Dynamics of Private Industrial Space Demand in Singapore

Author Tien F. Sing

Abstract

This study empirically examines the dynamics of the private industrial market in Singapore using a Vector Error Correction Model (VECM), which is derived based on the theoretical framework of an extended accelerator investment model. The GDP in manufacturing sector (*LMGDP*) and the composite leading indicator (*LCLI*) were two unrestricted long-run forcing variables included in the VECM for the industrial space demand. In the generalized forecast error variance decomposition analysis, one-standard deviation shocks to the manufacturing GDP (*LMGDP*) was found to account for an average 67.10% of the variances of the private industrial space demand (*LPRD*). It was also found that the most volatile impulse responses from the industrial demand variance were inflicted by one-standard error shocks on the ecm and the manufacturing GDP terms.

Introduction

In Singapore, industrial real estate demand or take up in both private and public markets has been predicted in an adaptive process by looking at the absorption rate in the previous periods. The supply of new industrial real estate stocks was adjusted in a piece-meal basis with the objective of meeting the demand projection, which would presumably not differ substantially from the previous year's take-up.[1] Koh (1987) undertook a rigorous study of industrial real estate stock demand using a two-stage least squares model. He found significant relationships between the industrial space demand and economic variables like industrial output, gross domestic product, manufacturing employment and wage, interest rate and investment commitment. In Koh's model, the positive effects of industrial output on the industrial real estate demand were indirectly channeled via the employment equation. There were also other unpublished researches that used Shenkel's (1965) employment model (Lam, 1984) and multiple regression models (MRM) (Chan, 1976; and Mao, 1977)[2] to determine the industrial real estate stock investment in Singapore.

There were no direct tests of the acceleration effect of the industrial output on the industrial real estate stock in Singapore. The earlier empirical studies that tested the flexible accelerator models were based primarily on the industrial real estate data in the United States and the United Kingdom (Nicholson and Tebbutt, 1979; Wheaton and Torto, 1990; Giussani and Tsolacos, 1994; and Tsolacos, 1995). They all found positive relationships between industrial real estate stock adjustments and manufacturing outputs. When the test of the acceleration effects is done on the industrial real estate market in Singapore, two factors need to be taken into consideration. First, Singapore has gone through different phases of industrialization than the U.S. and the U.K. (Zhu, 2000).[3] For manufacturing firms that move up the technological ladder, more physical real estate stock would be substituted for investments in advanced productive capitals. As a result, the level of production output may increase at the expense of smaller real estate capitals. Second, the constraint of land resource in Singapore may create inelasticity in the supply of physical industrial real estate stocks. Firms may, therefore, be induced to invest and procure more physical real estate stocks than required during the weak output cycle. They could then optimize the excess real estate stocks when the output cycle rebounds.

The technology-related substitution and the land resource constraint factors may create negative acceleration effects on the industrial real estate stock adjustment process. This study thus attempts to test the dynamics of private industrial real estate stock demand in Singapore using an expanded flexible accelerator model. This article is organized as follows. First, the empirical literature on industrial real estate is reviewed, which helps sets the objectives of the study. Next, the salient features of the structure and the stock-flow process of the industrial market in Singapore is discussed. This is followed by a discussion of the theoretical accelerator model that incorporates other economic variables. Next, the empirical methodology and data are discussed. An industrial real estate demand function that comprises both the long run correction and short run fluctuations of the economic variables is formulated using a vector error correction model (VECM) with lag terms. Based on the proposed VECM structure, the post estimation analyses that include in-the-sample forecasting, impulse response and variance decomposition of the shocks to exogenous variables are discussed. The final section presents the conclusions.

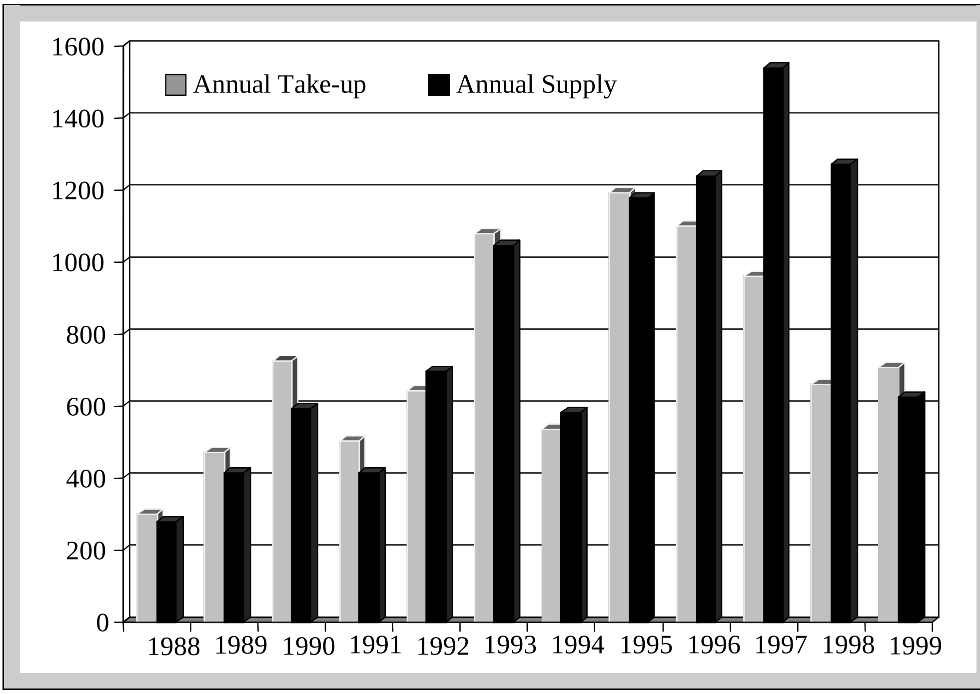
Singapore's Private Industrial Real Estate Market

For a land and resource scarce country, Singapore has been transformed into one of the fastest growing economies in the world in the thirty-five years since independence. The main engine of growth has been the manufacturing sector, which accounted for 25.17% of the total gross domestic product (GDP) on average for the periods from 1985:1 to 1999:4. Currently, the land allocated for industrial use constitutes 12.2% of the total available land,[4] of which approximately 76.2% (as in 1985) was made up of state lands.[5] The state lands for industrial use are supplied to the market via two channels: inter-government agency alienation and the government's land sale program. Industrial lands are alienated to government agencies involved in industrial development, which include Jurong Town Corporation (JTC), Housing Development Board (HDB), Port Authority of Singapore (PSA) and Land Transport Authority (LTA). Private developers or manufacturing firms are also allocated industrial lands via the land sale by tender program administered by the Urban Redevelopment Authority (URA). Privately owned industrial lands are another source of industrial real estate supply. Private industrial lands are mainly held in 99-year, 999-year or freehold tenures, whereas the industrial lands coming through the state-channels are either via the land sale or alienation arrangement on shorter leasehold tenures of either 30- or 60-years.

In 1968, the government of Singapore set up JTC to spearhead the industrialization plan and to develop large scaled industrial real estate facilities in the post-independent period. JTC has satisfactorily fulfilled its role as the national industrial development authority and become the largest supplier of industrial facilities in the country. To date, it has developed and managed thirty-five industrial estates in Singapore, which accommodate more than 7,000 companies in Singapore.[6] There are three types of industrial facilities developed and provided by JTC: ready-built detached and flatted factories and prepared industrial land. The ready-built industrial facilities can be procured through either rent or purchase schemes. For firms that require customized factory premises, they can lease a prepared industrial land from JTC on 30-year, 30+30-year or 60-year leases and develop on it a build-to-specification factory that meets the investment and building criteria stipulated by JTC (Sing, 2002). HDB is another major public industrial facilities supplier, which develops mainly multi-tenanted factories and workshops in housing estates to directly tap the source of labor supply. PSA and LTA are not directly involved in the supply of industrial real estate stocks. The former develops and manages warehouses, whereas the latter uses industrial land mainly for vehicle depots.

Based on the real estate statistics[7] compiled by the URA, the private market share of industrial stock varied from 65.24% to 75.49% from 1988 to 1999. A substantial portion of the private sector supply, as captured in the statistics, was made up of customized industrial premises built on land leased from JTC. The average annual private sector supply and take-up for 1988–1999[8] were recorded at 823,060 square meters (sm) and 739,670 sm. Exhibit 1 shows the annual supply and take-up data of industrial real estate stocks between 1988 and 1999. There was an apparent upward trend in the supply and demand of industrial real estate after 1992, which was partly caused by the active and more systematic industrial land sale program implemented by the URA. The annual supply of industrial real estate stock increased almost four-fold from 413,000 sm in 1992 to 1,538,000 sm in 1997. The industrial real estate demand also indicated a strong upward trend since 1988 before hitting the peak in 1995 with an annual take-up of 1,193,000 sm. Thereafter, the demand slowed down and hit the slump in 1998 following the aftermath of Asia's currency crisis in 1997. Weak demand and excess supply as a result of the failure of private industrial developers to defer their industrial development projects jointly contributed to the glut of industrial space in 1997 and 1998.

Exhibit 1 | Annual Supply and Take-up of Private Industrial Real Estate Stocks (1988–1999)



Notes: The data are computed up to 1999:3. Source: URA real estate statistics.

Theoretical Framework: Accelerator Model

The accelerator model predicts a positive relationship between investment expenditure and the rate of adjustment of the fixed capital stock to the desired level, on the assumption that there are no substitution and vintage effects between the real estate and other fixed capital stocks. Based on the accelerator model, investment in real estate stock can be derived in an acceleration pattern by increases in industrial output. There are variations in the time structure and rate of adjustment of the accelerator model. Clark (1917) proposed a rigid version of the accelerator model, which assumes no time lag in the delivery of the shortfall in capital stock. Chenery (1952) and Koyck (1954) proposed a flexible version of the accelerator model, which allows partial adjustments of actual and desired capital from period to period.

The accelerator model has been extended with variations to empirically analyze the industrial real estate stock adjustment process (Giussani and Tsolacos, 1994; Tsolacos, 1995; Nicholson and Tebbutt, 1979; and Wheaton and Torto 1990). In the early studies, different empirical data were used to proxy the industrial real estate stock, which include the new order of non-residential construction (U.K.) (Nicholson and Tebbutt, 1979), the stock of completed industrial space in fifty-two major metropolitan areas in the U.S. (Wheaton and Torto, 1990), the value of new orders of private industrial buildings and works in the U.K. at both the national level (Giussani and Tsolacos, 1994) and regional level (Tsolacos, 1995). The results all pointed to a significant positive relationship of the industrial stocks and the lagged changes in output.

In the neo-classical production function that consists only of two factors of production: capital (K) and labor (L), the output can be represented by a Cobb-Douglas function as $Q = AK^{\alpha}L^{\lambda}$, where A measures the scale or productivity of firms with a specific technology, α and λ denote the elasticity of scale, such that the constant return to scale is defined when $\alpha = 1 - \lambda$. In this model, K is invariably referred to the production capital (K_p), which takes the form of plant and machinery investment. The physical real estate investment (K_r) is either implicitly subsumed under K, or it can be made explicit as an arithmetic component of K (*i.e.*, $K = K_p + K_r$), on the assumption that the two capitals are perfectly substitutable. However, the perfect substitutability assumption will no longer be valid, if K_r is inelastic in the short-term and vintage effects exist between K_p and K_r.[9] The two-factor production function may have to be expanded to incorporate K_r and K_p as two independent variables in the output function, $Q = f(K_p, K_r, L)$.

For empirical analysis purposes, however, K_r is regarded as the sole endogenous variable in the capital-output function by assuming that K_p and L are perfectly elastic in supply. The desired real estate stock, K_r^*, can then be represented as:

$$K_{r,t}^* = \mu^{\sigma}\left(\frac{p_t}{c_t}\right)^{\sigma} Q_t, \qquad (1)$$

where p is the product price, c is the user cost of capital, σ is the elasticity of substitution and μ is the coefficient of capital in the production function. The user cost of capital, given the zero-tax environment, could be simplified to the following equation:

$$c = q^*(\delta + \iota) - dq, \qquad (2)$$

where q is the purchase price of new capital, δ is the rate of capital depreciation, ι is the interest rate and dq is the gain resulted by the product price increases. In the empirical model, q can be included as both supply-side and demand-side variables. From the developer's perspective (supply-side), q is represented by the building material costs, whereas from the user's perspective (demand-side), it is more appropriately represented by the industrial real estate price.

As ‘‘time to build’’ is an inherent feature in the delivery and construction of real estate stock (Kling and McCue, 1991), time lags in the stock adjustment process are inevitable. The rigid form of Clark's (1917) investment model is, therefore, not realistic. A more flexible form of stock adjustment model allows backlogs of undelivered or uncompleted stocks from the earlier periods to be partially fulfilled by the current period investment (I_t). β is the coefficient that regulates the previous periods' gaps between desired and actual stock. The desired level of new investment (I_t), which excludes the replacement capital (δK), is defined as:

$$
\begin{aligned}
I_t^* &= \beta^* \lambda(L)^* (K_t^* - K_{t-1}^*) \\
&= \beta^* \mu^* \lambda(L)^* \left[\left(\frac{p_t}{c_t}\right) Q_t - \left(\frac{p_{t-1}}{c_{t-1}}\right) Q_{t-1} \right], \qquad (3)
\end{aligned}
$$

where the elasticity of substitution is unity, $\sigma = 1$, and $\lambda(L)$ in the equation denotes the power series of the coefficient of adjustment in the lag operator, L. The theoretical model in Equation (3) forms the basic framework for the empirical analysis.

The composite leading indicator (CLI) that reflects the business confidence and prospects is included in the empirical model as a variable that represents the rational expectation of decision makers as argued in the critique of Lucas (1976). On the supply-side, unfilled space and changes in available floor space were found to be empirically significant in affecting industrial space demand by Giussani and Tsolacos (1994) and Tsolacos (1995). Therefore, the new annual industrial space supply by both public sector (PBS) and private sector (PRS) are included as flow variables that regulate the supply-demand mismatches in the industrial real estate market.[10]

Based on the extended flexible accelerator model and the user cost of capital function defined above, the reduced form empirical model for the industrial real estate stock demand (ΔK_r) is specified as:

$$
\Delta K_r = f(Q, q_b, q_r, \iota, dq, CLI, PBS, PRS), \qquad (4)
$$

where:

ΔK_r = Demand for private industrial space;
Q = Manufacturing output;
q_b = Building materials and construction costs;
q_r = Industrial real estate price;

ι = Current bank interest rate;
dq = Capital gain, which is represented by the changes in price level or the more commonly known inflation rate (IF) term;
PBS = Supply of public industrial space (JTC & HDB); and
PRS = Supply of private industrial space.

Empirical Methodologies

Data Source

In the earlier empirical studies, new construction order (Nicholson and Tebbutt, 1979; Giussani and Tsolacos, 1994; and Tsolacos, 1995) and completed stocks (Wheaton and Torto, 1990) of industrial real estate have been used to proxy the industrial stock demand. The construction starts and accumulated inventory figures are flow variables that represent the upstream process of investment decision. These variables may, however, not reflect adequately the time lags in the stock delivery and vacancy when the stock adjustment process is ''sticky,'' (Grenadier, 1995).

This study covers the demand for the private industrial space in Singapore for a twelve-year period from 1987:4 to 1999:3. The quarterly time-series data of the cumulative industrial real estate stocks compiled by the URA of Singapore[11] provides a direct measure of the actual take-up of physical industrial real estate inventory stocks. The net change in the occupied stocks between two consecutive quarters is used as a direct proxy for the private industrial space demand.

The industrial property price index published by the URA, which is computed based on caveats lodged with the Singapore's Land Registry, is the proxy for the price variable. This index shows the relative price between the current per square meter price and that in the base year of 1990. Other economic variables are obtained from the national statistic database, TRENDS, administered by the Department of Statistics of the Trade and Industry Ministry. The dependent and independent variables identified in the empirical model are listed in Exhibit 2. With the exception of the current bank interest rates and the inflation rate variables, all other variables are transformed into their natural logarithm terms. Then, the first order difference terms of the variables are computed.

Vector Error Correction Model for Industrial Space Demand

Based on the flexible accelerator and neo-classical investment model discussed earlier, the following empirical demand model is conceptually derived to explain the causal-relationships between the demand for private industrial space and other economic variables,

Exhibit 2 | Description of Dependent and Independent Variables in Empirical Model

Symbol in Theoretical Model	Empirical Model: Variable in Level	Empirical Model: Variable in Natural Logarithm Term	Variable in 1st Difference Term ($\Delta X_t = X_t - X_{t-1}$)	Definition of Time Series Data Used in the Empirical Analysis
Kr	*PRD*	*LPRD*	*DLPRD*	Private industrial space cumulative demand (sm)
Q	*MGDP*	*LMGDP*	*DLMGDP*	GDP in manufacturing at 1985 prices
q_b	*BMPI*	*LBMPI*	*DLBMPI*	Building Materials Price Index (1985 = 100)
q_r	*IPPI*	*LIPPI*	*DLIPPI*	Private Industrial Property Price Index (1990 = 100)
ι	*IR*	N.A.	*DIR*	Current Bank Interest Rates
dq	*IF*	N.A.	*DIF*	Inflation rate is estimated as $IF = ln(CPI_t / CPI_{t-1})$, where *CPI* = Consumer Price Index (1990 = 100)
CLI	*CLI*	*LCLI*	*DLCLI*	Composite Leading Indicator (1990 = 100)
PBS	*PBS*	*LPBS*	*DLPBS*	Public industrial space cumulative supply (sm)
PRS	*PRS*	*LPRS*	*DLPRS*	Private industrial space cumulative supply (sm)

Note: The time-series data are obtained from TRENDS database of the Department of Statistics, Ministry of Trade & Industry. The data are in their quarterly series.

$$LPRD = f(LMGDP, DLIPPI, LBMPI, IR, IF, LCLI, LPBS, LPRS). \tag{5}$$

The gross domestic manufacturing product (*LMGDP*) is the closer proxy for the firms' performance in the manufacturing sector. The Composite Leading Indicator (*LCLI*)[12] in the model provides a forward-looking indication of the economic outlooks and investors' confidence of the country. The two variables: *LMGDP* and *LCLI*, were found to establish significant long-run cointegrating relationships with the private industrial space demand (*LPRD*), in the pair-wise cointegration tests conducted using the Engle and Granger (E-G) (1987) two-stage estimation procedure (Exhibit 3). The results thus suggest that the manufacturing GDP and the composite leading indicator be included in the empirical model as long-run

Exhibit 3 | Results of Unit Root and Cointegration Tests

	Unit Rood Test[1]	Pair-wise Cointegration Test[2]		
Empirical Variables	Stationarity at Level (d)[3]	Regression Coeff. (β_t)	ADF(1) Test on Residual Term (Z_t)	Reject H_0?
LPRD	I(1)	na	na	na
LMGDP	I(1)	1.0282	−3.6610	Yes
LBMPI	I(0)	1.8982	n.a.	na[a]
LIPPI	I(2)	0.5008	n.a.	na[a]
IR	I(1)	−0.0022	−0.4503	No
IF	I(1)	−8.7357	−2.6190	No
LCLI	I(1)	1.5811	−4.3646	Yes
LPBS	I(1)	2.3911	−3.2347	No
LPRS	I(1)	0.9762	−0.6087	No

Notes: 95% critical value for the ADF statistic = −2.9320. 95% critical value for the cointegrating-residual ADF statistic = −3.4848. A non-stationary time-series X_t that can be transformed to a stationary series by differencing d times is said to be integrated of order d, which is conventionally denoted as $X_t \sim$ I(d). If X_t is stationary in level, then no differencing is necessary, and $X_t \sim$ I(0).

[a] Two non-stationary economic time series are said to be cointegrated if the residuals of the linear combination of two series of the same order of integration were stationary. However, the cointegration tests were not done between *LPRD* and *LBMPI* and *LIPPI* because the three variables are integrated of different orders: *LPRD* ~ I(1), *LBMPI* ~ I(0) and *LIPPI* ~ I(2).

variables. The rest of the variables would be considered as short-run variables in the empirical model.

Unlike the empirical models of Kling and McCue (1991), Giussani and Tsolacos (1994) and Tsolacos (1995), a rental variable is not included in the empirical model due to the short rental time-series data for the private industrial space.[13] The rental effect is captured by the private industrial property price index (*LIPPI*). However, as *LIPPI* is I(2) stationary as shown in the unit root tests[14] (Exhibit 3), its first-difference term (*DLIPPI*) is represented in the demand function.

Cost is an important consideration for profit maximizing firms when evaluating the feasibility of industrial real estate projects. Building Material Index (*LBMI*) is the supply side proxy for the construction costs of industrial space, whereas the user cost of capital is used as a demand-side variable that measures the feasibility of industrial real estate projects. Omitting the tax factor, the user cost of capital is empirically represented by the prime interest rate (*IR*) and the inflation (*IF*), which reflects the transitory gain component of the user cost of capital.

The availability of industrial real estate stocks was found to be a significant factor in affecting the choice of industrial space by firms (Giussani and Tsolacos, 1994; and Tsolacos, 1995). The private supply (*PRS*) and public supply (*PBS*) of industrial space[15] are included in the empirical model to examine the effects of private and public inventory stocks on the industrial space demand.

The vector error correction model (VECM) for private industrial space demand empirically combines both the long run and short run variables in a single regression equation. The manufacturing GDP and the composite leading indicator are unrestricted independent variables identified to have long-run relationships with the industrial demand variable. All other variables are included as exogenous stationary variables,[16] either as first (DX_i) or second ($D2X_i$) order differenced variables, where X_i denotes the variable, to capture the short-run effects in the demand function.

Formulation of Vector Error Correction Model (VECM)

The Johansen's Maximum Likelihood (ML) tests of a four-period lagged[17] Vector Autoregressive (VAR) private industrial space demand model with an unrestricted intercept and no trend term showed that there was at most one significant cointegrating vector in the model (Exhibit 4). The normalized cointegrating vector, which would be included as the long-run error correction mechanism (ecm) in the VAR model, is given below:

$$\text{ecm} = 1.0000{*}LPRD - \underset{(0.6796)}{2.6553{*}LMGDP} + \underset{(1.0483)}{2.5431{*}LCLI}. \tag{6}$$

The standard errors, given in the parentheses of Equation (6), show that the estimated coefficients for *LMGDP* and *LCLI* are significant at the 5% level.

The ecm identified in Johansen's ML process is incorporated into the empirical VAR model to adjust for short-term deviations in the system. The final model, which is known as vector error correction model (VECM), with 4-lag orders is formulated to explain the causal-relationships between the change in private industrial space demand and other economic variables. The estimation results of the VECM model that consists of two unrestricted long run variables: the manufacturing GDP (*LMGDP*) and the composite leading indicator (*LCLI*), an error correction mechanism (*ecm*) and other short-run variables in their respective differenced stationary order were summarized in Exhibit 5.

The R^2 of the VECM model indicated that the unrestricted long run variables, the error correction term and the exogenous economic and real estate market variables jointly explain 86.40% of the variations in the change in industrial stock demand.

Exhibit 4 | Johansen's Maximum Likelihood Cointegration Test

Null	Alternative	Statistic	95% Critical Value	90% Critical Value
Panel A: Maximum Eigenvalue				
$r = 0$	$r = 1$	24.276	21.12	19.02
$r <= 1$	$r = 2$	6.625	14.88	12.98
$r <= 2$	$r = 3$	0.004	8.07	6.50
Panel B: Trace Statistic				
Null	Alternative	Statistic	95% Critical Value	90% Critical Value
$r = 0$	$r >= 1$	30.9049	31.54	28.78
$r <= 1$	$r >= 2$	6.6288	17.86	15.75
$r <= 2$	$r = 3$	0.0042	8.07	6.50
Panel C: Selection of Cointegrating Vectors Using Model Selection Criteria				
Rank	Maximized LL	AIC	SBC	HQC
$r = 0$	422.441	374.441	331.620	358.561
$r = 1$	434.579	381.579	334.298	364.045
$r = 2$	437.891	381.891	331.934	363.365
$r = 3$	437.893	380.893	330.044	362.036

Notes: Forty-four observations from 1988:4 to 1999:3. Order of VAR = 4.
Variables included in the cointegrating vector: *LPRD*, *LMGDP* and *LCLI*.
Variables [I(0)] included in the VAR: *DLPBS, DLPRS, DIR, D2LIPPI, DLBMPI* and *DIF*.
Eigenvalues in descending order: .42405, .13977, .9466E-4.
AIC = Akaike Information Criterion
SBC = Schwarz Bayesian Criterion
HQC = Hannan-Quinn Criterion

The diagnostic test showed that the model has a robust functional form. The VECM model was also cleared of serial correlation problems, which was the result of a correct selection of the lag-length and the inclusion of the ECM term in the model.

The coefficient of *ecm* has a correct sign and is statistically significant at 5% level. However, the small value of −0.0559 for the *ecm* coefficient suggests that it would take a long time for the system to return to its equilibrium once it has been

Exhibit 5 | Vector Error Correction Model

Regressor	Coefficient	Standard Error	T-Ratio[Prob]
Intercept	−0.0859	0.0214	−4.0141[.000]
DLPRD(−1)	0.0144	0.0844	0.1708[.866]
DLMGDP(−1)	−0.0992	0.0286	−3.4662[.002]
DLCLI(−1)	0.2415	0.0632	3.8214[.001]
DLPRD(−2)	0.0435	0.0892	0.4872[.630]
DLMGDP(−2)	−0.0642	0.0218	−2.9414[.007]
DLCLI(−2)	−0.0217	0.0891	−0.2432[.810]
DLPRD(−3)	−0.0679	0.0860	−0.7890[.437]
DLMGDP(−3)	−0.0372	0.0159	−2.3401[.027]
DLCLI(−3)	0.1745	0.0692	2.5207[.018]
ecm(−1)	−0.0559	0.0141	−3.9713[.000]
DLPBS	0.0792	0.0708	1.1181[.273]
DLPRS	0.9405	0.0885	10.6210[.000]
DIR	−0.0007	0.0007	−1.0517[.302]
D2LIPPI	−0.0124	0.0139	−0.8872[.383]
DLBMPI	0.1969	0.0589	3.3431[.002]
DIF	0.2953	0.2029	1.4557[.157]
F-Stat. F(16, 27)			10.7198[.000]

R^2	0.8640
R^2-Bar	0.7834
S.E. of Regression	0.0042
Mean of Dependent Variable	0.0173
Std. Dev. of Dependent Variable	0.0091
Residual Sum of Squares	0.0005
Equation Log-likelihood	188.9476
Akaike Info. Criterion	171.9476
Schwarz Bayesian Criterion	156.7820
DW-Statistic	2.3437
System Log-likelihood	434.5789

shocked. Other variables that show significant explanatory relationships with respect to the changes in industrial space demand include the manufacturing GDP variables in their first, second and also third order lags [*DLMGDP*(−1), *DLMGDP*(−2), *DLMGDP*(−3)], the first and third order lagged composite leading variables [*DLCLI*(−1) and *DLCLI*(−3)], the private sector supply variable (*DLPRS*) and the building material price index variable (*DLBMPI*), both in level

Exhibit 5 | (continued)

Vector Error Correction Model

Notes: Forty-four observations are used for the estimation from 1988:4 to 1999:3. ECM for variable LPRD estimated by OLS based on cointegrating VAR(4). Dependent variable is *dLPRD*. The negative numbers in the parentheses after the variable name indicate the lag order of the variable.
S.E. = Standard errors
DW = Durbin-Watson
Std. Dev. = Standard Deviation
[Prob.] = Probability of not rejecting the null hypothesis, H_0: $b_i = 0$, $i = (1,2,...n)$, where b_i is regression coefficients.

Diagnostic Tests:

Test Statistics	**LM Version**	**F Version**
A: Serial Correlation	CHSQ(4) = 5.1572[.272]	F(4, 23) = .7634[.560]
B: Functional Form	CHSQ(1) = 3.0039[.083]	F(1, 26) = 1.9051[.179]
C: Normality	CHSQ(2) = 0.5596[.756]	na
D: Heteroscedasticity	CHSQ(1) = 0.0335[.855]	F(1, 42) = 0.0320[.859]

A: Lagrange multiplier test of residual serial correlation.
B: Ramsey's RESET test using the square of the fitted values.
C: Based on a test of skewness and kurtosis of residuals.
D: Based on the regression of squared residuals on squared fitted values.

terms. By dropping the variables that are not statistically different from zero, the parsimonious form of the VECM for the industrial demand (*DLPRD*) can be specified as follows:

$$\begin{aligned} DLPRD = {} & -0.0859 - 0.0991{*}DLMGDP(-1) \\ & + 0.2415{*}DLCLI(-1) - 0.0642{*}DLMGDP(-2) \\ & - 0.0372{*}DLMGDP(-3) + 0.1745{*}DLCLI(-3) \\ & + 0.9404{*}DLPRS + 0.1969{*}DLBMPI \\ & - 0.0559{*}ecm(-1). \end{aligned} \tag{7}$$

Manufacturing Output and Industrial Space Demand Relationship

For a 12-year sample period between 1987:4 and 1999:3, the empirical results of the VECM model using Singapore data showed a negative relationship between the industrial space demand and the lagged changes in manufacturing outputs.[18]

The results contradicted those found in the empirical studies in the U.K. (Nicholson and Tebbutt, 1979; Giussani and Tsolacos, 1994; and Tsolacos, 1994) and the U.S. (Wheaton and Torto, 1990).

There are three possible explanations hypothesized for the negative, but significant effects of the three lagged orders manufacturing GDP [*DLMGDP*(−1), *DLMGDP*(−2) and *DLMGDP*(−3)] on the demand for industrial space (*DLPRD*):

1. Given the constraint on resources, firms may increase their outputs by replacing existing physical real estate space with other factors of production assuming that these factors of production are substitutable. Firms may decide to use more high-technology equipment and/or employ more labor or increase the operational hours in order to lift the level of manufacturing output. By increasing investments in advanced production technology and adopting a more efficient operation process, firms can achieve a higher level of manufacturing outputs in a smaller physical production space, since real estate capital is inelastic in supply in the short-term.

Exhibit 6 | Actual and Forecasted Change in LPRD

Observation	Actual	Prediction	Error
Panel A: Multivariate Dynamic Forecasts for the Change in *LPRD*			
1999:1	0.0142	−0.0003	0.0145
1999:2	0.0056	0.0044	0.0012
1999:3	0.0062	0.0050	0.0012
Panel B: Summary Statistics for Residuals and Forecast Errors			
		Estimation Period 1988:4 to 1998:4	Forecast Period 1999:1 to 1999:3
Mean		0.0000	0.0056
Mean Absolute		0.0023	0.0056
Mean Sum Squares		0.0000	0.0001
Root Mean Sum Squares		0.0030	0.0084

Notes: 41 observations from 1988:4 to 1998:4. Order of VAR = 4, chosen r = 1.
Variables included in the cointegrating vector: *LPRD*, *LMGDP* and *LCLI*.
Variables [I(0)] included in the VAR: *DLPBS*, *DLPRS*, *DIR*, *D2LIPPI*, *DLBMPI* and *DIF*.

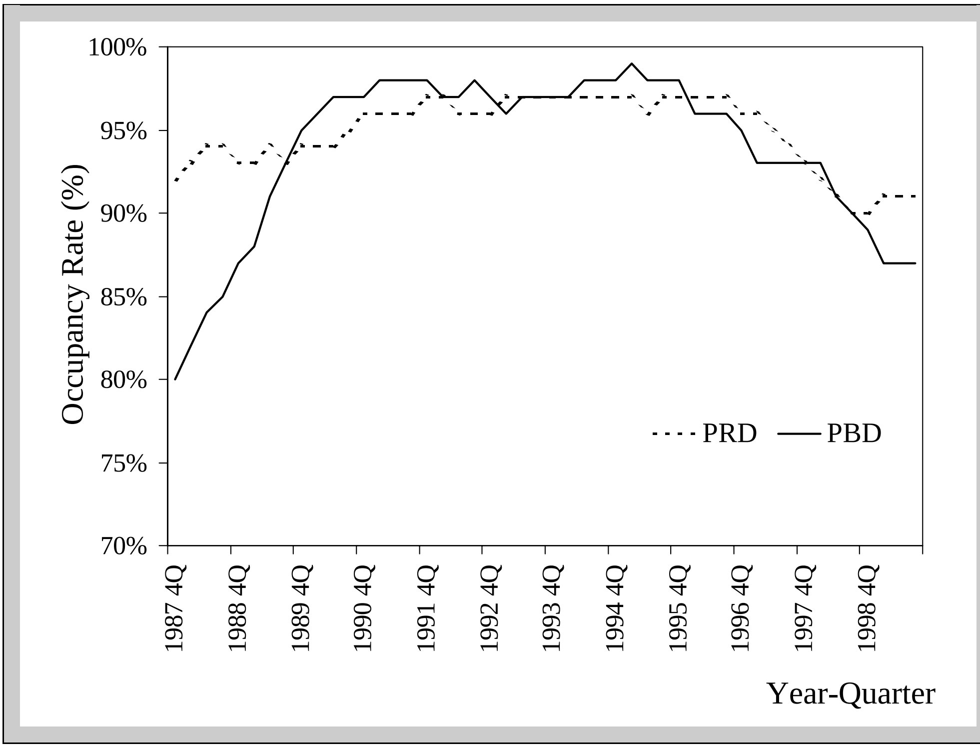
Exhibit 7 | Average Generalized Forecast Error Variance Decomposition for Variable LPRD

	Average Variance Decomposition		
Horizon	*LPRD*	*LMGDP*	*LCLI*
2 period	0.9205	0.1493	0.0390
3 period	0.8876	0.1928	0.0449
4 period	0.8537	0.2365	0.0468
5 period	0.8204	0.2787	0.0460
10 period	0.6619	0.4309	0.0593
15 period	0.5529	0.5167	0.0763
25 period	0.4233	0.6008	0.1075
50 period	0.2879	0.6710	0.1518

Notes: 41 observations from 1988:4 to 1999:3. Order of VAR = 4, chosen $r = 1$.
Variables included in the cointegrating vector: *LPRD*, *LMGDP* and *LCLI*.
Variables [I(0)] included in the VAR: *DLPBS*, *DLPRS*, *DIR*, *D2LIPPI*, *DLBMPI* and *DIF*.

2. Due to the inherent lumpiness and indivisibility of real estate, it would not be practical for manufacturing firms to acquire industrial space on a piecemeal basis to meet their needs from time to time. With a longer-term objective in mind, firms in Singapore tend to develop or purchase industrial real estate space in excess of that required for the scale of production at the time of investment. The excess space can be easily translated into productive use with minimal transitory disruption to the production process when the needs arise in the future. The consolidation and/or partial conversion of excess real estate space to improve productive capacity is not technically captured in the demand statistics, unless new planning submission is made to the URA in the process. This may be one of the reasons that explain why an increase in output can be met without a corresponding adjustment to industrial real estate stock.
3. Public industrial real estate space offers an alternative source of supply to firms, which may choose to switch their production facilities from private to public industrial real estate space. The spatial switching is possible when the cost incurred in the switch is less than the incremental revenue generated from an increased output. The crisscrosses of the occupancy rates between the private and industrial real estate stocks as observed over the sample periods (Exhibit 6) may be construed as evidence of the intra-market switching of industrial space demand. This partly explains the negative relationship between the manufacturing output growth rate and the change in the private industrial real estate demand.

Exhibit 8 | Occupancy Rates of Private and Public Industrial Space



Notes: PRD = Private industrial space demand. PBD = Public industrial space demand. Source: URA Real Estate Statistics Series: Stock & Occupancy, 1990 to 1999.

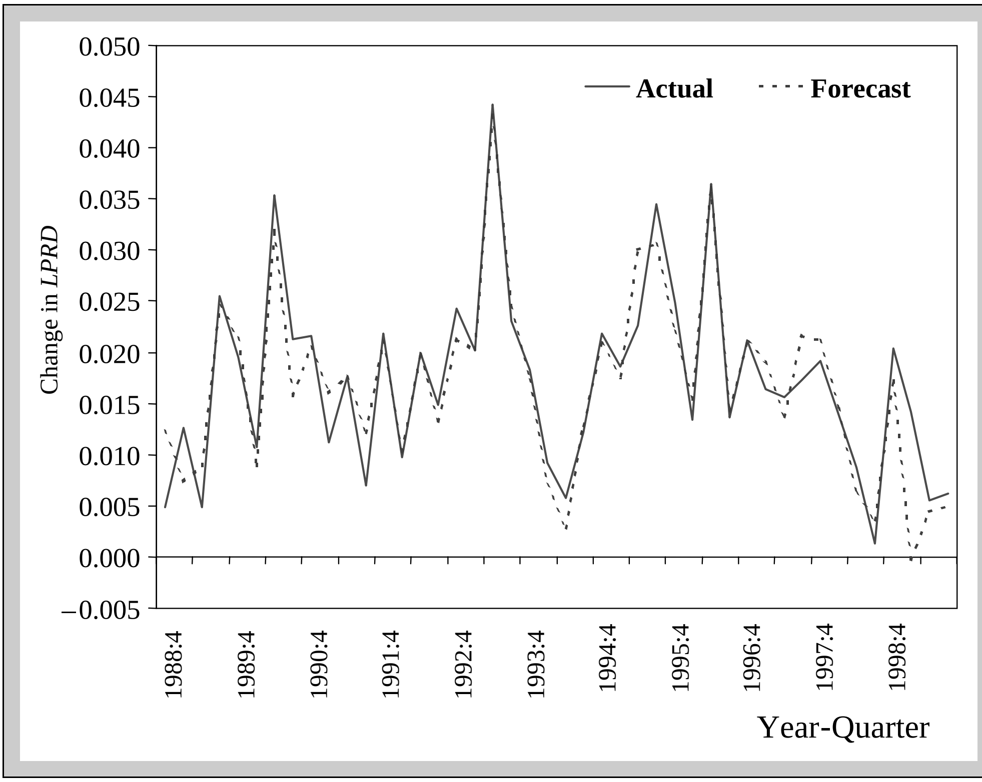
Post-Estimation Tests: Model Efficiency and Shocks

In-the-Sample Forecasting Tests

Using a shorter model estimation period from 1987:4 to 1998:4, *in-the-sample* forecasting tests for the VECM demand function for the period from 1999:1 to 1999:3 were carried out. The results of the in-the-sample residuals and forecast errors were summarized in Exhibit 7.

The results showed that the model was efficient in forecasting the short-term fluctuation of the *DLPRD* with a small root mean sum of squares of 0.0084. Exhibit 8 shows that the forecast values of the VECM closely track the actual changes in private industrial demand (*LPRD*) except for 1999:1, which could be due to the aftermath 'shocks' of the 1997 Asian currency crisis.

Exhibit 9 | Multivariate Dynamic Forecasts for the Change in LPRD

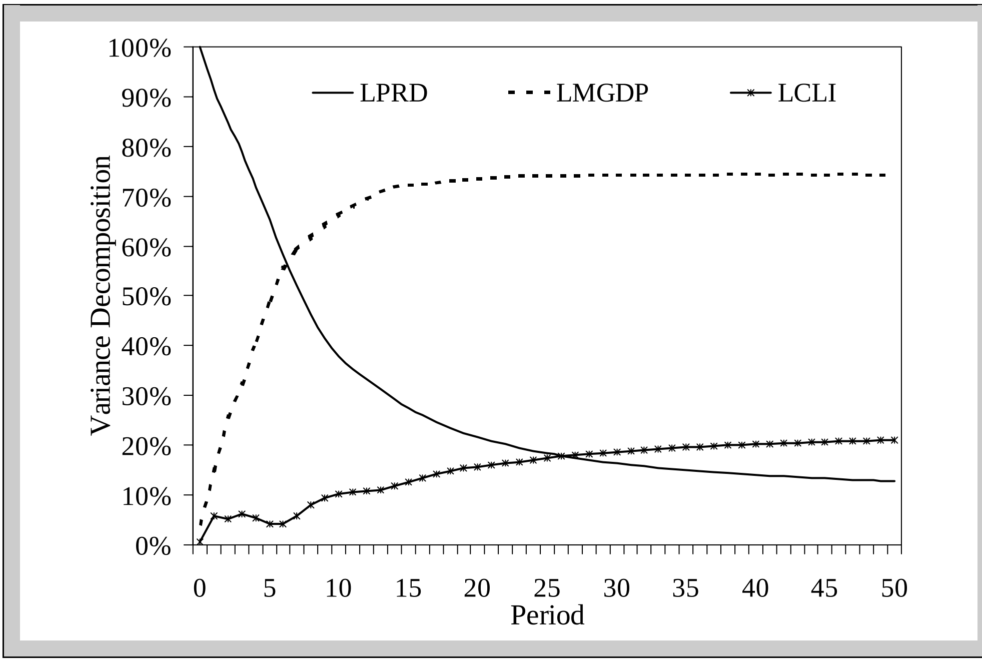


Variance Decomposition & Impulse Response

In the VAR model for industrial real estate construction that contains independent shocks like manufacturing employment, price, interest rates, real money stocks and real output, Kling and McCue (1991) found that employment shocks accounted for the majority of the variation in the industrial real estate construction. Employment, output and nominal interest rate shocks also inflicted significant positive responses in the industrial construction. In this study, dynamic responses of the industrial space demand to the shocks emanating from its own and other determinants were tested using the variance decomposition and impulse response analyses.

The generalized forecast error variance decomposition arising from one-standard error (S.E.) shock to the variables in the cointegrating relation was estimated. Exhibit 9 shows the decomposition of variances for the private industrial space demand (*LPRD*), the manufacturing GDP (*LMGDP*) and the composite leading indicator (*LCLI*) over fifty estimation periods. The private industrial demand factor

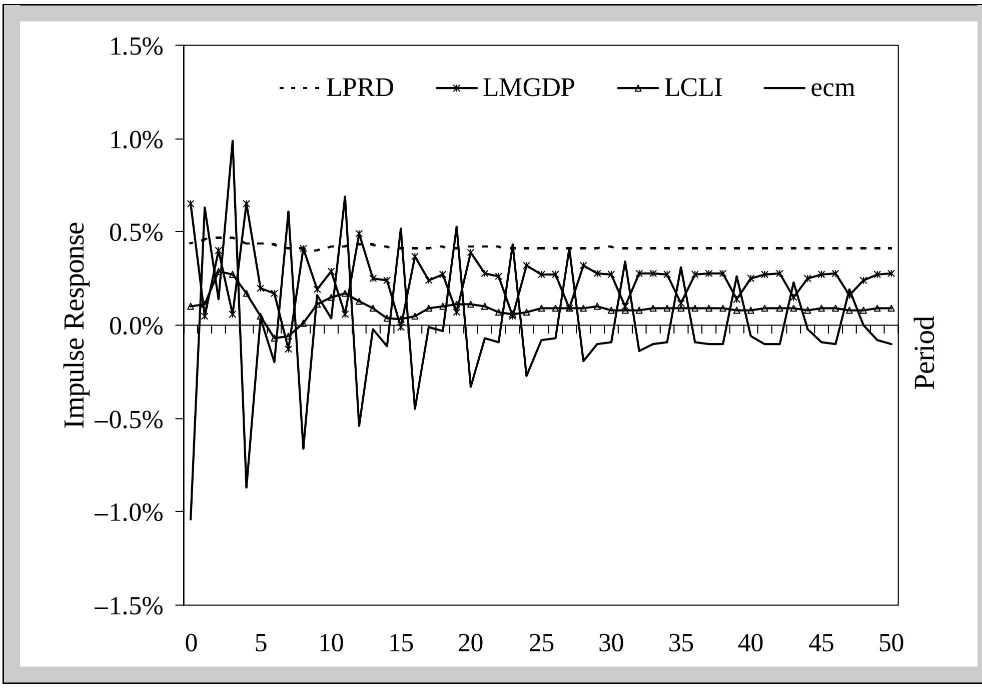
Exhibit 10 | Generalized Forecast Error Variance Decomposition for the Variable LPRD



(*LPRD*) accounted for the majority of its own variance for the first seven periods. The self-inflicted industrial demand (*LPRD*) variability effects were shifted to and dominated by those inflicted by the manufacturing GDP (*LMGDP*). The average variance decompositions for selected sub-periods were computed in Exhibit 10. It was shown that one-standard deviation shock to the manufacturing GDP (*LMGDP*) accounted for an average 67.10% of the variances of the private industrial demand (*LPRD*) followed by the self-inflicted shocks (*LPRD*) (28.79%) and the shocks on the composite leading indicator (*LCLI*) (15.18%). However, in the shorter terms of less than 15-periods, the own shocks from the industrial space demand (*LPRD*) appeared to be the most important determinant of the variation in industrial real estate demand.

The generalized impulse responses to one-standard error (S.E.) shocks in the industrial space demand VECM equation were plotted in Exhibit 11. The impulse responses to the shocks of the industrial space demand (*LPRD*) and the composite leading indicator (*LCLI*) were flat over the fifty estimation periods, though the responses inflicted by the composite leading indicator (*LCLI*) shocks fluctuated for the first sixteen periods, but within a narrow band of −0.06% and 0.29%. The strongest positive impulse response of 0.99% was inflicted by the shocks on the error correction mechanism (*ecm*) term at period 3, whereas the strongest negative *ecm*-inflicted impulse response of −1.04% was recorded at period $t = 0$. The

Exhibit 11 | Generalized Impulse Response(s) to One S.E. Shock in the Equation



shocks by the *ecm* and the manufacturing GDP (*LMGDP*) created the most volatile responses for the change in the industrial space demand (*LPRD*), whereas the own shocks on the demand variable (*LPRD*) inflicted the most consistent positive responses ranging between 0.41% and 0.47%.

It was also observed that opposite responses inflicted by the shocks on the manufacturing GDP (*LMGDP*) and the error correction mechanism (*ecm*) terms occurred consistently in four-period intervals. This may imply that the negative responses inflicted by the manufacturing GDP (*LMGDP*) shocks were corrected instantly in the model by the positive responses inflicted by the ecm shocks.

Conclusion

Based on the theoretical framework of an extended accelerator investment model, this study empirically formulated a VECM to explain the dynamic relationships between the private industrial space demand and other determinants. Compared to the earlier empirical studies that used U.S. and U.K. market data, the study that used data of Singapore—a small industrialized country that has undergone different phases of industrialization phases—offered significantly different insights into the predictability of the industrial space demand. Different institution and market structures between the U.S., the U.K. and Singapore also shed new light on how firms respond or react to economic and market shocks when making investment decisions on industrial real estate.

The GDP in the manufacturing sector (*LMGDP*) and the composite leading indicator (*LCLI*) were two variables that established cointegration relationships with the industrial real estate demand (*LPRD*) in the Engle-Granger cointegration tests. They were included as unrestricted long-run forcing variables together with a pre-determined error correction mechanism (*ecm*) in the VECM for the industrial space demand. The results of the VECM estimation showed negative relationships between the manufacturing GDP (*LMGDP*) of different lag orders and the private industrial demand (*DLPRD*). The empirical evidence contradicted the empirical findings in the U.S. and the U.K., which did not explicitly address the issues of substitution and vintage effects of the real estate stocks.

Three possible reasons are hypothesized for the negative manufacturing outputs and industrial space demand relationship observed in this study. First, firms may substitute space for other factors of production when the demand for their output increases. Second, firms may take up more space than required for the existing scale of production and the excess space can be converted to meet the production needs of the short-term surge in the outputs. A possible switch of demand from the private to the public industrial market during a period of strong output growth may be the third contributory factor.

The rest of the selected economic variables, namely public industrial space supply, private industrial space supply, interest rates, industrial property price index, building materials price index and inflation rate, were found to have no cointegration relationship with the private industrial space demand. However, in the short-run, the private industrial space supply and the building materials price index were found to have significant effects on the private industrial space demand.

The results of the in-the-sample forecasting test showed that the VECM is efficient in predicting the demand for private industrial space. The generalized forecast error variance decomposition showed that one-standard deviation shocks to the manufacturing GDP (*LMGDP*) accounted for an average 67.10% of the variances of *LPRD* followed by the private industrial demand self-inflicted shocks (*LPRD*) (28.79%) and the shocks on the composite leading indicator (*LCLI*) (15.18%). However, in shorter terms of less than fifteen periods, the own shocks on the private industrial demand (*LPRD*) appeared to be the most important determinant of the variation in industrial real estate demand. It was also found that the most volatile impulse responses of the industrial demand (*LPRD*) were inflicted by the shocks on the error correction mechanism (*ecm*) and the manufacturing GDP (*LMGDP*) variables.

Appendix

ECM for *LPRD* Estimated by OLS Based on Cointegrating VAR(4)

Regressor	Coefficient	Standard Error	T-Ratio[Prob]
DLPRD(−1)	0.1491	0.1572	0.9485[.349]
DLMGDP(−1)	−0.0509	0.0251	−2.0247[.050]
DLPRD(−2)	0.1409	0.1602	0.8795[.385]
DLMGDP(−2)	−0.0353	0.0243	−1.4523[.155]
DLPRD(−3)	0.0039	0.1604	0.0243[.981]
DLMGDP(−3)	−0.0382	0.0232	−1.6435[.109]
ecm1(−1)	−0.0437	0.0129	−3.3916[.002]
F-Stat.		F(6, 37)	1.4262[.231]
R^2	0.1878		
R^2Bar	0.0561		
S.E. of Regression	0.0088		
Mean of Dependent Variable	0.0173		
Std. Dev. of Dependent Variable	0.0091		
Residual Sum of Squares	0.0029		
Akaike Info. Criterion	142.6340		
Equation Log-likelihood	149.6340		
Schwarz Bayesian Criterion	136.3893		
DW-Statistic	2.0057		
System Log-likelihood	225.8169		

Notes: The dependent variable is *dLPRD*. 44 observations are used for estimation from 1988:4 to 1999:3. Only *DLMGDP* and lagged *DLPRD* are the independent variables.

S.E. = Standard errors

DW = Durbin-Watson

Std. Dev. = Standard Deviation

[Prob.] = Probability of not rejecting the null hypothesis, H_0: $b_i = 0$, i = (1,2,...n), where b_i is regression coefficients.

Diagnostic Tests:

Test Statistics	**LM Version**	**F Version**
A: Serial Correlation	CHSQ(4) = 3.0080[.556]	F(4, 33) = 0.6054[.662]
B: Functional Form	CHSQ(1) = 0.7601[.383]	F(1, 36) = 0.6328[.432]
C: Normality	CHSQ(2) = 6.6626[.036]	na
D: Heteroscedasticity	CHSQ(1) = 0.2677[.605]	F(1, 42) = 0.2571[.615]

A: Lagrange multiplier test of residual serial correlation.

B: Ramsey's RESET test using the square of the fitted values.

C: Based on a test of skewness and kurtosis of residuals.

D: Based on the regression of squared residuals on squared fitted values.

Endnotes

[1] The projection of industrial space demand based on the adaptive model was reliable in an expansionary phase of the economy in the early and mid 1990s, where sufficient demand is derived to absorb new industrial space supply. This adaptive projection, however, produced disastrous results in the declining phase of the economic growth at the end of 1997, during which mismatch of supply and demand projection led to a glut of industrial space.

[2] The use of non-stationary time-series economic variables in the MRM is one of the critical constraints that cause spurious results in the MRM when it is applied to model the industrial space demand.

[3] Singapore, as a newly industrialized country, has undergone different phases of industrial transformation from labor intensive, low value-added manufacturing in the 1960s and 1970s, to the high-technology, high value-added industrialization in the 1980s and 1990s and now the research-intensive and knowledge-based industries that concentrate in life-sciences, micro-electronic and wafer fabrication industries.

[4] The statistic was obtained from the final consultant report of the Concept Plan Review Focus Group on Land Allocation (2001). The review group was convened by the Urban Redevelopment Authority (URA), the national planning authority, to look into the issues of land use allocation and optimization in the future.

[5] A large proportion of state lands have been amassed over time by the government via the Land Acquisition Act (1966) (Zhu, 2000).

[6] Source: "The JTC Story—Conquering Challenges," at the JTC corporate webpage at: http://www.jtc.gov.sg/.

[7] The classification of public and private sector industrial property in the URA statistics was based on the details of the planning submission received from the applicants.

[8] The statistics for 1999:4 were not available at the time of the analysis, and therefore, the figures computed for 1999 did not include the last quarter supply and demand figures.

[9] Given the short-term inelasticity of Kr, coupled with the constraint on capital resources, *i.e.* K is not infinitely available, optimal choice of resources becomes critical in firms' decision-making process. Firms may substitute Kr for additional investments in advanced production technology, Kp. Firms thus achieve the output maximization objective at the expense of a smaller or even a negative change in fixed capital investment, Kr.

[10] Exhibit 1 shows that there were consistent mismatches between the supply and demand in the private industrial real estate space. The situation was particularly evident after the government's liberalization of industrial land sale program in 1992, which partly led to the glut of industrial space in 1997.

[11] The statistics on the existing stock of factory space are obtained through mail questionnaire surveys. Owners or managing agents of the completed industrial buildings are the respondents of these quarterly surveys.

[12] The CLI indicator is constructed by the Economic Development Board based on the commitments and projections made on the new orders, money supply, stocks of finished goods, stock prices, company formation, wholesale prices for manufactured goods, real unit labor cost, business forecast for wholesale trade and the Central Provident Fund (CPF). The CPF is a form of compulsory saving of workers, which helps to take care of their home mortgage financing and healthcare and also provide financial security in their retirement.

[13] The rental index for private industrial space in Singapore as compiled by the Inland Revenue Authority of Singapore is relatively short, and started only in 1990.

[14] The DF and ADF statistics are not included in here, but they can be made available upon request.

[15] In Singapore, the private and public sector share of the industrial space supply at 1999: 3 was estimated at 75% and 25% of the total industrial real estate stocks respectively.

[16] The Dickey-Fuller (DF) test and Augmented Dickey-Fuller (ADF) unit roots tests of up-to four lags showed that the building material price index (*LBMPI*) is stationary in level, ((0), and that the industrial property price index (*LIPPI*) is stationary in the second differencing order, ((2). All other variables are first-order differenced stationary, ((1), at a 5% significance level.

[17] The 4-lag orders of the VAR model were selected based on the Akaike Information Criterion (AIC) and the Shwarz Bayesian Criterion (SBC). The results of the lag-order selection criteria are not included, but will be made available upon request.

[18] To reaffirm the negative sign of the coefficients, a cointegration regression involving only *LMGDP* and *LPRD* and their respective 3-lag terms is estimated. The results support the negative relationship between *MGDP* and *PRD* (see the Appendix).

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Tien F. Sing, National University of Singapore, Singapore 117566 or rststf@nus.edu.sg.