poledna et al.[4, 5] is already capable of simulating small economies at a 1:1 scale, there are no computationally capable implementation to simulate large-scale economies consisting of hundreds of millions of agents. Diessenberg et al.[6] attempted to use high performance computing to simulate the Eurozone economy with hundreds of millions of agents, but their implementation has not been successfully applied to simulations of large economies.

The long-term objective of this research is to comprehensively evaluate a given set of recovery plans considering the highly heterogeneous conditions encountered by different entities during the recovery period. To achieve this objective, it is important to simulate the economy at a 1:1 scale, which requires a High-Performance Computing (HPC) implementation of an ABEM. Realizing the need for an HPC-enhanced ABEM to simulate large economies with fine-grained details and conduct comprehensive assessments of post-disaster economies, we developed an HPC extension capable of efficiently simulating large-scale economies consisting of hundreds of millions of agents. While the developed HPC-enhanced framework can be applied to any ABEM, the model developed by Poledna et al.[5], which has been validated by comparing model forecasts with past observed data, was used as the base model. In this short paper, we present some details of our HPC extension and the application of the new implementation to simulate the Japanese economy. The validation of the model at the national and sectoral levels was done by comparing the simulation results with the observed macroeconomic indices in the Japanese economy. Finally, we demonstrate an application of the developed framework using hypothetical disaster case scenarios, highlighting the potential use of the simulator in studying the economic impacts of disasters. This research presents a promising approach for policymakers, think tanks, and disaster management organizations, who need to make informed decisions on how to accelerate economic recovery after a disaster.

2. HPC EXTENSION OF THE AGENT-BASED ECONOMIC MODEL

2.1 Overview of the ABEM

An agent-based economic model is a time-step-driven system of interacting autonomous agents that try to mimic the activities of their real-world counterparts. The agents in the model represent various economic entities, such as individual households, firms, banks, and government. Each agent's behavior and its interaction with other agents are defined by a set of rules that are mathematically well-defined based on behavioral economics. The agents interact with each other, making decisions and acting based on the information available to them. The ABEM is initialized only at the base period, after which the economy evolves depending on the millions of complex interactions of its agents.

A schematic diagram of a typical ABEM consisting of various types of agents is shown in Fig. 1. As shown in the figure, the types of agents include firms, investors, active and inactive households, banks, the central government, and the central bank. Each arrow in the figure indicates the flow of goods and services and/or money between different types of agents in the ABEM. The model mimics various real-world economic interactions such as buying and selling (i.e., goods market) by allowing the agents to interact with each other. The firms hire workers based on their labor requirements and pay wages to these workers. The firms also buy capital and intermediate goods from firms of other industries depending on their production requirements. Foreign sellers import goods from external economies and foreign buyers export products to external economies. The firms then produce goods considering their production demands and available labor, capital, and raw materials. Aside from active households (i.e., workers), other household types include investors and inactive households. Investor agents represent owners of firms and receive dividends as their income. Inactive household agents represent the non-working population, such as children, retirees, and persons with disabilities, who receive social benefits from the government. The households buy goods and services from the industry for consumption and investment. The bank keeps deposits from firms and households and provides loans to them when requested. The government consumes various goods and services from the industry, provides social benefits, and collects taxes, while the central bank manages the monetary policies and policy rates. Millions of these processes happen at each time step of the simulation, making the economy evolve over time depending on the interactions and decision-making of the participating agents. Further details regarding the agents' behavioral rules and interactions can be found in the article by Poledna et al.[5)]

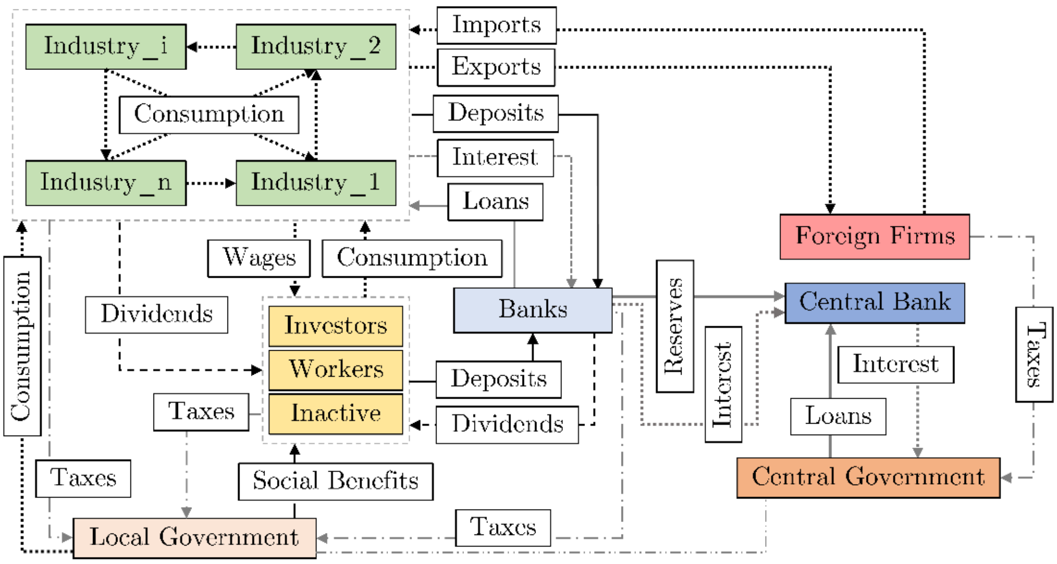


Fig. 1 Schematic diagram of a typical ABEM

2.2 Scalable HPC Extension

The major challenge in developing a scalable HPC implementation is the complicated interactions of the agents on centralized graphs such as the credit network and scale-free randomly growing graphs such as the labor market and the goods market. We addressed this problem by partitioning the agents based on a representative graph of the labor market and by employing various computational strategies to minimize the number of Message Passing Interface (MPI) communications. Furthermore, we eliminated performance bottlenecks caused by memory-intensive operations by implementing cache-friendly data structures and algorithms. We conducted scalability test simulations with 330 million agents and our tests showed that the implementation has 70% strong scalability on 128 CPUs using the Oakbridge-CX supercomputer at the University of Tokyo. The short execution time of 110 seconds per one period shows that our HPC implementation requires relatively low computational resources. The attained high computational performance makes it possible to conduct Monte-Carlo simulations of large economies at a 1:1 scale, which is essential to address various uncertainties involved within the economic model. Readers interested in the details of the implementation of the distributed memory parallel HPC-enhanced code are referred to the study by Gill et al.[7)]

3. DATA GENERATION FOR SIMULATING JAPANESE ECONOMY

The potential of the model to produce reasonably accurate forecasts for an economy can only be realized when the model parameters and the agents' data are derived from real data. The ABEM requires two types of data: (1) parameters that are shared by all agents of a particular class (e.g., industry); and (2) agent-specific data that is unique for each agent. Chapter 9 of Hori's book[8)] provides a detailed list of required input parameters for the agent-based economic model and it is not reproduced here due to space limitations. This section only provides a brief outline of how these data were generated from analyzing data from various sources.

3.1 Data Sources

Since the ABEM is a micro-founded model, the parameters of each agent should be ideally set according to the balance sheet of its real-world counterpart (e.g., individual firm). However, data at such fine resolution is either hardly available or too expensive to procure. Although some major companies publish their financial data on a regular basis, no information is available regarding their production decisions. A similar problem is present with the households' data and banks' data.

The next best alternative to the individual economic entity data would be macroeconomic data published by the Japanese government, from which a consistent set of the required parameters could be extracted and generated. Publicly available data from the following Japanese organizations are the main sources for this study:

- The Cabinet Office of Japan (CAO)
  - https://www.cao.go.jp/index-e.html
- Portal site of the official statistics of Japan (e-Stat)
  - https://www.e-stat.go.jp/en
- The Bank of Japan
  - https://www.boj.or.jp/en/index.htm/

The Input-Output (IO) Table[9)] at producers' price for Japan, which can easily be accessed from e-Stat, is the major source of input data for simulating the Japanese economy with the ABEM. The IO Table describe the demand and supply relationships between the producing and consuming entities within the economy. The parameters defining the interdependencies between the industries and the consumption behavior of households, government, foreign buyers, and foreign sellers are also extracted from the IO Table. Table 1 shows a representative IO Table and the model parameters obtained from the IO Table.

In generating the industry-specific parameters, the System of National Accounts (SNA) from CAO and the Sector-wise Employment data from e-Stat are also used. The SNA contains information such as the total capital, bank deposits, and bank loans of the firms for each industry. On the other hand, the number of workers in each industry is obtained from the Sector-wise Employment Data. Since the latest available IO Table for Japan is the 2015 Table, the 2015 Japanese IO Table[9)] was set to be the base data for this research and all other datasets were normalized to the IO Table data to maintain consistency among different datasets. The base year for the simulations in this research was also set to 2015.

Table 1 Overview of the IO-table

Supply sector (seller) / Demand sector (buyer)		Intermediate demand					Final demand									(less) Imports	Domestic Production
		Sector-1	Sector-2	…	Sector-n	Total	Consumption expenditure outside households	Private consumption expenditure	Consumption expenditure of general government	Consumption expenditure of general government (social fixed capital)	Gross domestic fixed capital formation (public sector)	Gross domestic fixed capital formation (private sector)	Increase in stocks	Exports	Total		
Intermediate input	Sector-1	m_{11}	m_{21}	…	m_{n1}	A_1	h_1^1	h_1^2	g_1	c_1^1	c_1^2	c_1^3	s_1	e_1	d_1	i_1	y_1
	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…
	Sector-n	m_{1n}	m_{2n}	…	m_{nn}	A_n	h_n^1	h_n^2	g_n	c_n^1	c_n^2	c_n^3	s_n	e_n	d_n	i_n	y_n
	Total	M_1	M_2	…	M_n	A	H^1	H^2	G	C^1	C^2	C^3	S	E	D	I	Y
Gross value added	Consumption expenditure outside households	w_1^1	w_2^1	…	w_n^1	W^1											
	Consumption of employees	w_1^2	w_2^2	…	w_n^2	W^2											
	Operating surplus	π_1	π_2	…	π_n	Π											
	Consumption of fixed capital	k_1^1	k_2^1	…	k_n^1	K^1											
	Consumption of fixed capital (social fixed capital)	k_1^2	k_2^2	…	k_n^2	K^2											
	Indirect taxes (except custom duties and commodity taxes on imported goods)	t_1^Y	t_2^Y	…	t_n^Y	T^Y											
	(less) Current subsidies	t_1^P	t_2^P	…	t_n^P	T^P											
	Total of Gross value added	GVA_1	GVA_2	…	GVA_n	GVA											
	Total Domestic Production	y_1	y_2	…	y_n	Y											

3.2 Parameters of Individual Firm Agents

Ideally, the parameters of firm agents should be set based on the characteristics of the represented real-world company. Since obtaining data for each company in Japan is not feasible, we have adopted the next best option of generating firm agents' parameters based on available macroeconomic data. However, the available macroeconomic data, such as the IO Table, is activity-based. Since most companies have a single economic activity within a sector or operate across a few related sectors, we believe it is reasonable to represent a company as one or more firm agents depending on its economic activities. We utilized the activity-based IO Table to estimate how much an individual firm would buy from other firms in different sectors, how much labor is required for production, and other relevant parameters. Since the quantity of goods produced by a firm is directly related to its number of employees, the size distribution of firms can be estimated from the labor size distribution among firms. The sector-wise labor size distribution of Japanese firms for 2016 is provided in e-Stat. As the firm size distribution does not change much within a year, it was assumed that the firm size distribution in 2016 is the same as that in 2015. The industrial classification used in the enterprise census data for 2016 is also different from that in the 2015 IO Table. To resolve this mismatch, the firms and labor distribution for the sectors of the 2015 IO Table were derived by merging or splitting relevant sectors of the 2016 enterprise census data according to the definition of each sector in both datasets.

The required parameters for the remaining agents: households, government, foreign firms, and the central bank are also obtained from the above-mentioned sources. The data generation process for these agents is not presented here due to limited space.

4. VERIFICATION AND VALIDATION OF THE AGENT-BASED MODEL

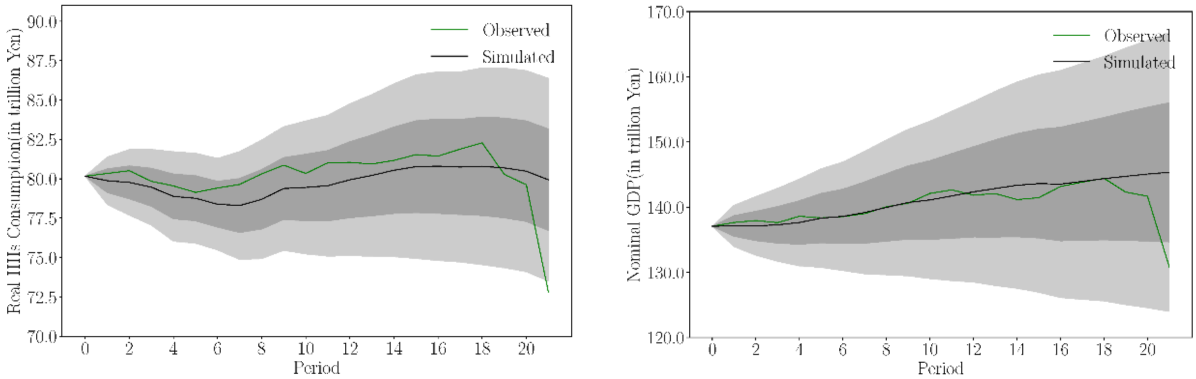
The process of verification and validation is essential for ensuring the accuracy, reliability, and credibility of simulation models. Verification involves comparing the simulation outputs with the results obtained from a previously verified implementation, ensuring that the new implementation is free from errors and reproduces the expected results accurately. On the other hand, validation aims to assess the model's ability to replicate real-world behavior by comparing the simulation results with past observed data. We verified our HPC-enhanced implementation by comparing the simulation results with the results from Dr. Poledna's implementation[5)] in MATLAB. Further details of the verification are available in Chapter 9 of Hori's book[8)].

For the validation of the implemented HPC-enhanced ABEM, we simulated the Japanese economy and compared the model results with the observed Japanese macroeconomic indices to check whether the new implementation can reproduce the real-world observation with a substantial degree of accuracy. For this, we used the input parameters for the Japanese economy that we prepared as discussed in Section 3. In the problem settings, the model parameters and the initial parameters of the agents are generated according to the process mentioned in the previous section using the Japanese economic data of Q1 2015. Table 2 shows the number of various types of agents in the generated model. Once the agents were initialized in the first period, no additional external inputs or instructions were given to the model. The economy and markets were allowed to evolve autonomously based on the complex interactions of the agents. The simulation is conducted for 22 periods starting from the first quarter of 2015 and concluding with the second quarter of 2020. One simulation period represents one financial quarter. The results are then compared with the observed data obtained from the SNA. Auto Regression with a lag of 1 (AR(1)) process is used for making economy-wide forecasts of growth and inflation rates. These forecasts are used by the firm agents to make production and pricing decisions. AR(1) models are constructed based on the economy-wide production and GDP-deflator data from Q1 2011 to Q4 2014, obtained from SNA. The model involves various uncertainties, such as in the decision-making of agents and the forecasting of growth and inflation rates. To account for these uncertainties, Monte-Carlo simulations are conducted with 1,000 random samples.

Table 2 Number of various agents in the ABEM for the Japanese economy

Agent Type	Number of Agents
Industrial Sectors	104
Domestic Firms	1.84 million
Foreign Buyer Firms	920,000
Foreign Seller Firms	104
Investors	1.84 million
Workers	60 million
Inactive Households	62 million
Bank	1
Government Agencies	460,000
Central Bank	1
Total	127 million

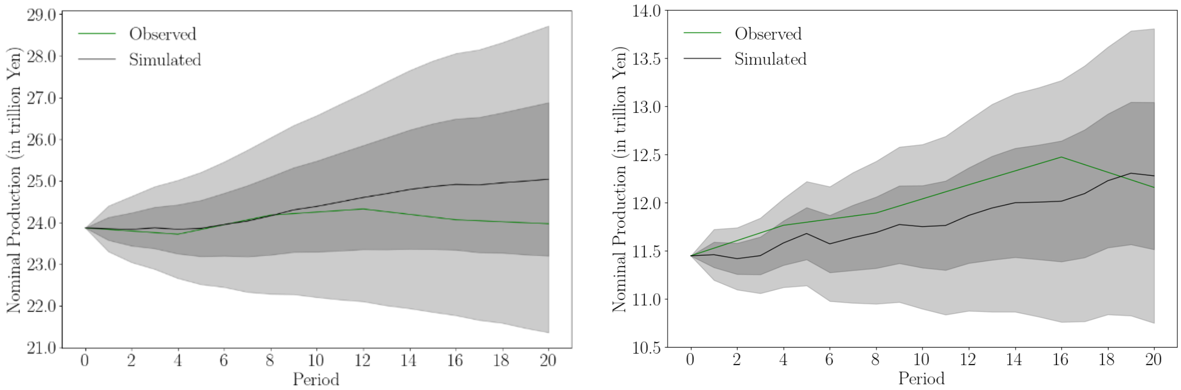
Figure 2 shows the comparison of the simulation results using the HPC-enhanced agent-based economic simulator with Japanese macroeconomic indices. The dark and light gray regions in the plots represent the $\pm\sigma$ and $\pm 2\sigma$ uncertainty bands, respectively. As the figures show, the simulation results are in good agreement with the observed data, except for the last two periods. These periods correspond to the COVID-19 pandemic, which the model agents are not aware of.



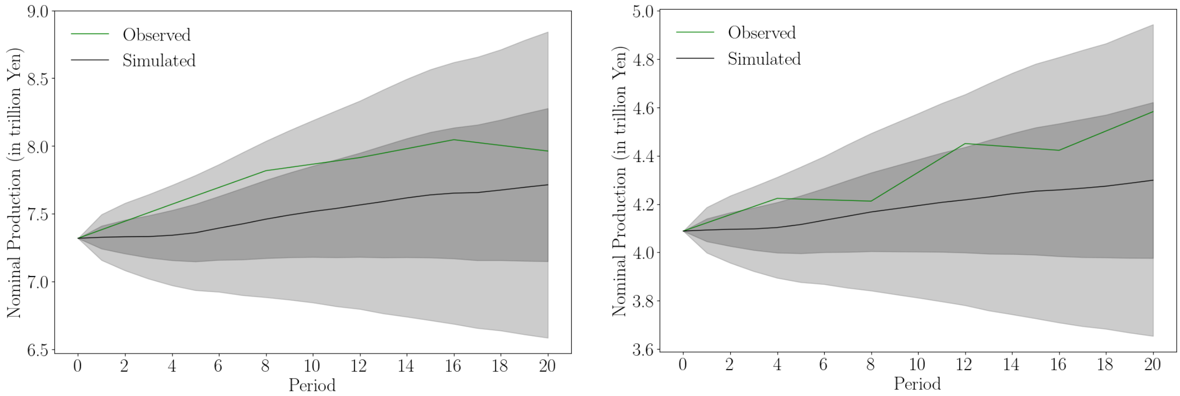
(a) Real Consumption by Households (b) Nominal Gross Domestic Product

Fig. 2 Comparison of model outputs and observed macroeconomic indices at the national level

The comparison of the simulation outputs at the sectoral level and the observed sector-wise production data in the Japanese economy is shown in Fig. 3. The observed data, covering the period from 2015 to 2020, was obtained from the Research Institute for Economy, Trade, and Industry (RIETI). Although the model encompasses 104 industrial sectors, this paper presents the results for only eight sectors of varying production sizes due to space constraints.

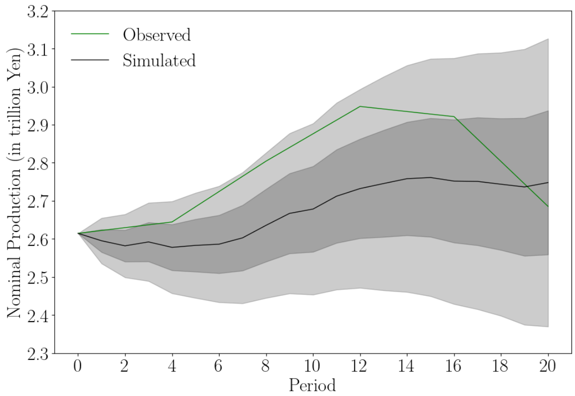


(a) "Commerce" sector (b) "Medical Services" sector

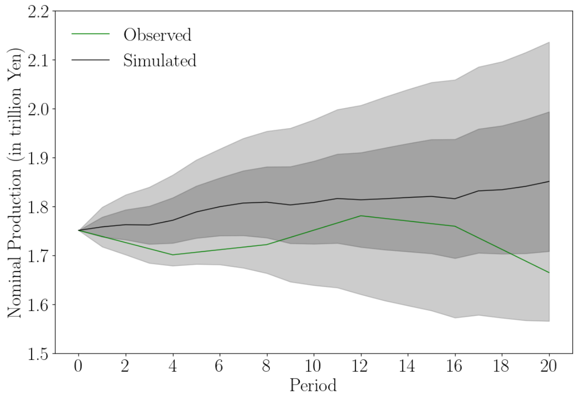


(c) "Building Construction" sector (d) "Communication" sector

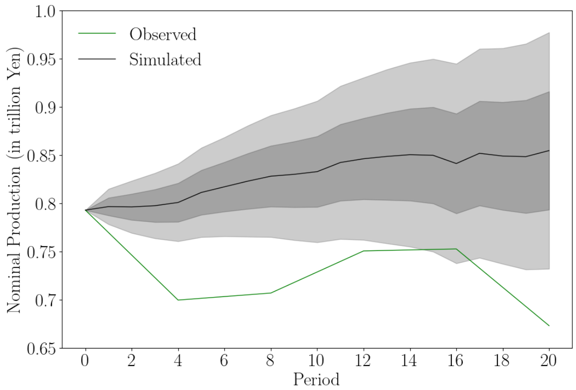
Fig. 3 Comparison of model outputs and observed sector-wise nominal production *(Figure continues on the next page)*



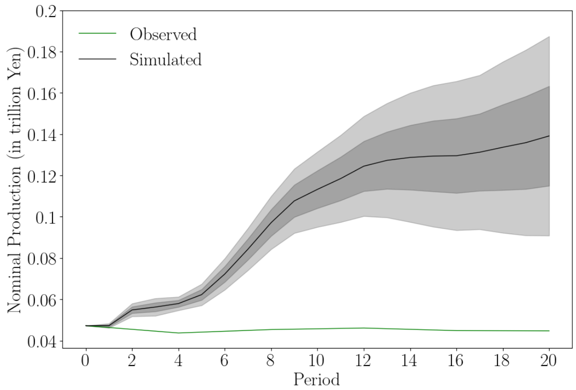
(e) “General-purpose Machinery” sector



(f) “Beverages” sector



(g) “Rubber Products” sector



(h) “Coal Mining, Crude Petroleum, and Natural Gas” sector

Fig. 3 Comparison of model outputs and observed sector-wise nominal production *(continued)*

The model performance varies among different sectors. As Fig. 3 illustrates, the model was able to produce accurate simulation results for large producing sectors such as the “Commerce”, “Medical Services”, “Building Construction”, and “Communication” sectors. For sectors with smaller production, such as the “General-purpose Machinery”, “Beverages”, “Rubber Products”, and “Coal Mining, Crude Petroleum, and Natural Gas” sectors, the model exhibited weaker performance, especially for the smallest producing sectors. One possible reason for the poor performance of the ABEM for some sectors is the use of different data sources. The agents' parameters were generated using data from e-Stat, while the validation data came from RIETI. This mismatch may have introduced inconsistencies, particularly in smaller sectors.

The ABEM also provides the simulation results at the individual agent level, such as the production forecasts for individual firms. This is one of the capabilities of the ABEM that is not available from other traditional economic models. However, due to the unavailability of firm-level validation data, the agent-level results were not included in this paper.

The good agreement between the simulation results and the observed data at both national and sectoral levels indicates that our HPC-enhanced ABEM can produce reasonably accurate forecasts under ordinary economic conditions.

5. DEMONSTRATIVE APPLICATION WITH HYPOTHETICAL DISASTER CASES

To demonstrate the application of the developed tool for simulating post-disaster economies, we simulated the Japanese economy subjected to hypothetical disaster scenarios based on the 2011 Great

East Japan Earthquake (GEJE). This section outlines the input data used for the disaster cases and the agents' behavioral rules under post-disaster conditions and presents the analysis of the simulation results.

5.1 Input Data for the Disaster Cases

The economic entities exposed to the disaster experience direct damages in terms of capital losses. Capital losses of firms refer to the damages to their buildings and machinery, and those for households refer to damages to their houses. Thus, to simulate post-disaster economies, two additional input data are included: the capital costs incurred by the firms and households, and the corresponding number of affected workers. With these two inputs, the capital losses can be assigned to the firm and household agents at the period where the disaster is assumed to occur.

The sector-wise capital losses brought by the GEJE were obtained from the data publicly available from the Cabinet Office of Japan (CAO), the Ministry of Agriculture, Forestry, and Fisheries (MAFF), and the National Police Agency of Japan (NPAJ). The MAFF provides direct capital damages to the crop cultivation, agricultural services, forestry, and fishery sectors, while the CAO provides direct capital damages to buildings, lifeline utilities, and infrastructure sectors.

Meanwhile, the sector-wise number of affected workers was obtained from e-Stat. In this dataset, the sector classification used is the Japan Standard Industrial Classification. To maintain consistency with the other inputs of the model, this sector classification was mapped into e-Stat's IO Table sector classification and the number of affected workers was reassigned to the corresponding equivalent sectors accordingly.

5.2 Agents' Behavioral Rules

The behavioral rules of agents under normal economic conditions are provided in Poledna et al.[5)] For the disaster case scenarios, the agents' behavior is assumed as follows:

1. The firms account for the damaged capital as an expense. Thus, their profit falls, impacting their financial capability and their investor's income.
2. Disaster-affected firms try to buy the lost capital starting from the next period after the disaster. However, the availability of loans from the bank and the availability of capital goods in the goods market determine the amount of time it takes for them to recover the lost capital.
3. Disaster-affected households also attempt to recover their lost capital in the period after the disaster. We assumed that the government pays the total amount of the damages incurred by the households as disaster aid since this is a standard practice in many developed countries. The availability of capital goods in the market is the only constraint for households.

5.3 Simulations of Post-Disaster Economies

The Japanese economy was simulated under three different scenarios. The first scenario represents normal economic conditions (hereafter referred to as "Normal Scenario") and the other two correspond to post-disaster economic conditions resulting from two hypothetical disaster cases. In the first disaster case (hereafter referred to as "Disaster Scenario 1"), the capital damages from the GEJE were introduced as an economic shock at the end of Period 0 (i.e., the start of the first quarter of 2015) of the simulation. In the second disaster case (hereafter referred to as "Disaster Scenario 2"), we added random variations within a 20% range for the sectors that incurred the largest capital losses from Disaster Scenario 1. This scenario represents a case where the direct impacts of the hypothetical disaster differ slightly. To ensure that the total capital damages in Disaster Scenario 2 are consistent with the total capital losses from the GEJE, any variation applied to the sectoral capital damages was redistributed to other randomly selected sectors. Figure 4 shows the sector-wise capital losses used for Disaster Scenario 1 and Disaster Scenario 2.

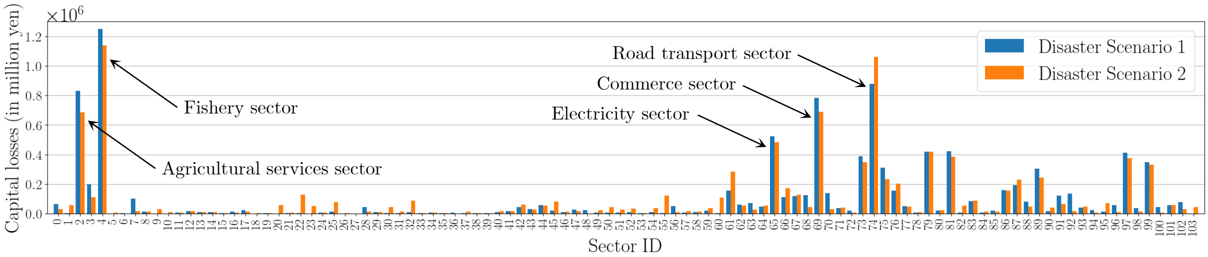
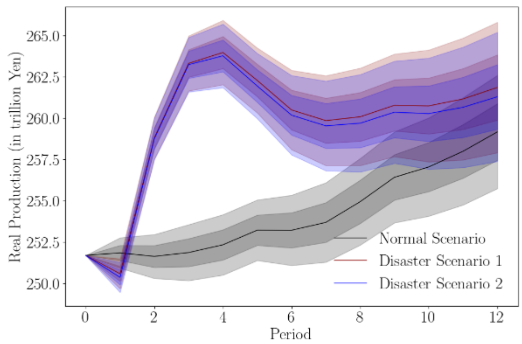


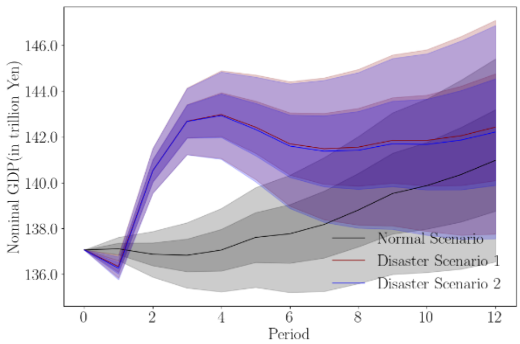
Fig. 4 Capital losses assigned at the end of the Period 0 for the hypothetical disaster scenarios

The sectors that incurred the largest capital losses are the "Fishery" sector (1.25 trillion JPY), the "Road Transport" sector (0.88 trillion JPY losses), and the "Agricultural Services" sector (0.83 trillion JPY), and the total capital costs assigned to the firm agents at the end of the Period 0 in the simulation amounts to 10.15 trillion JPY. The possible production loss due to the lost capital was estimated to be 12.73 trillion JPY, which is about 5% of the national total quarterly production. This suggests that only a small portion of the national economy could be directly affected by the hypothetical disaster.

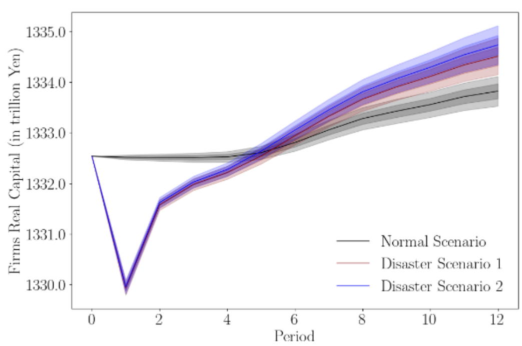
The simulation results for the normal scenario (i.e., without the disaster) and the two hypothetical disaster scenarios are presented in Fig. 5. Among various economic parameters, the real production, nominal GDP, real capital of firms, and real consumption by households are illustrated. Upon comparing the results for two hypothetical disaster cases, it can be observed from the plots that there is not much difference between the two scenarios. The underlying cause of this result can be traced back to the capital losses assigned for the two cases (see Fig. 4), where it can be noticed that even though the sector-wise capital losses were randomly varied within a wide range, the disaster profile for both scenarios remains nearly identical. Since there is little discrepancy in the outcomes of the two disaster cases, they are analyzed as one in the following discussion.



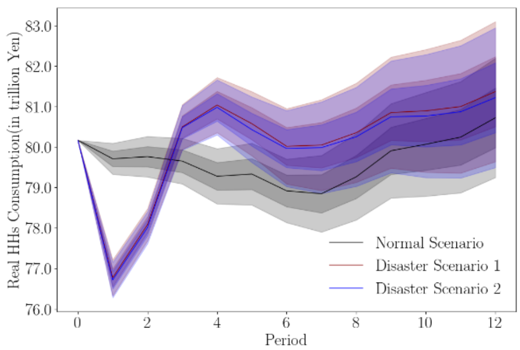
(a) Real Production



(b) Nominal Gross Domestic Product



(c) Real Capital of Firms



(d) Real Consumption by Households

Fig. 5 Simulation results on hypothetical disaster economies

Due to the affected firms losing a portion of their capital, their capability to produce goods and services is reduced. As we can see in Fig. 5a, a decrease of 1.5 trillion JPY in the real production in the period immediately after the disaster (i.e., Period 1) was observed, which is much lower than the estimated possible production loss (12.73 trillion JPY). This is because some firms had some extra capital stock which they used to immediately replace their lost capital.

After the disaster (i.e., from Period 1 onwards), the affected firm and household agents try to recover their lost capital (e.g., buildings and houses), which increases the demand for those goods in the market. To cater to that increased demand, the firms that produce those goods operate at full capacity and attempt to increase their production as much as possible. These firms would also require input goods from other industries, which in turn increases the total demand for other industries. As a result, almost all industries experience increased demands, leading to increased production. Figure 5a illustrates that there is a continuous increase in the real production from Period 1 to Period 4. As the firms increase their production, their labor requirements also increase. As a result, the firms employ more workers and the total wages paid to the households become higher. This, in turn, increases the consumption of households, as shown in Fig. 5d.

With the progress of recovery of the damaged capital, the extra demand in the market gradually decreases. In Period 5, the firms completely recovered their lost capital as can be seen in Fig. 5c, eliminating the additional demand for capital goods in the market. Hence, we observe a decrease in production from Period 5 to Period 7. From Period 7 onwards, the economy started to stabilize.

The results show that while the economy suffered from negative impacts brought on by the disaster in the short term, the firms were able to recover their lost capital after about four quarters. By about the eighth quarter, the economy stabilizes with approximately 2% more production than normal levels. As we can see in Fig. 5a, there is only a little overlap between the $\pm 2\sigma$ regions of the normal scenario and the post-disaster scenarios in the eighth period, indicating that the 2% increase in the mean production value is significant. However, in the latter simulation periods (e.g., period 12), this overlap becomes larger. Therefore, the 2% difference between the means becomes statistically less significant in these periods.

6. CONCLUDING REMARKS

Comprehensive and reliable estimation of the economic impacts of disasters requires fine-grained modeling of the economy that considers the complex interactions of economic entities with each other and other real-world constraints. Our research attempts to progress the field of disaster risk analysis by developing a large-scale agent-based economic simulator that is capable of simulating economies consisting of hundreds of millions of agents. This paper outlines the development of the tool by utilizing HPC strategies and presents the data generation done to simulate the Japanese economy. The validation tests show that the developed framework can replicate past macroeconomic observations to a substantial degree of accuracy. A demonstrative application of the developed system shows its potential use in analyzing post-disaster economy in the short to medium term. The model can be further improved by integrating it with other infrastructure components such as lifeline accesses and transportation networks and by using more realistic post-disaster behavioral rules of the economic entities. The developed system can be a useful tool in identifying critical portions of the economy and in quantitatively assessing candidate recovery plans, which can help accelerate economic recovery from disasters.

ACKNOWLEDGMENT

This work was supported by JSPS Kakenhi grant 18H01675. Parts of the results were obtained using the Oakbridge-CX supercomputer at the University of Tokyo.

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(Submitted: March 31, 2024)
(Accepted: November 21, 2024)