Analysis of the Tokyo Commercial Real Estate Market using the Torto-Wheaton model

by

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B.Eng., Urban Engineering
University of Tokyo, 1988

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University of Tokyo, 1990

Submitted to
the Department of Urban Studies and Planning
in Partial Fulfillment of the Requirements for
the Degree of Master of Science in Real Estate

at the
Massachusetts Institute of Technology

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Abstract

The thesis applies the a structural econometric model to the Tokyo office market. The model consists of three simultaneous equation. The first equation explains office space absorption by the employment or the output and the level of rent. The second explains the rent by vacancy and the rate of absorption. Finally, construction level is explained by vacancy and the change in rent.

The model was tested against the data of Tokyo since 1975. Each equation demonstrated a very high statistical significance, and the correlation of each variable to the dependent variable confirms the intuitive understanding. As a result, most of the behavior of Tokyo office market can be explained by one exogenous variable, Tokyo's gross regional output.

Based on the model, a contingent forecast is made for several economic growth scenarios. The unusually low vacancy of Tokyo office market gives rise to some problems. Under high growth, vacancy is insufficient to cope with the rising absorption, thus physically constraining the observable absorption. Since absorption is also used as a proxy for demand, the model fails to recognize the amount of actual demand under higher growth scenarios. As limited work-around is proposed by separating the desired absorption and the actual absorption, with a limited amount of success.

The model forecasts a falling market till 1995. The forecast result for 1994 rent is very close to the actual 1994 rent data that recently became available, which speaks favorably of this model. After that, under a low economic growth, the market will show a cyclical behavior with a cycle of five to six years. Under higher growth, the market will immediately become saturated, with virtually no vacancy after 1996.

Thesis Supervisor: William C. Wheaton
Title: Professor of Economics and Urban Studies and Planning
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1. Introduction and Thesis Outline

1.1. Introduction

Commercial real estate market in Tokyo has been a target of curiosity for some time. It maintained one of the most outrageously high land prices in the world. Furthermore, it experienced an almost eight fold appreciation in its real value during the 80s, which seemed too high to be justified through any underlying fundamentals. As Bacow (1990) states, “At first sight, the Tokyo land market seems to be a typical example of market failure”¹ Many of the land holdings and transactions were purely speculative². According the National Land Institute (1990), 50 percent of the surveyed firms acquired land “without any intention of utilizing it in the first place”. Naturally, the booming office construction of the late 80s were also believed to be a part of this speculative activities in real estate.

Possibly because of this belief, studies concerning the dynamics of the real estate market itself has been scarce. Also, there seems to be a tendency to consider the real estate boom in the late 80s a an anomaly based on speculation only (which gives it the name “bubble economy”) generated by the one time socio-economic conditions of the time. The fact that the market crashed in the 90s is often used as an evidence of this speculative bubble.

However, boom-and-bust behaviors are not necessarily products of speculative or irrational activities. It is a common knowledge in system dynamics that a system based on perfectly rational behaviors can oscillate if more than two lags or delays are involved in the system’s loop. Real estate market is precisely such a system with lags and delays. The

²Cf. Nihon Keizai Shimbun, April 18, 1990
stock of space is a variable that cannot adjust instantaneously, and the long construction process also causes a long delay. Lease contracts will also prevent tenants from moving, causing delays.

Tokyo has experienced similar boom-and-bust in the early 70s, which suggests that Tokyo real estate market is cyclical in nature, as with anywhere else. Therefore, in order to understand the Tokyo real estate market, it should be necessary to distinguish between the “normal” level of volatility, and the speculative portion of it. The experience of the late 80s should be studied and viewed under similar context.

The objective of this thesis is to provide such understanding of this dynamics. The thesis attempts to model the Tokyo commercial real estate market, based on the assumption that it behaves under rational expectations. The model used here assumes that the players in the market, namely the office users or tenants, the landlords and the developers, use all available information rationally and act accordingly. The success (or the lack of it) of this model should give us an idea of the nature of Tokyo’s commercial real estate market.

1.2. Thesis Outline

The thesis is organized as follows.

Chapter 2 provides the definition and the general description of Tokyo and its commercial real estate market over the past twenty five years.

Chapter 3 deals with the past studies on this subject. There has been a number of studies concerning the commercial real estate of Tokyo, but most focus on the issue of land price and its appreciation. They tend to be static comparisons between the fundamentals and the actual price, or they focus on events (ex. the financial deregulation) to explain the appreciation.
Chapter 4 explains the theoretical framework used in this paper, explains the available data on the subject, and the actual model that results from the data. The Torto-Wheaton model is employed, which derives from the search base theory. The model takes form of several simultaneous equations and identities. Based on employment, it models the absorption of office floor, the change in rent and the construction level. The model is tested against annual data since 1975-1993, giving us 19 observations.

The result shows a very high statistical fit, with expected signs on the independent variables. There are some questionable series of data that are used, and owner occupied properties are largely ignored in the model. These factors may cast doubt to the results. However, the overall outcome is satisfactory, and suggests that the Tokyo commercial real estate market acts quite rationally.

Chapter 5 provides some contingent forecasts based on the model, which reveals some problems of the model under the special condition of Tokyo office market. The very low vacancy in Tokyo physically constrains the absorption. Since absorption is used as a proxy for demand, the model fails to recognize the amount of actual demand under higher growth scenarios. A limited work-around is proposed, with a limited amount of success.

The model forecasts a falling market till 1995. The forecast result for 1994 is very close to the actual 1994 rent data that recently became available. After that, under a low economic growth, the market will show a cyclical behavior with a cycle of five to six years. Under higher growth, the market will immediately become saturated, with virtually no vacancy after 1996. Physical constraint on the absorption and the vacancy rate violate the assumption behind the model, which seem to distort the outcome. However, generally speaking, higher growth of the economy produces a faster rent appreciation and higher level of construction in the model, which is consistent with the past experience of the market.

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Office rent and Construction start were only available since this year.
Finally, chapter 6 concludes the thesis with a summary of the model and empirical findings, limitation of the model and areas of further study.
2. **The Tokyo Commercial Real Estate Market**

2.1. **Definition**

When “Tokyo” is mentioned, it can mean three things;

1) The greater Tokyo Metropolitan area (including adjacent cities such as Yokohama and Chiba)

2) The Prefecture of Tokyo

3) Tokyo ward district

Each respective region is shown on Figure 2.1 and 2.2. It should be noted that there is no entity named “Tokyo City”, due to various historical and political conditions.

In this paper, “Tokyo” usually refers to “the Tokyo ward district”. Several series of data, such as the regional output (GRP) were only available for the Prefecture of Tokyo. However, this should not cause too much of a problem, since most of the offices and office related employment are concentrated in the Tokyo Ward district.
Figure 2.1: Greater Tokyo Metropolitan Area

Figure 2.1 Tokyo Prefecture / Tokyo Ward District
2.2. Real Estate Market

Tokyo is the center of Japan in geographical, political, financial, administrative, cultural, industrial and almost any other sense imaginable. As Bacow (1990) puts it;

"To truly appreciate Tokyo’s role in Japan, one must contemplate a United States in which Washington D.C. housed not only the federal government, but also the financial markets of New York, the educational resources of Boston, the distributional services of Chicago, the port facilities of Los Angeles"

Because of its importance, Tokyo maintained high land price and land enjoyed a higher level of appreciation than any other investment or goods in Japan. From 1980 to 1990, the commercial land price in Tokyo appreciated more than 500% in real terms. Most of the appreciation is concentrated in the latter half of the 80s.

![Figure 2.3 Tokyo Commercial Land Price Index 1969-1992](image)
Several reasons have been pointed out. One is the financial de-regulation that started in 1979. In this year, the first CD with non-regulated interest rate was issued, followed by various other non-regulated vehicles. For the banks, this meant a transition from a protected and lucrative environment to a more competitive environment with smaller profit margins. This caused the banks to look for ways to make new (but safe) loans. Real estate was considered to be a very safe collateral, sufficient enough to cover any credit risk of the borrower. It also enabled banks to write larger loans. So, under the new environment, banks rushed into any real estate related loans that they can find.

Another factor was the various de-regulations concerning the urban re-development. Japan was in a depression in the early 80s. However, because of the huge trade surplus, the government was forced to adopted a policy to stimulate domestic consumption in order to improve the economy. At the time, the government was also under heavy attack concerning the inefficiencies of the public sector. This led to a policy “to better-utilize the power of private firms”. Encouraging development was a perfect way to cope with these factors. What happened was an overall increase of the FAR, faster implementation of public works projects and more generous construction permits. Town Planning and Zoning Act and the Building Standard Act had continuously been revised toward a more restrictive and tighter direction, but in 1982, these also made a turn toward deregulation.

Lastly, there was the expectation for demand increase. Real estate market in general was rather inactive in the early 80s. The only visible activity was in the office demand from growth industry such as computer software, or from foreign firms. According to Nikkei Real Estate (1993a), this created an optimistic expectation for office demand, which caused the developers to place more emphasis on rental office developments.

Their expectation was further reinforced by a report from the National Land Agency (1980), which stressed the increasing importance of Tokyo as the international financial
center. The report also forecasted a major shortage of office space in the ‘90s\(^4\). This increased the confidence of developers, which triggered to a rush of major commercial development activities, especially in the Tokyo bay area where relatively large parcels of land were available. And as the economy recovered, the office demand did grow at a substantial rate, even outgrowing the supply.

To summarize, the Tokyo commercial real estate market in the late 80s is said to have been driven by three factors: a relatively strong demand which led to a higher expectation for future demand, the financial de-regulation to fuel the development, and deregulation on the development activities to allow it. However, as the Japanese economy cooled down in the 90s, funds were tightened and the demand cooled down, which also drove the expectation down. This caused the huge drop of land price.

Of course, this was not the first time that this happened. The economic downturn from the oil shock in 1973 had also brought rent and land prices down. Prior to the experience in the 90s, however, there was a tendency to consider this as an anomaly. In the very optimistic economic environment of the 80s, it was seriously argued that the land price will keep appreciating at any given period of time. With the downturn in the 90s, it was finally acknowledged that land price can and does drop, and that it is also subject to various economic conditions as well as any other commodity.

\(^4\)This forecast was later revised to a lower figure, partly in response to the criticism that such bullish forecast was fueling the speculative developments, hiking up the land price.
3. **Previous Researches**

3.1. **Studies on Japanese Real Estate Market**

The rapid appreciation of land prices in the 80s attracted huge interest, resulting in numerous studies on the subject. The majority, however, tends to focus on high land price and whether it is justifiable. Very few deal with the market behavior.

Noguchi (1988) has assessed the theoretical land prices for major urban areas in Japan, including Tokyo. Theoretical land price here indicates the discounted present value of future rent revenue. Comparing this to the actual land prices, he found that Tokyo commercial land prices on average is twice the theoretical level.

Nomura Research Institute (1990a) has made similar assessment. This study focuses on a public auction of government land. The process was completely disclosed, and the assessed land price before and after the auction was closely monitored. The study attempts to model the change in land price by rent, construction cost, risk free rate and expectation for rent appreciation and land price appreciation is taken into account. The study then applies the model to other properties, concluding that about 40% of the land price movement in Tokyo is caused by the change in expectation for future appreciation.

The government of Tokyo (1989) has undertaken a simple regression analysis to determine the weight of various factors involved in the price formation of land in Tokyo. It distinguishes between three factors; Macroeconomic fundamentals, financial conditions and expectations. The result shows that the movement of land price up to 1984 is explainable by fundamentals and the financial conditions. After that, the expectations play a huge role in the appreciation of land price.
Steele (1991) has made a forecast of the office market in central Tokyo for the year 2010. It is a trend analysis on both the supply side and the demand side. Supply is given by the linear extrapolation of the current trend. The demand estimate is given by the estimated number of office workers and the estimate of office floor per worker. Rent is estimated by a rather qualitative manner, and these estimates for the supply, demand and rent are not integrated to form any comprehensive model. The study recognizes this weakness, and strongly recommends a further study based on an econometric model.

It is striking to notice that although almost every studies on land price uses office rent as their basis of their calculation, and yet, rent itself is hardly ever studied or scrutinized. The going rent or rent from comparable property is employed. Vacancy is hardly taken into account.

One of the few studies that actually attempt to model the market is made by Nomura Research Institute (1994). It uses a stock-flow model, taking rents, vacancy and construction lags into account, given as a simultaneous equation. However, the model equations do not have a solid theoretical base. Rather, it more or less tries out arbitrary combination of variables and lags, picking out the ones that have the best fit. The study makes a contingent forecast based on GDP growth and the employment growth.
4. **The Model**

4.1. **Methodology: Torto-Wheaton Model**

This paper attempts to apply the model developed by Wheaton and Torto (1987) and Wheaton (1987b) to the Tokyo commercial real estate market.

The Torto-Wheaton model consists of three behavioral equations, and several identities. The first equation models demand measured by absorption, determined by employment and other conditions. The second equation models the rent, based on vacancy and the level of demand. The third models the construction, based on the rent. Each equation may contain a lag, due to reporting delays and other factors. Each equation also takes into consideration the fact that these adjustments cannot happen instantaneously, due to rental agreements and the long construction periods.

4.1.1. **Absorption Equation**

Given a certain level of employment ($E_t$), firms will have a certain amount of office space that they would like to occupy each period, depending on the floor/worker. The amount of floor/worker should depend on the level of rent. Also, when a firm is under high growth, firms may want to secure some extra floor space for growth.

Therefore, the desired amount of occupied space $OC^*$ should be given by the following equation:
\[ OC^* = \alpha_0 + E_t \cdot (\alpha_1 + \alpha_2 \cdot (1 - \frac{E_{t-1}}{E_t}) + \alpha_3 \cdot Rent_t) \]

However, because of the lease, the approval processes and time required to search for the appropriate property, firms cannot achieve this level instantaneously. So, the absorption will be given by the following equation:

\[ Absorption_t = \gamma_1 \cdot (OC^* - OC_{t-1}) \]

\[ \therefore Absorption_t = \gamma_1 \cdot (\alpha_0 + E_t \cdot (\alpha_1 + \alpha_2 \cdot (1 - \frac{E_{t-1}}{E_t}) + \alpha_3 \cdot Rent_t)) - \gamma_1 \cdot OC_{t-1} \]

Because of various reporting and decision processes involved, there could be lags in each parameters.

4.1.2. Rent Equation

Rent should basically be determined by the level of vacancy. Vacancy represents the difference of the supply and demand. Higher vacancy would give the tenants more option to choose from, which would increase the option value of not closing the deal.

Another factor to be considered would be the number of potential tenants who are in search of a property. If there are more potential tenants, landlords will have more bargaining power.

Vacancy data is available. The number of potential tenants would be difficult to estimate, but absorption should serve as a proxy. The same absorption would have a
different implication in places with different level of stock. So, as a proxy for the rate of seekers, Absorption/Stock should suffice.

Given the vacancy and the absorption/stock, there would be a desired equilibrium level of rent, Rent*. Because the vacancy and absorption cannot be known in real time, this decision should be based upon lagged value. Based on the argument so far, it should be given by the following equation;

\[ \text{Rent}^* = \mu_0 + \mu_1 \cdot V_{t-1} + \mu_2 \cdot \frac{\text{Absorption}_{t-1}}{\text{Stock}_{t-1}} \]

Since this level of rent is the equilibrium rent, it assumes that the market will clear at this level. All the tenants/landlords who are willing to lease/rent property will be matched if there were no other restrictions.

Because of lease contracts, rents cannot adjust to this desired level instantaneously. Only a portion will achieve this level. So;

\[ \Delta \text{Rent}_t = \mu_3 \cdot (\text{Rent}^* - \text{Rent}_{t-1}) \]

\[ \therefore \Delta \text{Rent}_t = \mu_3 \cdot (\mu_0 + \mu_1 \cdot V_{t-1} + \mu_2 \cdot \frac{\text{Absorption}_{t-1}}{\text{Stock}_{t-1}}) - \mu_3 \cdot \text{Rent}_{t-1} \]

As with absorption, there may be more lags involved.

4.1.3. Construction Equation

Construction equation used here is slightly different from the original Torto-Wheaton model. Because of the available data, the equation here will deal with construction starts, instead of completion.
Developers will start construction, based on their expectation for the future. Their largest concern would be the rent that they could charge. Therefore, they would respond to the change in rent. They will also respond to the vacancy, because they would want to hold some amount of inventory. Based on these arguments, and assuming a linear function, the desired level of construction starts should be given as follows;

$$C_i^* = \beta_0 + \beta_1 \cdot \Delta Rent_i + \beta_2 \cdot Vacancy_i$$

Achieving this level should be a matter of getting a contractor. Because we are dealing with periods of one year, developers should be able to get what they want. However, actual data seem to suggest that the change in construction is gradual, not instantaneous. Taking this into account, the change in construction level will be given by the following:

$$C_i - C_{i-1} = \gamma_2 \cdot (C_i^* - C_{i-1})$$

$$\therefore C_i = \gamma_2 \cdot (\beta_0 + \beta_1 \cdot \Delta Rent_i + \beta_2 \cdot Vacancy_i) + (1 - \gamma_2) \cdot C_{i-1}$$

There are other ways to think about constructions. However, in Tokyo’s case, this rather simple relation seems to hold the best.

4.1.4. Identities

Based on absorption, occupancy is by definition given as follows;

$$Occupancy_i = Occupancy_{i-1} + Absorption_i$$
It is assumed that the average construction is completed in a year. Therefore, Stock would be given as follows;

\[ Stock_t = Stock_{t-1} + ConstructionStart_{t-1} \]

Vacancy is given by the following;

\[ Vacancy_t = 1 - \frac{Occupancy_t}{Stock_t} \]

Using the above equations and identities, variables for each period will be given by the conditions of the preceding periods.

4.2. Data

The model requires the following series of data; Stock of Commercial Floor space, Completion (or Starts), Employment, Rent, and Vacancy.

4.2.1. Office Stock Data

The Ministry of Home Affairs collect and publicizes the stock data in “Aggregated Survey of Real Property Prices and etc.”. Each local government maintains a record of properties within its jurisdiction, to be used as a base for property tax. Along with the monetary value, this record holds the physical floor space of each property, probably to confirm the declared monetary value.
Their tabulation does not have a straight forward entry for "offices". Therefore, in order to estimate office stock from this data, one must take the data for "Office, Retail and Department Stores", estimate the office portion and add data from the "Bank" category.

![Office Stock Graph](image)

**Figure 4.1 Tokyo Office Stock 1970-1993**

According to this time series, the office stock of Tokyo is 75 million m² as of 1993. It has grown rapidly during the last decade, almost doubling from the 1980 level.

Another series can be created, using the following formula.

\[ Stock_t = Stock_{t-1} + ConstructionStart_{t-1} \]
This series assumes that office buildings will be completed in a year. Description of the Construction Starts will be made in the next section. Demolition is not taken into account in this series, which may distort this series.

4.2.2. Construction Start

The ministry of Construction publicizes data based on building permits. From all the permits, buildings that fulfill the following conditions are considered to be office buildings;

1) Structure: RC, SRC, SC

2) “Office buildings” in the Japan Standard Building Use Classification.

![Office Construction Start](image)

Source: Ministry of Construction

Figure 4.2 Tokyo Office Construction Start 1977-1993
The building boom starting from the late 80s is apparent. The flat period between 1987 to 1989 may reflect the shortage of construction workers and engineers caused by the enormous construction boom of the period. During this period, contractors had their schedules fully booked till three years ahead, charging enormous premiums over the usual price, and construction workers were flown into Tokyo from all over the county, sometimes even from abroad.

It is interesting to note that even after 1991 when the recession became apparent and over-supply of offices became a fact, construction start of offices did not drop immediately. This may be because of how the contract with the contractors were set up. Or, it may be that developers simply were able to convince themselves that their building would show an above-market performance. In any case, the argument that response of construction activity is gradual seems to be highly applicable here.

4.2.3. Employment Data

There are several sources of employment data. The Population Census is considered to be the most accurate. It tabulates the population by their occupation and industry for each Prefecture. It is surveyed only every five years, however, which is insufficient for our purpose.

Another source is the Establishment Census of Japan, which was conducted every three years up to 1977, and every five years after that. As with the census, it provides the working population tabulated by the industry and occupation for each Prefecture, but the data points are too far apart.

The Census data tells us, however, that the number of office workers in Tokyo made a 50% increase over the 15 years from 1975 to 1990. This would have no doubt raised demand for office space in the area.
Figure 4.3 Tokyo Office Workers & Managers 1975-1990

We should note that the office stock has more than doubled in the same 15 years. Calculating the Office floor per worker based on these series, we get 13.6m²/worker in 1975 and 18.5m²/worker in 1990, a 40% increase over 15 years. This may reflect a change in the Japanese office work style. Although this is not within the scope of this thesis, it would have a strong effect on the office floor demand. If these results are to be trusted, using employment as the indicator of office demand may prove to be insufficient.

The third source of employment data is the Labor statistics. This is available monthly. However, it only addresses enterprises with fifty or more workers. Since a large number of Tokyo firms are small, this may skew the figures. Also, this survey does not provide data tabulated by industry AND prefecture. Therefore, it is difficult to model office demand based on this figure.
4.2.4. Gross Regional Output

Alternative indicator for employment is the output of the area.

Ministry of Home Affairs publicizes an estimate of the Gross Regional Product (Output) of each prefecture. Since this is the total output of Tokyo, it includes output from non-office works, such as manufacturing, agriculture and services. The trend shows a generally stable behavior in the late 70s, and then from 1980 to 1990, it nearly doubles.

![Graph](image)

**Figure 4.4 Tokyo Real GRP 1970-1991**

The figure for 1992-1993 has not become available yet. The output for these period were estimated based on the GDP growth, and the general consensus that the recession in
these periods hit the larger metropolitan areas harder and deeper. The estimated growth rate is -2% in 1992, and -1% in 1993.

The share of Tokyo among the national production was generally stable, or gradually decreasing in the 70s. In the ‘80s, however, it showed an increase from about 16% to 20% of the national output. This corresponds with the soar of land prices in the 80s.

![Share of Tokyo in the GDP](image)

*Figure 4.5 Share of Tokyo in the National GDP 1965-1991*
4.2.5. Rent

Data is provided by IDSS, a research firm backed by a real estate brokerage firm\(^5\). For Tokyo, IDSS divides it into several zones, selects a fixed area and surveys all the commercial property within. The asking rent for all vacant properties are averaged out by the floor area.

The rent here is the effective rent. It takes into account the interest (6%/year) accrued on the deposit. It also takes into account the rent charged for the common space, a common practice in Japan. Effective Rent is calculated as follows:

\[
\text{Effective Rent} = \frac{\text{Nominal Rent} + \text{Deposit} \times 6\% / 12}{1 - \text{Share of CommonSpace}}
\]

---

\(^5\)IDSS (Ikoma Data Service System) "Office Market Report '94"
A criticism toward this series may be that the figures represent the asking rent, and not the actual going rent. Since they represent the deals that are not yet closed, there is always the possibility that this figure is significantly higher than the actual going rent.

4.2.6. Vacancy Rate

Until very recently, vacancy was not considered to be an important data. Furthermore, under the tight market condition, it was almost natural for a building to be completely full by the time of completion. If not, the general perception would be that there must be something wrong with the property. This made vacancy a rather embarrassing phenomena, which caused landlords to conceal it as much as possible.

Recent downturn of the market and the increase of vacancy have generated interest in this series, causing several firms to gather and publicize vacancy data. Although it is still considered to be "a secondary indicator", some firms have begun to utilize the concept of "vacancy as inventory" in their operation. However, only one series date back before the 80s, namely the Japan Building Association data.

- Japan Building Association

Japan Building Association has been publicizing annual vacancy data since 1963. Japan Building Association is an association of building owners in Japan. Most of the members are owners of the better properties, and some properties are owner occupied.

The vacancy is surveyed by questionnaires sent out to its members. The members may or may not answer, so it is unclear which property is accounted for. It is said that many owners are reluctant about disclosing data on ill-performing properties. And as mentioned, the member buildings represents the better office buildings. Some of the
buildings are owner occupied, which is less likely to be vacant. All these factors distort the figure.

Therefore, this vacancy series tend to be extremely low. Since 1970, it has hardly exceeded 2%. Even under the stressed market of 1992, it shows a mere 0.5% vacancy. This is clearly not reflecting the actual market condition. It is, however, the only series that is available before 1980.

- **IDSS (Ikoma Data Service Systems)**

  Their series starts from 1988. It is a by-product of the rent survey conducted by IDSS, consistently covering all buildings within a fixed survey area.

  Because of the better survey method, this series is much more realistic and reliable. The vacancy of 7.5% in 1993 is a reasonable figure. However, because of the very small number of observations so far, we cannot use this series in this model.
4.2.7. CPI

In order to bring everything down to real terms, CPI (Consumer Price Index) is used as the deflator. This data is available from the Statistics Bureau, Management and Coordination Agency. Using this as a deflator, every monetary figure is deflated to 1987 yen value.
4.3. Results

4.3.1. The Absorption Model

Here, the actual absorption is calculated using the following identities:

\[ \text{Absorption}_t = \text{OC}_t - \text{OC}_{t-1} = \text{Vacancy}_t \cdot \text{Stock}_t - \text{Vacancy}_{t-1} \cdot \text{Stock}_{t-1} \]

For stock, the series using the sum of past construction starts is used throughout the model. There is no apparent reason that this series should be better. Possibly, the ministry of construction has the ability to keep better track of building activities. However, the lack of consideration for demolition should have a negative effect. The results, however, come out better using this series.

The equation that shows the best statistical fit is as follows:

\[ \text{Absorption}_t = -9e6 + 0.467 \cdot \text{GRP}_{t-2} - 0.000002 \cdot \text{GRP}_{t-2} \cdot \text{Rent}_{t-1} - 0.219 \cdot \text{OC}_{t-1} \]

(Absorption: m², GRP: millions of 1987 Yen, Rent: 1987 Yen/m²/month, OC(Occupancy): m²)

**Summary of Fit**

<table>
<thead>
<tr>
<th>Statistic</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>R²</td>
<td>0.900126</td>
</tr>
<tr>
<td>R² Adjusted</td>
<td>0.878725</td>
</tr>
<tr>
<td>Root Mean Square Error</td>
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</tr>
<tr>
<td>Mean of Response</td>
<td>3159467</td>
</tr>
<tr>
<td>Observations (or Sum Wgts)</td>
<td>18</td>
</tr>
</tbody>
</table>
Parameter Estimates

| Term       | Estimate | Std Error | t Ratio | Prob>|t| |
|------------|----------|-----------|---------|------|---|
| Intercept  | -8.9882e6| 2062202   | -4.36   | 0.0007 |
| GRPț-2     | 0.4674178| 0.081016  | 5.77    | 0.0000 |
| GRPț-2 Rentț-1 | -0.000002| 6.456e-7 | -2.43   | 0.0294 |
| OClț-1     | -0.219216| 0.040557  | -5.41   | 0.0001 |

![Graph showing Absorption and Predicted Absorption]

Figure 4.8 Absorption Model Fit

The absorption depends on the lagged value of output / employment (GRP) and rent. The reason for the lag would be reporting delays and the internal decision procedures of each firm, time required for the search of space. The GRP figure for 1992-1993 is an estimation, but since GRP here is lagged for two periods, the accuracy of these estimation does not affect the statistical fit of the model.

The Equation implies that in any given year, about 22% of the desired adjustment is made. The coefficient on the GRP suggests that at the current rent level of 40,000 Yen/m²/month, for every unit (one million Yen) of annual output, about 1.8m² of office
space is needed. Considering the wage level and the average office space per person in Tokyo, this is not an unreasonable figure.

The price elasticity of office demand per unit of output is about 0.2 at the current rent level, which means that floor demand is rather inelastic. Whatever the rent, firms seem to be unwilling to cut office space too much.

The employment growth did not show a strong effect on absorption. The reason for this is unclear. It may be that the bureaucratic management hierarchy within Japanese firms work against this sort of planned behavior. The communication between the personnel department (which handles all the hiring) and the general management department (which deals with property leases and acquisitions) is not necessarily well defined in Japanese firms. Or, it could be that Tokyo firms are simply unwilling to act upon future expectation of their output.

4.3.2. The Rent Model

The following is the equation with the best statistical fit:

\[ \Delta Rent_t = 0.129(22115 - 25972 \cdot Vacancy_t + 676328 \cdot \frac{Absorption_t}{Stock_t}) - 0.129 \cdot Rent_{t-1} \]

\(Rent\): 1987 Yen/m²-month, \(Vacancy\): %, \(Absorption\): m², \(Stock\): m²

**Summary of Fit**

<table>
<thead>
<tr>
<th>RSquare</th>
<th>RSquare Adj</th>
<th>Root Mean Square Error</th>
<th>Mean of Response</th>
<th>Observations (or Sum Wgts)</th>
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</thead>
<tbody>
<tr>
<td>0.704700</td>
<td>0.641422</td>
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### Parameter Estimates

<table>
<thead>
<tr>
<th>Term</th>
<th>Estimate</th>
<th>Std Error</th>
<th>t Ratio</th>
<th>Prob&gt;</th>
<th>tl</th>
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</thead>
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<tr>
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<td>$V_t$</td>
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<tr>
<td>$AB_t/S_t$</td>
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<td>21254.14</td>
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<tr>
<td>$Rent_{t-1}$</td>
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<td>0.045003</td>
<td>-2.88</td>
<td>0.0121</td>
<td></td>
</tr>
</tbody>
</table>

![Graph showing Rent Model Fit](image)

**Figure 4.9 Rent Model Fit**

The Equation implies that about 13% of the offices will be able to adjust to the new desired level of rent each year.

Also, given the 1993 level of vacancy (1%) and absorption/stock (0.04), the equilibrium rent (or desired rent) should be about 26,000 Yen. However, this level is highly sensitive to the vacancy. When Vacancy drops by 0.1%, it will push up the equilibrium rent by 2,600 Yen.
4.3.3. The Construction Model

The model shows the best statistical fit with the following equation.

\[ \text{Construction}_t = 0.44(3815.8 + 0.34 \cdot \Delta \text{Rent}_t - 1412.3 \cdot \text{Vacancy}_{t-1}) + (1 - 0.44) \cdot C_{t-1} \]

(Construction: Thousands of m², Rent: 1987 Yen/m²-month, Vacancy: %)

**Summary of Fit**

- RSquare: 0.887134
- RSquare Adj: 0.858917
- Root Mean Square Error: 538.4544
- Mean of Response: 3234.562
- Observations (or Sum Wgts): 16

**Parameter Estimates**

| Term  | Estimate  | Std. Error | t Ratio | Prob>|t| |
|-------|-----------|------------|---------|------|
| Intercept | 1694.7705 | 696.0325   | 2.43    | 0.0314 |
| Vac\_t-1 | -621.4498 | 365.1204   | -1.70   | 0.1145 |
| \(\Delta\)\text{Rent}_t | 0.1476080 | 0.050891   | 2.90    | 0.0133 |
| C\_t-1 | 0.5613072 | 0.144728   | 3.88    | 0.0022 |
Figure 4.10 Construction Model Fit

Because of the way this model is set up, the construction starts in this model is by definition the completion one year ahead.

The Equation implies that developers respond to available data almost immediately. The lag on $\Delta R_{t}$ is zero, and lag on vacancy is one period, which should consist primarily of reporting delay. 45% of adjustment is made in the same year. Considering the time required to design the building and get financing and permits, this is rather remarkable. This must mean that the developers make developing decisions almost on the spot.

This may reflect the "bubble" period of the late 80s. In these periods, rents always appreciated, so developers were always determined to develop as much as they can whenever a lot became available. Banks and other financial institutions were also determined to finance whatever the project was.
As mentioned in the explanation of the equation, I have tried other equations using different independent variables under different lags. The fact that this one stood out seem to suggest that Japanese developers are incredibly near sighted. If rents are appreciating today, they immediately start building. If vacancy is low today, they start building right away. However, the experience in the late 80s does not necessarily contradict this finding.

4.4. Known Problems of the Model

4.4.1. No Consideration for Speculative Construction

It is generally considered that the Tokyo commercial real estate market is highly speculative. This model does not take speculative factors into consideration. While the model’s high explanatory power suggests that such speculative activities may not be too significant, ignoring it totally may not be a good idea.

4.4.2. Ignores the Spill-over to adjacent Cities

Spill-over to the adjacent cities are not taken into account. As mentioned before, Tokyo (Tokyo ward district) forms a huge conurbation with surrounding cities such as Yokohama and Chiba (Figure 2.1). These cities do show their own behavior, but they are also strongly influenced by the conditions of Tokyo. Tight supply in Tokyo have caused a certain amount of spillovers to these cities. This factor is not taken into account.
4.4.3. Problems with the Data Series

- The Stock series is artificial (doesn’t assume any demolition)

The model uses stock data generated by adding up all previous construction starts. While this series works, it is an artificial data, in the sense that no demolition is taken into account. Tokyo is not a city with abundant construction sites, so new developments often occur as scrap-and-build processes. Since this is not considered, the stock series used here should be much higher than the actual level.

The series from the Ministry of Home Affairs should be much better in this regard, because it shows the actual existing property. Since this data is collected for taxation purposes, any demolition would be immediately reported. But this series does not yield a statistically significant result. The reason for this is unclear. There may be a reporting error involved. Or it may simply suggest that the model has a low explanatory power. To determine this, one must track down the possible distortions that may be involved in the process. This, however, is beyond the scope of this thesis.

- The vacancy series does not reflect the actual level of vacancy

As pointed out in the explanation of the data, the vacancy series used here reflects a sampling bias. It remains extremely low since the 70s, less than 1% in most periods. This is clearly too low, since there must be some vacancies associated with moving offices and obsolete properties. It does not correspond with the actual level. Since vacancy is one of the most crucial parameters in the model, the low reliability of this series may cast doubt to the whole model.

Combined with the problem of the stock series, the absorption in this model is probably higher than it actually is.
4.4.4. Possibility of Mixing Cause and Effect

The model uses Tokyo GRP as an indicator of office employment, which in turn determines absorption (i.e. demand) and the rent. However, since land serves as the best collateral for loans, there is a possibility that the appreciation of rent (and hence the property value) may be the source of GRP growth, and not the other way around. Appreciating property prices would certainly stimulate the real estate industry’s output, which is a major player in office use.

This would easily become a chicken-or-the-egg argument. Although the lag between the GRP and the absorption seems to suggest that GRP comes first, the movement of rent and land price must have significant effect on the economy in a country where 60% of the total wealth is in land. However, in this model, GRP is an exogenous variable, with no interaction with rents or land prices.

4.4.5. Ignoring the Owner-Occupied properties

The model ignores an important portion of the office market, which is the owner occupied properties. Many office properties are owner occupied, which means that a part of the construction start and the stock are not available for the rental market. There would be a buy-versus-lease decision on the tenant side, which would no doubt depend on the condition of the financial market and tax conditions. DiPasquale and Wheaton (1992) have provided a theoretical basis to understand the interaction of capital and property market, and Chai (1994) have provided a model to integrate the lease-versus-buy (LVB) decision in the dynamic property market. However, this is not taken into account here.
5. Forecast: Outlook of the Tokyo Office Market

The only exogenous variable in this model is the Gross Regional Product (output) of Tokyo. Therefore, based on various growth scenarios, it is possible to perform a contingent forecast of the Tokyo commercial real estate market.

Obviously, absorption cannot exceed the amount of available space. Also, because there will always be some level of transitional vacancies, the vacancy rate will never be zero. Historically, the vacancy has never dropped below 0.2%. To take these into account, in the forecast, I have constrained the absorption so that it always leaves a minimum 0.2% vacancy.

5.1. Growth Scenario

Official forecasts of Tokyo GRP do exist, but are limited to internal use within the Tokyo Prefectural Government, and are not available to the public. Therefore, we will examine several growth scenarios of our own, based on publicized forecasts of the national output (GDP).

5.1.1. No-Growth Scenario

Real GRP remains constant after 1994, and shows no growth. The main purpose of this scenario is to confirm the dynamics within the model. Although experiences in the 90s suggest that anything can happen, given that the Japanese economy is starting to
recover from a recession, this scenario is highly unlikely unless Tokyo is hit by a huge earthquake (which is not an unrealistic prospect in itself, but would probably render the fundamentals behind the model useless).

5.1.2. Low-Growth

Real GRP grows at 1.5% per annum. This seems to be the lower bounds of what people expect from the Japanese economy. The estimated growth for 1994 lie around this level. It is possible that the Japanese economy continues at this sluggish rate.

5.1.3. Standard

Real GRP will grow at 1.5% till 1995, and will keep growing at 3% from 1996. General consensus among various government agencies and think tanks is that, Japan as a whole would grow at this level.

5.1.4. High Growth

This scenario would be the return of the 80s. Although people in the real estate industry often dream and talk about such scenario, how this could be achieved is any one’s guess.

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5.2. Preliminary Results and Model Revision

Applying these scenarios to the model yielded an interesting result. The standard case and the High growth case turns out to be exactly the same (Figures 5.2, 5.3). In reality, this cannot happen. Since GRP here is an indicator of employment, a 5% growth will bring a much higher absorption, which should bid up rents much higher than 3% growth. This indicates a problem with this model.

This is caused by two factors in the model. One is the physically constrained absorption. This model uses the absorption as a proxy for user demand. It is an unsatisfactory proxy to begin with, because there is no way to tell how many potential tenants are out there who didn’t get any floor space. The absorption in this model,
Figure 5.2: Forecast under Standard Growth Scenario
(Original Model with Constrained Absorption)
Figure 5.3: Forecast under High Growth Scenario
(Original Model with Constrained Absorption)
however, is also constrained by the actual supply. When this constraint kicks in, the absorption figure would become completely irrelevant with the user demand. Although there would be more prospective tenants in the high growth case, the model only looks at the constrained absorption, decides that there aren’t much demand out there and determines the rent accordingly.

The other reason is the extremely low vacancy in this case. In other cities, vacancy acts as a cushion. High absorption leads to a lower vacancy rate, pushing up the rent and stimulating construction. In this model, vacancy can hardly go down than it is. Absorption cannot push down the vacancy, and it can only absorb what’s there. With no change in vacancy and absorption, rent and construction will naturally be identical.

There is no work around for the low vacancy. The problem of the constrained absorption can be avoided by setting up two series of absorption: the unconstrained absorption (= desired absorption) and the constrained absorption (= actual absorption). The model will use the desired absorption as the indicator of user demand, and use the actual absorption for all other purposes.

This also gives rise to the question whether we should constrain absorption in this manner to begin with. While it is true that such constraints exist in the real world, we don’t know if this has took place in the past. The statistical fitting process does not assume any constraints in absorption and vacancy. Therefore, to be consistent, the forecast may be better done by ignoring these physical constraints. Furthermore, the model assumes that the market clears at a given rent level. If the absorption is physically constrained, the market can not be cleared. Under such conditions, the landlords should have the ability to hike up the rent to a much higher level since there are many other prospective tenants. The model does not cope with this.

There is a possibility of another work around. A conditional branch could be incorporated into the rent determination process. Under normal vacancy (i.e. >0.2%), the
rent will be determined by the given rent equation. When the vacancy drops below 0.2%,
the rent will be determined by the demand function so that the level of demand comes down
to the level of the available property. However, due to various lags and the simultaneous
nature of the equations, this is difficult to implement under the present structure of the
model.

5.3. Results: 2

5.3.1. No-Growth Scenario

Employment or output will not grow. The dropping rents in 1994-95 will cause a
slight increase in absorption, and vacancy will drop. This will in turn stimulate
construction, which would bring vacancies up again. The rent will drop again, starting the
cycle again. Each cycle lasts for about five years.

The only factor that keeps this scenario going is the falling rent. Even though there
are no growth in the output, the absorption is sustained by the falling rent. Under this
scenario, firms will not grow, hiring will probably occur only to supplement the retirees,
and yet, firms will keep adding more space just because they can afford to. Because of this
absorption, new construction will continue.

In reality, if rents fall below a certain level, new construction would not be
justifiable, and there will be no construction at all. This model does not take construction
costs into consideration, so this does not happen. Rents can theoretically fall indefinitely.
Figure 5.5: Forecast under No Growth Scenario
(Revised Model with Constrained Absorption)
GRP Growth: 1994-1.5%

Figure 5.5: Forecast under Low Growth Scenario
(Revised Model with Constrained Absorption)
GRP Growth: 1994-95: 1.5%, 1996-: 3.0%

Figure 5.6: Forecast under Standard Growth Scenario (Revised Model with Constrained Absorption)
Figure 5.7: Forecast under High Growth Scenario (Revised Model with Constrained Absorption)
5.3.2. **Low-Growth**

The increase in employment will sustain a certain level of absorption. This causes the rent to be fairly stable over time around 27,000 Yen/m². Construction will respond to the drop in vacancy, which would eventually cause vacancy to rise again. Cyclical behavior is observed, although it is less pronounced than the no-growth case. Each cycle is five to six years long.

This scenario is very stable, and it looks very much like the condition during the late 70s and early 80s. Rent remains stable. Absorption remains stable because of the output growth. Vacancy fluctuates between 0.3% and 1%, which causes the construction to fluctuate, which in turn causes the vacancy to fluctuate. This results in the cyclic behavior, but it is minimal.

5.3.3. **Standard**

The growth of GRP causes the desired absorption to increase at a steady pace. This pushes up the rent, which in turn stimulates the new construction. Actual absorption catches up with the desired absorption around the year 2001.

Vacancy plays a very small role in this scenario. It is pushed down at 0.2%, and never moves. This limits the dynamics of the model significantly. No cyclical behavior is observed⁶.

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⁶ If we allow the vacancy to become negative as a pure mathematical exercise, the model demonstrates a cyclical behavior under any scenario. See appendix for these results.
If vacancy were allowed to play a more active role, it would have further increased the rent to cool off demand. It would also have caused more construction activity, which would eventually have overshooted and brought the vacancy up again.

Since vacancy cannot move, the increased absorption affects the model only through rent. However, the huge absorption takes up all the new construction, and the increasing rent is not enough to cool down the demand. Construction is responding to the rise in rent, but rent appreciation is not enough to push up construction above the desired absorption.

The reality of this outcome is debatable. Even if every property filled up as soon as it is completed and there are no vacancies what so ever, rents only grow at 3% per year. There are huge number of prospective tenants who never gets any property. Obviously, these tenants should bid up the rent to a level where demand matches supply. The higher rent would bring more construction activity. Clapp (1993) criticizes the Torto-Wheaton model, pointing out that it puts the burden of market adjustment solely on rent. Since vacancy is an “inventory” for the landlords, under a disequilibrium, landlords will make effort to adjust the vacancy rate as well as the rent, in order to achieve the desired level of inventory/vacancy. If such a mechanism were present in the model, it might help the faster appreciation of the rent, stimulating further construction.

5.3.4. **High Growth**

The fast growth of GRP causes the desired absorption to increase at an enormous pace. This pushes up the rent at a fast pace, which in turn stimulates the new construction. However, it never catches up with the desired absorption.
Here, the rent grows at a steady rate of about 5%. GRP growth and the rent growth are almost identical. This is not surprising, because with vacancy fixed, the rent depends entirely on GRP.

Vacancy is not allowed to do anything in this scenario. Once again, the increase in absorption only works through the rent appreciation, and the only thing different from the . With a better vacancy series, the high desired absorption will push down the vacancy, which will bring higher rents and construction levels. Construction will catch up faster, possibly overshooting, causing a cyclical behavior observed in the no-growth case.

The level of rent and construction achieved under this scenario is similar to that of the late 80s. Since the model is based on the data from these periods, this comes as no surprise. However, the same criticism as the standard growth scenario applies here, too. If there’s no vacancy, and demandis there, then the rent should soar. If the market is so tight and number of firms that might be willing to pay higher rent are looking for offices in vain, developers would decide to build much more than is suggested here.

5.3.5. Remarks

In every case, 1994 sees a significant drop in rents, absorption and construction. Vacancy will increase sharply. This is a result of the drop in GRP in 1992, and the new properties that come on to the market. 1995 will see a further drop in rent and construction.

As of this writing, the 1994 rent data has become available, which showed a 25% drop since 1993 in nominal terms. The model suggests a 23% drop in real terms. Inflation in Japan is about 1%, so the model forecast should translate into 22% nominal drop, . The two figures are very close, which speaks quite favorably for the forecasting power of this model.
With higher growth rate, the problem of the constrained supply casts doubt on the reliability of the result. However, it seems that given a sufficient growth of the economy, the activities in the real estate market will once again rise to the level of the late 80s.
6. Conclusion

6.1. Empirical Findings

The model here assumes that all firms use all available information rationally to determine their action. Judging from the statistical significance of each model equation, this assumption holds very well. It could be concluded that the Tokyo office market behaves quite rationally.

6.1.1. Absorption

88% of the office absorption in Tokyo can be explained by the lagged regional output (GRP) and lagged rent. It is positively correlated with the lagged GRP and negatively correlated with rent. This relation intuitively makes sense. About 22% of the desired adjustment in occupancy is made each year.

At the present level of rent at 40,000 Yen/m²/month, 1.8m² is demanded to produce one million yen of output. This will decrease / increase as the rent rise / fall. The price elasticity of office demand is 0.2 as of 1993, which shows that office demand is relatively inelastic in Tokyo.

In Tokyo, the “space banking” argument does not show significance unlike in the American cities. Even under a high growth situation, Tokyo firms would not want to occupy extra space.
6.1.2. \( \Delta \text{Rent} \)

64% of the rent movement is explained by the vacancy and the rate of absorption over office stock. As the search theory suggests, higher vacancy will cause the rent to drop, and higher absorption ratio will cause the rent to drop. This intuitively makes sense. In a market with higher vacancy, the prospective tenants will have more bargaining power. Higher absorption ratio (i.e. higher demand) will give more power to the landlord, since she can afford to wait for the next prospective tenant.

The change in desired rent is very sensitive to vacancy. If there are no absorption, 0.84% vacancy will stop the rent appreciation. Even under the current absorption ratio of 0.04, a vacancy of 2% will bring the desired rent to a halt.

Only 13% of the rent adjustment can actually be made each year. Re negotiation of rent in Japan usually happens every two years, so 13% is quite low.

There are no lags involved. This implies that landlords and tenants will try to adjust the rent in real time. Vacancy and absorption data are not available real time, but in the model, these are proxies for the negotiating power of each side. Both sides seem to have a very good feel for the market.

6.1.3. Construction Starts

In the construction model, 86% of the construction start is explained by lagged vacancy and the change in rent. Lagged vacancy is negatively correlated with construction starts, and the change in rent is positively correlated. Naturally, under high vacancy, developers will be reluctant to build, and when rents are appreciating, more developers will be willing to build.
Vacancy has one year lag. The rent appreciation has none. This means that developers react almost instantaneously to the market condition.

2.7% vacancy will bring the desired construction to zero, if there are no rent increases. 11,200 yen drop in rent will also cause the same effect. Even under these conditions, 56% of last year's construction level will happen this year, because construction start moves rather smoothly from year to year.

6.1.4. Forecast Results

The model has only one exogenous variable, namely the regional output (GRP) of Tokyo. A contingent forecast was made based on various growth scenarios.

1994 sees a significant drop in rents, absorption and construction. Vacancy will increase sharply. This is a result of the drop in GRP in 1992, and the new properties that come on to the market. 1995 will see a further drop in rent and construction.

The actual 1994 rent figure showed a 25% drop since 1993 in nominal terms. The model suggests a 23% drop in real terms. With 1% inflation, this translates into 22% nominal drop, which is very close to the actual figure.

After that, the market condition will be dependent on the GRP growth. Low growth will produce a cyclic behavior, with a cycle of five to six years.

Above 1.5% growth, the model and/or the market displays some problems. The vacancy immediately becomes non-existent. Absorption is constrained, which means that the market is not clearing, thus undermining the assumption behind the model.

Vacancy being held constant, half of the dynamics within the model is gone. Generally, a higher GRP growth will produce a higher rent, absorption and construction activity. The rent growth roughly matches that of the GRP.
6.2. Theoretical Implications

Tokyo office market provides us with an interesting case of a market under extremely low vacancy. Under such condition, observed absorption will physically be constrained by the available amount of floor space, which means that supply does not match demand. Under this condition, the original Torto-Wheaton model which uses the observed absorption as the proxy for user demand cannot function properly.

The thesis proposed a limited work around for this problem, by separating the desired absorption and the actual (physical) absorption. This provides a limited result. When there is a discrepancy between the two absorption, rents will appreciate slightly faster, causing a slightly higher construction activity. the rent growth is similar to the level of GRP (or employment) growth.

However, when the desired absorption is 60% above the physically available floor space as is demonstrated in the 5% growth scenario, it is hard to think that the rent appreciation will remain at 5% per year. The bidding process should result in a much higher level of rent, causing desired absorption to match the level of the available space.

This suggests that there should be another rent determination mechanism for such conditions, which takes into account the bidding process under limited supply. Since the rent equation of the Torto-Wheaton model gives us the demand curve, the new formula will choose the level of rent where demand matches the physical supply.

This is easy to say, but very difficult to test empirically. According to the vacancy series used here, Tokyo has historically maintained a very low vacancy rate, almost constantly below 2%. This means that Tokyo office market can and probably has went through this constrained supply situation. However, since the possible absorption under unconstrained supply cannot be observed, it cannot be tested using the historical data.
6.3. Limitations of the Model and Areas of Further Study

The limitation of the model comes from several areas. One is the problem with the available data, such as vacancy and office stock. Vacancy clearly is too low, even in the tight Tokyo market. Office stock used here does not assume demolition, and includes a large portion of owner occupied space. This may distort the results, and require further investigation. Hopefully, more reliable data series will become available in the future.

Another is the problem of its behavior under low vacancy or constrained supply, which is described in the theoretical implications above.

Owner occupied property is an area that require future attention. Although the tenancy data is not available, Tokyo office market includes a large amount of owner occupied properties. It would be a problem to treat them all as if they were rental properties. Furthermore, the proper grasp of the owner occupied properties will surely lead to a clearer understanding of the land/asset price in Japan, which should be extremely valuable. Interest rate, tax, construction costs would be taken into account for such a study.

Even given these limitation, this thesis provides a valuable insight toward the dynamics within the Tokyo commercial real estate market and the behavior of its players. The forecasting power that the model demonstrated for the 1994 rent shows its usefulness in practical application for anticipating the market condition in the near term future. Hopefully, these understandings will aid better decision making in the industry.
Appendix

A.1. Data Sets

The following data are used. All results should be reproducible using these figures.

<table>
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<th>Year</th>
<th>Construction Start (1000m²)</th>
<th>Office Stock (m²)</th>
<th>Vacancy (%)</th>
<th>Real Rent (1987 Yen)</th>
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<th>Tokyo GRP (mill., 1987 Yen)</th>
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Sources: Office Construction Start: Ministry of Construction
Office Stock: Ministry of Home Affairs
Vacancy: Jaoan Building Association
OfficeRent: IDSS
Land Price Index Japan Land Institute
Tokyo GRP: Ministry of Home Affairs
A.2. The Unconstrained Forecast

As stated in the text, the forecast used in the paper constrains absorption to make it consistent with the real world. However, the modeling, or the statistical fitting process totally ignores this constraint. Also, constraining absorption violates the assumption that the market clears. In order to be loyal with the assumption, I have made an unconstrained forecast model. It uses the model formulas without any modification.

In this variation, the absorption equation does not check whether there is enough floor space available to be absorbed. As a result, vacancy becomes negative in some periods, so the outcome does not have much meaning in the real world. This is more of a mathematical exercise. However, the results provide an understanding of the model mechanism.

Allowing the vacancy to do its job creates more dynamic results. The drop in vacancy stimulates both rent and construction. In every case, we can observe a boom and bust cycle of about five years. We can clearly see that the cyclic behavior is inherent in the model, and/or the market. The difference among the scenarios lie in the level of the peaks and their trend, which more or less follows the growth of the GRP.
Figure A.1: Forecast under No Growth Scenario (Absorption not Constrained)
Figure A.2: Forecast under Low Growth Scenario (Absorption not Constrained)
Figure A.3: Forecast under Standard Growth Scenario (Absorption not Constrained)
Figure A.4: Forecast under High Growth Scenario
(Absorption not Constrained)
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