

An Error Correction Model of Vancouver Housing Prices

By

Jacky Ka-Chun Wong

B.A. University of Victoria, 2001

PROJECT SUBMITTED IN PARTIAL FULFILLMENT
OF THE REQUIREMENTS FOR
THE DEGREE OF
MASTERS OF ARTS

In the Department Of Economics

© Jacky Ka-Chun Wong 2003

SIMON FRASER UNIVERSITY

April 2003

All rights reserved. This work may not
be reproduced in whole or in part, by
photocopy or other means, without
permission of the author.

APPROVAL

Name: **Jacky Wong**
Degree: **M. A. (Economics)**
Title of Project: **An Error Correction Model Of Vancouver Housing Prices**

Examining Committee:

Chair: Phil Curry

Ken Kasa
Senior Supervisor

Marie Rekkas
Supervisor

Brian Krauth
Internal Examiner

Date Approved: friday april 4, 2003

PARTIAL COPYRIGHT LICENSE

I hereby grant to Simon Fraser University the right to lend my thesis, project or extended essay (the title of which is shown below) to users of the Simon Fraser University Library, and to make partial or single copies only for such users or in response to a request from the library of any other university, or other educational institution, on its own behalf or for one of its users. I further agree that permission for multiple copying of this work for scholarly purposes may be granted by me or the Dean of Graduate Studies. It is understood that copying or publication of this work for financial gain shall not be allowed without my written permission.

Title of Project *An Error Correction Model Of Vancouver Housing Prices*

Author:

Jacky

Wong

Abstract

Housing prices in the city of Vancouver are experiencing a significant increase. Despite the lack of consensus as to exactly what causes fluctuations of housing prices, macroeconomic condition should, in the long run, provide a good indication of the fundamental pricing of houses. This paper examines the underlying long run relationship between macroeconomic fundamentals and observed house prices. The framework of this empirical investigation is based on a vector error correction model. It shows that when housing prices deviate from their fundamentals, an adjustment to pull the actual price back to the long run equilibrium will be observed. Empirical evidence suggests that the adjustment process is rather slow.

Dedication

To my parents

Acknowledgments

My greatest thanks are to Professor Kenneth Kasa for his invaluable assistances and comments. I would also like to thank Carrie Fong for bringing up the topic of real estate market to my mind. Finally, I want to extend my gratitude to my friends and classmates for their encouragements and supports.

TABLE OF CONTENTS

Approval.....	ii
Abstract.....	iii
Dedication.....	iv
Acknowledgment.....	v
Table of Contents.....	vi
List of Tables.....	vii
List of Figures.....	vii
I. Introduction.....	1
II. Literature Review.....	3
III. The Model.....	6
IV. The Data.....	10
V. Pretests.....	13
VI. Empirical Results.....	17
VII. Conclusion.....	23
References.....	24

LIST OF TABLES

Table 1. Variables and Descriptions.....	10
Table 2. Unit Root Test Results.....	14
Table 3. VAR Lag Order Selection Criteria.....	15
Table 4. Johansen Cointegration Test Results.....	16
Table 5. Results from VECM estimation.....	18
Table 6. Impulse Response.....	21

LIST OF FIGURES

Figure 1. Real House Price Index.....	2
Figure 2. Macroeconomic Fundamentals.....	13
Figure 3. Cointegration graph.....	20
Figure 4. Impulse Response Function-Response to Cholesky One S.D. Innovations.....	22

I. Introduction

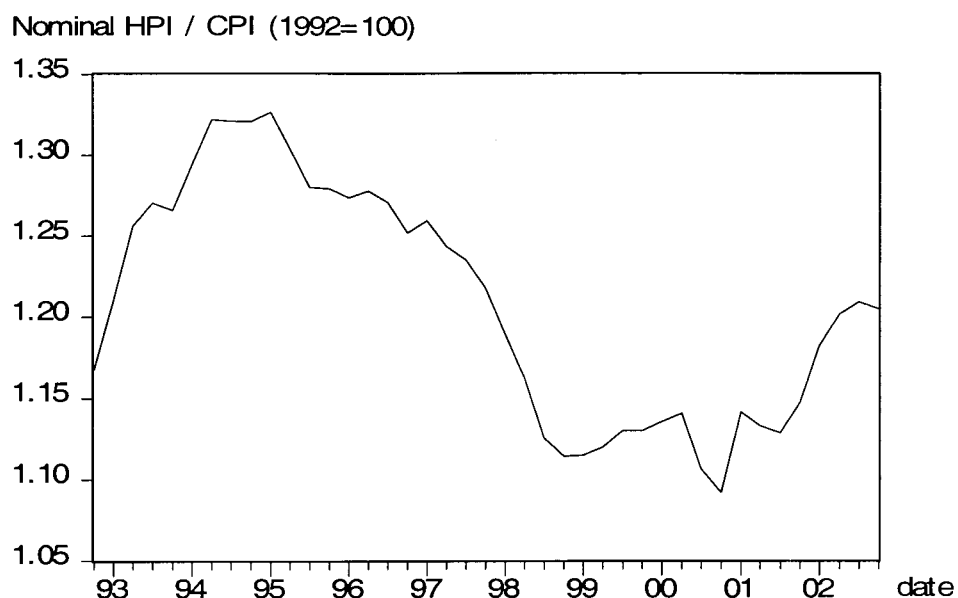
Traditionally, real estate is viewed by many homeowners and rational investors as a safe investment. However, in recent years, real estate markets have undergone several large boom and bust cycles. To what extent do highly volatile housing prices challenge the traditional belief that housing is a safe investment? Before answering this question, we first need to understand the causes of housing price fluctuations. In general, housing markets behave similarly to all other commodity markets, in the sense that market forces drive their prices. In particular, they are sensitive to movements in general economic conditions. A number of empirical studies report that the correlation between housing prices and economic fundamentals is strong and positive. Case and Shiller (1990), Clapp and Giaccotto (1994), Meese and Wallace (1993, 1994), Abraham and Hendershott (1996), and Malpezzi (1998) all find that housing price movements are heavily influenced by shocks to macroeconomic factors, such as construction costs, income growth, tax rates and the employment or unemployment rate.

Studies testing housing market efficiency show that favorable economic shocks can definitely stimulate the appreciation of housing prices. In the short run, housing prices can overshoot their fundamental prices. This influences the expectations of buyers, sellers, and builders. These expectations will be reflected in the long-run equilibrium pricing of houses. The existence of a long-run equilibrium condition for housing markets ensures the value of the houses is sufficiently priced. When the actual and fundamental prices are in disequilibrium, the actual prices will adjust, which forces the restoration of the long-run equilibrium.

Many different models have been developed to address real estate bubbles and to forecast real estate prices. They range from simple linear regression models to models with an error correction formulation. In addition, there are wide choices for model specification. The most popular variables include population, real GDP, the employment or unemployment rate, housing stocks, and interest rates. Most of the studies have focused on the US housing market. Instead, this paper will focus on the Vancouver housing market. Since real estate is the single largest component of wealth of most Canadian, developing a model to understand the housing market can definitely improve

the national or the regional wealth. In addition, it would be of interest of realtors and housing market participants to improve our understanding of housing markets. The purpose of the study is to derive an error correction model to examine the long-run relationship between the actual and fundamental prices for the Vancouver housing market.

Figure 1. Real House Price Index



The model is tested using a quality adjusted, monthly single-detached house price series for the Vancouver housing market, during the 1992-2002 sample period. Figure 1 shows that Vancouver has undergone a dramatic house price cycle. House prices were at a peak in the beginning of 1995, and then they started to decline. The rapid decline gained momentum between 1997-1998, and then they begin to rise again. By the end of 2002, it had risen back to its 1993 level. It would be interesting to find out if Vancouver is going through another boom and bust cycle.

The rest of the paper is organized as follows. The first section reviews previous research on the time path of housing prices. The second section derives the vector error correction model for the paper. The third section explains the choice of variables and the sources of the data. The fourth section pretests the data for unit roots, the lag orders and cointegration relationships among the variables. The fifth section applies the error correction model and presents the results. Finally, the last section is the conclusion.

II. Literature Review

Studies of house price dynamics have increased in number over the decade. They have examined the issue from both microeconomic and macroeconomics standpoints. The main issues include testing the efficient markets hypothesis, testing for speculative bubbles, and developing econometric models to forecast house prices. Only a few of them will be discussed in the paper.

Case and Shiller (1989, 1990), who have pioneered the analysis of housing price data, produced two of the most famous studies testing the efficiency hypothesis for the housing market. Using repeat sales data from four MSAs, they test for autocorrelation both in annual changes in real house prices and in estimated after-tax excessive returns. Evidence from their studies suggests that macroeconomic variables can be used to predict house prices. This implies housing markets are inconsistent with the joint hypothesis of efficient markets and risk neutrality. Moreover, their studies were cited and reviewed by a great number of subsequent researchers.

Although there are a large number of studies dealing with house price dynamics, the majority of the literature on housing markets studies the US market. There are only a few studies examining the Canadian market. Clayton (1994) used quality-adjusted Vancouver housing prices and tested the ability of a forward-looking rational-expectations housing prices model to explain short-run fluctuations in real house prices. Under a modified stock-flow housing market model, he rejects the joint hypothesis of rational expectations and semi-strong market efficiency. His finding is consistent with other studies.

Abraham and Hendershott (1994) presented a fundamental pricing model for houses as the sum of five components: the real value of agricultural land rent, the cost of developing the land for urban use, the value of "accessibility", the value of expected future real rent increases and the real cost of constructing houses. Their study tests for speculative bubbles in the metropolitan housing market of the US. Using 1977-1992 repeat sales data from four geographical areas with a total of thirty MSAs, they regressed real house price appreciations on the growth of equilibrium house prices, the bubble builder, the bubble buster and a random error term. The bubble builder and bubble buster

are the expectations of price appreciation over time and the periods with actual prices higher than the equilibrium, respectively. According to their paper, the equilibrium price is derived as a linear function of the growth in real construction costs, the growth in real income per working age adult, the growth in employment and the change in real after-tax interest rates. Their results indicate that either changes in market fundamentals, or adjustment dynamics, explain only a little over two-fifths of the variation in price movements. The two together explain about three-fifths.

Malpazzi (1998) presented a simple error correction model of housing price changes in 133 MSAs in the US. The long run equilibrium imposed in his model suggests the actual house price-to-income ratio equals equilibrium house price-to-income ratio. In his model the estimation of the equilibrium price-to-income ratio is derived from a linear regression model. The results support the idea that housing price changes do not follow a random walk. He finds housing price changes were well modeled by a simple error correction formation. He also argues that large departures from equilibrium tend to follow larger proportional changes in housing prices than small departures. The speed of adjustment is faster in less stringently regulated environments. In addition, the results of this study are consistent with other studies, which suggest house price changes are not random walks.

Instead of developing an econometric model, Quigley (1999) examines the linkage between real estate prices and business cycles with a simple model. In his study, he proposed two questions. The first question was - Do fundamentals explain property prices? The second question was - Do property price explain fundamentals? Using just a simple log regression model, he reports that economic fundamentals do not explain most of the variation in the property prices in the short run. The variables included are local consumer price index, employment and income disaggregated by industry category, the number of households and total population, vacancy rates for owner occupied housing, commercial offices, and rental housing, unemployment rates, the volume of mortgage lending for refinance, and the volume of housing sales. When fundamental are augmented by lags in housing price, the explanation of the variations increases. For the second question, he examined the Asian property markets during the 1990's. He reported that

Asian property bubbles have produced real consequences for the course of national and regional economic conditions.

III. The Model

The goal of this study is to examine the underlying long run relationship between economic fundamentals and observed housing prices. As discussed above, a variety of models have been developed to address the long run relationship between equilibrium and actual housing prices. The major shortcoming of the models derived by Abraham and Hendershott (1994) and Malpazzi (1999) concerns estimation of equilibrium prices. Since true long-run equilibrium prices are unobserved, estimation of these prices can be problematic. Instead, the model developed in this paper does not require this estimation. Moreover, the framework here is based on a vector error correction model (VECM).

The notion of an error correction model is considered to be a very powerful principle in applied econometrics. In fact, Alogoskoufis and Smith (1991) suggested that ‘the error correction formulation provides an excellent framework within which it is possible to apply both the data information and the information obtainable from economic theory’. Another advantage of the VECM is that it could disentangle long run effects from short run effects. Hence, short-run fluctuations and long-run deviations caused by movements of macroeconomic variables can be examined separately. However, no effort is made in this model to econometrically identify separate demand and supply curves for housing. As a result, the effects of the explanatory variables, which are assumed to represent exogenous demand shifts, will have price effects that depend on the relative elasticities of the demand and supply curves. The price effects will be larger the more inelastic is the housing supply curve.

Letting t denote the time period under consideration, actual housing prices, P_t , are the sum of fundamental prices, F_t , and a temporary deviation, D_t , in the same time period:

$$P_t = F_t + D_t \tag{1}$$

As discussed above, the fundamental price is unobserved, but is assumed to be a function of some observable variables. Hence, $F_t = f(X_t)$. Assuming the changes in house prices are related to changes in economic conditions of the local economy, we can

substitute economic fundamentals into the function. Equation (1) can then be rewritten as a function of economic fundamentals and a temporary deviation.

$$P_t = f(X_t) + D_t \quad (2)$$

Notice that equation (2) is only the housing price equation at one particular period in time. In the long run, actual housing prices would expect to revert to the fundamental price. Therefore, long run equilibrium requires:

$$P = f(X) = F \quad (3)$$

Given the long run equilibrium condition, the framework for a simple error correction model can be presented as follows:

$$\Delta P_t = \gamma(P_{t-1} - \beta F_{t-1}) + A(L)\Delta P_{t-i} + B(L)\Delta F_{t-i} + \varepsilon_t \quad \text{where } i=1,2,\dots,n \quad (4)$$

The left-hand side variable in equation (4) is the change of the actual price. On the right-hand side are four terms. The first term is the long-run condition with normalization to P_{t-1} . The second term is lagged changes in actual prices. The third term is lagged changes in fundamental prices. The last term is a well-behaved error. When the long-run equilibrium condition is not satisfied, an adjustment process would pull the actual price back until the condition is satisfied once again. Therefore, the expected sign for γ would be negative. That is, if the actual prices exceed the fundamentals, actual prices will tend to fall.

The vector error correction model is similar to a simple error correction model, except it is presented in matrix form. As shown below, there can be more than one cointegrating relationship in a vector error correction model.

$$\begin{pmatrix} \Delta P_t \\ \Delta X_t \end{pmatrix} = \Pi \begin{pmatrix} P_{t-1} \\ X_{t-1} \end{pmatrix} + \sum_{i=1}^{k-1} \Gamma_i \begin{pmatrix} \Delta P_{t-i} \\ \Delta X_{t-i} \end{pmatrix} + \Phi Z_t + \varepsilon_t \quad (5)$$

$$\text{Where } \Pi = \sum_{i=1}^k A_i - I_i \text{ and } \Gamma_i = - \sum_{j=i+1}^k A_j$$

In this model, the left-hand side variables are the vector of changes in actual prices and economic fundamentals. The right-hand side includes both the long-run equilibrium and the short run changes.

The first bracket on the right-hand side captures the long-run equilibrium conditions. For the long-run condition to exist, there must be a cointegration relationship among the endogenous variables. In Granger's representation theorem, if the coefficient matrix Π has reduced rank $r < k$, then there exist $k \times r$ matrices α and β , each with rank r , such that $\Pi = \alpha\beta'$ and $\beta'y_t$ is $I(0)$. r is the number of cointegrating relations (the cointegrating rank) and each column of β is the cointegrating vector. The elements of α are known as the adjustment parameters. In order to form the basis of the VECM specification, at least one cointegration relationship must exist. Johansen's method is to estimate the Π matrix from an unrestricted Vector Auto-regression (VAR) and to test whether we can reject the restrictions implied by the reduced rank of Π . The purpose of the cointegration test is to determine whether a group of non-stationary series is cointegrated or not.

Moreover, Engle and Granger (1987) pointed out that all variables within the cointegration relationship must have the same order of integrations. In addition, the series should not be integrated at order zero, since this will lead to trivial cointegrating vectors. Therefore, a pretest must be done on all variables to check if the series contain unit roots. Even though the existence of unit roots gives spurious results, Engle and Granger have shown that a linear combination of two or more non-stationary series may be stationary. If such a stationary linear combination exists, the non-stationary time series are said to be cointegrated. The stationary linear combination is called the cointegrating equation and may be interpreted as a long-run equilibrium relationship among the variables.

The second bracket on the right-hand side is the vector of all variables in first difference where k is the lag order. It shows the short run fluctuation to movements of economic fundamentals and the past changes in housing prices. The lag order can be

determined by testing for autocorrelation. The term Z_t is columns of relevant variables at time t that affect the left-hand side variables. The last term ϵ_t is a well-behaved error at time t .

Finally, the cointegrating parameters should be interpreted with some caution. Campbell and Shiller (1988) show that cointegrating relationships may not reflect gradual adjustment to a “long-run equilibrium”, but instead reflect forecasts of future changes in fundamentals. As always, Granger causality does not necessarily indicate causality in the normal sense of the word. Since we are interested in what happens when actual prices exceed the fundamentals, the choice of normalization within the cointegration relationship is to set $\beta_{11} = 1$. The interpretation of α for VECM is the same as the way we interpret a simple ECM. Again, we expect a negative sign for α_{11} .

IV. The Data

Due to the lack of consensus as to exactly what causes fluctuations of housing prices, macroeconomic condition should, in the long run, provide a good indication for the fundamental pricing of houses. All macroeconomic time series are publicly available from government authorities, which include Statistics Canada, Cansim, BCstats and Canadian Mortgage and Housing Cooperation (CMHC). The frequency of all datasets is monthly, except for real GDP, which is quarterly. In this study, the economic fundamentals being examined include the real after-tax mortgage rate, the employment rate, real GDP per capita, and the number of unoccupied dwelling after completion. Table 1 gives a brief summary of all variables.

Table 1. Variables and Descriptions

Series	Descriptions	Period	Frequency	No. Obs.
P_t	House Price Index	1992:11-2002:12	Monthly	122
M_t	Mortgage rate	1990:01-2002:12	Monthly	144
I_t	Consumer Price Index	1971:01-2002:04	Monthly	364
E_t	Employment rate	1987:01-2002:04	Monthly	172
N_t	Population	1987:01-2002:04	Monthly	172
Y_t	Real GDP	1961:01-2001:04	Quarterly	160
V_t	Unabsorbed Inventory	1988:01-2002:03	Monthly	159
p_t	Real House Price Index	1992:01-2002:04	Monthly	124
$ratm_t$	Real after-tax mortgage rate	1991:01-2002:04	Monthly	136
y_t	Real GDP per capita	1987:01-2002:02	Quarterly	58

Housing Price Index

P_t is the nominal Housing Price Index (HPI). The source for the HPI data is the Real Estate Board of Greater Vancouver (REBGV). According to REBGV, the House Price Index (HPI) technology was originally developed by two professors from University of British Columbia. The idea of HPI is constructed based on a constant quality time series of single-detached resale house prices in the city of Vancouver, British Columbia. The series looks at the changes in housing prices over time, given houses with the same characteristics. Unfortunately, the dataset only covers the 1992:11 to 2002:12. Only median and average house prices, which are not quality adjusted, are available prior to 1992. To get the real HPI, p_t , we simply take P_t and divide it by Consumer Price Index, I_t .

Consumer Price Index

I_t is the Consumer Price Index (CPI) for British Columbia. Instead of using the national CPI data, provincial CPI is chosen because British Columbia CPI better reflects the city's inflation conditions. The source of CPI at a constant dollar (1992=100) was available at Cansim. The dataset covers 1971:01 to 2002:04. The series number at Cansim is P118800. To get the inflation rate, i_t , we simply have the current period CPI minus the previous period then divided them by the previous period.

Mortgage rate

M_t is the nominal mortgage rate for British Columbia. The series is the chartered bank administrative interest rate on a conventional mortgage with a maturity term of one year. The source of the series is the Bank of Canada. This dataset covered 1990:01 to 2002:12, and the series number is B14050 (V122520). $ratm_t$, which is the real after-tax mortgage rate, is defined as $(1-\tau)M_t - i_t$. Where τ is the top marginal tax rate is for British Columbian and i_t is the inflation rate measured based on changes in CPI.

Real GDP

Y_t is the real GDP at market prices for British Columbia. The source of this series is from BC Statistics. This series is available on the BC Statistic website. The dataset covered 1961:01 to 2001:04. y_t is the real GDP per capita. The calculation of real GDP per capita is real GDP divided by the population.

Population

N_t is the population in the city of Vancouver, British Columbia. The series is monthly seasonally adjusted. The dataset covered from 1987:01 to 2002:04. The source of this series is from Cansim, and the series number is D980181.

Employment rate

E_t is the monthly seasonally adjusted employment rate in British Columbia. The sample age is over fifteen years of age. The dataset covered from 1989:01 to 2002:04. The source of this series is from Cansim, and the series number is D980185.

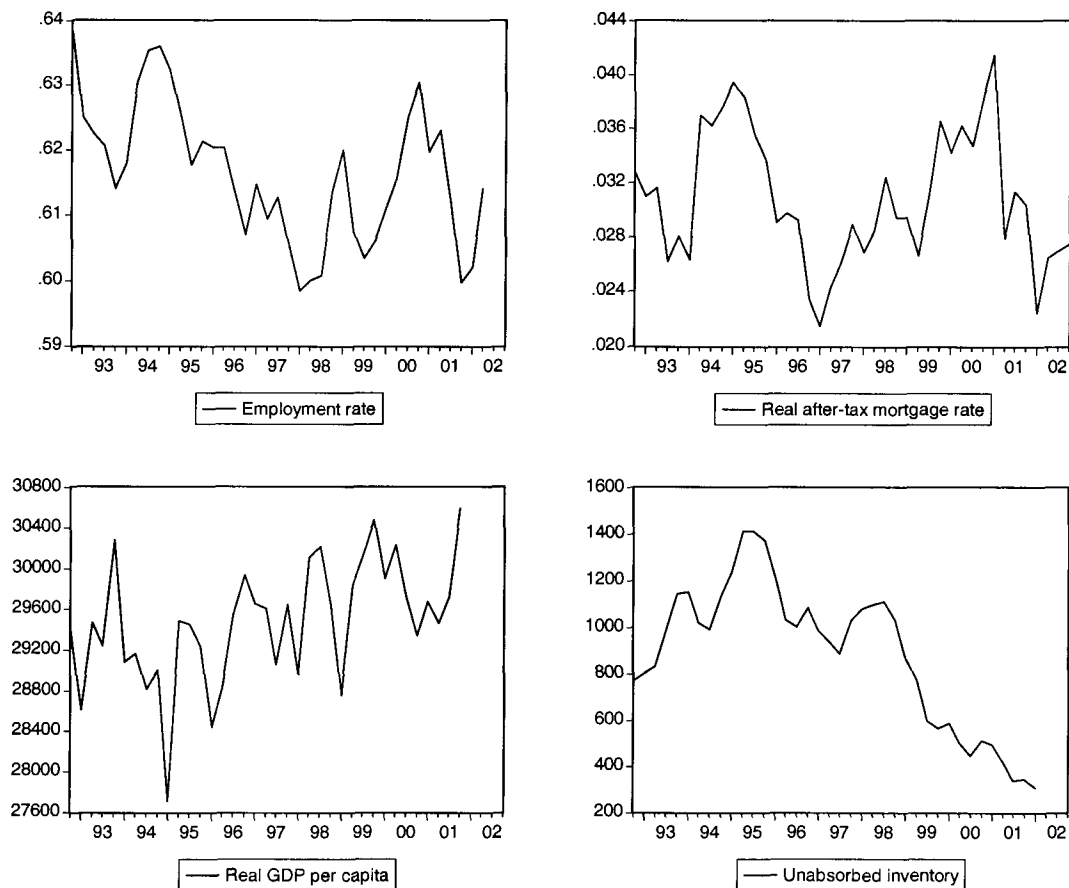
Inventories

V_t is the single-detached unabsorbed inventory in Vancouver. Rental units are excluded from these counts. The number of units in the unabsorbed inventory at the end of the period shown is the number of units that have been completed in or prior to the reporting month but have yet to be absorbed into the housing market. The dataset is collected by Canadian Mortgage and Housing Cooperation (CMHC) and is available from Cansim. The dataset covered from 1988:06 to 2002:03. The series number at Cansim is J87154.

V. Pretests:

All variables must first be tested for unit roots. As mentioned above, ECM requires the variables to be non-stationary and to have the same order of integration within a cointegration system. To determine the appropriate lag length for the variables, the number of lags was chosen based on the minimized Schwarz Information Criterion (SIC). The maximum number of lags applied in the tests varies depending on the sample sizes. The range is from nine to thirteen. All insignificant lags were then dropped from the specification. Figure 2 presents a graphical view of the four endogenous variables. It shows that all four variables have an intercept. Hence the unit root test must contain an intercept term. Moreover, some are also tested with a time trend.

Figure 2. Macroeconomic Fundamentals



The unit root tests being employed are the Augmented Dickey-Fuller (ADF) unit root tests. The ADF unit root test is based on the null hypothesis of a unit root. Table 2 gives the unit root test results for all variables. It reports that all the variables are integrated at order one, I(1), except for population and real GDP per capita, which have I(0). Given population and real GDP per capita are stationary; therefore, they are excluded from the cointegration system.

Table 2. Unit Root Test Results

Series	ADF (level)	5% Critical Value	Series	ADF (1 st differencing)	5% Critical Value
E_t	-2.7726 (0)	-2.9411	ΔE_t	-4.9616 (0)*	-2.9434
I_t	0.2970 (2)	-2.9411	ΔI_t	-3.6141 (2)*	-2.9434
M_t	-1.9180 (1)	-2.9390	ΔM_t	-4.9877 (0)*	-2.9434
N_t	-4.1952 ^ψ (1)*	-3.5366	ΔN_t	-4.8855 (0)*	-2.9434
P_t	-1.6853 (1)	-2.9390	ΔP_t	-3.8760 (0)*	-2.9390
V_t	-2.8980 ^ψ (1)	-3.5403	ΔV_t	-3.6097 (0)*	-2.9458
Y_t	-6.7754 ^ψ (0)	-3.5403	ΔY_t	-11.5612 (0)*	-2.9484
p_t	-2.1075 ^ψ (0)	-3.5266	Δp_t	-4.1897 (0)*	-2.9390
$ratm_t$	-2.7372 (0)	-2.9369	$\Delta ratm_t$	-7.6151 (0)*	-2.9390
y_t	-5.0914 ^ψ (0)*	-3.5403	Δy_t	-6.2767 (2)*	-2.9540

^ψ Include a time trend

* Significant at 5 % level

Paraphrase indicates the signification number of lags chosen based on SIC.

All variables are I(1), except N_t and y_t are I(0).

Alogoskoufis and Smith (1991) illustrated that the estimates in the ECM can be sensitive to lag order. To determine the appropriate lag length for differencing in lags variables in the VECM specification, the first procedure is to estimate a VAR for all variables. That is conditioning on the full set of past variables.

$$\begin{bmatrix} \log(p_t) \\ ratm_t \\ E_t \\ \log(V_t) \end{bmatrix} = \alpha_0 + \alpha_1 \begin{bmatrix} \log(p_{t-1}) \\ ratm_{t-1} \\ E_{t-1} \\ \log(V_{t-1}) \end{bmatrix} + \alpha_2 \begin{bmatrix} \log(p_{t-2}) \\ ratm_{t-2} \\ E_{t-2} \\ \log(V_{t-2}) \end{bmatrix} + \dots + \alpha_p \begin{bmatrix} \log(p_{t-p}) \\ ratm_{t-p} \\ E_{t-p} \\ \log(V_{t-p}) \end{bmatrix} + \varepsilon_t \quad (8)$$

Equation (8) represents the Vector Auto-regression that is used as a criterion for lag order selection. Table 3 presents the results of VAR lag order selection tests. Using VAR lag order selection criteria based on SIC, the appropriate lag order for the VECM specification is suggested to be one.¹

Table 3. VAR Lag Order Selection Criteria

Lag	LogLikelihood	LR	FPE	AIC	SIC	HQ
0	295.1713	NA	6.99E-13	-16.63836	-16.46061	-16.57700
1	408.2884	193.9149	2.74E-15	-22.18791	-21.29914*	-21.88111
2	429.6807	31.78281*	2.09E-15	-22.49604	-20.89625	-21.94379*
3	447.6469	22.58617	2.07E-15*	-22.60840*	-20.29759	-21.81071

* indicates lag order selected by the criterion

LR: sequential modified LR test statistic (each test at 5% level)

FPE: Final prediction error

AIC: Akaike information criterion

SIC: Schwarz information criterion

HQ: Hannan-Quinn information criterion

As we have mentioned above, ECM requires a test for cointegration relationships. Johansen cointegration test methodology is used to test for such cointegration relationships. This test requires an estimation of the Π matrix from an unrestricted VAR and to test whether we can reject the restrictions implied by the reduced rank of Π . The purpose of the cointegration test is to determine whether a group of non-stationary series is cointegrated or not. Table 4 reports the trace and the max eigenvalue statistics. Cheung and Lai (1993) illustrated that Johansen cointegration test is biased toward rejecting the null in small samples. Hence, either the test statistics or the critical values should be adjusted to improve the size of the test.²

¹ Kennedy (1994) suggests that SIC has performed well in Monte Carlo studies.

² Finite-sample correction is to adjust the C.V. – $SF=T/(T-nk)$ where T is the sample size, n is the number of variables in the estimated system, and k is the lag parameter.

Table 4. Johansen Cointegration Test Results

Null Hypothesis	Trace Statistics	5% Critical Value	Max Eigenvalue Statistics	5% Critical Value
$r=0$	58.34954*	53.30	37.70328*	30.56
$r\leq 1$	20.64626	33.51	14.72145	23.68
$r\leq 2$	5.924807	17.40	4.741208	15.89
$r\leq 3$	1.183599	4.25	1.183599	4.25

* Significant at 5% level

Finite-sample sizes of Johansen's Likelihood Ratio tests

The null hypothesis of no cointegration relationship can be rejected at the 5% significant level, and the null of at most one cointegration relationship fails to be rejected at the 5% level. Johansen's cointegration test confirms there is only one cointegration relationship in the system.

VI. Empirical Results:

The pretests are important for yielding a correct specification for the model. Since real GDP per capita seems to be $I(0)$ in level, which is different from all other variables in the cointegration system, y_t is excluded from the cointegrated equation. Following the VECM specification developed above, we estimate the changes in real house prices on the macroeconomic variables.³ Within the cointegration system, variables include real after-tax mortgage rate, employment rate and unabsorbed inventory. Outside the cointegration system, variables include differences in lags of all endogenous variables to the first order and real GDP per capita. Table 5 gives the results for VECM estimation.⁴

The cointegrating vectors represent the coefficients of the linear combination of non-stationary variables that are, in fact, stationary. The cointegration equation is as follows:

$$\log(p_t) = 15.227 - 33.017ratm_t + 27.008E_t - 0.03\log(V_t) \quad (6)$$

(6.12486) (3.39312) (0.07423)

We begin by inspecting the coefficient estimates within the cointegration relationship. Equation 5 presents the estimated cointegrating vectors with normalization on the variable of the log real housing price. Since the paper is interested in the movements of real house prices to economics fundamentals, normalizing on the log real house price will serve this purpose. It reports that all the variables have signs that are consistent with our economic theory. Homebuyers rarely pay the lump sum when purchasing a house. Most of them need mortgage financing. Therefore, higher real after-tax mortgage rate results a low real house prices is intuitively correct because higher real after-tax mortgage rate implies higher burden for homebuyers. In addition, employment rate indicates the status of the local economy. A higher employment rate means the economy is expanding, people would demand for higher quality houses that push up the prices of houses. So the expected sign for employment rate to log real house price is

³ For estimations purposes, all monthly data are converted into quarterly by taking three-month average.

⁴ Intercepts are included both inside and outside the cointegration relationship.

positive. Finally, unabsorbed inventories are there to provide information for the supply side of housing market. Builders would want to start building new houses only when there is a shortage, and they would stop building new houses when there is excess supply. Hence, we expect the unabsorbed inventories has a negative relationship to housing prices.

Table 5. Results from VECM estimation

Normalized on p_t				
Variables	D(log(p_t))	D(ratm $_t$)	D(E $_t$)	D(log(V $_t$))
CointEq1	-0.044342* (0.01732) [-2.56063]	-0.006667 (0.00440) [-1.51384]	0.027497* (0.00643) [4.27823]	-0.253410* (0.11284) [-2.24568]
D(log(p_{t-1}))	0.171536 (0.16999) [1.00907]	-0.059316 (0.04323) [-1.37202]	0.100387 (0.06309) [1.59108]	-1.234144 (1.10774) [-1.11411]
D(ratm $_{t-1}$)	0.822506 (0.76383) [1.07682]	-0.048392 (0.19425) [-0.24912]	-0.388102 (0.28349) [-1.36899]	14.19904* (4.97734) [2.85274]
D(E $_{t-1}$)	-0.494842 (0.45146) [-1.09610]	0.132213 (0.11481) [1.15155]	0.390455* (0.16756) [2.33026]	-1.462412 (2.94184) [-0.49711]
D(log(V $_{t-1}$))	0.019925 (0.02573) [0.77449]	7.56E-05 (0.00654) [0.01155]	-0.001895 (0.00955) [-0.19843]	0.440080* (0.16764) [2.62516]
Constant	-0.818165 (1.52974) [-0.53484]	-0.552470 (0.38904) [-1.42009]	1.177818* (0.56776) [2.07449]	-11.30156 (9.96829) [-1.13375]
log(y_t)	0.079378 (0.14866) [0.53394]	0.053682 (0.03781) [1.41988]	-0.114480* (0.05518) [-2.07479]	1.096580 (0.96874) [1.13196]
R-squared	0.315080	0.253253	0.441160	0.357699
F-statistic	2.146779	1.582662	3.683960	2.598880

* Significant at 5% level

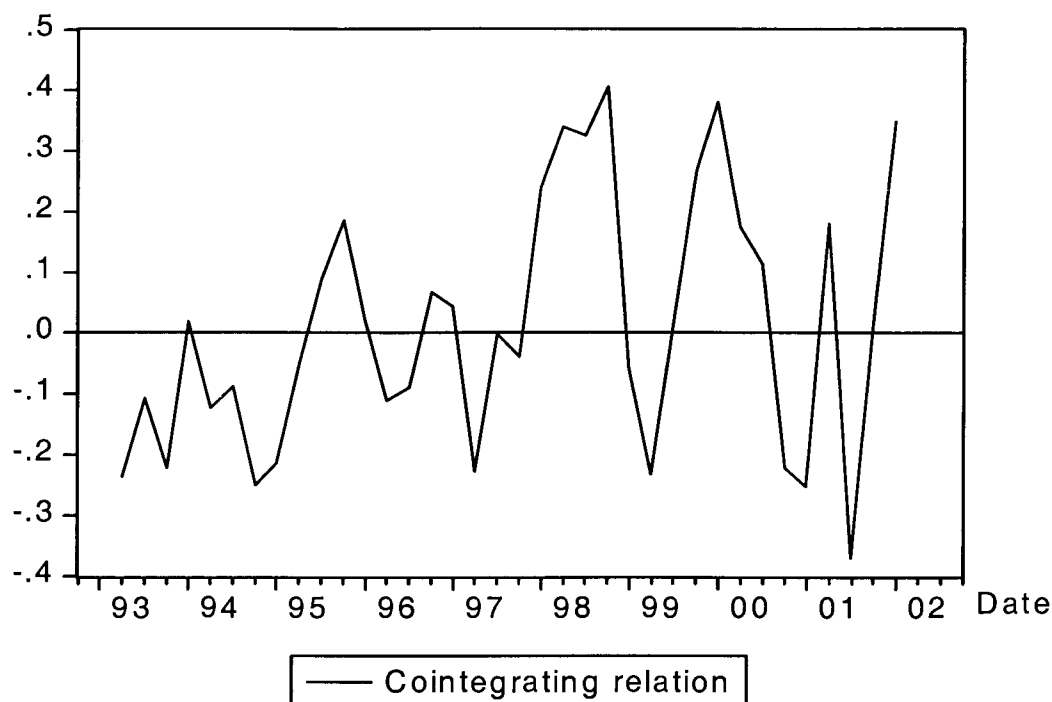
** Significant at 1% level

Standard Errors and t-statistics are denoted in paraphrase, respectively.

The three cointegrating coefficient estimates suggest the degrees of influence that each macroeconomic factors can have on the log real house prices. The estimated coefficient for real after-tax mortgage rate is -33.017 . All else being equal, when the real after-tax mortgage rate decreases by 1%, the real HPI is expected to go up by 33.017%. This suggests monetary and fiscal policy can have significant effects on the housing market. The estimated coefficient for employment is 27.008. All else being equal, when employment rate increases by 1%, the real HPI is expected to increase by 27.008%. Its implication supports economic conditions have significant effects on the housing market performance. Last, the coefficient estimate for unabsorbed inventory is -0.03 . All else being equal, when the inventory increases by 1% in, the real HPI is expected to decrease to go down by 0.03%. Even though it is statistically insignificant, the negative coefficient is consistent to the economic theory.

The long run equilibrium laid out in the above explains the cointegration relationship. The Johansen's cointegration test estimates of one cointegration relationship imply the long run equilibrium does in fact exist. When the actual housing prices deviate from the economic fundamentals, the error correction will be triggered automatically. The speed of adjustment is expected to have a negative sign. When the actual prices move higher than the fundamental prices, the actual prices will soon be correcting itself by lowering the actual prices. Figure 3 provides the cointegration graph. Here, it suggests that the current housing prices in Vancouver are above the fundamentals. Soon or later housing price will start to fall.

Figure 3. Cointegration graph



The estimated speed of adjustment to disequilibrium is -0.044. It indicates how fast equilibrium is restored. Taking half-life, it will take approximately four years to converge to the long-run equilibrium.⁵

The vector of coefficient estimates for the first lag difference explains the effect they have on the changes in the current period. To answer the questions of how economic fundamentals explain house prices dynamics, we want to adopt the specification with $D(\log(p_t))$ regresses on the cointegration equation, the one lags differencing of all variables, and $\log(y_t)$. Only the lag growth of housing price has an expected sign and all others have alternate signs. The coefficient of the lag growth of house price suggests that a ten percent increase on the $\log(P_t)$ three months ago will have about two percent increase in the growth of real housing prices. In addition, all coefficient estimates, except the cointegration equation, are insignificant at 5% level. Moreover, this specification explains about thirty two percent of the variation in log real housing price. F-statistic supports the model is well specified.

⁵ The half-life, $t^* = -\ln(0.5)/\lambda \approx 0.69/\lambda$ where λ is the rate of decrease per year.

Using the estimated VEC models, the dynamic responses of the log real housing price to a shock in the fundamentals and its lag can also be analyzed using the impulse response functions. A shock to the one variable not only directly affects itself but is also transmitted to all of the other endogenous variables through the dynamic (lag) structure of the VAR. An impulse response function traces the effect of a one-time shock to one of the innovations on current and future values of the endogenous variables. Table 6 reports the impulse response of $\log(p_t)$ over 10 periods on the $\log(p_t)$, ratm_t , E_t , and $\log(V_t)$. Cholesky uses the inverse of the Cholesky factor of the residual covariance matrix to orthogonalize the impulses.⁶ This option imposes an ordering of the variables in the VAR and attributes all of the effect of any common component to the variable that comes first in the VAR system. The degree of freedom (d.f.) adjustment makes a small sample degrees of freedom correction when estimating the residual covariance matrix used to derive the Cholesky factor.

Table 6. Impulse Response

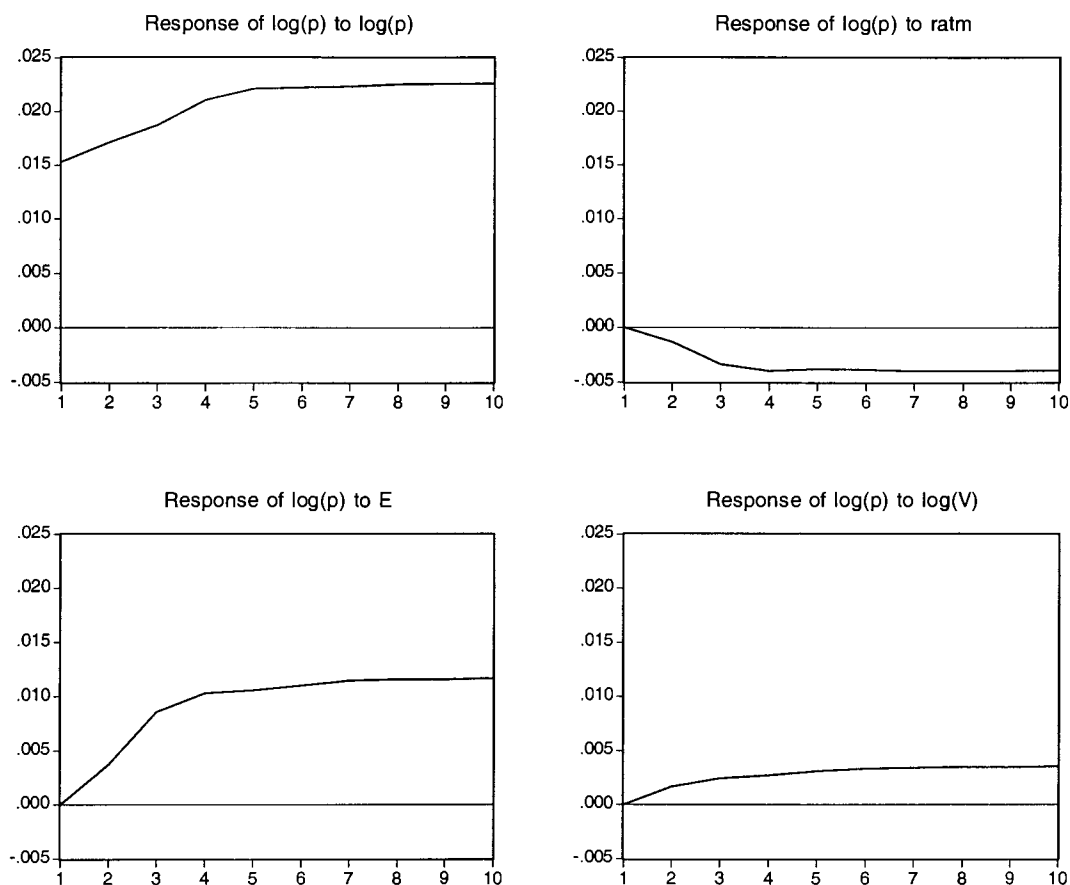
Response of $\log(p_t)$ to Cholesky (d.f. adjusted) One S.D. Innovations				
Period	$\log(p_t)$	ratm_t	E_t	$\log(V_t)$
1	0.015285	0.000000	0.000000	0.000000
2	0.017091	-0.001335	0.003701	0.001684
3	0.018712	-0.003348	0.008616	0.002444
4	0.021098	-0.003985	0.010327	0.002736
5	0.022107	-0.003846	0.010548	0.003066
6	0.022205	-0.003869	0.011019	0.003320
7	0.022351	-0.003989	0.011470	0.003421
8	0.022547	-0.004004	0.011597	0.003463
9	0.022612	-0.003977	0.011610	0.003499
10	0.022610	-0.003975	0.011652	0.003521
Cholesky Ordering: $\log(p_t)$ ratm_t E_t $\log(V_t)$				

The results suggest a shock at the current period can have a significant effect on logged real HPI in the longer run. Due to inefficient housing market, a shock on either one of the fundamental variables would not have an immediately effect on the log house price, but it will definitely affecting the housing price in the long run. Figure 4 provides a graphical view of the impulse response function. A positive shock in real after-tax

⁶ As noted by Runkle (1987), the standard error bands for these impulse response functions are likely to be quite wide, so one must interpret these point estimates with caution.

mortgage rate lower the housing price slightly in six months, but have a much greater effect to the further future. A positive shock in employment stimulates the housing market over time. These results, except for $\log(V)$, are consistent with the fact that housing prices can be influential by economic fundamentals in the long run.

Figure 4. Impulse Response Function - Response to Cholesky One S.D. Innovations



VII. Conclusion:

From the macroeconomic standpoint, this paper uses a dataset from the city of Vancouver, British Columbia to examine house price dynamics. Real housing price changes are well modeled by an error correction formulation. The empirical results suggest that housing prices are volatile and sensitive to movements in general economic conditions. This is consistent with the findings of previous studies. Even though housing prices can overshoot their fundamentals, they eventually converge back to their fundamentals. The reversion back to long-run equilibrium can be estimated from the speed of adjustment parameter. This study also finds that the adjustment process is rather long and slow, which might take over four years. Finally, it suggests that current house prices in Vancouver are above their fundamentals. This suggests that unless fundamentals increase, Vancouver house prices might be heading lower in the future...caveat emptor!

Reference:

- Abraham, Jesse M., and Patric H. Hendershott (1996). "Bubbles in Metropolitan Housing Markets". *Journal of Housing Research* 7(2): 191-207.
- Alogoskoufis, George, and Ron Smith (1991). "On Error Correction Models: Specification, Interpretation, Estimation". *Journal of Economic Surveys* 5(1): 97-128.
- Campbell, John Y., and Robert J. Shiller (1988). "Interpreting Cointegrated Models". *Journal of Economic Dynamics and Control* 12: 505-522.
- Case, Karl E., and Robert J. Shiller (1989). "The Efficiency of the Market for Single Family Homes". *American Economic Review* 79(1): 125-37.
- Case, Karl E., and Robert J. Shiller (1990). "Forecasting Prices and Excess Returns in the Housing Market". *AREUEA Journal* 18: 253-73.
- Cheung, Yin-Wong, and Kon S. Lai (1993). "Finite-Sample Sizes of Johansen's Likelihood Ratio Tests for Cointegration". *Oxford Bulletin of Economics and Statistics* 55(3): 311-328.
- Cho, Man (1996). "House Price Dynamics: A Survey of Theoretical and Empirical Issues". *Journal of Housing Research* 7(2): 145-172.
- Clayton, Jim (1996). "Rational Expectations, Fundamentals, and Housing Price Volatility". *Real Estate Economics* 24(4): 441-470.
- DiPasquale, D., and William C. Wheaton (1996). *Urban Economics and Real Estate Markets*. Prentice-Hall.
- Elder, John and Peter E. Kennedy (2001). "Testing for Unit Roots: What Should Students be Taught?". *Journal of Economic Education* 32(2): 137-146.
- Engle, Robert F. and C. W. J. Granger (1987). "Co-integration and Error Correction: Representation, Estimation, and Testing". *Econometrica* 55(2): 251-276.
- Kennedy, Peter (1994). *A Guide to Econometrics*. Oxford: Blackwell Publishing.
- Malpezzi, Stephen (1999). "A Simple Error Correction Model of House Prices". *Journal of Housing Economics* 8: 27-62.
- Quingley, John M (1999). "Real Estate Prices and Economic Cycles". *International Real Estate Review* 2(1): 1-20.

Runkle, David (1987). "Vector Autoregressions and Reality". *The Journal of Business and Economic Statistics* 5(4): 437-442.