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Asymmetric Dynamics of Rent and Vacancy Rates in the Tokyo Office Market

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In recent years, it has been shown that the dynamics of office markets are asymmetric depending on the market conditions and the direction of supply and demand shocks. However, the actual state of asymmetry varies significantly from market to market, and an overview of the discussion is needed. In this study, we test our hypothesis on asymmetric dynamics in the Tokyo office market, one of the world's largest markets. We employ the rent-adjustment process model proposed by Englund et al. (2008), an improved and more realistic version of the error correction model that captures the interaction between rent, vacancy rates, and stock. The data of the Tokyo office market range from January 2000 to September 2015 and cover ten regions. The results reveal that the mechanism of rent and vacancy rate fluctuation depends largely on the direction of change in supply and demand and on market conditions, especially the upward and downward movements of rents. It is also shown that increases in demand and

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supply not only encourage rents toward equilibrium, but also have the effect of overshooting them. These results can be valuable in properly capturing future shocks in demand and supply.

Keywords

Tokyo office market, Office market dynamics, Asymmetric rent-adjustment process, Office supply and demand shocks, Vacancy rate.

1. Introduction

Office market dynamics, also known as the rent-adjustment process, have been the subject of research for half a century, particularly in Europe and the United States. The rent-adjustment process proposed by Smith (1974) is based on the concept of the natural vacancy rate—the vacancy rate in equilibrium—proposed by Blank and Winnick (1953) and assumes that rent dynamics may be represented as a process of imbalance correction. Early studies have focused on the relationship between rent and vacancy rates and their adjustment paths. However, after Hendershott et al. (2002a, 2002b) apply the framework of error correction model (ECM), interest in the time required for the rent-adjustment response to employment and supply shocks, is growing.

In recent years, it has become clear that the effect of employment and supply shocks is asymmetric and depends on the direction of the shock and the state of the market (Brounen and Jennen, 2009). The state of asymmetry has yielded different results for different cities, and a consensus has not been reached. In addition, studies on the dynamics of the office market often use time-series data, and because of the limited sample size, the verification of asymmetry is still in its infancy (e.g., Nowak et al., 2020).

By contrast, this study examines the dynamics of rent, vacancy rates, and office stock in the Tokyo office market, and the asymmetry of their responses to employment and supply shocks using panel data from January 2000 to September 2015. The study addresses ten regions with the most extensive office stock in the Tokyo office market. Such data by a subregion within a city is known to reduce the aggregation bias caused by viewing the entire city as a uniform market (Malone and Redfearn, 2022). Although the Tokyo office market is one of the largest globally and a primary target for investment, very few empirical studies have addressed this issue because of the inaccessibility and poor quality of publicly available data. This empirical analysis overcomes these data issues by using information provided by one of the leading private office brokers in Japan.

This study contributes by closely following the asymmetric dynamics of the office market by using detailed data on a sub-regional and monthly basis within the city. Most studies of market dynamics assume symmetric dynamics; few have dealt with asymmetric dynamics, and there is still space for validation in terms of quantity and quality of data. This study fills these gaps. In particular, Asian office markets tend to have shorter lease terms than those in Europe and the United States, and have not been the subject of much research. The differences in characteristics among Asian, European, and US markets may mean that the findings of existing studies may not apply. Therefore, the results of this study, which focuses on Tokyo, one of the leading markets in Asia, may provide guidelines for understanding the Asian office market.

2. A Model of the Rent-Adjustment Process

2.1 Classical Rent-Adjustment Process Model

The concept of the natural vacancy rate—the basis of the rent-adjustment process—is an adaptation of the natural employment rate concept in labor economics. If the market is efficient, the vacancy rate immediately adjusts to the natural rate. However, the real estate market is inefficient because of high transaction costs, constraints imposed by long-term contracts, and the time required for realizing new supply, as adjustment takes time.

Smith (1974) expresses rent dynamics as a function of the deviation from the natural vacancy rate for the residential market:

$$\Delta lnR_t = \lambda(V^* - V_{t-1}) = \lambda V^* - \lambda V_{t-1} \quad (1)$$

where ΔlnR_t is the logarithmic difference series of rents, V^* is the natural vacancy rate– constant over time, and V_t is the vacancy rate. If there is a natural vacancy rate V^* at a specific time *t*, and the vacancy rate at time *t* is V_t, then when $V_t > V^*$, an adjustment may occur. Hence, V_t approaches V^* by decreasing the rent level. Conversely, when $V_t < V^*$, an adjustment occurs in the same direction, thereby increasing the rent level. In this case, the natural vacancy rate is treated as a stationary equilibrium, obtained by dividing the constant term of the linear regression equation (Equation 1) by the coefficient of the vacancy rate, λ.

After Shilling et al. (1987) apply this theory to the office market and demonstrate its effectiveness, many empirical analyses have targeted the office market, where information on vacancy rates is readily available.

In response to the model in Smith (1974), Wheaton and Torto (1994) proposed an equilibrium-rent-type model that uses equilibrium rents lnR^* rather than natural vacancy rates V^* in the formulation of the rent adjustment process to explain rent dynamics:

$$\Delta lnR_t = \beta(lnR^* - lnR_{t-1}) \tag{2}$$

They argue that the model in Smith (1974) represents changes in rents due to adjustments in the vacancy rate and, therefore, cannot be called a "process of rent adjustment". According to Englund et al. (2008), most rent-adjustment processes have considered equilibrium rents (e.g., Nowak et al., 2020) in recent years. However, the proposed model cannot simplify the calculation by including the equilibrium rent as an intercept, as is the case with the natural vacancy rate in the baseline model.

In response to this issue and as an alternative to dynamic models without micro foundations (Lucas critique; Lucas, 1976), Hendershott et al. (2002a) resorted to the use of the ECM. Consistent with the economic theory, this model introduces the concept of long-run equilibrium; it assumes that economic variables will eventually converge to a long-run equilibrium, while allowing for deviations from the short-run equilibrium to improve the fit of the model to the data. This approach has been widely used in recent years because it deals with cointegration effectively, thus providing a solid theoretical background for using the derived dynamic model as a short-run adjustment procedure. The ECM may be regarded as a general version of the partial adjustment model; hence, when the change of a variable is determined by correction of deviation from equilibrium, only partial convergence is achieved at some cost.

Englund et al. (2008) improve the framework of the short-run adjustment proposed in Hendershott et al. (2002a) by formulating and estimating the short-run adjustment equations for rent, vacancy rates, and stocks, by considering their interactions.

In the next section, we describe the model devised by Englund et al. (2008), which is adopted in this study.

2.2 The Interaction of Rent, Vacancy Rate, and Stock

The model devised by Englund et al. (2008), called the Englund, Gunnelin, Hendershott and Soderberg (EGHS) model, derives a long-run equilibrium equation based on the ECM framework and formulates realistic, short-run adjustment equations for rent, vacancy rates, and stocks.

Initially, the demand $D(R, E)$ for the office space market is defined by the Cobb-Douglas function:

$$D(R, E) = \lambda_0 R^{\lambda_R} E^{\lambda_E} \tag{3}$$

where R is rent, E is office employment, and $\lambda_R (< 0)$ and $\lambda_E (> 0)$ are price and income elasticity, respectively.

In the long-run equilibrium, demand is equal to the stock minus the natural vacancy rate since all adjustments have been made:

$$D(R^*, E) = S(1 - V^*) \tag{4}$$

where S is the total office space available for lease, hereafter referred to as "stock". Substituting Equation (3) into (4), taking the logarithm, and solving for lnR^*, we obtain:

$$\begin{aligned} lnR_t^* &= -\frac{1}{\lambda_R} ln\lambda_0 + \frac{1}{\lambda_R} ln(1 - V^*) - \frac{\lambda_E}{\lambda_R} lnE_t + \frac{1}{\lambda_R} \ln S_t \\ &= \alpha_0 + \alpha_E \ln E_t + \alpha_S lnS_t \end{aligned} \tag{5}$$

where V^* is included in the constant term α_0 because it is a stationary equilibrium. When a long-run equilibrium relationship (i.e., a cointegration relationship) exists between these variables, the estimated value in Equation (5) represents the long-run equilibrium rent.

For the short-term adjustment process, the ECM assumes that rents correct the deviation from equilibrium rent. Therefore, it considers the deviations of rents from equilibrium—the error term $u_t (= ln\, R_t - lnR_t^*)$, in Equation (5)—as explanatory variables. Englund et al. (2008) formulate the model by including the deviation of the vacancy rate from equilibrium as an explanatory variable in addition to the rent, as the vacancy rate may also deviate from equilibrium:

$$\begin{aligned} \Delta\, ln\, R_t &= \beta_V (V^* - V_{t-1}) + \beta_R (lnR_{t-1}^* - ln\, R_{t-1}) + \beta_{R^*} \Delta lnR_t^* \\ &= \beta_0 - \beta_V V_{t-1} - \beta_R u_{t-1} + \beta_E \Delta\, ln\, E_t + \beta_S \Delta\, ln\, S_t \end{aligned} \tag{6}$$

where v* is a constant. The adjustment coefficients are β_E for the response to employment shocks, β_S for supply shocks, β_V for the vacancy rate deviation from equilibrium, and β_R for the rent deviation from equilibrium, which indicate their adjustment rates. The natural vacancy rate is equal to $-\beta_0/\beta_V$ because the constant term β_0 represents $\beta_V V^*$.

Englund et al. (2008) formulate an independent vacancy rate adjustment equation like the rent adjustment equation because the vacancy rate mirrors the rent. In other words, if R is above R^*, V is always below V^*, and vice versa:

$$\begin{aligned} \Delta\, ln\, V_t &= \gamma_V (V^* - V_{t-1}) + \gamma_R (lnR_{t-1}^* - ln\, R_{t-1}) + \gamma_{R^*} \Delta lnR_t^* \\ &= \gamma_0 - \gamma_V V_{t-1} - \gamma_R u_{t-1} + \gamma_E \Delta\, ln\, E_t + \gamma_S \Delta\, ln\, S_t \end{aligned} \tag{7}$$

where γ_E and γ_S indicate the effect of employment and supply shocks, respectively, and γ_R and γ_V are the responses of the disequilibrium indicators. As in Equation (6), V^* is included in the constant term γ_0 and may be calculated as $-\gamma_0/\gamma_V$. Hendershott et al. (2010) impose a constraint on the system, such that the values of the natural vacancy rate in Equations (6) and (7) are equal.

Regarding the short-run adjustment process of supply, Englund et al. (2008) point out that it takes time to react to an imbalance. Such a reaction may take longer than one period to generate. Similarly, it is unlikely that changes in lnE affect changes in lnS over the same period. Hence, the EGHS model specifies a short-run adjustment model for supply, as follows:

$$\begin{aligned} \Delta\, ln\, S_t &= \delta_V(V^* - V_{t-\tau}) + \delta_R(lnR^*_{t-\tau} - ln\, R_{t-\tau}) \\ &= \delta_0 - \delta_V(V_{t-\tau}) - \delta_R u_{t-\tau} \end{aligned} \tag{8}$$

where δ_R and δ_V represent the supply response to disequilibrium, and the delay τ represents the time required from decision-making to the completion of the adjustment. The value of τ is empirically determined by maximizing the explanatory power of the model, namely, the adjusted R-square (Englund et al., 2008).
We estimate the three short-run adjustment equations for rent, vacancy rate, and supply by using seemingly unrelated regressions (SUR; Zellner, 1962). When the Durbin-Watson test confirms the existence of a serial correlation, we deal with it by introducing the lagged dependent variable as an explanatory variable.

As mentioned above, this study applies the EGHS model to panel data from the Tokyo office market. In conducting the panel data analysis, we perform model selection based on the F-test and Hausman test for the long-run equilibrium model. In the short-run adjustment model, we assume that the value of the natural vacancy rate is different for each region, and we add dummy variables for each region to perform the estimation.

3. Literature Review on the Asymmetric Response

The literature on office market dynamics focuses on the relationships among rents, prices, vacancy rates, and economic indicators, and various studies have been conducted (e.g., Wheaton, 1999; Hendershott et al., 2002a, 2002b; Coffinet and Kintzler, 2019). Of these, rents and vacancy rates are critical variables in explaining property prices and have received particular attention in the literature (Lang et al., 2022). Most of these studies assume that the effect of supply and demand shocks is constant, that is, symmetric, regardless of the direction of the shock or the state of the market. However, in reality, the effect is asymmetric. Englund et al. (2008), Brounen and Jennen (2009), McCartney (2012), Hendershott et al. (2010, 2013), and Nowak et al. (2020) provide evidence of asymmetry in the rent-adjustment process. Previous studies examine various cities; however, this issue is still under debate. This section describes the asymmetries revealed in previous studies, divided into three major categories: by level of vacancy rate, direction of the shock, and state of the market.

3.1 Asymmetry of response by the level of vacancy rate

The vacancy rate has a non-negative constraint, and a transition around the natural vacancy rate characterizes it. Therefore, a decrease in employment or an increase in supply may lead to a sharp rise in the vacancy rate. However, when the vacancy rate is sufficiently low, changes in the opposite direction cannot lower it. In addition, because tenants are tied to long-term contracts, they cannot immediately reduce their office space in response to a decrease in employment, thus creating hidden vacancies.

Englund et al. (2008) provide a framework for estimating hidden vacancies based on the results of the EGHS model. They assume that hidden vacancies exist when the market is imbalanced. However, they do not clarify the effect of asymmetric supply and demand shocks based on the vacancy rate.
By contrast, Brounen and Jennen (2009) use data from fifteen US cities to examine the asymmetry of supply and demand shocks based on the level of vacancy rates. Using dummy variables, they divide the response of rents to supply and demand shocks into periods when vacancy rates are lower and higher than the average of the entire period in each city. They find that lower vacancy rate periods are more sensitive to demand shocks. McCartney (2012) and Nowak et al. (2020) find similar results for the Dublin and Warsaw office markets.

3.2 Asymmetry of response by the direction of the shock

Depending on the direction of the shock (positive or negative), we expect the effect of supply and demand shocks on the rent and vacancy rates to be different. A positive demand shock represents an increase in employment, which encourages tenants to expand their office space. Conversely, a negative demand shock indicates a decrease in employment but is unlikely to lead tenants to reduce their office space in the short term. In this case, tenants are likely to maintain their office space in anticipation of future growth unless their business performance deteriorates significantly.

Positive supply shocks, that is, new supply shocks, represent an increase in total office floor space, causing vacancy rates to rise and rents to fall. By contrast, negative supply shocks have more complex effects, as their causes include demolition and change in use due to depreciation and future redevelopment (Hendershott et al., 2010).

Hendershott et al. (2010), who first demonstrate asymmetry in the direction of shocks, show that only positive demand and supply shocks affect changes in rent significantly. By contrast, McCartney (2012) examines asymmetry in demand shocks, and show the opposite result with the use of gross domestic product (GDP) instead of employees as the demand variable. Since the GDP is strongly correlated with the construction of new office buildings, McCartney

(2012) finds that rent decreases may offset increases because of higher demand from the simultaneous completion of several building projects.

3.3 Asymmetry of response by the state of the market

Hendershott et al. (2010) point out that market conditions—whether rents are above or below equilibrium—may also lead to an asymmetric response in rents to supply and demand shocks.

If supply and demand shocks act as adjustments, pushing rents toward equilibrium, a positive demand shock, will substantially keep rents below equilibrium. By contrast, a positive supply shock decreases rents toward equilibrium when they are above the equilibrium.

Although the results in Hendershott et al. (2010) tend to support these hypotheses, they are not statistically significant. McCartney (2012) and Nowak et al. (2020) test the same hypotheses and find different results. Nowak et al. (2020) use the cyclicality of the market to explain why demand shocks have a stronger positive effect when rents are above the equilibrium. This result implies that an increase in demand raises rents, and the time lag between investment and construction causes an increase in supply, which lowers rents to equilibrium values.

As mentioned earlier, several empirical hypotheses have provided evidence on asymmetry, with mixed results (Table 1). McCartney (2012) explains that this variation in results is because of the lack of degrees of freedom caused by the observation period and market specificity.

4. Data and Market Characteristics

4.1 Office Market in Tokyo's 23 Wards

The Tokyo office market is one of the largest globally, with rents in the central area (Marunouchi) thus ranking sixth highest in the world, only behind Hong Kong, New York, Beijing, London, and Silicon Valley (JLL 2021b). Tokyo has 23 special wards where people, goods, and money are concentrated.

The Tokyo office market is largely characterized by fast depreciation and the peculiarities of the contract system. Chegut et al. (2015) compare the differences in rent formation factors for six major cities (Hong Kong, London, Los Angeles, New York, Paris, and Tokyo) and find the effect of building age on rents is the greatest in Tokyo. Behind this faster depreciation in Japan than in other countries is a scrap-and-build culture (e.g., Barlow and Ozaki, 2005). Looking at the office stock by age, less than 10% of the office buildings were built before 1970, which is less than one-third of those in London, Paris, New York, and San Francisco (Wani et al., 2022).

Table 1 Results of previous studies examining asymmetric responses

Publication (Authors)	Region	Period	Model	Type of property	Hypotheses on asymmetric responses				
					A	B-1	B-2	C-1	C-2
Brounen and Jennen (2009)	15 U.S. cities	1990Q1-2007Q4	ECM	office	T	-	-	-	-
McCartney (2012)	Dublin	1978-2010	ECM	office	T	F	-	F	-
Hendershott et al. (2010)	London	1977-2006	EGHS	office	-	T	T	T	T
Hendershott et al. (2013)	13 U.S. cities	1982–2007	EGHS	retail	T	-	-	-	-
Nowak et al. (2020)	Warsaw	2005Q1-2016Q1	ECM	office	T	-	-	F	F

***Notes*:** ECM represents the rent adjustment process model based on the error correction model proposed by Hendershott et al. (2002a), and EGHS represents the model proposed by Englund et al. (2008). The details of the hypothesis on asymmetric responses are as follows.

Hypothesis A: When vacancy rates are low, changes in rents are sensitive to changes in demand.

Hypothesis B-1: Positive demand shocks have a stronger effect on rent changes than negative demand shocks.

Hypothesis B-2: Positive supply shocks have a stronger effect on rent changes than negative demand shocks.

Hypothesis C-1: Rent changes more sensitively to demand shocks when last-period rents are below equilibrium.

Hypothesis C-2: Rent changes more sensitively to supply shocks when last-period rents are above equilibrium.

In terms of the contract system, two systems are in use in Japan: one is the fixed-term lease contract, which is similar to the contract system in Europe and the United States, and the other is the ordinary lease contract, which has been in use for many years and is unique to Japan. Fixed-term leases are terminated at the end of the lease term and generally cannot be terminated before the lease term. Conversely, in the case of an ordinary lease, the contract is automatically renewed at the expiration of the lease term, and the tenant can continue the tenancy or even cancel the contract mid-term if a certain period of notice is given. The contract term for an ordinary lease is customarily two years. The term of a fixed-term lease is often longer, sometimes exceeding 10 years. In addition, because there are more restrictions on the lessor than in the case of a standard lease, rents are less expensive. Therefore, large companies, which can more easily make long-term forecasts and move their offices infrequently, often use fixed-term leases. The average lease term in the Tokyo office market is said to be 2 to 5 years, shorter than those in the US and European office markets, where leases can exceed 10 years. This is close to Hong Kong, where the average lease term is 2 to 3 years, and China, where the average lease term is 3 to 5 years[1].

All of the markets studied for asymmetric responses presented in the previous section are Western markets, and no studies have examined markets in Asia, which has a relatively short lease period. In this study, we develop and test a new hypothesis based on these differences in market characteristics.
This study uses information on the Tokyo office market provided by Sanko Estate Co., Ltd. In addition to basic information on the structure and location of each standard rental office building in the 23 wards of Tokyo, this dataset contains data on offer rent, vacant office space, and rentable office space (stock) at the end of each month. A standard rental office building is leased only for office use. Therefore, we exclude office buildings owned by the company, those used for warehouses or stores, and single-story buildings or one-rooms in apartment buildings used as offices.

The office building data is limited to buildings known to Sanko Estate Co., Ltd. and does not cover all leased office buildings in Tokyo. It is impossible to determine the data coverage rate accurately, as there are no official statistics on leased office buildings. Miki Shoji Co., Ltd., a Japanese office brokerage firm similar to Sanko Estate Co., Ltd., estimates the stock of rental office buildings as of the end of December 2020 to be approximately 780,000 *tsubos*[2] in the five wards of central Tokyo with a standard floor area of 100 tsubos or more[3]. The data used in this study estimate an approximate 750,000 *tsubos*, and in comparison with these standards, this indicates that the data coverage rate is similar.

Figure 1 shows the distribution of office stock at the end of September 2015. The target areas of this study are the ten wards with the highest office stock, namely, the regions with the highest concentration of offices in the 23 wards.

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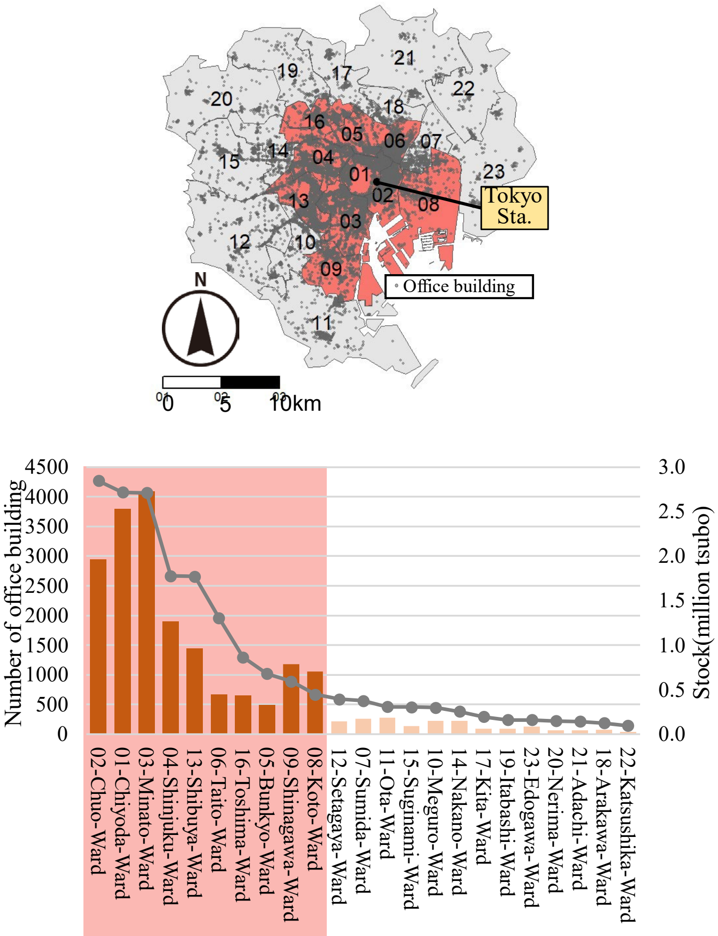
[1] For more information on the characteristics of lease agreements in various countries, see REALWORLD LAW, a guide prepared by DLA Piper, an international law firm. <https://www.dlapiperrealworld.com/>

[2] "*tsubo*" is a unit of land measurement unique to Japan, with one tsubo representing approximately 3.3 square meters.

[3] Published data for Miki Shoji Co., Ltd. are available here. < https://www.miki-shoji.co.jp/rent/report>

Figure 1 Office concentration regions in Tokyo's 23 wards



4.2 Rent (R)

This study uses the offer rent, namely, the rent per tsubo announced by landlords when recruiting tenants, as an indicator of rent. Offer rent is the starting price of negotiation that landlords disclose as a reference price when they place real estate on the market. Data on offer rent are more comprehensive than data on "contract rent", namely, the prices at which transactions are concluded after negotiation. The data report standard offer rents for each building rather than offering rents for each tenant space. Standard offer rents exclude specific cases such as retail use, and one value is adopted for each office building.

This study uses quality-adjusted rent (unit rent per tsubo adjusted to the standard-offer rent) and the most widely used quality-adjustment method - the hedonic time dummy method:

$$lnR_{it}^{offer} = \sum_{k}^{K} \beta_k X_{kit} + \theta_t + \epsilon_{it} \tag{9}$$

where lnR_{it}^{offer} represents the real offer rent of office building i at time t adjusted by the consumer price index, X_{kit} is the kth explanatory variable of office building i at time t, β_k is the coefficient of the kth explanatory variable, θ_t is the time effect, and ϵ_{it} is the error term. We use a dummy variable to proxy the time effect. Table 2 presents the explanatory variables. The estimation results of the hedonic time dummy method for each region are shown in Table 3.

The quality-adjusted rent, lnR_t^{adj}, is obtained by using the average logarithm of the real asking rent at time $t = 1$ as the initial value and the time effect, θ_t, estimated by using the hedonic time dummy method described above (e.g., Diewert et al., 2020):

$$lnR_t^{adj} = \frac{\sum_i^{N_1} lnR_{i0}^{offer}}{N_1} + \theta_t \tag{10}$$

where N_1 is the sample size at time $t = 1$.

Table 2 Description of the explanatory variables used to adjust the quality of rents

Variable	Unit	Description
Age	year	Building age
OSF	tsubo(log)	Office space per floor
Walk	min	Walking time from the nearest station
Floor	floor(log)	Number of building floors
Cool	dummy	Cooling system dummy
EV	machine(log)	Number of elevators
STR_EP	dummy	Building structure for earthquake protection (seismic force-resisting system, damping systems, isolated structure, or none)
STR	dummy	Building structure (SRC, RC, S, PC)
CBD	m(log)	Distance to CBD (Tokyo station)
Density	m(log)	Average distance to the 20 nearest office buildings
Height ratio	%	Ratio to the average floors of office buildings located within a 500-meter radius
District	dummy	Dummy variables based on district classification in Sanko Estate (2021)

Table 3 Results of the hedonic time dummy model for each region

	Chiyoda-Ward			Chuo-Ward			Minato-Ward			Shinjuku-Ward			Shibuya-Ward		
	β	t-value		β	t-value		β	t-value		β	t-value		β	t-value	
Intercept	9.357	413.8	***	10.536	577.0	***	8.785	330.5	***	12.475	208.3	***	9.815	111.9	***
Walk	-0.019	-87.5	***	-0.012	-47.9	***	-0.022	-109.3	***	-0.023	-72.2	***	-0.027	-100.4	***
OSF	0.094	140.2	***	0.085	113.2	***	0.088	116.5	***	0.059	52.4	***	0.067	69.3	***
Height ratio	0.031	12.6	***	-0.113	-40.8	***	-0.036	-18.1	***	-0.049	-17.0	***	-0.028	-9.2	***
Cool	-0.024	-7.0	***	-0.110	-26.8	***	-0.205	-59.5	***	-0.077	-17.1	***	-0.105	-32.5	***
CBD	-0.064	-37.8	***	-0.228	-116.8	***	0.082	32.5	***	-0.351	-51.2	***	-0.012	-1.3	
Density	-0.091	-64.9	***	-0.075	-51.0	***	0.036	28.7	***	0.040	23.6	***	0.024	13.1	***
EV	0.110	71.1	***	0.183	98.4	***	0.139	74.1	***	0.137	55.1	***	0.120	53.0	***
Floor	0.060	17.8	***	0.222	57.4	***	0.164	52.8	***	0.139	31.5	***	0.086	20.2	***
Age	-0.008	-185.9	***	-0.006	-151.5	***	-0.009	-176.0	***	-0.005	-59.6	***	-0.008	-117.4	***
Adj-Rsq	0.668			0.667			0.601			0.487			0.563		
n	218455			228803			191513			115935			97129		

(continued…)

(Table 3 Continued)

	Toshima-Ward			Bunkyo-Ward			Taito-Ward			Shinagawa-Ward			Koto-Ward		
	β	t-value		β	t-value		β	t-value		β	t-value		β	t-value	
Intercept	8.703	60.1	***	9.173	142.3	***	7.437	169.0	***	15.908	110.3	***	9.093	202.3	***
Walk	-0.034	-90.1	***	-0.014	-32.9	***	-0.024	-71.9	***	-0.016	-38.4		-0.022	-48.5	***
OSF	0.078	57.0	***	0.099	69.8	***	0.077	63.4	***	0.087	52.7	***	0.079	36.9	***
Height ratio	-0.129	-23.5	***	-0.113	-11.6	***	0.281	22.8	***	-0.036	-5.7	***	0.034	6.2	***
Cool	-0.188	-38.7	***	-0.103	-12.6	***	-0.002	-0.4		-0.110	-12.1	***	0.024	2.9	***
CBD	0.120	7.4	***	-0.047	-5.9	***	0.296	61.4	***	-0.684	-44.7	***	0.027	5.6	***
Density	0.078	38.1		0.002	0.8		0.103	45.0	***	0.093	41.9	***	0.065	27.2	***
EV	0.123	36.5	***	0.163	40.7	***	0.147	54.4	***	0.130	35.8	***	0.171	35.8	***
Floor	0.249	35.7	***	0.193	17.5	***	-0.241	-18.2	***	0.079	10.1	***	-0.002	-0.3	
Age	-0.004	-43.8	***	-0.006	-47.3	***	-0.006	-74.8	***	-0.007	-54.5	***	-0.006	-33.0	***
Adj-Rsq	0.524			0.487			0.426			0.529			0.607		
n	54663			40640			81669			39746			22123		

Notes: ***p<0.01; **p<0.05; and *p<0.1. The dependent variable is log rent. The period covered by the analysis is from January 2000 to September 2015 for monthly and from the first quarter of 2000 to the second quarter of 2015 for quarterly. Coefficients for time dummy, STR, STR_EP, and district are omitted from the table.

4.3 Stock (S)

The stock, which reflects the total rentable floor space, is calculated by aggregating the rentable floor space (tsubo) of each building by region and point in time. These data include new supply from new construction and the increase in the stock of leased office space from the conversion of company-owned buildings to rental space. The data also reflect a decrease in stock from retirements and conversions from leasing to owning. In line with the rent data, the sample is limited to the area known as Sanko Estate (2022). For buildings in which the rentable floor area is not disclosed, we estimate the rentable floor area and use it as {[office space per floor] x [(number of floors)] x [effective rate (0.8)]} by following the vacancy rate estimation method of Sanko Estate Co. The effective ratio refers to the ratio of the rentable space to the total space of the office building, and 0.8 is the average effective ratio based on data held by Sanko Estate Co.

4.4 Vacancy Rate (V)

We calculate the vacancy rate V_{it} by aggregating the data of vacant office space (tsubo) and rentable office space (tsubo) of each building at each point in time for each region:

$$V_{it} = \frac{\sum_{b}^{B_{it}} VS_{bit}}{S_{it}} \tag{11}$$

where VS_{bit} denotes the vacant office space of the bth office building in region i at time t, and B_{it} indicates the number of office buildings in region i at time t.

4.5 Employment (E)

This study uses the number of employees per region and per occupation in the census to proxy employment in office buildings. We use the number of employees in “professional and technical occupations”, “managerial occupations”, and “clerical occupations”, which are characterized by an exceptionally high percentage of office workers.
In research on the office market, the number of employees in industries with a high share of people working in office buildings, such as finance, real estate, and services, is often treated as a proxy for office workers (e.g., DiPasquale and Wheaton, 1996; Hendershott et al., 2002a). However, occupational classifications from the national census are often used in Japan (e.g., Kawai et al., 2019).

The Census is a statistical survey conducted once every five years, and is less frequently tabulated than other variables. Therefore, this study uses Equation 12 to calculate the monthly number of employees per region:

$$\hat{E}_{i,t} = LF_t \times W_{i,t}, W_{i,t} = spline\left(\frac{\sum_i^n E_{i,t}}{LF_t}\right) \times spline\left(\frac{E_{i,t}}{\sum_i^n E_{i,t}}\right) \tag{12}$$

where WP_t is the number of employees based on the monthly labor force survey[4] in the South Kanto region (Tokyo, Saitama, Chiba, and Kanagawa prefectures), which is published by the Statistics Bureau of the Ministry of Internal Affairs and Communications, $W_{i,t}$ represents the weight for downscaling WP_t to the number of employees in each region ($\hat{E}_{i,t}$). $W_{i,t}$ is derived by multiplying the cubic spline interpolation of the ratio of the number of employees in the target region ($\sum_i^n E_{i,t}$) to that of the South Kanto region (LF_t) by the cubic spline interpolation of the ratio of the number of employees in each region ($E_{i,t}$) to the number of employees in the entire target region ($\sum_i^n E_{i,t}$).

A key feature of the interpolated number of employees is that the monthly fluctuations are synchronized with those of the entire South Kanto region. The monthly labor force data for the South Kanto region is the most detailed region-by-region data available on a monthly basis in Japan. In addition, according to the 2015 National Census, 45.8% of the office workers in the target area (10 wards) reside in prefectures other than Tokyo, primarily Saitama, Chiba, and Kanagawa prefectures. Therefore, it is reasonable to assume that trends in the labor force in the South Kanto region as a whole and trends in the office workers in the subject area are similar. This methodology is considered beneficial in that it allows for more detailed interpolation of monthly fluctuations than the method using only general splines (Figure 2). Although there are various interpolation methods including linear interpolation as well as spline interpolation, spline interpolation is often used because of the balance of overshoot, computational complexity, and other factors. From the same perspective, a spline-based interpolation method is devised and applied in this study.

However, because data capturing the number of office employees by region is limited to the Census, there is no other way to distinguish trends in regional changes other than to rely on the Census at five-year intervals. Therefore, it is difficult to statistically verify the validity of monthly changes in the number of employees by region calculated by these methods. This is one of the limitations of studies of the Japanese office market.

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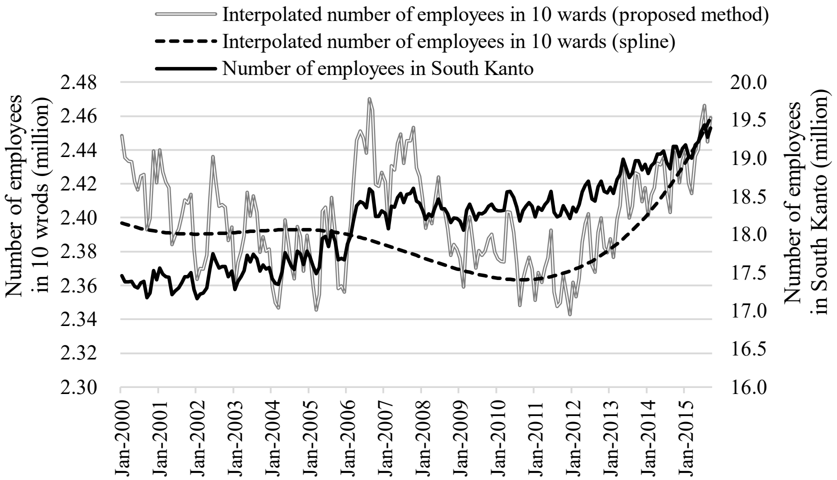
[4] The number of employees based on the Labor Force Survey is a sample survey and statistic of the number of employees based on place of residence. In contrast, the National Census is a full-count survey, which includes the number of employees based on their place of employment.

Figure 2 Number of Office Workers in Southern Kanto and Tokyo's 10 Wards

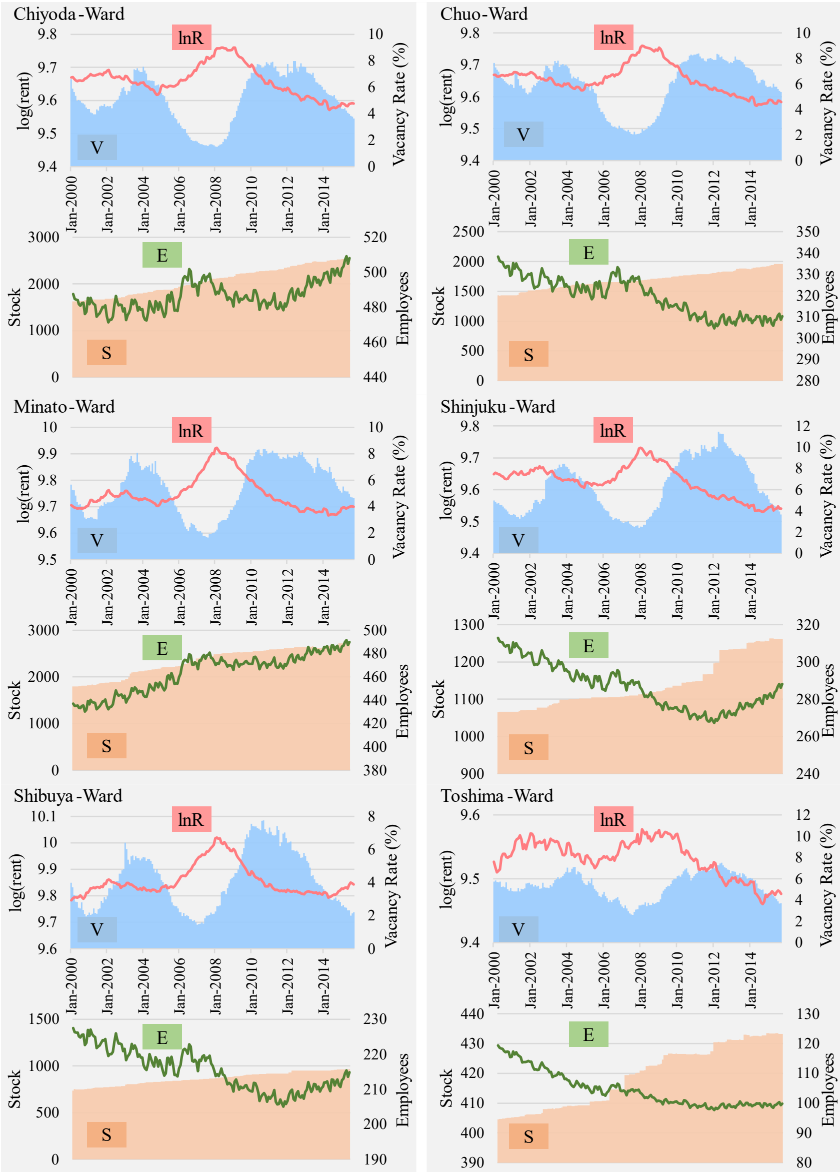


4.6 Market Overview

This section reviews the overall trends in the Tokyo office market. Figure 3 summarizes the trends in rent, vacancy rates, stock, and employees for each region from January 2000 to September 2015. In all regions, rent moves in the opposite direction to the vacancy rate and, the stock shows an increasing trend. The trends in the number of employees, which are interpolated for deficiencies, vary widely from region to region, thus expressing the characteristics of each region. For details of the basic statistics for each variable, please refer to Table A3 in the Appendix.

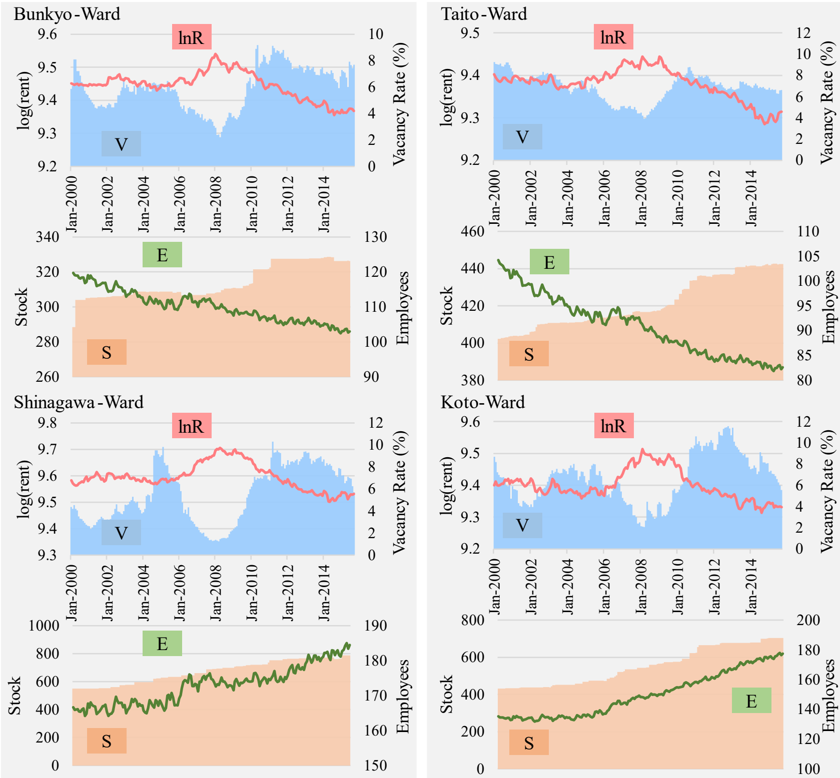
Within the period covered by this study, Japan experienced the financial crisis and earthquake disaster shocks. The office market is expected to experience these shocks as well. It is also possible that there are structural changes in the adjustment mechanism triggered by these shocks. However, to elucidate the adjustment mechanism, it is essential to capture multiple cycles and the number of cycles captured in this study is limited, which makes it difficult to identify structural changes associated with exogenous shocks accurately. Therefore, this study considers the aforementioned exogenous shocks as being reflected in the market through changes in demand and supply.

Figure 3 Trends in the office market in each region



(continued…)

(Figure 3 Continued)



5. Development of Hypotheses

Based on the previous discussion, this section develops the hypotheses to be tested in this study. As this study uses the EGHS model to account for hidden vacancies, the focus is on examining asymmetries from the direction of the supply and demand shocks and market conditions.

Hypothesis 1-1: *Rents and vacancy rates are sensitive to positive demand shocks.*

The first hypothesis is that positive demand shocks have a more substantial effect on changes in rents and vacancy rates than negative shocks. Firm behavior in response to changes in employment is unlikely to differ significantly across cities. Therefore, asymmetries due to the direction of demand shocks are expected to be similar to those in previous studies (Hypothesis B-1 in Table 1).

Hypothesis 1-2: *Rents are sensitive to negative supply shocks and vacancy rates to positive supply shocks.*

The Tokyo office market, where a scrap-and-build construction culture has taken root, is characterized by a daily high level of new supply (positive supply shocks). In addition, negative supply shocks in the Tokyo office market are likely to indicate future redevelopment. Therefore, in contrast to previous studies (Hypothesis B-2 in Table 1), negative supply shocks may account for a more sensitive rent response. However, vacancy rates, which are less susceptible to future information, may be more sensitive to positive supply shocks, as in previous studies.

Hypothesis 2: *Supply and demand shocks act strongly when rent and vacancy rate changes move toward equilibrium because of high and low rents in the previous period.*

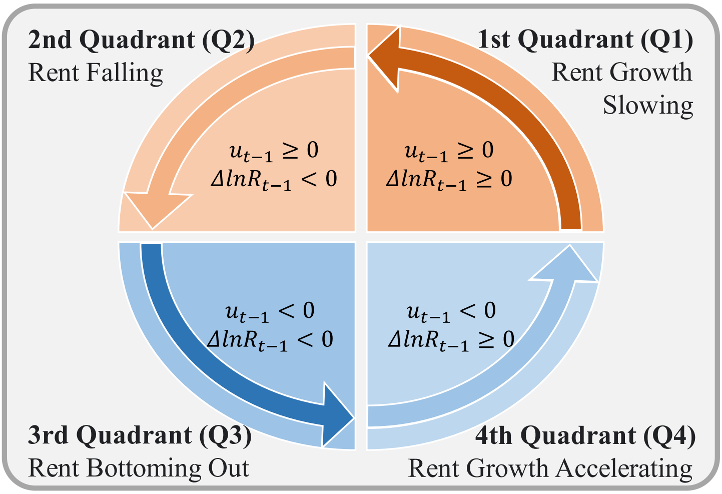
As in previous studies, supply and demand shocks are expected to act as corrective actions to the deviations of rents and vacancy rates from equilibrium. In other words, a positive demand shock is expected to push rent up firmly and push vacancy rates down strongly when the rents of the previous period are below equilibrium, as in Hypothesis C-1 in Table 1. Moreover, a positive supply shock is expected to push rents down strongly and push vacancy rates up when the rents of the previous period are above equilibrium, as in Hypothesis C-2 in Table 1. Asymmetric movements are likely to go undetected for negative supply shocks because these shocks occur less frequently.

Hypothesis 3: *Supply and demand shocks act strongly when changes in rent and vacancy rates move toward equilibrium depending on the market state in the four quadrants.*

Hypothesis 2, which has been tested in previous studies, discusses market conditions in two states, where the previous rent is lower or higher than the equilibrium. This study extends this hypothesis by ensuring sufficient degrees of freedom by using panel data.

Many market reports discuss market conditions by using a property clock divided into four quadrants: rent growth slowing, rent falling, rent bottoming out, and rent growth accelerating (e.g., JLL 2021a). In line with these reports, this study divides the market state into four quadrants according to the deviation of rents from equilibrium and the direction of change in rents (Figure 4).

Figure 4 Four-quadrant classification of the office market state



The first and second quadrants and the third and fourth quadrants correspond to the two market state categories in Hypothesis 2, respectively.

As in Hypothesis 2, given that supply and demand shocks act to bring rent and vacancy rates closer to equilibrium, a positive demand shock is expected to have a significant effect on rent and vacancy rates when rents accelerate (in the fourth quadrant) and a positive supply shock when rents begin to fall (in the second quadrant).

6. Empirical Results

6.1 Long-run Equilibrium

Before estimating the long-run equilibrium, we conduct a panel unit root test (Fisher augmented Dickey–Fuller (ADF) test) and a panel cointegration test (Johansen test) to ascertain the cointegrating relationship among the variables. The results suggest that all variables follow a unit root process. There are two cointegrating relationships among the three variables; hence, a long-run equilibrium relationship exists. For more details, please refer to Tables A1 and A2 in the Appendix.

As the F-test and Hausman test support the fixed effects, we adopt the least square dummy variable (LSDV) for the estimation (Table 4). All of the coefficients are consistent with the theory, with almost no difference in the observation frequency (monthly or quarterly). These results indicate that the long-term equilibrium relationship becomes robust over time.

Table 4 Results of the long-run equilibrium

Frequency	(1) Monthly			(3) Quarterly		
	Coef	t-value		Coef	t-value	
$lnE_{i,t}$	0.11	4.90	***	0.11	2.75	***
$lnS_{i,t}$	-0.12	-10.89	***	-0.11	-5.99	***
n	1890			630		
Adj-Rsq	0.936			0.934		
F-test	1073***			348***		
Hausman	8.22**			6.29**		

Notes: ***p<0.01; **p<0.05; and *p<0.1. The dependent variable is log rent. The period covered by the analysis is from January 2000 to September 2015 for monthly and from the first quarter of 2000 to the second quarter of 2015 for quarterly. We use LSDV to estimate the model. We omit the coefficients of the constant terms and regional dummies.

6.2 Symmetric Short-Run Adjustment

Using the results of the long-run equilibrium equation described above, we estimate short-run adjustment equations for rent, vacancy rates, and stock. First, we estimate a general short-run adjustment equation that assumes that the responses of rent and vacancy rates to supply and demand shocks are symmetric (Table 5).

The results show that the deviation of rents and vacancy rates from equilibrium leads rents and vacancy rates toward equilibrium. The speed of the rent adjustment is approximately 2.21-2.68 years (=1/(β_R×[Number of observations per year])), in line with Stockholm (2.58 ; Englund et al., 2008) and London (2.27 years; Hendershott et al., 2010). The natural vacancy rate estimated from this result ranges from 4% to 7% (Figure 5), depending on the region, consistent with the approximate 5% that has been identified by industry rules of thumb (e.g., Nikkei Asia, 2014; Nikkei, 2020; Takemoto, 2014) and existing studies (Sanderson et al., 2006).

Regarding the short-run effects of the number of employees and stock, an increase in the number of employees decreases rent and vacancy rates, whereas an increase in stock raises vacancy rates. These results are consistent with the intuition for the vacancy rate but not for rents. One possible reason for the inconsistent results is that the trends in rent changes are more diverse and more prone to irrational adjustments than the vacancy rate, which is an aggregate variable. Further discussion is provided after the asymmetry is verified.

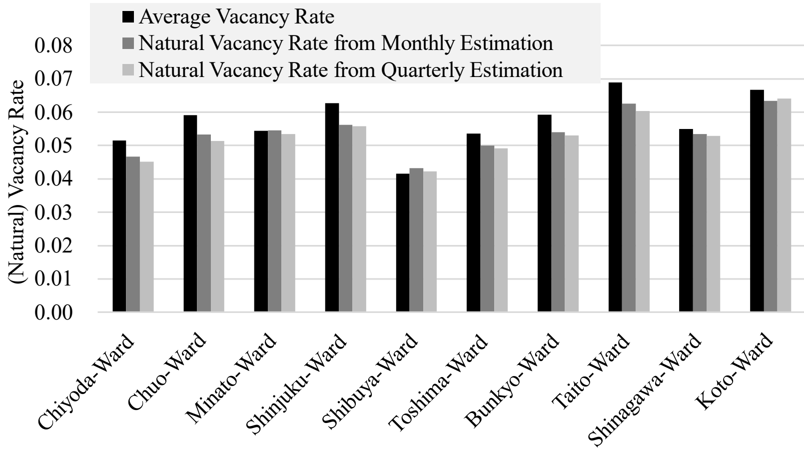
The short-term adjustment process of the stock adjusts with a long delay (29 periods). This result implies that when vacancy rates are low, or rents are lower than the equilibrium, new properties are supplied, and the stock increases with a delay of two or three years. The estimated response of the stock to rent deviations from equilibrium is opposite to that of existing studies, which suggests preventive decision-making in anticipation of future rent increases.

Table 5 Results of the symmetric short-run adjustment

Frequency		(1) Monthly			(2) Quarterly		
		coefficient	t-value		coefficient	t-value	
$\Delta lnR_{i,t}$	Intercept	0.005	7.20	***	0.016	7.77	***
	$V_{i,t-1}$	-0.097	-11.51	***	-0.350	-12.49	***
	$u_{i,t-1}$	-0.031	-8.91	***	-0.113	-10.09	***
	$\Delta lnE_{i,t}$	-0.145	-6.95	***	-0.296	-6.16	***
	$\Delta lnS_{i,t}$	-0.007	-0.22		0.076	1.22	
	$\Delta lnR_{i,t-1}$	0.078	3.50	***	-0.136	-3.63	***
	Adj-Rsq		0.421			0.545	
	DW		2.054			1.948	
	n		1870			610	
$\Delta V_{i,t}$	Intercept	0.000	0.75		0.001	1.25	
	$V_{i,t-1}$	-0.003			-0.016		
	$u_{i,t-1}$	0.014	7.53	***	0.041	7.15	***
	$\Delta lnE_{i,t}$	0.022	2.07	**	-0.024	-1.01	
	$\Delta lnS_{i,t}$	0.191	11.88	***	0.152	5.80	***
	Adj-Rsq		0.159			0.243	
	DW		1.954			1.914	
	n		1880			620	
$\Delta lnS_{i,t}$	Intercept	0.004	7.87	***	0.011	7.74	***
	$V_{i,t-\tau}$	-0.022	-3.57	***	-0.058	-3.21	***
	$u_{i,t-\tau}$	-0.008	-2.71	***	-0.022	-2.66	***
	Adj-Rsq		0.042			0.114	
	DW		1.943			1.936	
	τ		29			10	
	n		1600			530	

***Notes*:** ***p<0.01; **p<0.05; and *p<0.1. We use SUR for estimation. The period covered by the analysis is from January 2000 to September 2015 for monthly and from the first quarter of 2000 to the second quarter of 2015 for quarterly. The coefficient on the lagged vacancy rate does not affect the estimation of the vacancy rate because of the constraint of maintaining a constant estimated natural vacancy rate. DW represents the Durbin-Watson ratio, and τ is the time required for the supply to adjust, which is empirically estimated to be 29 months and ten quarters. We omit the coefficients of the region dummies.

Figure 5 Estimated value of the natural vacancy rate by region



6.3 Asymmetric Short-Run Adjustment

6.3.1 Asymmetric adjustment depending on the direction of shocks

Based on Hypotheses 1-1 and 1-2, we examine the asymmetry in the response of rent and vacancy rates depending on the direction of supply and demand shocks. In line with existing studies, we split the supply and demand variables into indicators that only represent positive and negative shocks (e.g., Hendershott et al., 2010). We incorporate these variables in the model, as follows:

$$\begin{aligned} \Delta \ln R_{i,t} &= \beta_{0,i} - \beta_V V_{i,t-1} - \beta_R u_{i,t-1} + \beta_E^{+} \Delta ln E_{i,t}^{+} + \beta_E^{-} \Delta ln E_{i,t}^{-} \\ &\quad + \beta_S^{+} \Delta ln S_{i,t}^{+} + \beta_S^{-} \Delta ln S_{i,t}^{-} \\ \Delta \ln V_{i,t} &= \gamma_{0,i} - \gamma_V V_{i,t-1} - \gamma_R u_{i,t-1} + \gamma_E^{+} \Delta ln E_{i,t}^{+} + \gamma_E^{-} \Delta ln E_{i,t}^{-} \\ &\quad + \gamma_S^{+} \Delta ln S_{i,t}^{+} + \gamma_S^{-} \Delta ln S_{i,t}^{-} \\ \Delta \ln S_{i,t} &= \delta_0 - \delta_V V_{i,t-\tau} - \delta_R u_{i,t-\tau} \end{aligned} \tag{13}$$

$$\Delta ln E_{i,t}^{+} = \begin{cases} \Delta ln E_{i,t} \ if \ \Delta ln E_{i,t} \geq 0 \\ 0 \ else \end{cases}, \Delta ln E_{i,t}^{-} = \begin{cases} \Delta ln E_{i,t} \ if \ \Delta ln E_{i,t} < 0 \\ 0 \ else \end{cases}$$

$$\Delta ln S_{i,t}^{+} = \begin{cases} \Delta ln S_{i,t} \ if \ \Delta ln S_{i,t} \geq 0 \\ 0 \ else \end{cases}, \Delta ln S_{i,t}^{-} = \begin{cases} \Delta ln S_{i,t} \ if \ \Delta ln S_{i,t} < 0 \\ 0 \ else \end{cases}$$

where β_E^{+} and β_S^{+} represent the rent response to positive supply and demand shocks, respectively, and β_E^{-} and β_S^{-} indicate the rent reaction to negative supply and demand shocks, respectively. Similarly, γ_E^{+}, γ_E^{-}, γ_S^{+}, and γ_S^{-} represent the response of vacancy rates to positive or negative supply and demand shocks, respectively.

Table 6 shows the results of the estimation of Equation (12). Only those areas that differ from the symmetric model are specifically discussed in the following.

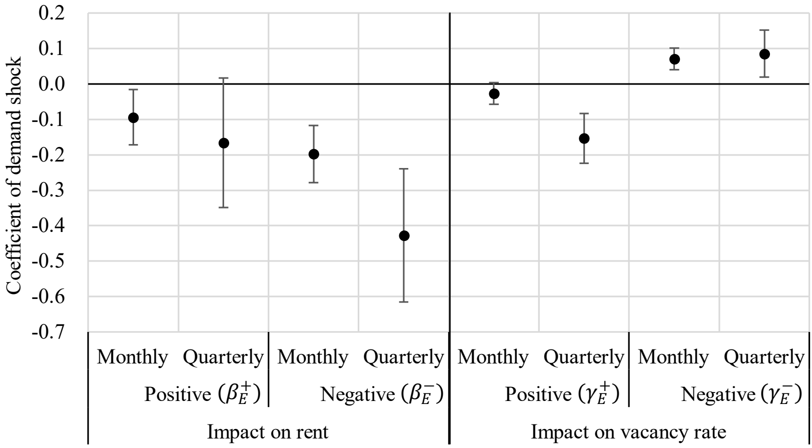
Table 6 Results of short-run adjustment model assuming asymmetry in the direction of the shocks

Frequency		(1) Monthly coefficient	t-value		(2) Quarterly coefficient	t-value	
$\Delta lnR_{i,t}$	Intercept	0.004	6.60	***	0.015	6.85	***
	$V_{i,t-1}$	-0.097	-11.55	***	-0.351	-12.51	***
	$u_{i,t-1}$	-0.031	-8.87	***	-0.111	-9.84	***
	$\Delta lnE^{+}_{i,t}$	-0.094	-2.36	**	-0.166	-1.77	*
	$\Delta lnE^{-}_{i,t}$	-0.198	-4.81	***	-0.428	-4.46	***
	$\Delta lnS^{+}_{i,t}$	-0.020	-0.59		0.067	1.04	
	$\Delta lnS^{-}_{i,t}$	0.287	1.21		-0.513	-1.00	
	$\Delta lnR_{i,t-1}$	0.077	3.43	***	-0.137	-3.69	***
	Adj-Rsq	0.111			0.258		
	DW	2.003			1.840		
	n	1870			610		
$\Delta V_{i,t}$	Intercept	0.000	0.45		0.000	0.88	
	$V_{i,t-1}$	-0.002			-0.011		
	$u_{i,t-1}$	0.014	7.86	***	0.042	7.54	***
	$\Delta lnE^{+}_{i,t}$	-0.027	-1.73	*	-0.153	-4.27	***
	$\Delta lnE^{-}_{i,t}$	0.070	4.50	***	0.086	2.54	**
	$\Delta lnS^{+}_{i,t}$	0.227	13.56	***	0.238	8.35	***
	$\Delta lnS^{-}_{i,t}$	-0.295	-2.41	**	-0.575	-2.23	**
	Adj-Rsq	0.122			0.185		
	DW	1.903			1.776		
	n	1880			620		
$\Delta lnS_{i,t}$	Intercept	0.004	7.89	***	0.011	7.79	***
	$V_{i,t-\tau}$	-0.022	-3.63	***	-0.061	-3.38	***
	$u_{i,t-\tau}$	-0.008	-2.68	***	-0.022	-2.59	***
	Adj-Rsq	0.042			0.114		
	DW	1.943			1.936		
	τ	29			10		
	n	1600			530		

Notes: ***p<0.01; **p<0.05; and *p<0.1. We use SUR for estimation. The period covered by the analysis is from January 2000 to September 2015 for monthly and from the first quarter of 2000 to the second quarter of 2015 for quarterly. The coefficient on the lagged vacancy rate does not affect the estimation of the vacancy rate because of the constraint of maintaining a constant estimated natural vacancy rate. DW represents the Durbin-Watson ratio, and τ is the time required for the supply to adjust, which is empirically estimated to be 29 months and ten quarters. We omit the coefficients of the region dummies.

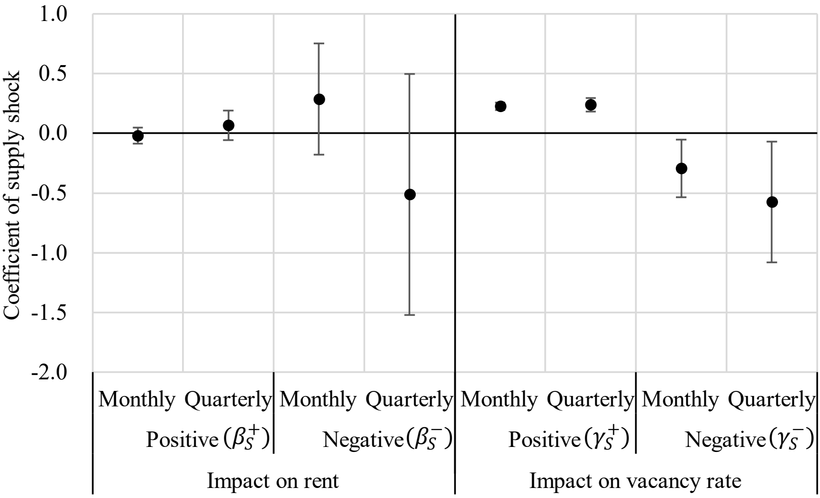
Figure 6 shows the effect of positive and negative employment shocks on rent and vacancy rates. The positive effect of increased employment on rent is stronger than the negative effect of decreased employment, but it is not significant. In addition, the effect on the vacancy rate is significantly lower than that of a decrease in the employment rate. Decreased employment increases rents and decreases vacancy rates significantly. This result is counterintuitive but consistent with the asymmetric adjustment hypothesis (Hypothesis 1-1), which states that responses to positive shocks are more sensitive.

Figure 6 Effect of positive or negative demand shocks on rents and vacancy rates



Notes: Error bars represent 95% confidence intervals.

Figure 7 Effect of positive or negative supply shocks on rents and vacancy rates



Notes: Error bars represent 95% confidence intervals.

Figure 7 shows the response of rent and vacancy rates to positive or negative shocks in supply. The rent response to increases or decreases in supply is small and insignificant, whereas changes in vacancy rates respond significantly at the 1% level to positive supply shocks. The instability of the estimation results for negative supply shocks can be attributed to the small number of observation points for negative shocks. These results are partially indicative of Hypothesis 1-2.

6.3.2 Asymmetric adjustment depending on the rent level in the previous period

Based on Hypothesis 2, we test the asymmetric effect of supply and demand shocks on rent and vacancy rates depending on whether the rents of the previous period are lower or higher than equilibrium. Like Nowak et al. (2020), we partition the supply and demand variables by the state of rents in the previous period. We incorporate these variables in the model, as follows:

$$\begin{aligned}\Delta\, ln\, R_{i,t} &= \beta_{0,i} - \beta_V V_{i,t-1} - \beta_R u_{i,t-1} + \beta_E^{+,h} \Delta lnE_{i,t}^{+,h} + \beta_E^{+,l} \Delta lnE_{i,t}^{+,l} \\ &+ \beta_E^{-,h} \Delta lnE_{i,t}^{-,h} + \\ &\beta_E^{+,l} \Delta lnE_{i,t}^{+,l} + \beta_S^{+,h} \Delta lnS_{i,t}^{+,h} + \beta_S^{+,l} \Delta lnS_{i,t}^{+,l} + \beta_S^{-,h} \Delta lnS_{i,t}^{-,h} + \\ &\beta_S^{-,l} \Delta lnS_{i,t}^{-,h}\end{aligned}$$

$$\begin{aligned}\Delta\, ln\, V_{i,t} &= \gamma_{0,i} - \gamma_V V_{i,t-1} - \gamma_R u_{i,t-1} + \gamma_E^{+,h} \Delta lnE_{i,t}^{+,h} + \gamma_E^{+,l} \Delta lnE_{i,t}^{+,l} \\ &+ \gamma_E^{-,h} \Delta lnE_{i,t}^{-,h} + \\ &\gamma_E^{-,l} \Delta lnE_{i,t}^{-,l} + \gamma_S^{+,h} \Delta lnS_{i,t}^{+,h} + \gamma_S^{+,l} \Delta lnS_{i,t}^{+,l} + \gamma_S^{-,h} \Delta lnS_{i,t}^{-,h} + \gamma_S^{-,l} \Delta lnS_{i,t}^{-,h} \qquad (14)\end{aligned}$$

$$\Delta\, ln\, S_{i,t} = \delta_0 - \delta_V V_{i,t-\tau} - \delta_R u_{i,t-\tau}$$

$$\Delta x_{i,t}^{+,h} = \begin{cases} \Delta x_{i,t}\ if\ \Delta x_{i,t} \geq 0\ and\ u_{i,t-1} \geq 0 \\ 0\ else \end{cases},$$

$$\Delta x_{i,t}^{+,l} = \begin{cases} \Delta x_{i,t}\ if\ \Delta x_{i,t} \geq 0\ and\ u_{i,t-1} < 0 \\ 0\ else \end{cases},$$

$$\Delta x_{i,t}^{-,h} = \begin{cases} \Delta x_{i,t}\ if\ \Delta x_{i,t} < 0\ and\ u_{i,t-1} \geq 0 \\ 0\ else \end{cases},$$

$$\Delta x_{i,t}^{-,l} = \begin{cases} \Delta x_{i,t}\ if\ \Delta x_{i,t} < 0\ and\ u_{i,t-1} < 0 \\ 0\ else \end{cases}$$

where $\beta_E^{+,h}$, $\beta_E^{+,l}$, $\beta_E^{-,h}$, $\beta_E^{-,l}$, $\beta_S^{+,h}$, $\beta_S^{+,l}$, $\beta_S^{-,h}$, $\beta_S^{-,l}$, $\gamma_E^{+,h}$, $\gamma_E^{+,l}$, $\gamma_E^{-,h}$, $\gamma_E^{-,l}$, $\gamma_S^{+,h}$, $\gamma_S^{+,l}$, $\gamma_S^{-,h}$, and $\gamma_S^{-,l}$ are the coefficients of interest that represent the responses of positive or negative supply and demand shocks, respectively. Although previous studies have only focused on positive shocks, this study also addresses negative supply shocks.

The results show that positive demand shocks depress rent strongly when rent is higher than equilibrium (Table 7). However, the effects of positive demand shocks on vacancy rates and negative demand shocks on rent and vacancy rates, respectively, are independent of whether rents are higher or lower than equilibrium (Figure 8). The effects of positive and negative supply shocks on rents are non-significant regardless of whether rents are higher or lower than the equilibrium. Both effects on vacancy rates are more sensitive when rents are lower than equilibrium, but the differences are slight (Figure 9). This result indicates that Hypothesis 2, which is formulated in the same way as previous studies, is incorrect. A more in-depth discussion of these results will be provided after testing Hypothesis 3, which is intended to be a specific test of Hypothesis 2.

Table 7 Results of the short-run adjustment model assuming asymmetry in previous period rents above and below equilibrium

Frequency		(1)			(2)		
		Monthly			Quarterly		
		coefficient	t-value		coefficient	t-value	
$\Delta lnR_{i,t}$	Intercept	0.004	6.61	***	0.015	6.70	***
	$V_{i,t-1}$	-0.098	-11.63	***	-0.347	-12.39	***
	$u_{i,t-1}$	-0.031	-7.33	***	-0.098	-6.90	***
	$\Delta lnE_{i,t}^{+,h}$	-0.210	-3.41	***	-0.390	-2.42	**
	$\Delta lnE_{i,t}^{+,l}$	-0.042	-0.90		-0.081	-0.78	
	$\Delta lnE_{i,t}^{-,h}$	-0.285	-4.81	***	-0.292	-2.26	**
	$\Delta lnE_{i,t}^{-,l}$	-0.142	-2.91	***	-0.518	-4.49	***
	$\Delta lnS_{i,t}^{+,h}$	-0.040	-0.77		0.118	1.23	
	$\Delta lnS_{i,t}^{+,l}$	-0.003	-0.06		0.044	0.53	
	$\Delta lnS_{i,t}^{-,h}$	-0.135	-0.17		-1.736	-0.97	
	$\Delta lnS_{i,t}^{-,l}$	0.311	1.25		-0.501	-0.93	
	$\Delta lnR_{i,t-1}$	0.074	3.31	***	-0.132	-3.53	***
	Adj-Rsq		0.116			0.258	
	DW		2.005			1.825	
	n		1870			610	

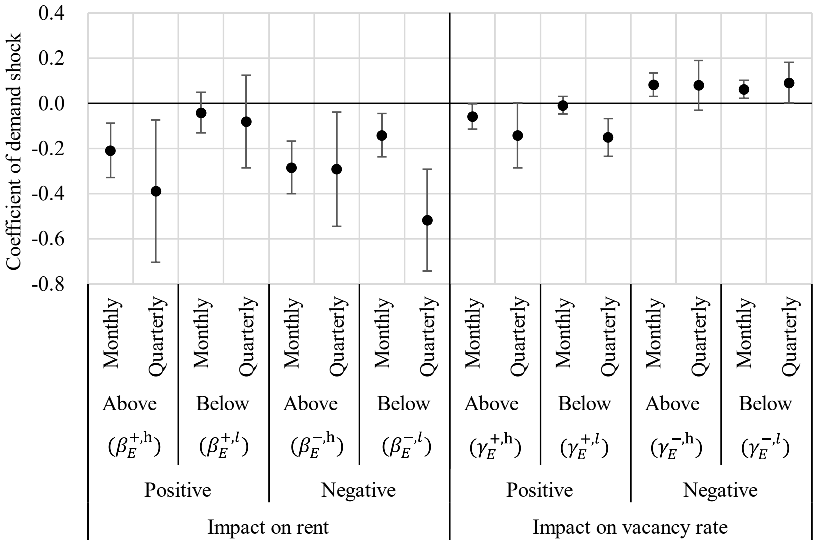
(Continued…)

(Table 7 Continued)

		(1)			(2)	
Frequency		Monthly			Quarterly	
		coefficient	t-value		coefficient	t-value	
$\Delta V_{i,t}$	Intercept	0.000	0.49		0.001	0.93	
	$V_{i,t-1}$	-0.002			-0.012		
	$u_{i,t-1}$	0.017	7.86	***	0.044	6.26	***
	$\Delta lnE_{i,t}^{+,h}$	-0.059	-2.04	**	-0.143	-1.94	*
	$\Delta lnE_{i,t}^{+,l}$	-0.009	-0.45		-0.152	-3.51	***
	$\Delta lnE_{i,t}^{-,h}$	0.083	3.08	***	0.079	1.42	
	$\Delta lnE_{i,t}^{-,l}$	0.062	2.99	***	0.091	1.98	**
	$\Delta lnS_{i,t}^{+,h}$	0.174	6.57	***	0.203	4.30	***
	$\Delta lnS_{i,t}^{+,l}$	0.256	11.81	***	0.256	6.94	***
	$\Delta lnS_{i,t}^{-,h}$	0.074	0.18		-0.162	-0.18	
	$\Delta lnS_{i,t}^{-,l}$	-0.349	-2.72	***	-0.627	-2.33	**
	Adj-Rsq		0.125			0.181	
	DW		1.901			1.779	
	n		1880			620	
$\Delta lnS_{i,t}$	Intercept	0.004	7.88	***	0.011	7.78	***
	$V_{i,t-\tau}$	-0.022	-3.61	***	-0.061	-3.36	***
	$u_{i,t-\tau}$	-0.008	-2.69	***	-0.022	-2.59	***
	Adj-Rsq		0.042			0.114	
	DW		1.943			1.936	
	τ		29			10	
	n		1600			530	

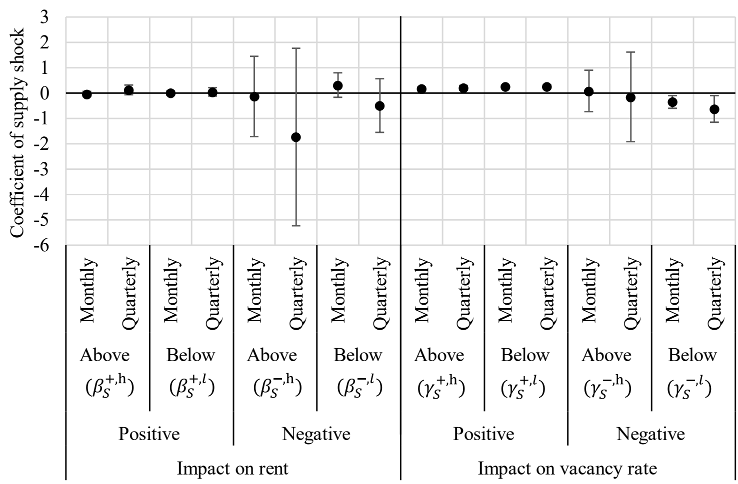
Notes: ***p<0.01; **p<0.05; and *p<0.1. We use SUR for estimation. The period covered by the analysis is from January 2000 to September 2015 for monthly and from the first quarter of 2000 to the second quarter of 2015 for quarterly. The coefficient on the lagged vacancy rate does not affect the estimation of the vacancy rate because of the constraint of maintaining a constant estimated natural vacancy rate. DW represents the Durbin-Watson ratio, and τ is the time required for the supply to adjust, which is empirically estimated to be 29 months and ten quarters. We omit the coefficients of the region dummies.

Figure 8 Effect of positive or negative demand shocks by high or low from equilibrium



Notes: "Above equilibrium" indicates that the previous period's rent is higher than the equilibrium, and "Below equilibrium" indicates that the previous period's rent is lower than the equilibrium. Error bars represent the 95% confidence interval.

Figure 9 Effect of positive or negative supply shocks by above or below equilibrium



Notes: "Above equilibrium" indicates that the previous period's rent is higher than the equilibrium, and "Below equilibrium" indicates that the previous period's rent is lower than the equilibrium. Error bars represent the 95% confidence interval.

6.3.3 Asymmetric adjustment depending on the state of the market

Based on Hypothesis 3, we test the asymmetry of adjustment by the market state. As in the previous section, we identify the supply and demand shocks in each of the four quadrants through the short-run adjustment formula for rent and vacancy rates shown in Figure 4 and compare the magnitude of each coefficient, as follows:

$$\begin{aligned}
\Delta lnR_{i,t} &= \beta_{0,i} + \beta_V V_{i,t-1} - \beta_R u_{i,t-1} \\
&\quad + \sum_{q=1}^{4} \beta_E^{+,q} \Delta lnE_{i,t}^{+,q} + \sum_{q=1}^{4} \beta_E^{-,q} \Delta lnE_{i,t}^{-,q} \\
&\quad + \sum_{q=1}^{4} \beta_S^{+,q} \Delta lnS_{i,t}^{+,q} + \sum_{q=1}^{4} \beta_S^{-,q} \Delta lnS_{i,t}^{-,q} \\
\Delta V_{i,t} &= \gamma_{0,i} + \gamma_V V_{i,t-1} - \gamma_R u_{i,t-1} + \sum_{q=1}^{4} \gamma_E^{+,q} \Delta lnE_{i,t}^{+,q} \\
&\quad + \sum_{q=1}^{4} \gamma_E^{-,q} \Delta lnE_{i,t}^{-,q} + \sum_{q=1}^{4} \gamma_S^{+,q} \Delta lnS_{i,t}^{+,q} \\
&\quad + \sum_{q=1}^{4} \gamma_S^{-,q} \Delta lnS_{i,t}^{-,q} \\
\Delta lnS_{i,t} &= \delta_{0,i} + \delta_V V_{i,t-\tau} - \delta_R u_{i,t-\tau}
\end{aligned} \tag{15}$$

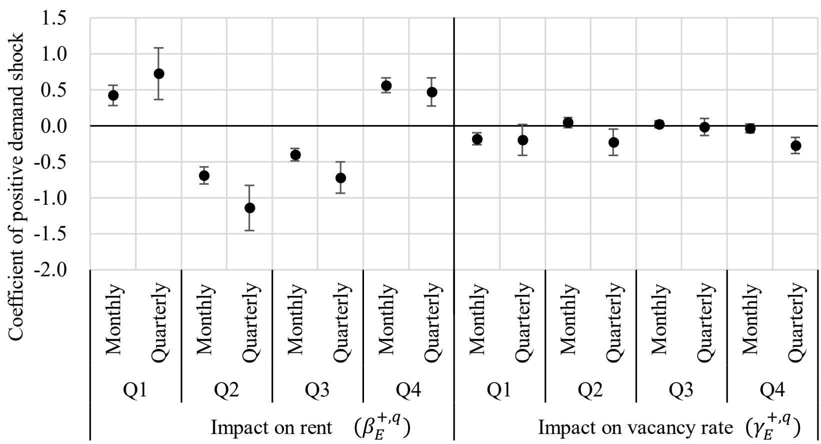
$$\Delta x_{i,t}^{+,q} = \begin{cases} \Delta x_{i,t} \ if\ q = 1\ and\ \Delta x_{i,t} > 0\ and\ u_{i,t-1} \geq 0\ and\ \Delta lnR_{i,t-1} \geq 0 \\ \Delta x_{i,t} \ if\ q = 2\ and\ \Delta x_{i,t} > 0\ and\ u_{i,t-1} \geq 0\ and\ \Delta lnR_{i,t-1} < 0 \\ \Delta x_{i,t} \ if\ q = 3\ and\ \Delta x_{i,t} > 0\ and\ u_{i,t-1} < 0\ and\ \Delta lnR_{i,t-1} < 0 \\ \Delta x_{i,t} \ if\ q = 4\ and\ \Delta x_{i,t} > 0\ and\ u_{i,t-1} < 0\ and\ \Delta lnR_{i,t-1} \geq 0 \\ 0\ else \end{cases},$$

$$\Delta x_{i,t}^{-,q} = \begin{cases} \Delta x_{i,t} \ if\ q = 1\ and\ \Delta x_{i,t} < 0\ and\ u_{i,t-1} \geq 0\ and\ \Delta lnR_{i,t-1} \geq 0 \\ \Delta x_{i,t} \ if\ q = 2\ and\ \Delta x_{i,t} < 0\ and\ u_{i,t-1} \geq 0\ and\ \Delta lnR_{i,t-1} < 0 \\ \Delta x_{i,t} \ if\ q = 3\ and\ \Delta x_{i,t} < 0\ and\ u_{i,t-1} < 0\ and\ \Delta lnR_{i,t-1} < 0 \\ \Delta x_{i,t} \ if\ q = 4\ and\ \Delta x_{i,t} < 0\ and\ u_{i,t-1} < 0\ and\ \Delta lnR_{i,t-1} \geq 0 \\ 0\ else \end{cases}$$

where $\beta_E^{+,q}$, $\beta_E^{-,q}$, $\beta_S^{+,q}$, $\beta_S^{-,q}$, $\gamma_E^{+,q}$, $\gamma_E^{-,q}$, $\gamma_S^{+,q}$, and $\gamma_S^{-,q}$ are the coefficients of interest that represent the positive or negative supply and demand shocks for each market state, respectively. Although previous studies have only focused on positive shocks, this study also addresses negative supply shocks.

The results show that the effect of positive and negative demand and supply shocks on rent and vacancy rates varies widely depending on the market state (Table 8). In particular, positive demand shocks push rents up firmly and vacancy rates down when rents are in the first and fourth quadrants, that is, in an upward phase (Figure 10). Negative demand shocks also have a similar tendency, and have a more substantial downward effect on rent when it is in a declining phase, that is, in the second and third quadrants (Figure 11). However, the response of vacancy rates to negative demand shocks is mainly independent of the state of rents. We read that positive supply shocks push rents up when they are in the first quadrant and push vacancy rates up strongly in other phases (Figure 12). Negative supply shocks push rents up more strongly when they are below equilibrium and diverging from equilibrium (in the third quadrant) (Figure 13). The effect of negative supply shocks on vacancy rates is non-significant except in the fourth quadrant, and the differences in their coefficients are also slight. The effect of negative supply shocks on rents may be a preemptive response to future redevelopment (increased supply), as indicated in Hypothesis 1-2.

Figure 10 Effect of positive employment shocks by the market state



Notes: Q1, Q2, Q3, and Q4 represent the state of the market, as per the four quadrants in Figure 1. Error bars represent the 95% confidence interval.

Table 8 Results of a short-run adjustment model assuming asymmetry due to market state

Dependent variable	$\Delta lnR_{i,t}$						$\Delta V_{i,t}$					
	(1)			(2)			(3)			(4)		
Frequency	Monthly			Quarterly			Monthly			Quarterly		
	coeff	t-value		coeff	t-value		coeff	t-value		coeff	t-value	
Intercept	0.002	4.34	***	0.008	4.79	***	0.000	2.24	**	0.001	2.31	**
$V_{i,t-1}$	-0.054	-7.88	***	-0.183	-7.85	***	-0.010			-0.033		
$u_{i,t-1}$	-0.015	-4.37	***	-0.058	-5.20	***	0.014	6.77	***	0.038	5.48	***
$\Delta lnE_{i,t}^{+,1}$	0.424	5.96	***	0.725	3.97	***	-0.180	-4.19	***	-0.193	-1.77	*
$\Delta lnE_{i,t}^{+,2}$	-0.686	-11.23	***	-1.139	-7.09	***	0.047	1.28		-0.224	-2.40	**
$\Delta lnE_{i,t}^{+,3}$	-0.399	-9.22	***	-0.717	-6.53	***	0.023	0.92		-0.015	-0.25	
$\Delta lnE_{i,t}^{+,4}$	0.561	10.74	***	0.472	4.75	***	-0.035	-1.14		-0.274	-4.79	***
$\Delta lnE_{i,t}^{+,1}$	-0.735	-12.61	***	-0.893	-6.98	***	0.074	2.18	**	0.146	1.96	*
$\Delta lnE_{i,t}^{+,2}$	0.502	7.26	***	0.561	4.32	***	0.059	1.43		-0.017	-0.22	
$\Delta lnE_{i,t}^{+,3}$	0.351	6.84	***	0.386	2.64	***	0.064	2.16	**	0.209	2.61	***
$\Delta lnE_{i,t}^{+,4}$	-0.570	-11.81	***	-0.690	-7.10	***	0.039	1.43		0.025	0.48	
$\Delta lnS_{i,t}^{+,1}$	0.174	2.69	***	0.400	3.91	***	-0.006	-0.15		-0.034	-0.55	
$\Delta lnS_{i,t}^{+,2}$	-0.167	-3.09	***	-0.167	-1.59		0.315	9.32	***	0.455	7.02	***
$\Delta lnS_{i,t}^{+,3}$	-0.071	-1.69	*	-0.079	-0.95		0.278	10.57	***	0.273	5.96	***
$\Delta lnS_{i,t}^{+,4}$	0.109	1.84	*	0.209	2.22	**	0.218	6.07	***	0.201	3.57	***
$\Delta lnS_{i,t}^{-,1}$	-0.547	-0.21		-6.898	-1.06		-0.005	0.00		-0.080	-0.02	
$\Delta lnS_{i,t}^{-,2}$	-0.473	-0.70		-3.607	-2.46	**	0.246	0.58		-0.525	-0.58	

(Continued…)

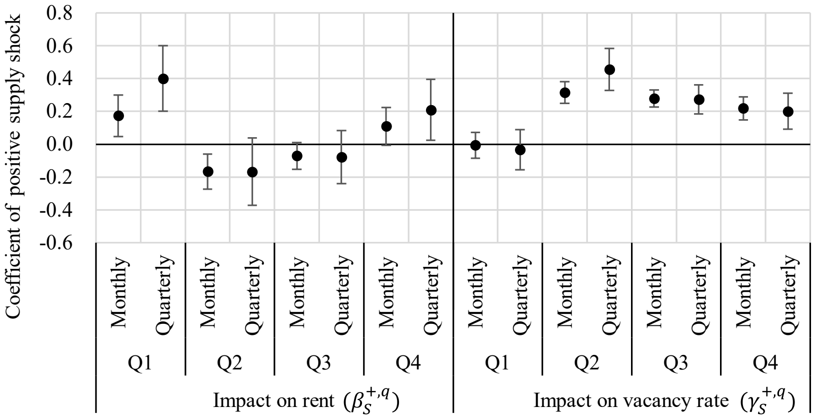
(Table 8 Continued)

Dependent variable	$\Delta lnR_{i,t}$						$\Delta V_{i,t}$					
		(1)			(2)			(3)			(4)	
Frequency		Monthly			Quarterly			Monthly			Quarterly	
	coeff	t-value		coeff	t-value		coeff	t-value		coeff	t-value	
$\Delta lnS^{-,3}_{i,t}$	1.313	3.33	***	6.734	3.25	***	0.117	0.48		0.836	0.65	
$\Delta lnS^{-,4}_{i,t}$	-0.099	-0.43		-0.608	-1.43		-0.498	-3.43	***	-0.677	-2.57	**
$\Delta lnR_{i,t-1}$	0.035	1.93	*	-0.069	-2.30	**						
Adj-Rsq	0.421			0.545			0.159			0.243		
DW	2.054			1.948			1.954			1.914		
n	1870			610			1880			520		

Dependent variable	$\Delta lnS_{i,t}$					
		(5)			(6)	
Frequency		Monthly			Quarterly	
	coeff	t-value		coeff	t-value	
Intercept	0.004	7.89	***	0.011	7.79	***
$V_{i,t-\tau}$	-0.022	-3.63	***	-0.061	-3.37	***
$u_{i,t-\tau}$	-0.008	-2.68	***	-0.022	-2.59	***
Adj-Rsq	0.042			0.114		
DW	1.943			1.936		
τ	29			10		
n	1600			530		

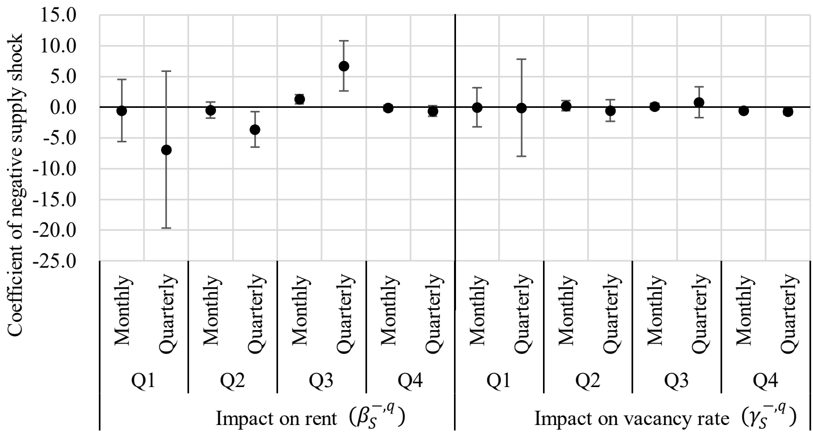
Notes: ***p<0.01; **p<0.05; and *p<0.1. We use SUR for estimation. The period covered by the analysis is from January 2000 to September 2015 for monthly and from the first quarter of 2000 to the second quarter of 2015 for quarterly. The coefficient on the lagged vacancy rate does not affect the estimation of the vacancy rate because of the constraint of maintaining a constant estimated natural vacancy rate. DW represents the Durbin-Watson ratio, and τ is the time required for the supply to adjust, which is empirically estimated to be 29 months and ten quarters. We omit the coefficients of the region dummies

Figure 11 Effect of positive supply shocks by the market state



Notes: Q1, Q2, Q3, and Q4 represent the state of the market, as per the four quadrants in Figure 1. Error bars represent the 95% confidence interval.

Figure 12 Effect of negative supply shocks by the market state



Notes: Q1, Q2, Q3, and Q4 represent the state of the market, as per the four quadrants in Figure 1. Error bars represent the 95% confidence interval.

These results are roughly consistent with Hypothesis 3 but indicate that positive supply and demand shocks may adjust and overshoot the vacancy rate in the equilibrium direction.

7. Conclusion

This study examines the asymmetric adjustment process in the Tokyo office market. The analysis reveals that fluctuations in the Tokyo office market are highly dependent on the direction of supply and demand shocks and market conditions. In particular, we find that positive supply and demand shocks move rent and vacancy rates toward equilibrium and overshoot them. This result is very different from McCartney (2012), Hendershott et al. (2010) and Nowak et al. (2020), which focus on the asymmetry of dynamics due to rents being higher or lower than equilibrium, and shows a new perspective on asymmetric dynamics.

The contribution of this study lies in enhancing the current understanding of the dynamics in the Tokyo office market, as an increasingly important investment target. The characteristics of the Asian office market, including Tokyo, differ from those of the US and European markets with respect to lease terms. This study is the first to focus on cities with relatively short lease terms, and will serve as a reference for other Asian cities. This study also demonstrates the importance of a new perspective on whether rents are in an upward or downward phase in the asymmetric dynamics of the office market.

Determining whether the market dynamics are asymmetric or symmetric is critical for predicting future markets. However, the challenge is that this study does not address market forecasting. In the Tokyo office market, a large amount of office space is expected to be supplied in the future. It will be necessary to capture how those shocks will affect the market. In addition, because this study uses offered rents, it does not fully capture changes in executing rents. There is a move to make face rents (offered rents) appear higher by setting rent-free periods (RFPs) during economic downturns. In the Seoul office market, FRPs have been shown to represent seemingly irrational dynamics of face rents (Ryu and Kim, 2021). It is unclear the extent that FRPs are introduced in the Tokyo office market, thus causing differences in the movement of executing rents and face rents. Still, it is essential to investigate this issue in detail in the future. Furthermore, when considering subregions within a city, it will be necessary to consider the relocation activities of firms between cities, that is, inter-regional interactions. Therefore, further development of studies of rent dynamics that deal with within-city subregions is essential.

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Table A1 Panel root unit test

	$lnR_{i,t}$				$lnS_{i,t}$				$lnE_{i,t}$			
	level		1st		level		1st		level		1st	
IPS	-1.52	*	-14.21	***	2.54		-23.13	***	1.16		-6.79	***
ADF	39.67	***	310.02	***	7.47		492.10	***	16.27		90.43	***
PP	4.35		834.02	***	13.40		990.43	***	24.20		1105.98	***

Notes: ***p<0.01; **p<0.05; and *p<0.1. IPS stands for the Im, Pesaran, and Shin W-stat, ADF for the augmented Dickey-Fuller test, and PP for the Phillips-Perron test. The lags used for estimation are automatically determined based on the AIC. Both sample sizes are 1890 and the time period covered is from January 2000 to September 2015. The "level" shows the test results using the original series panel data, and "1st" shows the test results by using the difference series panel data.

Table A2 Panel cointegration test (Johansen test)

	Monthly					Quarterly				
		Trace		Max-Eigen			Trace		Max-Eigen	
variable		statistic	p-value	statistic	p-value		statistic	p-value	statistic	p-value
$lnR_{i,t}$, $lnE_{i,t}$, $lnS_{i,t}$	R(0)	2546.0	0.00	2540.0	0.00	R(0)	2184.0	0.00	2129.0	0.00
	R(1)	86.3	0.00	87.1	0.00	R(1)	52.1	0.00	51.0	0.00
	R(2)	21.1	0.39	21.1	0.39	R(2)	20.2	0.44	20.2	0.44
n	1890					630				

Notes: ***p<0.01; **p<0.05; and *p<0.1. R(0) represents the null hypothesis that there are at most zero, R(1) indicates at most one, and R(2) indicates at most two cointegration relationships between the variables.

Table A3 Descriptive statistics for rent, stock, vacancy rate, and employees

	Rent (lnR)				Stock (lnS)			
	Average	Max	Min	SD	Average	Max	Min	SD
Chiyoda-Ward	9.66	9.75	9.58	0.05	14.53	14.74	14.30	0.14
Chuo-Ward	9.65	9.75	9.57	0.04	14.34	14.49	14.17	0.09
Minato-Ward	9.75	9.91	9.67	0.06	14.66	14.82	14.40	0.13
Shinjuku-Ward	9.62	9.71	9.52	0.05	13.94	14.05	13.88	0.06
Shibuya-Ward	9.86	10.01	9.78	0.06	13.67	13.78	13.51	0.08
Toshima-Ward	9.54	9.58	9.47	0.03	12.95	12.98	12.91	0.02
Bunkyo-Ward	9.45	9.53	9.35	0.04	12.66	12.70	12.57	0.03
Taito-Ward	9.39	9.45	9.29	0.03	12.95	13.00	12.90	0.03
Shinagawa-Ward	9.59	9.70	9.50	0.05	13.41	13.58	13.22	0.12
Koto-Ward	9.40	9.51	9.31	0.05	13.21	13.47	12.97	0.18
	Vacancy Rate (V)				Employees (lnE)			
	Average	Max	Min	SD	Average	Max	Min	SD
Chiyoda-Ward	0.0515	0.0798	0.0149	0.0190	13.09	13.14	13.06	0.017
Chuo-Ward	0.0592	0.0840	0.0205	0.0191	12.67	12.73	12.63	0.028
Minato-Ward	0.0544	0.0836	0.0165	0.0200	13.05	13.11	12.97	0.037
Shinjuku-Ward	0.0627	0.1148	0.0243	0.0252	12.56	12.65	12.50	0.042
Shibuya-Ward	0.0415	0.0776	0.0146	0.0179	12.28	12.33	12.23	0.027
Toshima-Ward	0.0536	0.0751	0.0259	0.0119	11.55	11.69	11.49	0.055
Bunkyo-Ward	0.0592	0.0918	0.0221	0.0162	11.61	11.69	11.54	0.040
Taito-Ward	0.0688	0.0926	0.0392	0.0124	11.41	11.55	11.31	0.066
Shinagawa-Ward	0.0550	0.1028	0.0124	0.0259	12.06	12.13	12.01	0.032
Koto-Ward	0.0667	0.1157	0.0207	0.0228	11.91	12.09	11.79	0.096

Notes: The observation period for each variable is January 2000 to September 2015. The rents are quality-adjusted by using the hedonic time dummy method, and we interpolate employees by using the spline method