

Article

Economic, Equity and Environmental Impacts of Transport and Industrial Policy Interventions: An Urban CGE Model Analysis

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Abstract

Policy interventions are widely used to promote regional development and reshape economic structure, yet their broader transport, spatial, and environmental impacts have received limited attention. This study develops an integrated urban computable general equilibrium (CGE) model that combines CGE theory with a computable urban economics (CUE) framework, overcoming the limitations of conventional CGE models in representing intra-urban transportation dynamics and capturing spatial heterogeneity within urban areas. By incorporating transport sectors and endogenous transport mode substitution, the model captures the interaction between industrial activities and transport systems, enabling a more comprehensive assessment of the economic, equity, and transport-related environmental impacts induced by policy interventions. A case study of the Kofu metropolitan area in Japan shows that transport improvement policy generates broad welfare gains and industrial expansion but may induce modal shifts that reinforce road dependence and increase environmental burdens. In contrast, tax reduction and subsidy policies also stimulate significant industrial growth while reducing aggregate transport demand through spatial concentration and industrial structural adjustment, but tend to exacerbate interregional inequality. The findings highlight trade-offs among efficiency, equity, and environmental sustainability, while demonstrating the analytical value of incorporating a CUE framework and transport–industry interaction mechanisms into a CGE model for policy-relevant evaluation.

Keywords: urban CGE model; policy intervention; industrial restructuring; spatial heterogeneity; mode substitution



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1. Introduction

Against the backdrop of population aging, many medium-sized regional cities are facing challenges such as population decline, industrial stagnation, and economic downturn. To achieve regional revitalization, governments need to implement effective policy measures. The World Bank emphasizes that transportation infrastructure plays a crucial role in promoting economic growth, generating employment opportunities, and linking people to opportunities across every sector of the economy [1]. However, according to estimates by the International Energy Agency (IEA), road transportation is also a major source of carbon emissions. In 2023, private cars and vans accounted for more than 25% of global oil consumption and approximately 10% of global energy-related CO₂ emissions [2].

Additionally, the OECD reports that as successful cities continue to grow and attract skilled workers, other areas are grappling with an aging and shrinking population [3]. Regional equity has emerged as an increasingly important policy objective. Therefore, policy design needs to simultaneously consider economic growth, social equity, and environmental sustainability. There is a growing need for analytical frameworks capable of simultaneously evaluating the complex interactions among economic, social, and environmental systems.

In policy evaluation, policymakers require not only *ex post* empirical analysis [4,5], but also *ex ante* predictions of policy effects. Among the available *ex ante* evaluation approaches, computable general equilibrium (CGE) models have become one of the most widely used tools. CGE models are computer-based simulations that use systems of equations to represent the whole economy and intersectoral interactions [6]. By providing an internally consistent general equilibrium structure, CGE models enable the evaluation of how policy shocks are transmitted throughout the economy. Building on this framework, researchers have further developed spatial computable general equilibrium (SCGE) models to address the limitations of conventional CGE models in representing spatial structures and transportation mechanisms. By explicitly incorporating regional disaggregation and transportation sectors, SCGE models integrate spatial dimensions into the general equilibrium framework, thereby enabling a more systematic evaluation of the economic impacts of policies and infrastructure improvements.

Although CGE and SCGE models have been widely used as effective tools for evaluating aggregate economic impacts and intersectoral interactions, their ability to represent localized spatial changes and capture spatial heterogeneity across zones is often limited. This constrains their capacity to analyze policy interventions closely linked to spatial resource allocation, such as real estate subsidies and land supply policies.

In contrast, computable urban economics (CUE) models divide a city metropolitan area into a set of zones and explicitly represent household location choice, land and real estate markets, and commuting behavior [7]. As a result, they are well-suited to capturing the effects of transport and real estate policies on urban spatial equilibrium. Therefore, incorporating CUE-based mechanisms into a CGE framework is essential for representing the interactions between intra-urban transport and real estate markets.

Moreover, the close interdependence between transport systems and socioeconomic activities also gives rise to spatial heterogeneity through interactions among transport, industry, and households. On one hand, improvements in transportation infrastructure can reduce logistics and commuting costs, thereby promoting industrial development and spatial reallocation of economic activities. On the other hand, industrial policies may also reshape the spatial distribution of employment and household travel demand, further influencing transport demand patterns and modal choice. Such interactions between transportation and industry can ultimately affect regional welfare and spatial disparities. However, existing studies have largely examined the impacts of transportation or industrial changes separately, while lacking an integrated analytical framework capable of capturing the interaction mechanisms among transportation, industry, and spatial heterogeneity.

Given this context, this study develops an integrated CGE–CUE model (hereafter referred to as the CGEUE model, computable general equilibrium and urban economic) that explicitly incorporates transport sectors and an endogenous mode choice mechanism, incorporating multiple transport modes, including rail, public transit, and private automobiles, into a unified general equilibrium framework. The model captures the interactions among transport, industry, and spatial heterogeneity, as well as the feedback relationships between industrial change and transport demand. This enables a more comprehensive assessment of the economic, equity, and environmental impacts of policy interventions.

This study contributes to the existing literature in two main respects. First, from a methodological perspective, it develops an integrated CGEUE framework that endogenizes travel mode choice among rail, public transit, and private automobiles. By explicitly linking industrial activities, transportation behavior, and environmental impacts within a unified general equilibrium framework, the proposed model is able to capture the endogenous interactions and feedback mechanisms among industrial restructuring, urban transportation systems, and carbon emissions. Second, from an applied perspective, the study moves beyond the conventional focus on aggregate economic outcomes by establishing a unified framework for evaluating the multidimensional effects of policy interventions. Specifically, the proposed framework enables the simultaneous assessment of trade-offs and synergies among economic efficiency, regional equity, and environmental sustainability (the “3E” impacts). This holistic approach provides a more comprehensive evidence base for regional policy design in the face of complex societal challenges.

The remainder of this paper is organized as follows. Section 2 reviews the literature on policy evaluation and spatial CGE models. Section 3 presents the CGEUE model framework in detail. Section 4 applies the CGEUE model to the Kofu metropolitan area and analyzes the welfare-, industrial-, and transport-related environmental impacts of four policy interventions. Section 5 concludes the paper.

2. Literature Review

Scholars have conducted extensive research on the economic impact of policy interventions. In the field of transportation, various evaluation methods have been developed over the past few decades, including cost–benefit analysis (CBA) [8,9], Wider Economic Impacts (WEIs) analysis [10,11], and computable general equilibrium (CGE) models [12–14]. Among these approaches, CBA remains the most widely used method. However, it is generally limited in its ability to capture broader economic impacts, such as changes in sectoral output, income distribution, and productivity gains arising from agglomeration economies [15]. In contrast, WEI analysis focuses on broader economic impacts beyond the transportation sector, although it may involve a risk of double counting. When the objective is to understand the impact and distribution of transportation infrastructure projects on households, businesses, and the broader economy, CGE models are regarded as an effective approach [16]. CGE models are classified into urban CGE models [17] and regional CGE models [18], depending on the spatial scale of analysis.

In CGE-based evaluations of transport policies, a mainstream approach is to represent policy interventions through indicators such as accessibility improvements or travel time reductions and transmit these shocks through the general equilibrium system. For example, Rokicki et al. (2021) use accessibility improvements, expressed as reductions in transport margins, to evaluate the long-term impacts of major transport infrastructure investments in Poland’s NUTS2 regions [19]. Ishikura and Yokoyama (2022) [20], as well as Ishikura (2025) [15], model travel time reductions as policy shocks to examine the regional economic and industrial effects of expressway and high-speed rail investments. Meanwhile, Muto et al. (2022) associate travel time reductions with productivity improvements by modeling transport policies as increases in the productivity of transport-related labor and capital inputs to analyze decarbonization effects [21]. Recent studies have increasingly focused on integrating CGE models with transportation models to explicitly capture the interactions between economic activities and travel behavior. Shahriari et al. (2023) develop an integrated framework that combines a CGE model with the traditional Four-Step Transportation Model [22]. In this framework, household and firm behaviors are incorporated into travel demand generation, trip flows are assigned to the transport network based on user equilibrium principles, and the resulting travel costs are fed back into the CGE

model, thereby establishing a two-way feedback mechanism between the transportation and economic systems. Furthermore, Katayama and Koike (2025) propose a spatial CGE framework that incorporates passenger travel behavior through an aggregate Logit model and simultaneously accounts for both passenger and freight transportation costs [23]. Applying the model to the Linear Chuo Shinkansen and highway investment projects in Japan, they demonstrate that the framework could evaluate not only aggregate economic benefits but also the spatial distribution of gains across regions, thereby providing insights into regional equity and balanced spatial development.

Although these studies incorporate spatial heterogeneity to some extent, they have largely focused on large-scale spatial evaluation and have paid relatively limited attention to small-scale infrastructure projects and intra-urban economic responses. While Muto's framework captures heterogeneity within urban areas, it primarily addresses transport decarbonization policies, leaving scope for further research on the evaluation of industry-oriented policy interventions.

In the evaluation of industrial policies, empirical approaches have been widely used to assess their economic effects. For example, Du et al. (2014) examine the effects of tax policies in China and show that foreign investments receiving tax incentives generate larger productivity spillovers than unsubsidized investments, while tariff liberalization contributes to industrial productivity growth [24]. Xu et al. investigate the relationship between government subsidies and innovation performance, showing that subsidies contribute to innovation performance, but their effectiveness is constrained by firm characteristics as well as the size and continuity of the subsidies [25]. Lane (2025) uses a dynamic difference-in-differences approach, compares output changes before and after industrial policy interventions in South Korea, and finds that output in targeted heavy and chemical industries (HCI) increased by more than 100% relative to unaffected manufacturing sectors, accompanied by labor productivity gains of over 15% [26]. Similarly, Barwick et al. show that industrial policies significantly expanded the scale of China's shipbuilding industry [27]. However, their effectiveness depends strongly on business cycles and firm heterogeneity, with production and investment subsidies found to be relatively effective [28].

Taken together, tax reductions and subsidies are commonly used instruments for industrial promotion. However, these policies not only affect firms directly but also generate spillover effects through land (or real estate), labor, and other markets, thereby influencing household welfare more broadly. For example, the study by Suárez Serrato and Zidar (2016) [29] shows that the benefits of tax reductions accrue to three groups—firm owners, workers, and landowners. Changes in tax policy can also affect employment [30] and population mobility [31,32]. These findings suggest that industrial policy evaluation should consider not only policy effectiveness in fostering target industries but also broader spillover effects on regional welfare and resource allocation.

In summary, CGE and SCGE models have proven to be powerful tools for evaluating the economic and industrial impacts of policy interventions at the regional and macroeconomic levels. However, their ability to represent intra-urban spatial heterogeneity and zone-specific interactions remains limited. In the context of industrial policy evaluation, existing studies have generally paid insufficient attention to the endogenous feedback mechanisms between industrial restructuring and urban travel behavior. Moreover, few studies have simultaneously quantified the multidimensional impacts of policy interventions in terms of economic efficiency, social equity, and environmental sustainability within a unified urban analytical framework. To address these gaps, this study develops an integrated CGEUE framework with endogenous travel mode choice, allowing for the analysis of interactions among industrial structures, transportation systems, and environmental outcomes.

3. Model Framework

The urban CGE model adopted in this study is an improved version of the CGEUE model proposed by Muto [21]. This model represents a general equilibrium extension of the CUE model and incorporates elements of a CGE framework. The model integrates two key features. The first originates from the CGE model, namely the ability to measure economy-wide spillover effects using an input–output table. The second derives from the CUE model, namely the ability to account for location choice behavior and changes in travel patterns. The CGEUE model assumes that an urban area is divided into a set of zones, and there are households, representative firms producing goods, a real estate firm providing land services, and transport firms in each zone. The behavior of agents is explicitly formalized as expenditure- or cost-minimizing within the model.

The present study extends the model by incorporating transportation mode sectors and introducing an endogenous modal choice module. While retaining the strengths of the CGEUE model’s framework, the extended model captures the interaction between the transportation system and industrial activities, allowing it to reflect shifts in travel patterns induced by policy interventions, providing a more behaviorally realistic representation and improving simulation accuracy. Furthermore, by incorporating changes in transport mode choice, the model captures variations in transport-related carbon emissions, thereby enabling an assessment of the environmental spillover effects generated by industrial policies.

3.1. Firm’s Behavior

The nested tree structure is commonly used to visually represent the hierarchical decision-making processes of economic agents in CGE models. Figure 1 presents the production structure of firms in this study.

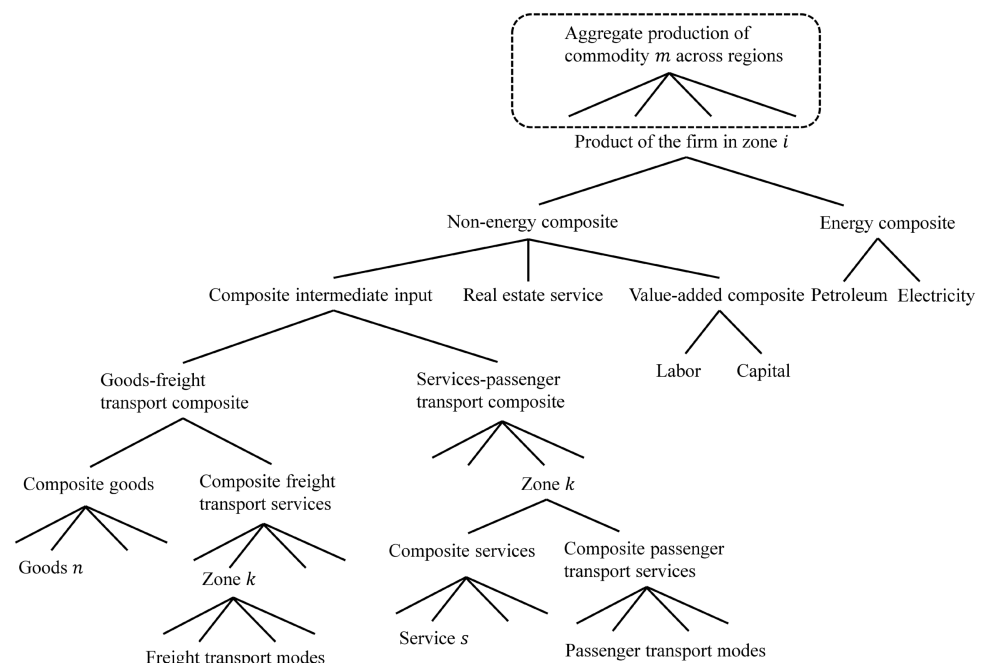


Figure 1. Nested production structure of firms.

The structure outside the dashed line corresponds to service firms, whose outputs are non-tradable across zones and thus cleared at the zonal level. In contrast, agricultural and manufacturing goods are tradable across zones, allowing firms to choose production locations. This is captured by introducing a production location choice at the top level of the

nesting structure (dashed line), with market clearing occurring at the city-wide level. All firms share an identical production structure and are modeled as cost-minimizing agents.

Taking the production of commodity m as an example, at the top level of the firm's production structure, the production location choice behavior is modeled as follows:

$$C_m = \min_{y_m^i} \sum_i p_m^i y_m^i, \quad (1)$$

$$\text{s.t. } y_m = \gamma_m \left[\sum_i \alpha_m^i \left\{ \beta_m^i y_m^i \right\}^{\frac{\sigma_m-1}{\sigma_m}} \right]^{\frac{\sigma_m}{\sigma_m-1}}, \quad (2)$$

where C_m denotes the production cost of firm m . y_m^i and p_m^i represent the output and price of firm m in region i , respectively. α_m^i and β_m^i are share parameters, γ_m is the efficiency parameter, and σ_m represents the elasticity of substitution.

By solving the optimization problem using the method of Lagrange multipliers, the zonal output equation and the price equation for commodity m can be derived.

$$y_m^i = \frac{1}{\gamma_m (\beta_m^i)^{1-\sigma_m}} \left(\frac{\alpha_m^i}{p_m^i} \right)^{\sigma_m} \Psi_m^{\frac{\sigma_m}{1-\sigma_m}} \cdot y_m, \quad (3)$$

where $\Psi_m = \sum_i (\alpha_m^i)^{\sigma_m} \left(\frac{p_m^i}{\beta_m^i} \right)^{1-\sigma_m}$.

By substituting Equation (3) into Equation (1), we obtained the price of commodity m (under the zero-profit condition, total cost equals total revenue, $C_m = p_m y_m$).

$$p_m = \frac{1}{\gamma_m} \Psi_m^{\frac{1}{1-\sigma_m}}, \quad (4)$$

In zone i , firms producing commodity m combine a non-energy composite and an energy composite to produce output. The formulation is as follows.

$$p_m^i y_m^i = \min_{z_{(1)m}^i, z_{Om}^i} \left[q_{(1)m}^i z_{(1)m}^i + q_{Om}^i z_{Om}^i \right], \quad (5)$$

$$\text{s.t. } y_m^i = \gamma_m^i \left[\alpha_{(1)m}^i \left\{ \beta_{(1)m}^i z_{(1)m}^i \right\}^{\frac{\sigma_m^i-1}{\sigma_m^i}} + (1 - \alpha_{Om}^i) \left\{ (1 - \beta_{Om}^i) z_{Om}^i \right\}^{\frac{\sigma_m^i-1}{\sigma_m^i}} \right]^{\frac{\sigma_m^i}{\sigma_m^i-1}}, \quad (6)$$

By solving Equation (5), we obtained the demand functions.

$$z_{(1)m}^i = \frac{1}{\gamma_m^i (\beta_{(1)m}^i)^{1-\sigma_m^i}} \left(\frac{\alpha_{(1)m}^i}{q_{(1)m}^i} \right)^{\sigma_m^i} \Psi_m^i{}^{\frac{\sigma_m^i}{1-\sigma_m^i}} \cdot y_m^i, \quad (7)$$

$$z_{Om}^i = \frac{1}{\gamma_m^i (1 - \beta_{(1)m}^i)^{1-\sigma_m^i}} \left(\frac{1 - \alpha_{(1)m}^i}{q_{Om}^i} \right)^{\sigma_m^i} \Psi_m^i{}^{\frac{\sigma_m^i}{1-\sigma_m^i}} \cdot y_m^i, \quad (8)$$

where $\Psi_m^i = (\alpha_{(1)m}^i)^{\sigma_m^i} \left(\frac{q_{(1)m}^i}{\beta_{(1)m}^i} \right)^{1-\sigma_m^i} + (1 - \alpha_{(1)m}^i)^{\sigma_m^i} \left(\frac{q_{Om}^i}{1 - \beta_{(1)m}^i} \right)^{1-\sigma_m^i}$.

By substituting Equations (7) and (8) into Equation (5), we obtained the price of good m in zone i .

$$p_m^i = \frac{1}{\gamma_m^i} \Psi_m^i{}^{\frac{1}{1-\sigma_m^i}}, \quad (9)$$

The non-energy composite is defined as a composite of intermediate inputs, real estate services, and value added, with net indirect tax and real estate tax included in its formulation. The formulation is as follows.

$$q_{(1)m}^i z_{(1)m}^i = \min_{z_m^i, x_{REm}^i, c_{fm}^i} \left[q_{(2)m}^i z_{(2)m}^i + (1 + \tau_{RE}^i) p_{RE}^i x_{REm}^i + (1 + \tau_m^i) p_{fm}^i c_{fm}^i \right], \quad (10)$$

$$\text{s.t. } z_{(1)m}^i = \gamma_{Zm}^i \left[\alpha_{(2)m}^i \left\{ \beta_{(2)m}^i z_{(2)m}^i \right\}^{\frac{\sigma_{Zm}^i - 1}{\sigma_{Zm}^i}} + \alpha_{REm}^i \left\{ \beta_{REm}^i x_{REm}^i \right\}^{\frac{\sigma_{Zm}^i - 1}{\sigma_{Zm}^i}} + \alpha_{cfm}^i \left\{ \beta_{cfm}^i c_{fm}^i \right\}^{\frac{\sigma_{Zm}^i - 1}{\sigma_{Zm}^i}} \right]^{\frac{\sigma_{Zm}^i}{\sigma_{Zm}^i - 1}}. \quad (11)$$

By solving Equation (10), we obtained the demand functions.

$$z_{(2)m}^i = \frac{1}{\gamma_{Zm}^i (\beta_{(2)m}^i)^{1 - \sigma_{Zm}^i}} \left(\frac{\alpha_{(2)m}^i}{q_{(2)m}^i} \right)^{\sigma_{Zm}^i} \Psi_{Zm}^i \frac{\sigma_{Zm}^i}{1 - \sigma_{Zm}^i} \cdot z_{(1)m}^i, \quad (12)$$

$$x_{REm}^i = \frac{1}{\gamma_{Zm}^i (\beta_{REm}^i)^{1 - \sigma_{Zm}^i}} \left(\frac{\alpha_{REm}^i}{\{1 + \tau_{RE}^i\} p_{RE}^i} \right)^{\sigma_{Zm}^i} \Psi_{Zm}^i \frac{\sigma_{Zm}^i}{1 - \sigma_{Zm}^i} \cdot z_{(1)m}^i, \quad (13)$$

$$c_{fm}^i = \frac{1}{\gamma_{Zm}^i (\beta_{cfm}^i)^{1 - \sigma_{Zm}^i}} \left(\frac{\alpha_{cfm}^i}{\{1 + \tau_m^i\} p_{fm}^i} \right)^{\sigma_{Zm}^i} \Psi_{Zm}^i \frac{\sigma_{Zm}^i}{1 - \sigma_{Zm}^i} \cdot z_{(1)m}^i, \quad (14)$$

where

$$\Psi_{Zm}^i = (\alpha_{(2)m}^i)^{\sigma_{Zm}^i} \left(\frac{q_{(2)m}^i}{\beta_{(2)m}^i} \right)^{1 - \sigma_{Zm}^i} + (\alpha_{REm}^i)^{\sigma_{Zm}^i} \left(\frac{p_{RE}^i}{\beta_{REm}^i} \right)^{1 - \sigma_{Zm}^i} + (\alpha_{cfm}^i)^{\sigma_{Zm}^i} \left(\frac{\{1 + \tau_m^i\} p_{fm}^i}{\beta_{cfm}^i} \right)^{1 - \sigma_{Zm}^i}.$$

By substituting Equations (12)–(14) into Equation (10), we obtained the price of the non-energy composite in zone i .

$$q_{(1)m}^i = \frac{1}{\gamma_{Zm}^i} \Psi_{Zm}^i \frac{1}{1 - \sigma_{Zm}^i}, \quad (15)$$

The remaining stages are modeled analogously and are omitted for brevity; see Muto et al. [21] for details. In the transport mode choice module, the value of travel time in commuting and substitution across modes is incorporated, and composite passenger transport services are specified as follows.

$$q_{Pm}^{ik} z_{Pm}^{ik} = \min_{x_{Psm}^{ik}} \sum_{P_s} \left(1 + \omega \zeta_{P_s}^{ik} t^{ik} \right) p_{P_s}^{ik} x_{Psm}^{ik}, \quad (16)$$

$$\text{s.t. } z_{Pm}^{ik} = \gamma_{Psm}^{ik} \left[\sum_{P_s} \alpha_{Psm}^{ik} \left\{ \beta_{Psm}^{ik} x_{Psm}^{ik} \right\}^{\frac{\sigma_{Pm}^{ik} - 1}{\sigma_{Pm}^{ik}}} \right]^{\frac{\sigma_{Pm}^{ik}}{\sigma_{Pm}^{ik} - 1}}, \quad (17)$$

Here, q_{Pm}^{ik} and z_{Pm}^{ik} denote the price and quantity of composite passenger transport service from zone i to zone k , respectively; $p_{P_s}^{ik}$ and x_{Psm}^{ik} represent the price and quantity of transport services using mode P_s from zone i to zone k , respectively; $\zeta_{P_s}^{ik}$ denotes the conversion parameter from transport expenditure to trips; ω represents the wage rate, interpreted as the value of time.

3.2. Household's Behavior

The household behavior model consists of a residential location choice model and a consumption behavior model. As shown in Figure 2, the left part represents the residential location choice model, whereas the right part represents the consumption behavior model.

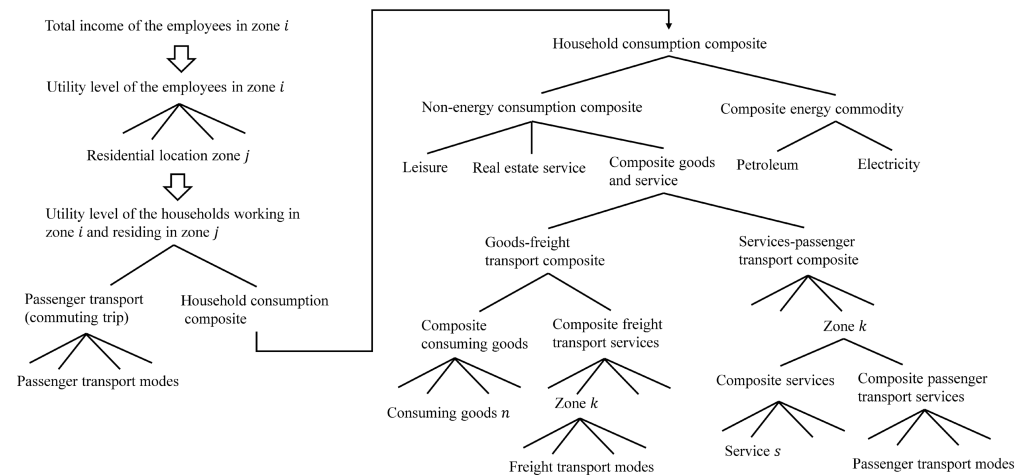


Figure 2. Nested location choice and consumption structure of households.

In the present model, the residential location choice behavior of households is formulated using an aggregate model, like the production location choice model of firms presented in Section 3.1.

$$e_H^i = \min_{v_H^{ij}} \sum_j p_V^{ij} v_H^{ij}, \quad (18)$$

$$u_H^i (= v_H^i) = \gamma_{LH}^i \left[\sum_j \alpha_{LH}^{ij} \left\{ \beta_{LH}^{ij} v_H^{ij} \right\}^{\frac{\sigma_{LH}^i - 1}{\sigma_{LH}^i}} \right]^{\frac{\sigma_{LH}^i}{\sigma_{LH}^i - 1}}, \quad (19)$$

where v_H^{ij} denotes the utility level of households working in zone i and residing in zone j ; p_V^{ij} denotes the price of composite utility; and e_H^i denotes the expenditure of households working in zone i .

By solving Equation (18), we obtained the utility functions.

$$v_H^{ij} = \frac{1}{\gamma_{LH}^i (\beta_{LH}^{ij})^{1 - \sigma_{LH}^i}} \left(\frac{\alpha_{LH}^{ij}}{\beta_{LH}^{ij}} \right)^{\sigma_{LH}^i} \Psi_{LH}^i \frac{\sigma_{LH}^i}{1 - \sigma_{LH}^i} \cdot v_H^i, \quad (20)$$

where $\Psi_{LH}^i = \sum_j \left(\alpha_{LH}^{ij} \right)^{\sigma_{LH}^i} \left(\frac{p_V^{ij}}{\beta_{LH}^{ij}} \right)^{1 - \sigma_{LH}^i}$.

By substituting Equation (20) into Equation (18), the expenditure equation can be derived.

$$e_H^i = \frac{1}{\gamma_{LH}^i} \Psi_{LH}^i \frac{1}{1 - \sigma_{LH}^i} \cdot v_H^i \equiv p_V^i \cdot v_H^i, \quad (21)$$

The total income of households working in zone i , denoted by Ω_H^i , is determined by allocating the total income of the entire urban area in proportion to the total labor input across all industries in each zone, i.e., $\sum_m l_m^i$, as follows:

$$\Omega_H^i = \left[\left\{ wT + rK + \sum_i r_{RE}^i K_{RE}^i \right\} (1 - \tau_H) - S_H \right] \frac{\sum_m l_m^i}{\sum_j \sum_m l_m^j}, \quad (22)$$

where T and w denote the total available time and wage rate in the metropolitan area, respectively; K and r represent the total capital stock and the rate of return to capital in the metropolitan area; K_{RE}^i and r_{RE}^i denote the real estate capital stock and its rental rate in zone i ; τ_H is the income tax rate; and S_H represents total savings in the metropolitan area.

Next, in the second stage illustrated in Figure 2, households determine the allocation between consumption composite and passenger transport for commuting, conditional on the utility level v_H^{ij} . The corresponding optimization problem, demand functions, and price equation are given as follows.

$$p_V^{ij} v_H^{ij} = \min_{z_{VH}^{ij}, z_{PCH}^{ij}} [q_{VH}^j z_{VH}^{ij} + q_{PCH}^{ij} z_{PCH}^{ij}], \quad (23)$$

$$\text{s.t. } v_H^{ij} = \gamma_{CH}^{ij} \left[(1 - \alpha_{CH}^{ij}) \left\{ (1 - \beta_{CH}^{ij}) z_{VH}^{ij} \right\}^{\frac{\sigma_{CH}^{ij}-1}{\sigma_{CH}^{ij}}} + \alpha_{CH}^{ij} \left\{ \beta_{CH}^{ij} z_{PCH}^{ij} \right\}^{\frac{\sigma_{CH}^{ij}-1}{\sigma_{CH}^{ij}}} \right]^{\frac{\sigma_{CH}^{ij}}{\sigma_{CH}^{ij}-1}}, \quad (24)$$

the following functions can be derived.

$$z_{VH}^{ij} = \frac{1}{\gamma_{CH}^{ij} (1 - \beta_{CH}^{ij})^{1-\sigma_{CH}^{ij}}} \left(\frac{1 - \alpha_{CH}^{ij}}{q_{VH}^j} \right)^{\sigma_{CH}^{ij}} \Psi_{CH}^{ij} \frac{\sigma_{CH}^{ij}}{1 - \sigma_{CH}^{ij}} \cdot v_H^{ij}, \quad (25)$$

$$z_{PCH}^{ij} = \frac{1}{\gamma_{CH}^{ij} (\beta_{CH}^{ij})^{1-\sigma_{CH}^{ij}}} \left(\frac{\alpha_{CH}^{ij}}{q_P^{ij}} \right)^{\sigma_{CH}^{ij}} \Psi_{CH}^{ij} \frac{\sigma_{CH}^{ij}}{1 - \sigma_{CH}^{ij}} \cdot v_H^{ij}, \quad (26)$$

$$p_V^{ij} = \frac{1}{\gamma_{CH}^{ij}} \Psi_{CH}^{ij} \frac{1}{1 - \sigma_{CH}^{ij}}, \quad (27)$$

$$\text{where } \Psi_{CH}^{ij} = (1 - \alpha_{CH}^{ij})^{\sigma_{CH}^{ij}} \left(\frac{q_{VH}^j}{1 - \beta_{CH}^{ij}} \right)^{1-\sigma_{CH}^{ij}} + (\alpha_{CH}^{ij})^{\sigma_{CH}^{ij}} \left(\frac{q_P^{ij}}{\beta_{CH}^{ij}} \right)^{1-\sigma_{CH}^{ij}}.$$

Here, z_{VH}^{ij} and q_{VH}^j denote household consumption composite and its price in zone j ; z_{PCH}^{ij} and q_P^{ij} denote commuting-related composite passenger transport service and its price; α , β , γ , and σ are the share, scale, efficiency, and substitution parameters, respectively. The modeling process for household consumption behavior is analogous to that for firms' production behavior described in Section 3.1, except that the composite value-added input is replaced by leisure consumption; therefore, the details are omitted here for brevity.

3.3. Behavior of Other Economic Agents

The behavioral models for the transportation and real estate sectors are also specified in the model. However, since their formulations are almost identical to firms' production behavior models, the detailed specification is omitted here.

Finally, the model incorporates the behavior of the government, the public investment sector, and the private investment sector. The government's tax revenues consist of household income taxes and firms' net indirect taxes. A portion of these revenues is allocated to public investment, while the remainder is used for government consumption to provide public services. The public investment sector undertakes public projects by allocating public investment funds across industries. The private investment sector finances investment using household savings and similarly allocates these funds across industries. The

allocation mechanism described above is largely analogous to the modeling of household composite goods behavior, with the exception that leisure consumption is excluded.

3.4. Market Equilibrium Conditions and Constraints

(a) Commodity market equilibrium

$$y_n = \sum_i \left(\sum_m x_{nm}^i + x_{nH}^i \right) + x_{nGC} + x_{nGI} + x_{nI}. \quad (28)$$

(b) Service commodity market equilibrium

$$y_n^i = \sum_m x_{nm}^i + x_{nH}^i + x_{nGC}^i + x_{nGI}^i + x_{nI}^i. \quad (29)$$

(c) Transport service commodity market equilibrium

$$y_T^{ki} = \sum_m x_{Tm}^{ki} + x_{TH}^{ki} + x_{TGC}^{ki} + x_{TGI}^{ki} + x_{TI}^{ki}. \quad (30)$$

(d) Labor Market Equilibrium

$$T - \sum_i l_H^i = \sum_i \left(\sum_m l_m^i + l_T^i \right). \quad (31)$$

(e) Capital Market Equilibrium

$$K = \sum_i \left(\sum_m k_m^i + \sum_T k_T^i \right). \quad (32)$$

(f) Real Estate Market Equilibrium

$$K_{RE}^i = k_{RE}^i. \quad (33)$$

where y_n denotes the output of commodity n ; y_n^i denotes the output of service commodity n produced in zone i ; y_T^{ki} denotes the output of transport services from zone k to zone i . x_{nm}^i and x_{nH}^i represent the quantity demand for commodities or services n by firm m and households in zone i , respectively. x_{nGC} , x_{nGI} , and x_{nI} denote the demand for commodity n by government consumption, public investment and private investment sector, respectively, while x_{nGC}^i , x_{nGI}^i , x_{nI}^i represent the corresponding demand for service commodity n in zone i . x_{Tm}^{ki} , x_{TH}^{ki} , x_{TGC}^{ki} , x_{TGI}^{ki} , and x_{TI}^{ki} denote the demand for transport service from zone k to zone i by firms, households, government consumption, public investment sector, and private investment sector, respectively. K , k_m^i , and k_T^i denote the total capital endowment and the capital inputs used by firm m and transport firm in zone i , respectively. T , l_H^i , l_m^i , and l_T^i denote the total time endowment, household leisure consumption, and labor inputs used by firm m and transport firm in zone i , respectively. Finally, K_{RE}^i and k_{RE}^i denote the total real estate capital stock and the amount of real estate capital employed in zone i , respectively.

From these market equilibrium conditions, the equilibrium prices of goods, services, and production factors can be obtained. Furthermore, by substituting these into the following equivalent variation (EV) equation, the impact of policies can be quantitatively evaluated.

$$V(p^{WO}, \Omega^{WO} + EV) = V(p^W, \Omega^W), \quad (34)$$

where the subscripts WO and W indicate the cases without and with the policy, respectively. p denotes the price vector; Ω denotes household income.

3.5. Parameter Calibration

In the present model, the parameters are calibrated based on the social accounting matrix (SAM) of the target metropolitan area, which describes the transactions among production sectors, households, the government, and the rest of the economy. Given the benchmark equilibrium values of prices and quantities, the share parameters and scale

parameters in the production, consumption, and trade functions are calibrated so that the model equations exactly reproduce the base-year observations. In CGE models, substitution elasticities are generally treated as exogenous parameters and are typically specified based on previous empirical studies and established modeling practice.

4. Case Study

4.1. Overview of the Study Area

This study focuses on the Kofu metropolitan area located in Yamanashi Prefecture, Japan. The study area consists of seven cities and two towns, with a total population of approximately 530,000 and a total land area of about 780 km².

The Kofu metropolitan area represents a typical medium-sized regional center in Japan. Located approximately 120 km west of Tokyo, Kofu has experienced population aging, population decline, and economic stagnation, all associated with the concentration of economic activity in major metropolitan areas. At the same time, the region has actively promoted industrial transformation through initiatives such as the “Yamanashi Medical Device Corridor” (Yamanashi Medical Device Corridor. <https://www.pref.yamanashi.jp/seichosangyo/yamanashimedicaldevicecorridor.html> (accessed on 5 May 2026)), which aims to foster knowledge-intensive and high-value-added manufacturing industries. These characteristics make Kofu a representative and policy-relevant case for evaluating regional revitalization strategies and examining the interactions among economic development, social welfare, and environmental sustainability within the proposed CGEUE framework.

In this case study, due to the general equilibrium structure of the CGEUE model, policy interventions directed at a particular industry or location generate economy-wide effects through intersectoral linkages. Furthermore, the CGEUE model incorporates elements of the CUE model, enabling a detailed assessment of how policy impacts propagate across industries and spatial zones within the study area. For analytical purposes, all industries are grouped into five categories: the primary sector, the secondary sector excluding the target industry, the tertiary sector excluding real estate, the target industry, and the real estate sector. In addition, the study area is subdivided into 66 zones to examine spatial heterogeneity and regional disparities. The detailed zoning system is reported in Appendix A.

4.2. Data and Calibration

Because no dedicated dataset is available for the Kofu metropolitan area, a new dataset is constructed using the input–output table (Yamanashi Prefecture Input–Output Table. https://www.pref.yamanashi.jp/toukei_2/HP/23renkan.html (accessed on 20 October 2025)) of Yamanashi Prefecture and employment data by industry for Yamanashi Prefecture and the Kofu metropolitan area. The CGEUE model is calibrated using this dataset. The procedure is as follows.

- (1) In the absence of a localized input–output table, the proportional allocation method based on industry-specific employment is a widely accepted approach in regional CGE modeling [33–35]. The method has also been extensively applied in Japanese regional economic analyses [20,21]. Using the input–output table of Yamanashi Prefecture as the benchmark, value-added and total output for each industry in the Kofu metropolitan area are estimated by proportionally allocating prefectural totals according to industry-level employment data for the Yamanashi Prefecture and the Kofu metropolitan area.
- (2) On the demand side, private consumption is allocated according to the number of households; government consumption and public investment are allocated based on the number of public employees; and private investment as well as interregional trade

(exports and imports) are allocated according to total employment. These procedures yield estimates for the Kofu metropolitan area.

- (3) Intermediate input demand for the Kofu metropolitan area is calculated using input coefficients from the Yamanashi Prefecture input–output table and subsequently adjusted using the widely adopted RAS method [36–38].
- (4) The resulting input–output table is then converted into the SAM, which serves as the database for the CGEUE model.

4.3. Simulation Scenarios and Policy Design

Japan has long faced the social challenges of population aging and declining birth rates, which have exerted increasing pressure on regional labor markets and economic vitality. In response, the Yamanashi Prefecture has promoted the “Yamanashi Medical Device Corridor”, which aims to transform the regional economy toward high-value-added and technology-intensive industries, thereby mitigating the economic constraints of a shrinking labor force while meeting the growing demand for medical and healthcare services. Reflecting this policy objective, the present study selects the “Business-Oriented Machinery Manufacturing” sector in the SAM, which encompasses the medical equipment industry, as the target industry. Using the initial equilibrium of the CGEUE model as the baseline scenario, the economic effects of policies are evaluated. The details of the policy scenarios considered in this study are as follows:

- (1) Transport improvement policy

Transport improvements enhance regional accessibility and reduce transport costs by improving the infrastructure network. The Yamanashi Prefecture has planned the construction of the Shin–Kagami–Nakajo Bridge to strengthen transportation infrastructure in the Tsukiji industrial cluster area and improve its external connectivity. In this study, bridge construction is represented as the addition of a new link to the transportation network topology. This network modification alters travel times between zones, and the resulting changes in interzonal travel times are modeled as policy shocks.

- (2) Real estate supply expansion policy

The establishment of industrial parks is a widely used policy measure to stimulate industrial development. Increasing the supply of developable land or optimizing land allocation can relax factor constraints. In this study, this policy is implemented by increasing the endowment of real estate services in the targeted industrial agglomeration area.

- (3) Sector-specific tax reduction policy

Tax reduction is a common instrument for industrial support. By lowering the tax rate for targeted industries, firms’ production costs and tax burdens are reduced, leading to an expansion of output and improved competitiveness. In this study, the policy is implemented as a reduction in the net indirect tax rate applied to the target industry, represented by a decrease in the parameter (τ_m^i) in Equation (10).

- (4) Sector-specific rental subsidy policy

Fiscal subsidies to specific industries or firms can directly reduce production costs or increase returns. The Yamanashi Prefecture has implemented a series of support measures for the medical device industry (Subsidy program for creating model companies to drive growth in the medical device related industry (Japan). <https://www.pref.yamanashi.jp/seichosangyo/hojokin/iryokikikanrensagyo.html> (accessed on 10 May 2026)). In CGE models, subsidies are commonly represented as negative taxes [39]. Accordingly, in this study, the subsidy policy is implemented by specifying the real estate tax rate (τ_{RE}^i) in Equation (10) as a negative value.

4.4. Results and Discussion

4.4.1. Simulation Results

Table 1 summarizes the simulation results under different policy scenarios with a comparable fiscal cost. Infrastructure investments are one-off capital expenditures; tax reductions and subsidies entail recurrent fiscal effects. To ensure comparability, investment costs are annualized, and the magnitudes of tax reductions and subsidies are calibrated accordingly. The simulation results indicate that transport improvement and real estate supply expansion policies increase aggregate regional welfare, whereas tax reduction and subsidy policies reduce it. At the sectoral level, both transport improvement and real estate supply expansion policies lead to output growth across all industries. In contrast, under sector-specific tax reduction and sector-specific subsidy policies, output in the secondary and tertiary sectors declines, while output in the primary sector, the real estate sector, and the targeted industry increases. Regarding policy effectiveness, the tax reduction policy demonstrates the highest efficacy in achieving intended objectives, followed by the subsidy policy, the real estate supply expansion policy, and finally the transport improvement policy.

Table 1. Simulation results of policy interventions in the Kofu metropolitan area.

Policy	EV	Primary Industry	Secondary Industry (Excluding the Targeted Sector)	Tertiary Industry (Excluding Real Estate)	Real Estate Sector	Targeted Sector
Transport improvement	44.8	1.9	26.8	18.0	0.7	1.1
Real estate supply expansion	128.9	0.1	43.3	30.3	230.1	3.5
Sector-specific tax reduction	−8.6	3.1	−82.0	−284.7	0.2	395.3
Sector-specific rental subsidy	−2.5	3.5	−113.7	−237.5	112.6	167.3

Unit: million JPY.

The simulation results are broadly consistent with previous studies. Transport improvement and real estate supply expansion generate positive welfare effects by reducing economic frictions and relaxing factor constraints. Similar findings have been reported in CGE and urban economic studies examining transportation investment and land supply policies [20,40,41]. In contrast, the simulation results indicate that sector-specific tax reductions and rental subsidies substantially expand the targeted industry but reduce aggregate welfare. This phenomenon reflects the “distortions” introduced by selective industrial policies. As highlighted by Chen (2022) [42] and Huang (2024) [43], selective industrial policies can inadvertently lead to resource misallocation and exert a negative impact on Total Factor Productivity (TFP). These findings suggest that different policy instruments affect regional economy and welfare through different economic mechanisms. To better understand these differences, the mechanisms underlying the policy outcomes can be interpreted as follows.

(1) Transport improvement policy

The construction of a new bridge improves network connectivity, reduces travel time between zones, and lowers generalized transport costs. As a result, the regional utility price index declines. At the same time, reduced transport costs stimulate production expansion by firms, increasing factor demand and raising factor prices. This, in turn, leads to higher household income and ultimately results in an overall improvement in regional welfare.

(2) Real estate supply expansion policy

Increasing the stock of real estate services relaxes spatial resource constraints. In the target area (zone 45, Tsukiji), the expansion of real estate supply reduces the price of real estate services, thereby attracting both households and firms to relocate to the target zone

and increasing local welfare. While some regions may experience welfare losses, the gains from the relaxation of resource constraints outweigh these losses, leading to a positive net welfare effect overall.

(3) Sector-specific tax reduction policy.

Tax reductions for a targeted industry increase its demand for production factors. Within zones, this induces a reallocation of labor and capital toward the targeted industry; across zones, factors tend to flow toward areas where the targeted industry is concentrated. Therefore, it can be observed that output in other secondary industries and the tertiary sector declines, while the targeted sector expands substantially. However, tax reduction policies are inherently distortionary, leading to inefficient resource allocation and generating deadweight losses. In addition, they reduce government revenue, which in turn constrains public consumption and investment, ultimately resulting in an overall welfare loss for the city.

(4) Sector-specific rental subsidy policy.

Subsidies operate in a manner similar to tax reductions. By distorting the price of an intermediate input—real estate services—they stimulate the expansion of the targeted sector but exert negative impacts on other industrial and service sectors, thereby leading to welfare losses. However, the overall welfare loss is smaller than that under the tax reduction policy. This is because subsidies lower the effective cost of real estate services for the targeted sector, thereby increasing input demand. Under the assumption of inelastic supply of real estate services, this increased demand drives up the equilibrium price in the real estate market. The resulting gains are ultimately captured by households and are capitalized on welfare improvements.

4.4.2. Spatial Characteristics of Policy Impacts

To evaluate the spatial characteristics of different policies, this study first examines regional inequality in welfare changes. As shown in Figure 3, the welfare effects induced by different policy shocks exhibit pronounced spatial heterogeneity.

Specifically, the transport policy generates widespread welfare gains, although these benefits are primarily concentrated in areas surrounding the improved transport infrastructure. In contrast, the expansion of real estate supply mainly improves welfare in the targeted zone, while generating welfare losses in most other zones, thereby exacerbating regional inequality. Subsidy and tax reduction policies likewise produce uneven spatial welfare effects. Under the rent subsidy policy, most regions experience positive welfare gains, whereas welfare losses are significant in the industrial agglomeration zone. By contrast, under the tax reduction policy, welfare increases are concentrated in the industrial agglomeration zone, while most other zones experience welfare losses.

These patterns can be explained by the distinct mechanisms through which each policy operates. Transport improvements enhance network connectivity and reduce travel times between zones, thereby generating positive welfare gains across the entire urban zone. Zones located closer to the improved infrastructure benefit more due to greater reductions in travel time and higher induced traffic flows, resulting in a spatial gradient of welfare gains that decrease with distance from the new infrastructure.

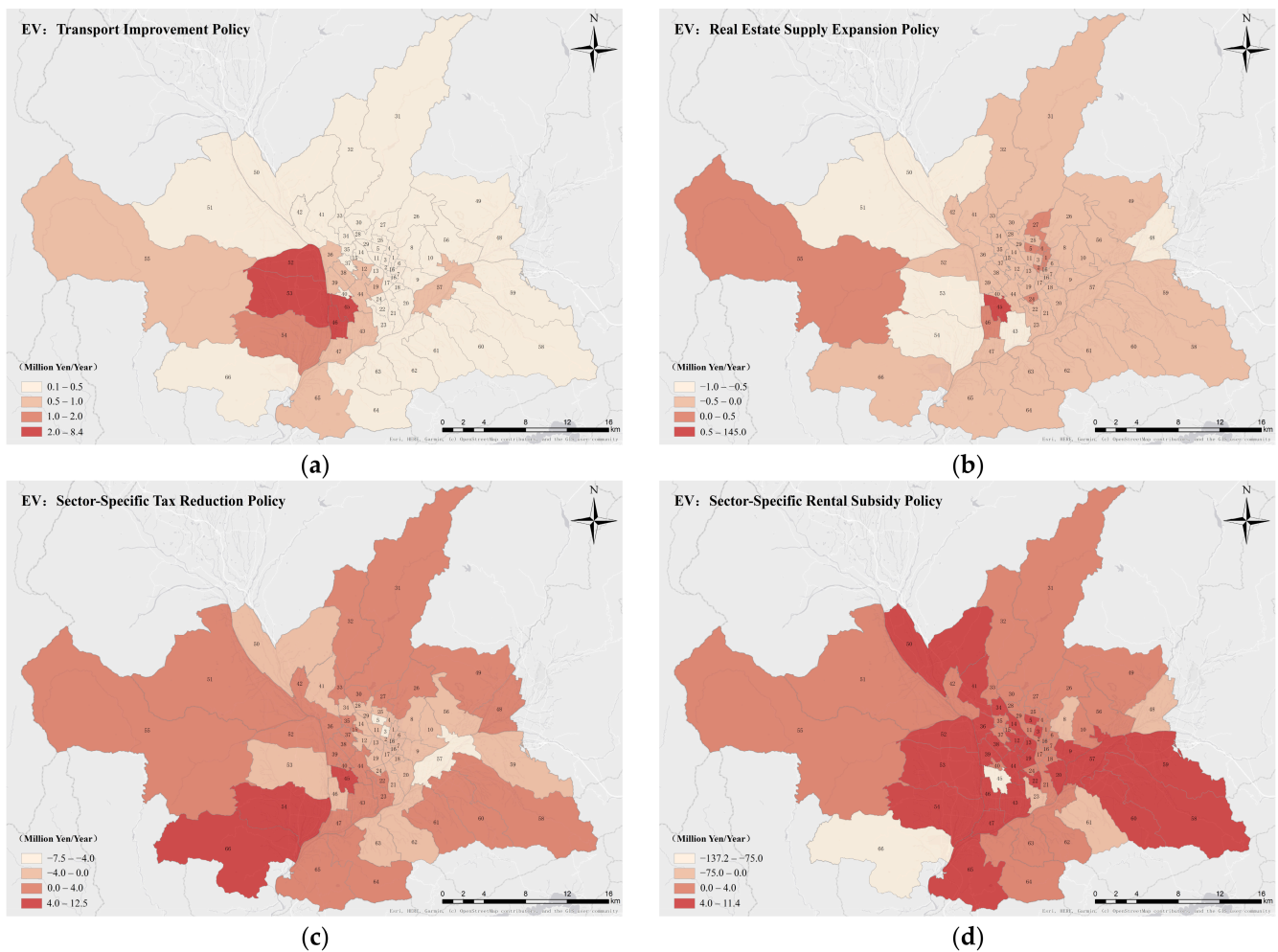


Figure 3. Zonal characteristics of EV under policy interventions: (a) transport improvement policy; (b) real estate supply expansion policy; (c) sector-specific tax reduction policy; (d) sector-specific rental subsidy policy.

In contrast, real estate supply expansion lowers the price of real estate services in the targeted zone (e.g., zone 45), thereby increasing its attractiveness. This induces a “siphoning effect” from other zones, leading to welfare losses in other zones. At the same time, the reduction in production costs in the targeted zone is partially transmitted through price linkages, generating positive spillover effects that improve welfare in other zones. As a result, the overall spatial pattern reflects both welfare gains and losses across different areas.

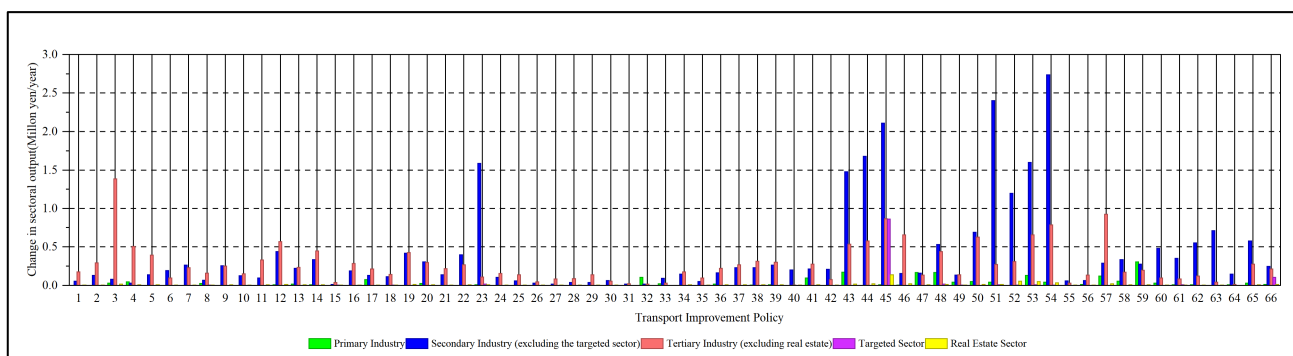
Although both subsidy and tax reduction policies operate through price distortions and apply to all zones, their spatial impacts differ markedly. Under the tax reduction policy, increased labor demand in the industrial agglomeration zones raises total labor income, leading to welfare gains in these areas. However, in some zones, outflows of industries and labor reduce labor demand and household income, resulting in welfare losses. This explains the significant welfare gains observed in zones 45 and 66, alongside welfare declines in some zones.

Under the subsidy policy, in zones where subsidized industries are concentrated, the induced production expansion substantially increases demand for real estate services. Given the limited elasticity of real estate supply, this leads to crowding-out effects on other industries and households, ultimately reducing local welfare. In contrast, because subsidies are effectively transferred to households in other regions, these regions experience welfare gains. Consequently, welfare declines are observed in zones 45 and 66, while most other regions experience improvements.

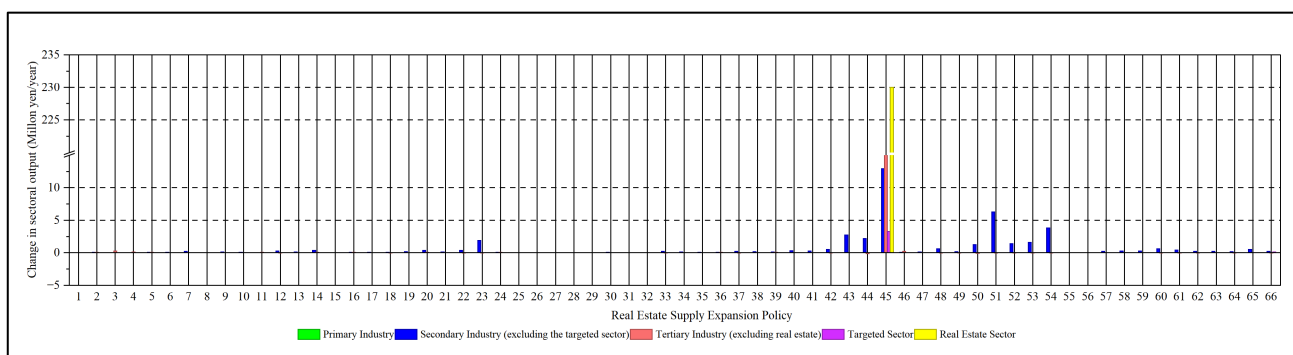
Overall, all policy scenarios generate regional welfare redistribution effects to varying degrees. The transport policy exhibits a pattern of “broad coverage but unevenly distributed welfare gains”, whereas the real estate supply expansion, subsidy, and tax reduction policies tend to intensify regional disparities.

At the sectoral level, the targeted industry expands under all policy scenarios, with the most pronounced growth occurring under the tax reduction and subsidy policies. At the same time, however, total output in other secondary industries declines across most zones, suggesting that under tax reduction and subsidy policies, the expansion of the targeted industry is driven primarily by intersectoral factor reallocation rather than by an expansion of overall industrial scale. In contrast, different patterns emerge under the transport improvement and real estate supply expansion policies. Although the growth of the targeted industry is relatively smaller, outputs across industries generally increase simultaneously, indicating that these policies enhance overall productive efficiency mainly by reducing spatial costs or relaxing resource constraints, thereby generating broad-based economic expansion rather than relying on resource reallocation across sectors. Therefore, these policies are more consistent with a “Pareto-improving” growth path, in the sense that they promote multi-sector expansion without significantly crowding out other industries.

From a zonal perspective, transport improvement policy also exhibits broad-based effects, with output increasing across all sectors and zones (Figure 4a). The most pronounced growth is observed in the secondary sector, followed by the tertiary sector. This is consistent with the economic structure of the Kofu metropolitan area, where the secondary and tertiary industries are relatively well-developed and therefore generate larger increments in output.

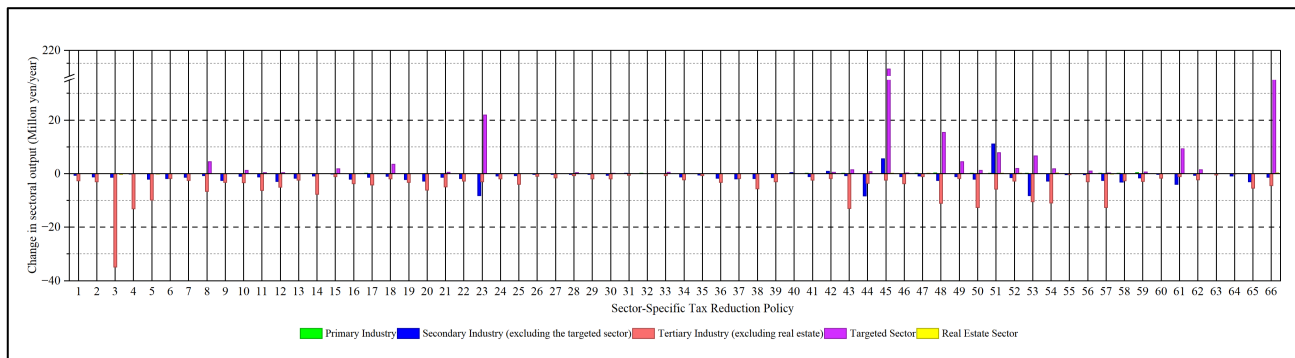


(a)

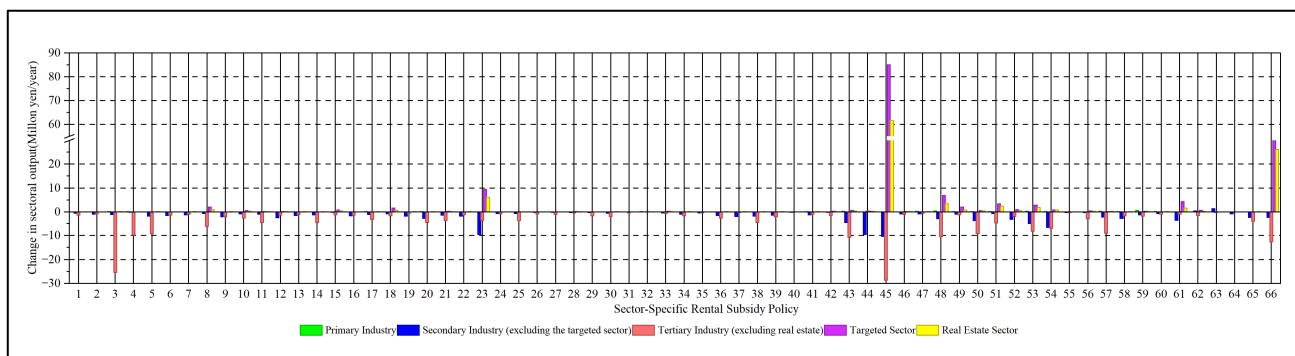


(b)

Figure 4. Cont.



(c)



(d)

Figure 4. Zonal changes in sectoral output under policy interventions: (a) transport improvement policy; (b) real estate supply expansion policy; (c) sector-specific tax reduction policy; (d) sector-specific rental subsidy policy.

In contrast, the real estate expansion policy demonstrates clear sectoral and spatial targeting (Figure 4b). The expansion of real estate supply in zone 45 significantly increases output in the real estate sector within that zone, which in turn boosts the output of industrial and service sectors that use real estate services as an input. However, the effects on other regions are relatively limited, with only some areas experiencing increases in industrial output. This can be attributed to interregional spillover effects arising from the decline in the price of intermediate inputs produced in zone 45.

Tax reduction and subsidy policies also exhibit pronounced regional heterogeneity. Under the tax reduction policy, due to the interregional and intersectoral mobility of population and factors, the targeted sector shows substantial output growth in zones with high initial concentration such as zones 23, 45, and 66, while output in other sectors generally declines across zones (Figure 4c). Under the subsidy policy, the spatial pattern of sectoral changes is similar to that under tax reductions, but the magnitude is smaller, indicating that subsidies induce more moderate structural adjustments. In addition, subsidies lead to an increase in real estate output, suggesting that part of the benefits from industrial subsidies are captured by the real estate sector (Figure 4d).

4.4.3. Policy-Induced Transport and Environment Effects

Figure 5 illustrates the changes in total transport output and modal transport demand under different policy interventions. From the perspective of total transport output, both transport improvement and real estate supply expansion policies increase transport output, indicating a rise in transport demand. In contrast, subsidy and tax reduction policies reduce transport output, implying a decline in overall transport demand. This divergence arises because the former two policies promote broad-based production expansion across the

economy, thereby increasing both passenger and freight transport demand. By contrast, the latter two policies mainly induce the reallocation of factors across regions and sectors rather than economy-wide expansion, leading to different outcomes.

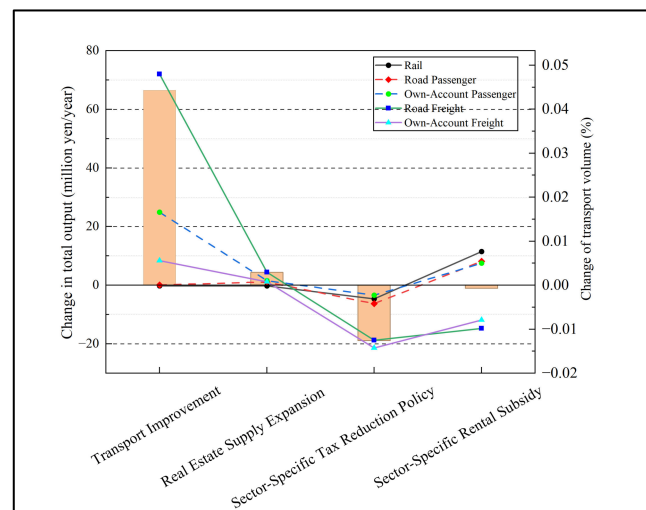


Figure 5. Changes in the output of the transport sector under policy interventions.

Specifically, the tax reduction policy promotes labor relocation to the targeted sector and induces households to move closer to industrial agglomerations, thereby strengthening the spatial concentration of economic activity. This agglomeration effect shortens commuting and freight linkages, thereby reducing overall transport demand. Although the rental subsidy policy also reduces total transport demand, the underlying mechanism is different. The policy contracts non-target sectors and reduces freight demand, while expanding production in the target sector. However, because the target sector, business-oriented machinery manufacturing, is a medium–high-tech industry with relatively low transport intensity compared with the economy-wide average, aggregate transport demand still declines. At the same time, unlike the tax reduction policy, rental subsidies do not generate strong spatial concentration, and thus their suppressing effect on transport demand is less pronounced.

A notable finding is that while transport improvement policy increases overall transport demand, it also induces a shift from rail passenger transport toward road passenger transport, leading to a slight decline in rail passenger volume after the policy shock. This reflects modal substitution caused by reduced road travel times and lower generalized travel costs, which increases households' preference for road transport. This result suggests that transport improvements, while enhancing welfare and stimulating economic growth, may also reinforce road dependence and potentially increase environmental burdens. Although both tax reductions and subsidies reduce total transport demand, their underlying mechanisms differ. Tax reductions reduce both commuting and freight demand through stronger industrial spatial concentration. In contrast, rental subsidies mainly reduce freight demand, while higher household income stimulates passenger travel demand, as the subsidy is ultimately accrued to households. This distinction highlights that similar aggregate transport outcomes may arise through fundamentally different behavioral and spatial adjustment mechanisms.

4.4.4. Policy Implications and Summary of Findings

The simulation results offer critical insights for formulating development policies in Kofu City and similar medium-sized regional cities grappling with demographic contraction and economic stagnation (Table 2).

Table 2. Summary of policy simulation findings and implications.

Policy	Key Findings	Economic Interpretation	Policy Relevance
Transport improvement	Aggregate welfare enhancement and generalized output expansion.	Reducing spatial friction costs and fostering multi-industry linkages.	Serving as a foundation for long-term regional revitalization, while necessitating vigilance against automobile dependency.
Real estate supply expansion	Strong expansion in the focal area, albeit coupled with a “siphoning effect” on neighboring regions.	Alleviating spatial constraints and attracting factors to aggregate in specific areas.	Suitable for targeted investment promotion in industrial parks, requiring a balance of regional disparities.
Sector-specific tax reduction	A dramatic expansion in the target sector’s production at the expense of total social welfare.	Strongly distorting price signals, leading to resource misallocation and reduced public revenue.	Most effective but with high social costs, suitable for emergencies or key strategic breakthroughs.
Sector-specific rental subsidy	The target sector exhibits moderate expansion, accompanied by only a marginal impairment of aggregate welfare.	Reducing specific input costs, with part of the welfare transferred to households through rents.	Relatively moderate industrial policy that balances regional welfare and the target industrial development.

First, we look at improvements in transport infrastructure function as a universal policy instrument. By reducing travel time and transportation costs, these measures stimulate output across various sectors and enhance overall regional welfare. However, their impact on specific industries is less pronounced, and the expansion of road networks tends to increase the environmental burden. Second, while the expansion of real estate supply promotes economic growth by relaxing resource constraints, it may exacerbate regional inequalities. Furthermore, specific industrial interventions, such as subsidies and tax cuts, successfully catalyze growth within the targeted sectors; however, the resulting severe price distortions and resource misallocations lead to a net loss in aggregate social welfare.

Overall, the findings suggest that policies aimed at alleviating fundamental economic constraints—such as infrastructure improvements and expanded real estate supply—are more effective in enhancing total regional welfare. In contrast, industry-specific interventions are superior for achieving targeted sectoral objectives but often do so at the expense of regional welfare and equity. These findings underscore the imperative for regional development policies to simultaneously account for industrial targets, regional well-being, and environmental sustainability to achieve a balanced performance across the “3E” (Economy, Equity, and Environment) dimensions.

5. Conclusions

This study developed an integrated CGEUE framework that incorporates endogenous transport mode choice into a unified urban general equilibrium model, and applied it to evaluate the economic, equity, and environmental impacts of four policy interventions in the Kofu metropolitan area.

The results reveal clear differences in effectiveness across policy instruments. Transport improvements and real estate supply expansion enhance overall regional welfare and stimulate industrial growth by reducing spatial friction and relaxing resource constraints. In contrast, sector-specific tax reductions and rental subsidies achieve stronger targeted industrial expansion, but at the cost of reallocating resources away from other sectors

and reducing aggregate welfare. A consistent trade-off emerges across all four scenarios: policies that maximize targeted sectoral growth tend to reduce overall welfare, whereas policies that enhance regional welfare generate only modest effects on the target industry. These findings underscore that not all growth-oriented policies are welfare-enhancing, particularly when they rely on distortionary incentives.

In terms of regional equity, all policy scenarios exhibit pronounced spatial heterogeneity. Transport improvement policy generates broadly distributed welfare gains across zones, albeit with limited targeted industrial expansion. By contrast, tax reductions and subsidies effectively promote growth in specific industries but also induce welfare losses in certain regions, thereby exacerbating spatial inequality. This highlights an inherent trade-off between regional equity and targeted industrial development, suggesting that policies aimed at stimulating specific sectors may unintentionally widen spatial disparities.

Concerning transport and environmental outcomes, policy interventions not only affect the overall level of transport demand but also reshape modal choices. Transport improvement policies increase total travel demand and shift preferences toward road-based transport, whereas tax reductions and subsidies reduce overall transport demand through different mechanisms. These results indicate that policy-induced changes in economic structure and spatial organization can propagate through the transport system, ultimately generating differentiated environmental impacts.

These findings suggest that policy interventions typically involve trade-offs among economic efficiency, regional equity, and environmental sustainability, and that improvements in one dimension do not necessarily translate into gains in others. Therefore, effective policy design requires an integrated evaluation framework capable of capturing the complex interactions among transportation systems, land markets, industrial development, and household behavior. By providing such a framework, this study contributes to more evidence-based urban planning and offers a transferable analytical approach for assessing development strategies in cities facing similar socioeconomic challenges.

Several limitations should be acknowledged. First, the input–output data are approximated from prefectural-level tables, as city-level tables are unavailable. Second, the environmental analysis is confined to transport-related emissions and does not account for sectoral emission intensity changes induced by industrial restructuring. Third, the model is formulated as a static equilibrium framework and does not capture long-term demographic dynamics such as population aging and decline. Future research could address these limitations by incorporating higher-resolution economic data, sector-specific emission coefficients, and recursive dynamic extensions to examine how demographic trends interact with policy interventions over time.

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Abbreviations

The following abbreviations are used in this manuscript:

CGE	Computable General Equilibrium
CUE	Computable Urban Economic
IEA	International Energy Agency
OECD	Organization for Economic Co-operation and Development
SCGE	Spatial Computable General Equilibrium
CGEUE	Computable General Equilibrium and Urban Economic
CBA	Cost–Benefit Analysis
WEIs	Wider Economic Impacts
EV	Equivalent Variation
SAM	Social Accounting Matrix
HCI	Heavy and Chemical Industries
JPY	Japanese Yen

Appendix A

Table A1. Zoning system of the Kofu metropolitan area.

ID	Zone Name	ID	Zone Name	ID	Zone Name	ID	Zone Name
1	Fujigawa	18	Sumiyoshi	34	Shikishima Central	51	Nirasaki West
2	Aioi	19	Kokubo	35	Shikishima South	52	Hatta
3	Kasuga	20	Kose	36	Ryuo	53	Shirane
4	Shinkonya	21	Yamashiro	37	Tomitake Shinden	54	Ogasawara
5	Shiobe	22	Oosato	38	Shinohara	55	Ashiyasu
6	Takumi	23	Horinouchi	39	Nishiyahata	56	Kasugai
7	Azuma	24	Ookuni	40	Tamagawa	57	Isawa
8	Satogaki	25	Kitashin	41	Futaba North	58	Misaka
9	Tamao	26	Aikawa	42	Futaba West	59	Ichimiya
10	Kouun	27	Tsukahara	43	Tamaho	60	Yatsushiro
11	Anakiri	28	Yumura	44	Saijo (Showa Town)	61	Sakaigawa
12	Kugawa	29	Chiduka	45	Tsukiji	62	Nakamiti
13	Ishida	30	Haguro	46	Tatomi North	63	Toyotomi
14	Ikeda	31	Chiyoda	47	Tatomi South	64	Mitama
15	Shinden	32	Shikishima North	48	Yamanashi South	65	Ichikawadaimon
16	Yuda	33	Shikishima	49	Yamanashi North	66	Masuhō
17	Ise		Central–North	50	Nirasaki East		

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