Irreversible Investment, Real Options, and Competition:

Evidence from Real Estate Development

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ABSTRACT

The real options framework has been used to characterize the timing of irreversible investment in the presence of uncertainty. Despite a well developed theoretical literature, there are few empirical studies that use investment level data to examine the link between real options theory and investment. We examine 1,214 individual real estate developments in Vancouver, Canada using neighborhood level returns over a twenty year period to identify the extent to which uncertainty delays investment. The condominium developments in our sample cannot easily be redeployed to alternative uses, which allows us to isolate the call option, the value of delay, from the put option, which is based on the disinvestment potential of an asset. We find that increases in both idiosyncratic and systematic (market) risk lead developers to delay new real estate investments. Empirically, a one-standard deviation increase in the volatility of real estate returns reduces the hazard rate of investment by 13 percent, equivalent to a 9 percent decline in the real price level. Finally, we show that the value of the (call) option to delay a project is eroded by competition. Increases in the number of potential competitors negates the negative effect of idiosyncratic risk on the probability of development. This competition result provides support for the real options interpretation over alternatives such as risk aversion.

I. INTRODUCTION

Over the last two decades, the application of financial option theory to investment in real assets has altered the way researchers model the effect of uncertainty on investment. Under the real options approach, firms should apply a higher user cost to new investments in irreversible assets when returns are stochastic, reflecting the option to delay that is lost when investment occurs. However, firms that invest also acquire a put option on the new capital that may increase in value with uncertainty. While complete irreversibility leads to delayed investment relative to a situation where capital can be costlessly deployed to alternative uses, this prediction is more ambiguous when capital is at least in part reversible. The existing empirical literature on irreversible investment and uncertainty has often obtained mixed results when estimating the relationship between uncertainty and the level of investment. In this paper, we use data on investment in individual condominium developments that typically cannot be converted to alternative uses or redeployed elsewhere. This setting allows us to isolate the effect of the option to delay, the call option, from the put option to redeploy capital to alternative uses. In addition, we examine the effect of competition on irreversible investments. Doing so helps support the view that our estimated effects of uncertainty on investment are related to the option to delay over the alternative interpretation of simple risk aversion.

Many economists note the important connection between investment and business cycles (see Zarnowitz, 1999). Basu and Taylor (1999) suggest that the high volatility of investment relative to output, documented over long periods of time and across countries, is one of the great puzzles of macroeconomic cycles. Abel and Eberly (1999) demonstrate that uncertainty and the irreversibility of investment can affect the capital stock. Uncertainty and the role of competition in investment also have potentially important macroeconomic effects. For instance, Rotemberg and Saloner (1986) and Rotemberg and Woodford (1991, 1992) argue that tacit collusion is difficult to sustain in booms, relative to busts. Thus, if competition reduces the sensitivity of investment to uncertainty by lowering the call option component of user cost, we would observe changes in the dynamics of aggregate investment over the business cycle for reasons beyond the level of economic activity. Firms might optimally further delay investment in busts when product markets are less competitive, but undertake equivalent investments in booms when they face greater competition.

We use data on 1,214 individual real estate projects (condominium or strata buildings) to test the relationship between competition, uncertainty, and irreversible investment. These data offer a number of appealing features for this type of analysis. First, we examine individual developments, which provide much more direct evidence about the investment-specific decision than can be observed from aggregate data. Second, we directly observe the level and volatility of individual investment returns in a specific market, rather than inferring the volatility of returns based on firm-level stock returns. By segmenting the Vancouver market into distinct neighborhoods, we can examine changes in volatility over time and across neighborhoods using twenty years of data from 1979-1998. Third, these condominium projects are typically quite difficult to convert to alternative uses.[1] Finally, in looking at real estate, we examine a sector that represents a large component of national investment and wealth and exhibits great cyclical volatility in investment.

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[1] In fact, conversions are usually impossible if the developer has pre-sold any individual units to the public, as is common in this market.

The empirical work uses a survival time specification to examine the probability that a condominium project is developed at a given point in time as a function of the real price level, the volatility of returns, and several measures of the risk-adjusted discount rate. We separate uncertainty into market risk, which is predicted to reduce investment in a variety of models including the CAPM, and idiosyncratic volatility, which has a negative impact on investment that is more directly tied to the real options model. We find substantial empirical evidence that investment activity falls with increases in uncertainty. The probability of development occurring at a given site is negatively related to the volatility of returns. Decomposing the volatility, we find that exposure to both idiosyncratic and market volatility delay investment to nearly the same extent. A one standard deviation increase in idiosyncratic volatility reduces the hazard rate of development by 13 percent, about the same predicted impact on new investment as a 9 percent decrease in real prices. A similar one standard deviation increase in market volatility is equivalent to a 7 percent fall in real prices.

We also consider the impact of competition on the relationship between volatility and the option value of waiting, a subject ignored in previous empirical studies. Here we test Caballero (1991) and Grenadier's (2001) prediction that competition should diminish the impact of uncertainty on investment. These papers argue that competition reduces the impact of volatility on the timing of investment by increasing the cost of delay because of the threat of preemption.[2] Not only is the impact of competition on investment of interest in its own right, the findings

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[2] Caballero (1991) and Grenadier (2001) argue that imperfect competition is vital to predicting a negative relationship between uncertainty and investment. In contrast, Leahy (1993) and Dixit and Pindyck (1994) argue that the value of waiting, and thus the adverse effect of uncertainty on investment, is preserved even with perfect competition. Their findings require the endogeneity of prices in a competitive equilibrium model or the existence of firm or industry-specific risk.

regarding competition also help us separate two alternative interpretations of our results: real options and risk aversion. At times of greater uncertainty, investors might simply shy away from risky investments in real estate simply because they cannot adequately diversify these risks. It is difficult to find a comparable prediction that competition diminishes the relationship between investment and uncertainty in a model of risk aversion that does not rely on real options behavior.

Our results suggest that competition, measured by the number of potential competitors for a project, reduces the impact of volatility on investment. Empirically, competition has little direct effect on investment. Instead, competition only matters when interacted with volatility. Volatility has a smaller impact on option exercise for developments surrounded by a larger number of potential competitors. In fact, for the 5 percent of all units facing the greatest number of potential competitors, volatility has virtually no effect on the timing of investment. These findings provide unambiguous support for the existence of a call option in the ability to delay irreversible investment. As well, we validate Caballero and Grenadier over alternative hypotheses on the effect of competition on option exercise.

The remainder of the paper is structured as follows. Section II provides a review of relevant issues in the theoretical literature and a discussion of the empirical real options literature. In Section III, we present a summary of the basic theoretical model and discuss the impact of various assumptions in terms of the completeness of capital markets and the dynamic properties of real estate prices. We present a more detailed discussion of the data in Section IV. The empirical results are presented in Section V, and in Section VI we summarize with a brief conclusion and agenda for future research.

II. LITERATURE REVIEW

A well-developed theoretical literature on real options examines the impact of uncertainty on irreversible investments.[3] While some papers have suggested that uncertainly should unambiguously reduce investment, Abel, Dixit, Eberly, and Pindyck (1996) argue that such a prediction is complicated by the presence of dual options in any investment that is not completely irreversible. In the presence of demand and cost uncertainty, an investment in a real asset has a call option, the ability to delay investment, and a put option, the opportunity to disinvest and deploy that asset in an alternative use. Uncertainty raises the value of the call option, increasing the user cost and reducing investment, but it may also raise the value of the put option, increasing investment. Though the importance of each option depends on the degree of irreversibility in the investment, much of the literature focuses on the call option. Using simulations, Dixit and Pindyck (1994) show that the optimal hurdle price triggering new investment can be 2 to 3 times as large as the trigger value when investments are reversible. Abel, et. al. (1996) demonstrate circumstances under which this result for the call option can be weakened or even reversed.

Real options have been applied to describe a broad range of investments.[4] Macroeconomic aggregate studies by Pindyck and Solimano (1993) and Caballero and Pindyck

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[3] The theoretical literature is reviewed in Dixit and Pindyck (1994), Trigeorgis (1996), and Brennan and Trigeorgis (2000). Among the seminal papers in this areas are Abel (1983), Bernanke (1983), Brennan and Schwartz (1985), McDonald and Siegel (1986), Majd and Pindyck (1987), Pindyck (1988), Dixit (1989), and Abel, Dixit, Eberly, and Pindyck (1996).

[4] Applications include investments in natural resources extraction (Brennan and Schwartz 1985; Paddock, Siegel, and Smith 1988), patents and R&D (Pakes 1986), and real estate (Titman 1985, Williams 1991, Williams 1993 and Grenadier 1996). Lander and Pinches (1998) summarize the applied literature.

(1996) find a negative relationship between aggregate investment and uncertainty, using the variance in the maximum observed marginal revenue product of capital as the measure of uncertainty. Other recent papers (Holland, Ott, and Riddough 2000, Sivitanidou and Sivitanides 2000, and Sing and Patel 2001) examine the correlation between different types of uncertainty and aggregate real estate development. Although these papers use a number of different data sources, each finds a negative relationship between uncertainty and development, though not for all measures of uncertainty or development. Leahy and Whited (1996) and Bulan (2001) obtain mixed results when examining the effect of a firm's daily stock return volatility on the firm-level investment-capital stock ratio for a panel of manufacturing firms. However, real options models apply to individual investment projects and predict that trigger prices are non-linear, so aggregate investment studies can obscure these relationships.

Studies that use project level investment data have often found very weak evidence of a link between investment and volatility. Hurn and Wright (1994) find that the volatility of oil prices has a negative, but insignificant effect on the probability that a well site is appraised for development and production begun. Bell and Campa (1997) demonstrate that the volatility of exchange rates has a negative effect on new capacity investment in the international chemical industry, but that the volatility of input prices and demand have small and insignificant effects. In these studies, the weak results may be driven by the difficulty in properly measuring forward looking proxies for demand and price uncertainty and the selection bias in the investment decision.[5] More recently, Downing and Wallace (2001) find a stronger link between volatility

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[5] Quigg's (1993) simulation-based study finds option values to be small. She compares sales prices with an estimated intrinsic value and finds the option to wait is worth 6 percent of the value of undeveloped industrial land in Seattle.

and the decisions of homeowners to improve their homes.

In using micro-data on real estate investments this paper addresses a number of weaknesses in the existing literature. First, investments in real estate developments are essentially irreversible, so that the put option for disinvestment, which could otherwise obviate the negative relationship between uncertainty and investment, is not present.[6] Second, we avoid potential problems associated with other research by using a relatively large data set of individual investments. Our strategy looks at the timing of development of each parcel measured from a fixed point in time, instead of linking the analysis with the potentially timing of a change in ownership We observe both individual real estate investments and directly measure the volatility of output (condominium) prices for these investments. In contrast, many papers only have access to aggregate (firm or sector) investment series and imperfect proxies for demand uncertainty such as the volatility of firm-level stock market returns. Third, our approach also identifies the effect of volatility on investment timing rather than on investment levels. The former is a direct prediction of the real options model while the latter is only an implication. Finally, we provide a clear test of the effect of uncertainty on irreversible investment by taking advantage of the interaction between the extent of competition and the relationship between uncertainty and investment.

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[6] For the option to disinvest to be a factor we need market dynamics to differ across different land uses and for buildings to be converted easily across uses. These conditions are not consistent with our understanding of real estate markets. Conversions, such as between residential and office uses, are rare; when one sector in an area is down, others tend to be down as well.

III. THEORETICAL FRAMEWORK AND EMPIRICAL IMPLEMENTATION

Most real options models solve for the price level that triggers new investment. In the simple form of the model, the only source of uncertainty is the path of future asset prices. Here we assume that investments are completely irreversible, thus ignoring the put option to sell for an alternative use. Following Dixit and Pindyck (1994), the asset price is assumed to follow geometric Brownian motion:

$$dP/P = \alpha dt + \sigma \; dz \; , \tag{1}$$

where α and σ are the drift (expected capital appreciation) and variance parameters, respectively, and dz is the increment of a Wiener process. The asset is also assumed to have a (constant) convenience (dividend) yield δ. The literature uses two approaches to obtain closed-form solutions for the trigger value. The dynamic programming solution assumes that each investment has an exogenously-given, project-specific discount rate, ρ. To solve the dynamic programming problem, Dixit and Pindyck assume a market equilibrium with the following equivalence:

$$\rho \equiv \alpha + \delta . \tag{2}$$

The contingent claims pricing solution requires complete markets, so that a short position can be taken in the asset.[7]

If investors are risk-neutral, the contingent claims solution is similar to that of the Black-Scholes (1973) options pricing problem and the discount rate is the risk-free rate of return. Alternatively, if investors are risk-adverse, the return on an asset is derived from the capital asset

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[7] See Dixit and Pindyck (1994) and Abel, et. al. (1996) for more detail on these competing approaches.

pricing model (CAPM):

$$\mu = r_f + \phi \rho_{\text{pm}} \sigma . \tag{3}$$

Here μ is the risk-adjusted expected rate of return for the asset, φ is the market price of risk, σ is the standard deviation of the excess returns on the asset, and ρ_{pm} is the correlation between excess returns on the asset, in our case real estate, and excess returns for the broader market.

In either solution, the asset hurdle price (P^*) that triggers a discrete investment of cost (I) is given by the following equation:

$$\frac{P*}{I} = \frac{\beta}{(\beta - 1)} \tag{4}$$

where r >1 is the positive root of the fundamental quadratic of the differential equation of motion:

$$\beta_1 = \tfrac{1}{2} - (\rho - \delta)/\sigma^2 + \sqrt{\left[(\rho - \delta)/\sigma^2 - \tfrac{1}{2}\right]^2 + 2\rho/\sigma^2}. \tag{5}$$

For tractability, we abstract from the choice of optimal land use or quantity of units per project in this model, assuming that both are optimal scale as permitted by zoning and other government restrictions.[8] Thus, P^* is measured as a per-unit price.

In the empirical analysis below, we consider three alternatives to characterize the real estate development hurdle rate P*. First, consider the simplest and probably least realistic case in our context--complete markets and risk-neutral investors. Here ρ would be replaced by r_f. As in

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[8] This assumption is consistent with the endogenous zoning literature.

Black-Scholes, the trigger price is given as:

$$P^* = f_1(r_f^{\,+}, \delta^{\,-}, \sigma^{\,+}), \tag{6}$$

where the superscript sign represents the expected sign of the effect. Second, if markets are complete, but investors are risk-averse, we use the Capital Asset Pricing Model (CAPM) to price assets. Rearranging terms in (3) and equating the market return μ with ρ:

$$\rho = \mu = r_f + \beta\phi\sigma_m\,, \tag{7}$$

where β is the well-known CAPM covariance between excess returns in real estate and the aggregate market and σ_m is the standard deviation of excess returns in the overall market. Under the standard assumption of a constant market price of risk, ϕ, we have:

$$P^* = f_2(r_f^{\,+}, \beta\sigma_m^{\,+}, \delta^{\,-}, \sigma^{\,+}), \tag{8}$$

Finally, assume markets are constantly in equilibrium but are incomplete and investors are risk averse. This general case yields:

$$P^* = f_l(\rho^{\,+}, \delta^{\,-}, \sigma^{\,+}) \tag{9}$$

At first glance, it might appear as if the third case is the most realistic of the modeling frameworks. Clearly there are incomplete markets for individual real estate assets, which prevent investors from assembling the spanning portfolio needed in the contingent claims approach. Nonetheless, if real estate markets are not in constant equilibrium, the assumption that the discount rate equals the expected rate of return might not be appropriate, either.

We choose to include factors from all three models to control for the discount rate. Even without complete markets, we expect the discount rate (ρ) to depend, at least in part, on the covariance between the volatility of prices in the local market and aggregate risk. As well, though we do not observe ρ directly, it is important to control for aggregate volatility and (time-varying) beta as in the CAPM.

While the real options results mentioned above are well-developed in the literature, we face a number of issues in implementing them empirically. Many of the explanatory variables such as the risk-free discount rate and the dividend yield are not constant over time. In addition, existing empirical work strongly suggests that real estate prices do not operate according to geometric Brownian motion but exhibit short-run positive serial correlation and long-run mean reversion.[9] Schwartz (1997) uses numerical methods to obtain comparative statics for a model with some of these characteristics. He has stochastic factors in mean reverting prices, mean reverting convenience–dividend-- yields and time-varying interest rates.[10] Without a closed form solution for β_1 in this relatively realistic setting, structural estimation of P^* is nearly impossible. Instead, we take advantage of time series changes in the volatility of real estate returns to identify the impact of volatility on new construction, while using various controls for changes in expected returns over time.

IV. DATA DESCRIPTION

We obtain data on all 1,297 strata (or condominium) projects with at least four units per project built in the city of Vancouver, Canada between January, 1979 and February, 1998. Projects are identified based on the date that the government responds to the filing of a strata plan

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[9] See Case and Shiller (1989), Meese and Wallace (1993), and Quigley and Redfearn (1999)

[10] Miltersen (2000) solves for a closed form solution for the optimal development path when mean-reverting interest rates and the convenience yield are stochastic. He finds similar qualitative effects, but the option value is lower than in the standard Black-Scholes (1973) framework.

to convert the single title for the lot into multiple strata titles.[11] By law this can only occur near the completion of construction. We convert the granting of a strata title to the start of construction by introducing a one-year lag in the dependent variables.

Over this period there are several bursts of development activity. Figure 1 shows four peaks in the number of strata real estate projects in 1982, 1986, 1991, and 1996. In addition, there has been a large secular increase in the average project size. The increase in condominium development activity over this time period was much greater than the growth in single family construction. Local commentators describe the mid-1980's as the point at which a broad, general acceptance of the strata form of ownership began, so that over this period the growth in strata project activity exceeded that of single family development. Many single-family units were torn down or converted to strata projects as condominium prices rose.

Table 1 presents the descriptive statistics for the monthly data used in the paper, including citywide and neighborhood real prices, the volatility of real returns, expected price appreciation, the project specific discount rate, systematic risk, and the extent of competition across projects. The construction of these variables is described below. All data are presented in real terms.[12]

We compute a monthly repeat sales index of condominium prices using data obtained from the British Columbia Assessment Authority (BCAA) on all condominium transactions between 1979 to 1998. The repeat sales index has the advantage of controlling for changes in the

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[11] In British Columbia condominium units are those with a strata title to allocate ownership of the land among the units. Strata title legislation was first enacted in British Columbia in September 1966 and the first units under this legal form were built in 1968. While non-residential strata-titles exist, over 95 percent of strata projects are residential. For discussion of strata title legislation and the first years of strata development in British Columbia see Hamilton (1978).

[12] We deflate with an inflation series that is defined as the moving average of the previous 6 months inflation with declining weights by month.

quality of units sold over time.[13] The index is computed using the geometric repeat sales methodology outlined in Shiller (1991). Figure 2 presents the real price index for Vancouver condominiums. Our period of analysis covers three clear real estate price cycles. The first is a striking run-up between mid 1980 and mid 1981 with a sharp fall from mid 1981 to mid 1982. The second is the 1988-1990 increase in prices that coincided with the post-Tiananmen Square wave of immigration from Hong Kong. The third is the much more moderate 1991-1994 period of increasing prices. Since 1994, real condominium prices in Vancouver have fallen approximately 15 percent.

In addition, we create separate price indexes for seven sections of the city using BCAA neighborhood boundaries. Three neighborhoods are unique while the other four are amalgamations that are geographically contiguous, demographically similar, and have sufficient transactions to create a monthly price index. We exclude 83 observations in neighborhoods that are difficult to combine into homogenous sub-markets, leaving a total sample of 1,214 units.[14]

To measure uncertainty, we compute a time-varying measure of the volatility of monthly neighborhood returns using a GARCH (1,1) estimate for the variance of residuals from an AR(2) first stage equation. This GARCH model is quite general and allows a specification of asset

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[13] These condominium data are less susceptible to some of the flaws of repeat sales indexes. First, it is very hard to add to or substantially renovate these units, so unit quality and quantity are more likely to remain constant over time. Second, these units transact more frequently than do single family units, so we discard fewer transactions when requiring that units used for the repeat sales index must sell at least twice over the sample period. See Thibodeau (1997) for a summary of the issues associated with computing real estate price indexes.

[14] We ~~also~~ use all 1,297 projects in citywide aggregated regressions. All of the results presented below remain substantively unchanged with this larger sample, but we lose cross-sectional variation. Regression results with the entire sample were presented in previous versions of the paper and are available upon request.

volatility that is more appropriate to real estate than is pure Brownian motion. It also captures the predictable component of real estate returns in a manner that is consistent with Lo and Wang's (1995) work on option pricing models with serial correlation in returns. Note that the indexes show evidence of short horizon negative serial correlation, even though underlying real estate returns have positive long-run serial correlation.[15] The repeat sales indexes will have higher estimated variance during periods when the underlying index has fewer transactions. We believe that this pattern captures an important source of uncertainty faced by developers. In most search models, a thin market or a market with heterogenous properties has greater underlying price uncertainty than a thick market or a market with homogeneous properties. The thinner the market, the more difficult it is for developers to extract signal from noise.

To test for robustness we examine two additional measures of uncertainty. The first is the simple variance in returns over the previous two years. The second is a GARCH specification with a correction for the component of volatility caused by differences in the ratio of repeated sales of the same unit to total transactions in a month. This latter GARCH measure adjusts for possible differences in the volatility observed by a developer who considers all transactions in the market compared with the volatility measured by a repeat sales index that only includes sales of units that transact at least twice in the sample.[16] The three series of return volatilities are

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[15] In this specification, the coefficient on the first and second lags of returns are negative in all neighborhoods. This finding is consistent with what often happens with a repeat sales index of real estate prices. The presence of an unusually high price in one period "biases" the index upward in the current period, resulting in a negative return next period. See Case and Shiller (1989) for a discussion of price indexes and serial correlation in real estate returns.

[16] We correct for this potential bias by scaling mean returns to zero and then multiplying the calculated return for a given month by the square root of the ratio of repeat sales transactions to total transactions. The adjusted GARCH measure effectively smooths volatility as the share of sales in the repeat data base falls, offsetting a higher measured variance in months where we have relatively fewer

presented in Figures 3a and 3b for 1979-1998 and for the sub period 1986-1998, respectively. Return volatilities are substantially lower in the 1986-1998 period because we exclude the 1981 price spike. We believe that the transactions-adjusted GARCH volatility measure is the appropriate measure to use in the regressions that follow, although the same basic results hold for the other measures as well. In Figures 3a and 3b, it is clear that the transaction-adjusted GARCH measure is a lower bound to the two other volatility measures.

We compute expected price appreciation, α, from an auto-regressive process up to order three for each of the neighborhood return series. Expected price appreciation (the drift rate) is the one month ahead return forecast from this specification. The project specific discount rate, ρ, is defined as the sum of expected price appreciation, α, and the dividend yield, δ, as in equation (2). The dividend yield is obtained from a quality-controlled rent series from neighborhood level CMHC (Canada Mortgage Housing Corporation) surveys.

Finally, we measure exposure to market volatility, as in the CAPM, by multiplying monthly Toronto Stock Exchange (TSE) 300 stock market returns by a time varying measure of β, the covariance between excess returns in the condo market and the TSE 300. Time variation in the CAPM beta is smoothed using Cleveland and Devlin's (1988) locally weighted regression.[17]

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repeat sales. We thank Bob Shiller for pointing out this issue.

[17] Excess neighborhood returns are regressed against excess TSE 300 returns for a given month using the nearest 60% of months. These observations are weighted using a tri-cubic function so that the importance of an observation declines with distance in time from the month for which we are estimating the beta.

V. EMPIRICAL RESULTS

Our empirical specification follows from equation (4). A firm will exercise its option to develop when $P > P^*$, where P^* is the price threshold that triggers development. The trigger price depends positively on the volatility of real estate returns in a given period. Ideally, we would be able to observe the determinants of P^* such as costs of development and profitability at each site for each point in time. We cannot do so as we lack project specific information on these variables. Instead, we estimate the hazard rate of investment *h(t)*, the conditional probability of development occurring at time t, as:

$$h(t) = \Pr(P_t \geq P_t^* | P_x < P_t^* \forall x < t). \qquad (10)$$

Given the current price level, the hazard rate is decreasing in the price trigger P^*. We can therefore estimate a reduced form hazard specification, where the hazard rate is a function of the determinants of P^*, holding the current price level fixed.

One possible source of complication is that we do not observe the start of construction. By the time the developer has filed a strata plan, the building is mostly completed and ready for sale. However, the irreversible investment–option exercise–takes place months earlier when the developer begins physical construction of the project. To compensate, the date of our dependent variable is lagged by one year to reflect the time required for physical construction. Somerville (2001) shows that 59 percent of new multi-family projects are completed within one year of the start of construction. This built-in lag also reduces or eliminates any possible problems relating to simultaneity between prices and new construction. Reducing the lag length to six or nine months has little impact on the results. We also include linear, quadratic and cubic terms for project size in the regression to proxy for differences in construction time.

The analysis below must also address possible censoring. It is possible for a developer to start and subsequently abandon a project prior to filing a strata plan. Extensive discussion with market participants suggests that such a scenario is relatively uncommon in this market.[18] Abandonment is rare, in part, because it involves extinguishing a valuable put option on the completed project. Most developments are highly leveraged. Once a project has been granted financing, loan agreements typically make future draws on the construction loan contingent on meeting certain engineering hurdles in the construction process. Given that the developer has put his own money into the project up front, if the developer stops prior to completion, he will likely lose all of his equity. If the developer continues with the project, there is always a chance that the market will improve. In this case there is a nearly costless put option that is extinguished by abandoning prior to completion. Even so, we address the possible impact of actual censoring by artificially censoring the data on our own. To do so, we assume that abandoned projects are eventually completed in a future recovery. This would occur when the lender forecloses and then at a later date sells it to another developer. As described below, our results are unchanged under these circumstances.

A. Base Specification

Our empirical specification is derived from a survival function in which a site "dies" when development occurs. The survival function is inverted into a hazard rate for the probability that investment occurs and a site is developed at a given point in time. The hazard has the following empirical specification:

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[18] Somerville (2001) finds that generally contingent on the number of units started, new information on market conditions and demand shocks have no effect on the rate at which units under construction are completed.

$$h(t) = \exp(X_t'\beta)h_0(t) \tag{11}$$

where X_t is a vector of explanatory variables and β is the vector of coefficients to be estimated. The base model assumes a Weibull distribution for *t;* that is, the baseline hazard rate, h_0, is monotonically increasing or decreasing over time. In this relative hazard specification, the coefficient on a variable X is the proportional effect on the hazard rate of a unit change in X. A coefficient greater than one suggests that an increase in the variable has a positive impact on the baseline hazard--that is, a higher probability of development--while a coefficient less than unity implies the reverse effect.[19] Standard errors are corrected for the correlation across time in the hazard rate of individual projects.

The first three columns of Table 2 present maximum likelihood estimates for our base specification with the alternative measures of the project discount rate, ρ. All regressions use neighborhood level prices and volatilities. We also include building type and neighborhood fixed effects and controls for project size. The regression coefficients are generally of the expected sign for the real options model and are almost uniformly statistically different from one. Not surprisingly, developers choose to develop a parcel more quickly when neighborhood prices are higher. Price coefficients are greater than one in six of the seven neighborhoods and statistically significant in five of those neighborhoods. Even controlling for prices, however, the coefficient on the volatility of condo returns is less than one and statistically significant at the 5 percent level in all specifications, suggesting that developers wait longer to develop when the volatility of returns is higher. The coefficients on volatility suggest stronger effects than have been

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[19] In the regressions below, a one unit change in X leads to a $(\beta-1)$ percent change in the hazard rate.

documented in most previous micro studies. In column (1), a one standard deviation increase in the condo return volatility (35 percent) decreases the monthly hazard rate of development by 13 percent. Evaluated with the average neighborhood price coefficient of 1.014, this increase in volatility is equivalent to a 9 percent decrease in prices.[20]

Using equation (2), we substitute for the convenience yield δ, and include the expected price appreciation α instead. We do so because our measure of the convenience yield--quality controlled rents on a neighborhood basis--varies only once or twice a year. The presence of a changing rent control regime also makes it difficult to identify the correct ~~α~~ δ. Here, the drift rate, α, has little impact on the probability of development. Finally, the risk-free interest rate, measured as the real short-term Canadian T-Bill rate, has a large impact on construction. A one percentage point increase in the risk-free rate leads to a 52 percent decline in the monthly hazard rate.

In column (2) we include a separate control for systematic risk based on the CAPM, where ρ is measured as the risk-free interest rate plus a control for the risk premium that equals time-varying β multiplied by the volatility of the TSE 300 index. Including market volatility decreases the effect of idiosyncratic volatility somewhat–the coefficient on idiosyncratic volatility moves closer to one, from 0.9961 to 0.9968, but it remains statistically different from one and economically important. The coefficient on market volatility is 0.8371 and is statistically different from one at the 6 percent level. In this case, a one standard deviation increase in the average market volatility across the neighborhoods (0.45) leads to an 8 percent decline in the

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[20] Papers on housing supply such as DiPasquale and Wheaton (1994), and Mayer and Somerville (2000) find that controlling for house prices, starts or permits consistently fall in non-price measures of demand such as expected time to sale. We also run the model including the level and volatility of two other measures of demand, existing single family home sales and the ratio of units listed for sale to actual sales. We find that increases in the volatility of sales or the ratio of listings to sales also leads to a statistically significant decline in the hazard rate.

hazard rate, while an equivalent one standard deviation increase in idiosyncratic volatility leads to a 11 percent decrease in the hazard rate.

Our measure of the project specific discount rate does not do as well as the other proxies for the actual discount rate. The third column measures the project specific ρ as the sum of the dividend yield and the expected short-term appreciation. The former, as explained above, is measured from a quality-controlled rents series and the latter variable is estimated from an AR-3 regression on past real estate condo returns. There are a couple of possible reasons why the project specific discount rate does not perform very well. First, this measure of ρ does not exhibit much time series variation in the dividend flow, so it is strongly correlated with α. In addition, as noted above, the model that uses this measure of the project specific discount rate makes the questionable assumption that the real estate market is in perpetual equilibrium. Previous research (Case and Shiller 1989 and Meese and Wallace 1993) suggests that real estate markets exhibit important periods where prices are inefficiently determined over the real estate cycle. As a result, we use the second measure of the discount rate (column 2), where the project discount rate is equivalent to the risk free rate plus an adjustment for market risk, as our base model in all future regressions.

An insignificant coefficient on α, the expected price appreciation parameter, is consistent with the standard real options model in which the hurdle rate is independent of the drift rate. However, one might be concerned that volatility is picking up factors related to periods of rapidly increasing or decreasing prices that might have an independent effect on investment. For example, given the positive short-run serial correlation in prices that has been documented in many markets, a developer might choose to delay construction in anticipation of further short-run price increases. Alternatively, rising prices can provide capital gains that allow developers to overcome liquidity constraints, enabling them to pursue a larger number projects. Thus future expected price increases might lead to a greater hazard rate of new construction.

More interestingly, Grenadier (1996) raises the possibility that falling prices could also trigger a cascade of development. In a game theoretic model with two owners of competing parcels, Grenadier demonstrates the existence of a "panic" equilibrium where developers each race to build before prices fall too far. As in the prisoner's dilemma, both developers choose to build rather than be preempted. In the Grenadier framework, holding the price level constant, both expected price increases and decreases can spur development activity.

In column (4) we differentiate between positive and negative expected price appreciation. These variables are calculated by multiplying α by a dummy variable that equals one if α is positive (negative) and zero otherwise. In fact, the inclusion of these terms does not affect the coefficient on volatility. However, the coefficient on positive expected price appreciation is above one while the coefficient on negative expected price appreciation is less than one, with both coefficients significant at the 5 % level. These results suggest that holding price constant, development is more likely when prices are rising *and* when prices are falling. This result supports Grenadier's strategic behavior analysis of the "price equilibrium" as well as arguments for increased development during periods of rapid price increases.

In Table 3 we test for robustness, running these regressions over different time periods and for different hazard distributions. Over a three year period (1981-83) real prices in Vancouver rose by 100% and then fell to their original level. Elevated volatility over this period could dominate the data and drive the relationship between volatility and new construction. In column

(1) we run the model using data from 1986-98 only. The statistical significance of prices drops considerably in this later time period, but the coefficient on the volatility of condo returns remains below one and is statistically significant at the 10 percent level. The coefficients on the risk free rate and overall market volatility are also below one and are highly significant. In the second column, we truncate the sample in 1994, by including all projects developed after 1994 as artificially censored projects; to test for any censoring bias that may be due to the abandonment of projects that we do not observe. Again, although the statistical significance of prices is slightly reduced, the findings for volatility remain unchanged. The risk free rate however is now significant only at the 10 percent level, while our measure of systematic risk is not significant at all.

In column (3) we rerun the base specification using an exponential distribution for the underlying hazard, which assumes a constant baseline hazard rate. In column (4) we use the lognormal distribution, which allows the baseline hazard rate to be single-peaked. The latter is estimated in accelerated failure time and coefficients are reported in exponentiated form, so positive coefficients lead to increases in survival time (decrease in the hazard rate) and negative coefficients indicate a decrease in survival time. In both specifications the coefficients on systematic and idiosyncratic volatility are statistically significant, so increases in volatility lead to decreases (increases) in the hazard (survival) rate. The real risk free rate also has the expected sign and is statistically significant. The data suggest that the Weibull is the preferred specification. The log likelihood in both specifications increases in absolute value from the Weibull specification. In all Table 2 specifications the log-likelihood test strongly rejects that the estimated Weibull parameter is different from 1–the assumption in the exponential distribution. We use the Weibull specification in additional regressions below to analyze the effect of competition on option exercise.

B. Competition

The results in section A demonstrate that investment falls with increases in the volatility of returns. Next we examine the impact of competition on real option exercise. The theoretical real options models in Caballero (1991) and Grenadier (2001) predict that increases in competition reduce the value of the option to wait. By contrast competition should have no effect on the relationship between any measurement error in the calculation of the naive project-specific user costs and investment timing. This subject has been ignored in previous empirical analyses on real options exercise.

In addition to helping us better understand how the underlying structure of markets affects option exercise, our results on competition help differentiate between two competing interpretations of our findings. In the analysis above, we control for a variety of factors that might be part of the project specific user cost, but are unrelated to the option to develop. Nonetheless, it remains possible that idiosyncratic volatility impacts investment through risk-averse investors, rather than through a higher hurdle rate on the call option to make an irreversible investment. In this case, our measure of idiosyncratic risk would be capturing the effects of excluded components of this user cost, suggesting that risky projects demand a higher risk premium in the calculation of the investment's present value. To differentiate between these cases we explore the effects of competition on investment.

We see no reason why the correlation between unobserved portions of the user costs should be related to the degree of competition faced by a project. If anything, competition might even increase the expected volatility of future cash flows given uncertainty about the behavior of each of those competitors, making investment appear more sensitive to volatility.

We identify the number of competing projects within a given distance of each development site using computer generated mapping coordinates. At each point in time that project *i* in our sample has not yet been developed, we count the number of other potential, but as of yet unbuilt, projects within a one or two kilometer radius from project *i*. This measure is the actual number of all future developments that will be built around the development site *i*. To address the problem that our measure of competition naturally leads to a reduction in the number of competitors as time moves closer to the end of the sample, we include all projects in the sample up to 1998, but run the regressions only up to 1994. Furthermore, we compare the results using alternative measures of the relevant time horizon, counting all the projects that will be built in the future in our data and only those to be built in the next 4 years.

Table 4 presents regressions that include the various measures of competition, a variable for volatility, plus an interaction term for competition and condo return volatility. The results are consistent with theoretical real options papers that suggest that competition reduces the value of the option to wait. In all four columns, the coefficient on volatility is below one and significant, while the coefficient on the interaction between competition and condo return volatility is greater than one and significant at the 10% level or better suggesting that volatility has a smaller impact on option exercise in locations that face greater potential competition. Consider the estimates in column (2), where competition is measured as the number of projects four years into the future within a one kilometer radius. Using the mean number of potential projects (62), a one standard deviation increase in volatility (35 percent) leads to a 12.6 percent decline in new construction, which is slightly bigger than our earlier estimates. However, if the number of competitors increases by 50 percent, the same one standard deviation increase in volatility only leads to a 7.1 percent decrease in the hazard rate. Thus as a project is surrounded by more competitors, its hazard rate of construction becomes less sensitive to volatility. Competition appears to operate only by reducing the impact of volatility. In all cases, the coefficient on competition itself is never close to statistical significance at conventional levels. Other coefficients are of the expected signs and are similar to the base regressions in Table 2.

As an alternative, Table 5 measures competition as the number of condominium units in each potential project, and not just the number of potential projects. In this sense we differentiate between large and small projects, and also account for the increase in project size over time. Nonetheless, the impact of competition on volatility remains unchanged. In all columns, the interaction between the number of competitors and volatility is above one and significant at the 8 percent level or better and the coefficient on volatility is below one and highly significant as well. The coefficients on prices and other coefficients are all similar to the previous table's results.

VI. CONCLUSION

This paper supports many of the conclusions from the burgeoning theoretical literature on the importance of real options in explaining irreversible investment. We use data on 1,214 condominium projects built in seven neighborhoods of Vancouver, Canada between 1979 and 1998, along with relatively precise measures of output prices, to estimate a hazard rate of development. Our empirical results suggest that builders delay development during times of greater idiosyncratic uncertainty in real estate returns and when the exposure to market risk is higher. These findings hold across different time periods. The impact of volatility in our sample is economically significant. A one standard deviation increase in condominium return volatility leads to a 13 percent decline in the hazard rate of investment, the same effect as a 9 percent decline in prices. Similarly, our estimates suggest that the hazard rate falls 8 percent when exposure to systematic risk increases by one standard deviation.

We also show that competition significantly reduces the sensitivity of option exercise to volatility. Increases in competition appreciably decrease the coefficient on volatility in our hazard rate specification. In fact, volatility has no estimated effect on option exercise for the 5 percent of the project-months in our sample with the largest number of potential competitors. This finding is fully consistent with game-theoretic papers in real options, such as Grenadier (2001) and Cabellero (1991), where competition diminishes the value of waiting to invest. The fear of losing an investment opportunity to one's competitors creates incentives to invest earlier. Hence competitive firms are not able to capture the full benefits to waiting that a monopolist has. This result supports the real options model because this relationship should not affect the user cost of a reversible investment. In this way we provide clearer evidence in favor of the real options model.

In the future, we should be able to use this data set to explore other hypotheses regarding the exercise of real options. We are in the process of obtaining data on the date of land acquisition, which would allow us to explore the possible endogeneity of land purchase by developers. We can also use this data, along with other information identifying individual developers and loan-level data on mortgage amounts and lending rates, to examine the impact of financing and liquidity constraints on option exercise.

From a policy perspective, these results have important implications for understanding real estate cycles. An often-repeated claim in the real estate industry is that overbuilding in the real estate industry is due to irrational developers. Grenadier (1996) has suggested a rational basis for the bursts of construction that sometimes occur just as market prices begin to fall–strategic behavior by competing developers in imperfectly competitive markets. We find some evidence in favor of the Grenadier model; holding the level of prices constant, builders appear more likely to build when prices begin to fall.

More important, however, is the observation that the volatility of returns, exposure to market risk, and competition play important roles in the timing of investment. Builders are especially susceptible to business cycle shocks, as developer bankruptcies rise considerably in recessions. If competition is less pronounced in recessions, real options behavior may lead developers to delay irreversible investments in structures longer than they would in booms when markets are more competitive. Given that changes in investment are an important component in the business cycle, these results suggest that uncertainty and competition may play a role in understanding cyclical movements in investment in real estate and the macro economy.

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Table 1 - Descriptive Statistics: 1979-98

Variable	Location	Mean	Std	Min	Max
Real Condo Price (p)	Citywide	99.0	16.3	75.6	152.9
Real Condo Price (p)	Neigh. 1 (2)	107.0	19.6	76.9	165.5
Real Condo Price (p)	Neigh. 2 (7)	96.8	15.7	67.1	164.1
Real Condo Price (p)	Neigh. 3 (13)	94.3	19.5	63.9	157.9
Real Condo Price (p)	Neigh. 4 (40)	109.1	16.1	76.4	156.5
Real Condo Price (p)	Neigh. 5 (50)	93.1	17.8	56.4	158.5
Real Condo Price (p)	Neigh. 6 (51)	93.0	17.3	59.2	149.9
Real Condo Price (p)	Neigh. 7 (61)	105.7	17.9	70.6	163.8
citywide condo convenience yield (delta)	Citywide	0.34	0.07	0.21	0.53
condo convenience yield (delta)	Neigh. 1 (2)	0.28	0.07	0.15	0.45
condo convenience yield (delta)	Neigh. 2 (7)	0.33	0.05	0.17	0.54
condo convenience yield (delta)	Neigh. 3 (13)	0.39	0.10	0.25	0.67
condo convenience yield (delta)	Neigh. 4 (40)	0.36	0.07	0.23	0.59
condo convenience yield (delta)	Neigh. 5 (50)	0.31	0.09	0.20	0.63
condo convenience yield (delta)	Neigh. 6 (51)	0.31	0.09	0.20	0.63
condo convenience yield (delta)	Neigh. 7 (61)	0.26	0.05	0.14	0.45
project specific discount rate (rho)	Citywide	0.31	1.61	-4.35	9.48
project specific discount rate (rho)	Neigh. 1 (2)	0.33	1.10	-2.44	4.39
project specific discount rate (rho)	Neigh. 2 (7)	0.28	2.37	-7.71	9.44
project specific discount rate (rho)	Neigh. 3 (13)	0.46	1.89	-5.65	7.51
project specific discount rate (rho)	Neigh. 4 (40)	0.34	3.81	-11.22	13.40
project specific discount rate (rho)	Neigh. 5 (50)	0.46	1.89	-5.82	7.17
project specific discount rate (rho)	Neigh. 6 (51)	0.49	2.97	-13.06	11.20
project specific discount rate (rho)	Neigh. 7 (61)	0.19	3.83	-19.99	22.17
systematic risk = market volatility * beta	Citywide	0.65	0.39	0.10	2.25
systematic risk = market volatility * neigh. beta	Neigh. 1 (2)	0.42	0.47	-0.54	1.44
systematic risk = market volatility * neigh. beta	Neigh. 2 (7)	0.65	0.45	-0.18	2.56
systematic risk = market volatility * neigh. beta	Neigh. 3 (13)	0.39	0.18	0.02	1.44
systematic risk = market volatility * neigh. beta	Neigh. 4 (40)	0.91	0.45	0.09	2.85
systematic risk = market volatility * neigh. beta	Neigh. 5 (50)	1.10	0.50	0.44	3.01
systematic risk = market volatility * neigh. beta	Neigh. 6 (51)	0.74	0.33	0.20	2.26
systematic risk = market volatility * neigh. beta	Neigh. 7 (61)	0.66	0.79	-0.60	3.95
Garch - Condo Return Variance (not transaction adj.)	Citywide	10.4	9.1	1.8	42.4
Garch - Condo Return Variance	Citywide	8.9	8.5	1.1	37.2
Garch - Condo Return Variance (not transaction adj.)	Neigh. 1 (2)	24.7	19.8	6.8	118.5
Garch - Condo Return Variance	Neigh. 1 (2)	21.3	16.9	6.1	96.2
Garch - Condo Return Variance (not transaction adj.)	Neigh. 2 (7)	34.4	37.0	4.8	169.0
Garch - Condo Return Variance	Neigh. 2 (7)	30.3	37.0	3.4	184.5
Garch - Condo Return Variance (not transaction adj.)	Neigh. 3 (13)	32.3	18.8	15.0	124.5
Garch - Condo Return Variance	Neigh. 3 (13)	29.4	24.4	9.3	146.0
Garch - Condo Return Variance (not transaction adj.)	Neigh. 4 (40)	49.5	48.1	19.0	470.2
Garch - Condo Return Variance	Neigh. 4 (40)	43.1	49.1	14.4	466.5
Garch - Condo Return Variance (not transaction adj.)	Neigh. 5 (50)	34.6	25.4	4.4	91.3
Garch - Condo Return Variance	Neigh. 5 (50)	32.6	28.3	2.6	106.3
Garch - Condo Return Variance (not transaction adj.)	Neigh. 6 (51)	30.5	28.2	7.6	140.9
Garch - Condo Return Variance	Neigh. 6 (51)	26.3	27.2	4.3	129.6
Garch - Condo Return Variance (not transaction adj.)	Neigh. 7 (61)	49.7	54.8	8.3	290.8
Garch - Condo Return Variance	Neigh. 7 (61)	43.8	59.6	4.0	356.1

Table 2 -- Neighborhood Hazard Specification: Time to Develop a New Site

Hazard is estimated using a Weibull distribution

Various years

(Z-statistics in parentheses, except where noted)

Variable	**Reg. (1)**	**Reg. (2)**	**Reg. (3)**	**Reg. (4)**	**Reg. (5)**
Real condo price - neighbor 2	0.9985	0.9999	0.9982	0.9999	0.9997
	-(0.34)	-(0.01)	-(0.42)	-(0.02)	-(0.03)
Real condo price - neighbor 7	1.0073	1.0047	1.0066	1.0047	0.9688
	(1.41)	(0.90)	(1.29)	(0.89)	-(2.16)
Real condo price - neighbor 13	1.0209	1.0191	1.0201	1.0190	1.0104
	(3.69)	(3.42)	(3.59)	(3.42)	(0.91)
Real condo price - neighbor 40	1.0005	0.9997	1.0000	0.9997	0.9923
	(0.08)	-(0.04)	(0.01)	-(0.04)	-(0.59)
Real condo price - neighbor 50	1.0266	1.0251	1.0260	1.0250	1.0058
	(6.41)	(6.01)	(6.26)	(6.01)	(0.51)
Real condo price - neighbor 51	1.0187	1.0167	1.0179	1.0166	1.0007
	(2.87)	(2.52)	(2.76)	(2.51)	(0.05)
Real condo price - neighbor 61	1.0161	1.0168	1.0151	1.0168	1.0205
	(3.86)	(4.00)	(3.66)	(3.98)	(2.25)
Garch condo return variance	0.9962	0.9970	0.9964	0.9970	0.9884
	-(2.46)	-(1.88)	-(2.29)	-(1.84)	(1.99)
Risk free rate	0.4980	0.4812		0.4815	0.5360
	-(4.12)	-(4.28)		-(4.27)	-(3.14)
Condo convenience yield	1.1150	0.6792	1.033	0.6838	1.6690
	(0.11)	-(0.38)	(0.03)	-(0.37)	(0.23)
Systematic risk		0.8034		0.8041	0.3882
		-(2.11)		-(2.11)	-(4.63)
Project specific discount rate			0.9954	0.9971	1.0182
			-(0.34)	-(0.21)	(0.76)
Weibull parameter	1.89	1.81	1.85	1.81	1.79
(standard error)	(0.08)	(0.08)	(0.08)	(0.09)	(0.15)
Years of Analysis	1979-98	1979-98	1979-98	1979-98	1986-1998
No. of Subjects	1053	1053	1053	1053	1053
Log Likelihood	-973	-970	-980	-970	-645

Notes

1) All real estate price and return variables use neighborhood specific values.
2) All regressions include building type and neighborhood fixed effects and linear, quadratic and cubic variables measuring project size.
3) All price variables are in real dollars.

Table 3 -- Neighborhood Hazard Specification: Time to Develop a New Site

Hazard is estimated using various distributions

1979-98

(Z-statistics in parentheses, except where noted)

Variable	**Reg. (1)**	**Reg. (2)**
Hazard Specification	Exponential	Lognormal
Real condo price - neighbor 2	0.9908	-0.0027
	-(2.31)	-(0.08)
Real condo price - neighbor 7	0.9862	-0.0013
	-(2.71)	(0.37)
Real condo price - neighbor 13	1.0013	-0.0163
	(0.23)	-(4.64)
Real condo price - neighbor 40	0.9884	0.0005
	-(1.95)	(0.10)
Real condo price - neighbor 50	1.0123	-0.0170
	(2.80)	-(6.37)
Real condo price - neighbor 51	1.0024	-0.0115
	(0.36)	-(2.20)
Real condo price - neighbor 61	1.0017	-0.0093
	(2.55)	-(2.84)
Garch condo return variance	0.9905	0.0023
	-(4.95)	(2.57)
Risk free rate	0.6102	0.7248
	-(2.80)	(4.85)
Condo convenience yield	0.0025	-1.4230
	-(6.22)	-(1.88)
Systematic risk	0.4757	0.3272
	-(7.57)	(3.71)
Project specific discount rate	1.0079	0.0031
	(0.53)	(0.36)
No. of Subjects	1053	1053
Log Likelihood	-1026	-1145

Notes

1) Estimated z values are in parentheses.
2) All regressions include building type and neighborhood fixed effects and linear, quadratic and cubic variables measuring project size.
3) All price variables are in real dollars.

Time to Develop a New Site

Hazard is estimated using the Weibull distribution

1979-98

(Z-statistics in parentheses, except where noted)

Variable	**Reg. (1)**	**Reg. (2)**
Real condo price - neighbor 2	1.0002 (0.06)	0.9978 -(0.50)
Real condo price - neighbor 7	1.0041 (0.77)	1.0035 (0.68)
Real condo price - neighbor 13	1.0181 (3.23)	1.0166 (3.00)
Real condo price - neighbor 40	1.0004 (0.07)	0.9981 -(0.29)
Real condo price - neighbor 50	1.0246 (5.87)	1.0234 (5.56)
Real condo price - neighbor 51	1.0167 (2.58)	1.0147 (2.25)
Real condo price - neighbor 61	1.0175 (4.14)	1.0147 (3.56)
Garch condo return variance	0.9965 -(2.06)	0.9971 -(1.87)
Risk free rate	0.4738 -(3.93)	0.3941 -(4.91)
Condo convenience yield	0.4674 -(0.72)	0.5003 -(0.67)
Systematic risk	0.7977 -(2.14)	0.8468 -(1.62)
Project specific discount rate	0.9878 -(0.90)	0.9995 -(0.03)
units sold	0.9999 -(1.14)	
Garch units sold variance	0.9999 -(3.16)	
Avg. months to sale		1.0415 (3.07)
Garch avg. months to sale variance		0.9732 -(3.16)
Weibull parameter (standard error)	2.03 (0.11)	1.82 (0.09)
No. of Subjects Log Likelihood	1053 -956	1053 -959

Notes

1) All real estate price and return variables use neighborhood specific values.
2) Estimated z values are in parentheses.
3) All regressions include building type and neighborhood fixed effects and linear, quadratic and cubic variables measuring project size.
4) All price variables are in real dollars.

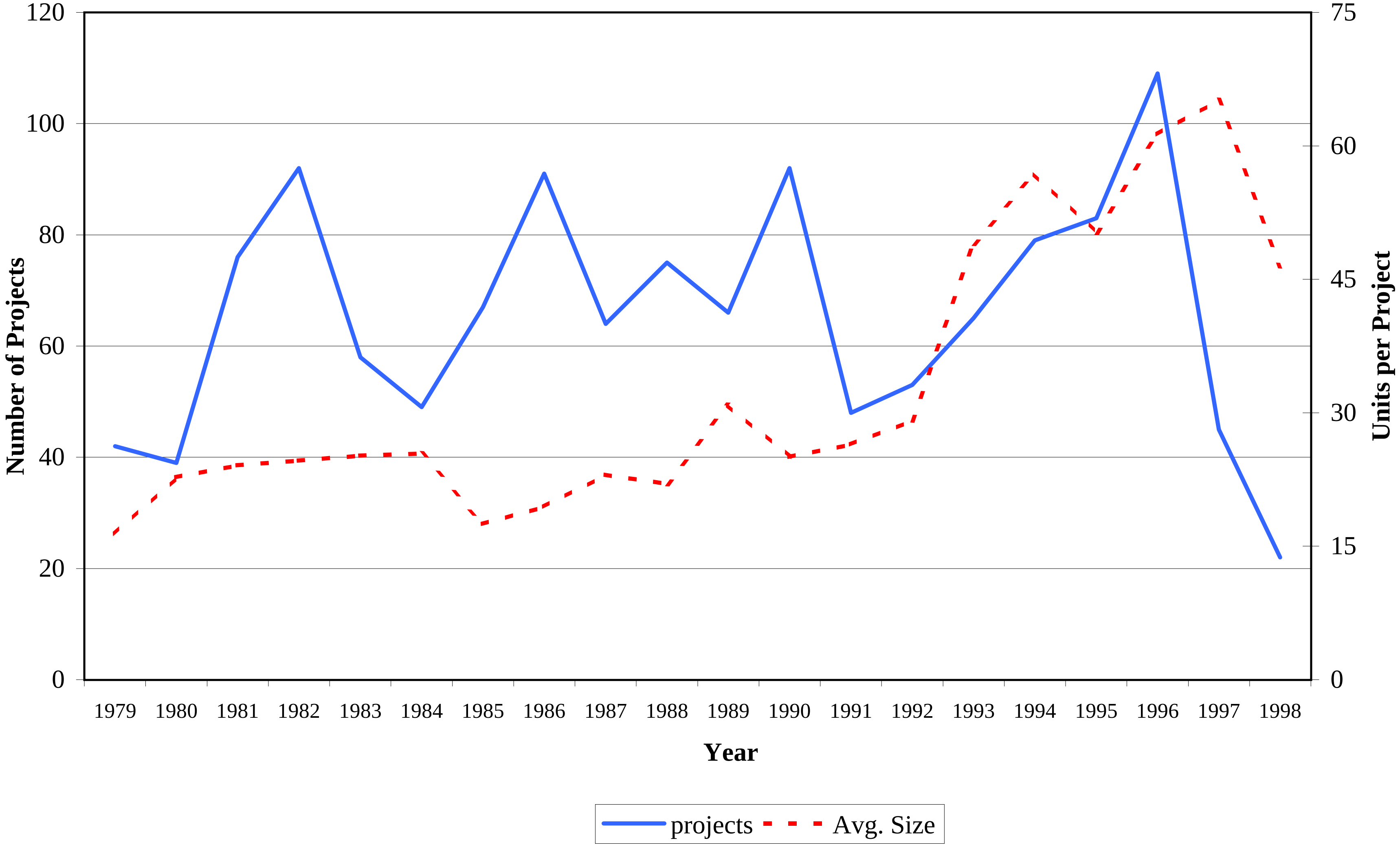
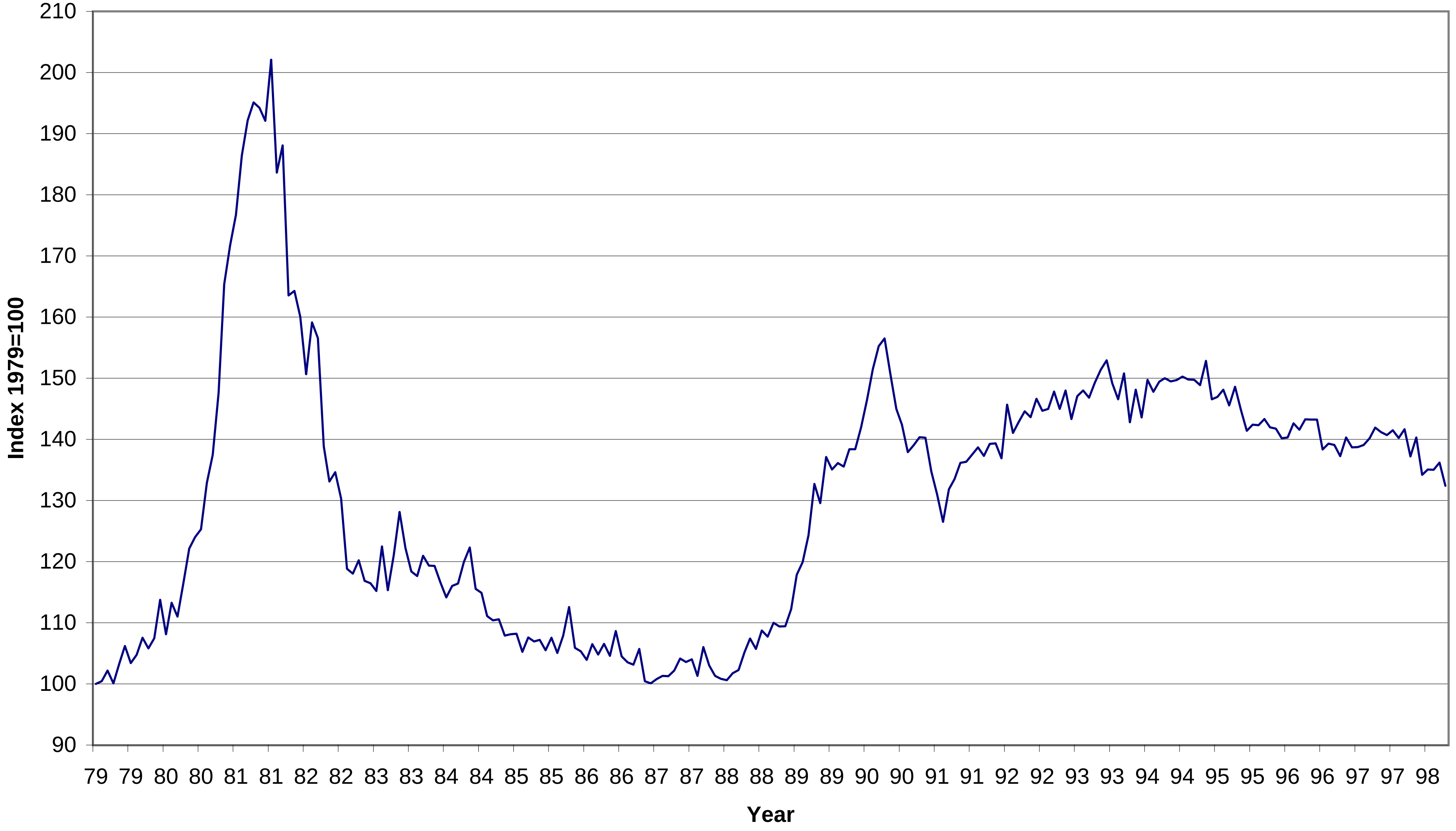


Figure 1
Vancouver Condominium Projects

Figure 2
Vancouver Condominium Monthly Real Price Index



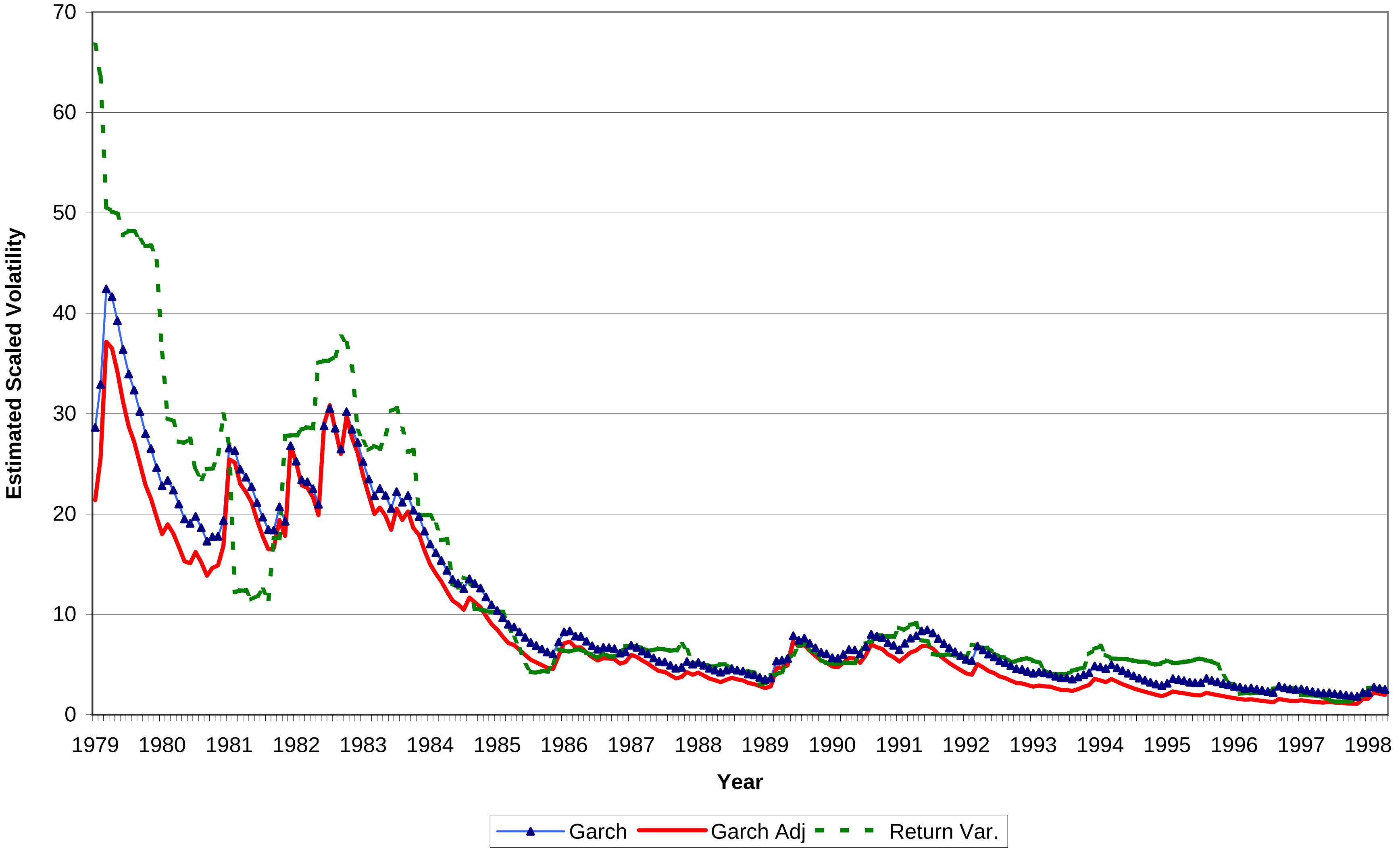


Figure 3a
Estimated Time Varying Volatility of Returns on Real Condo Prices
1979-98

Figure 3b
Estimated Time Varying Volatility of Returns on Real Condo Prices
1986-98

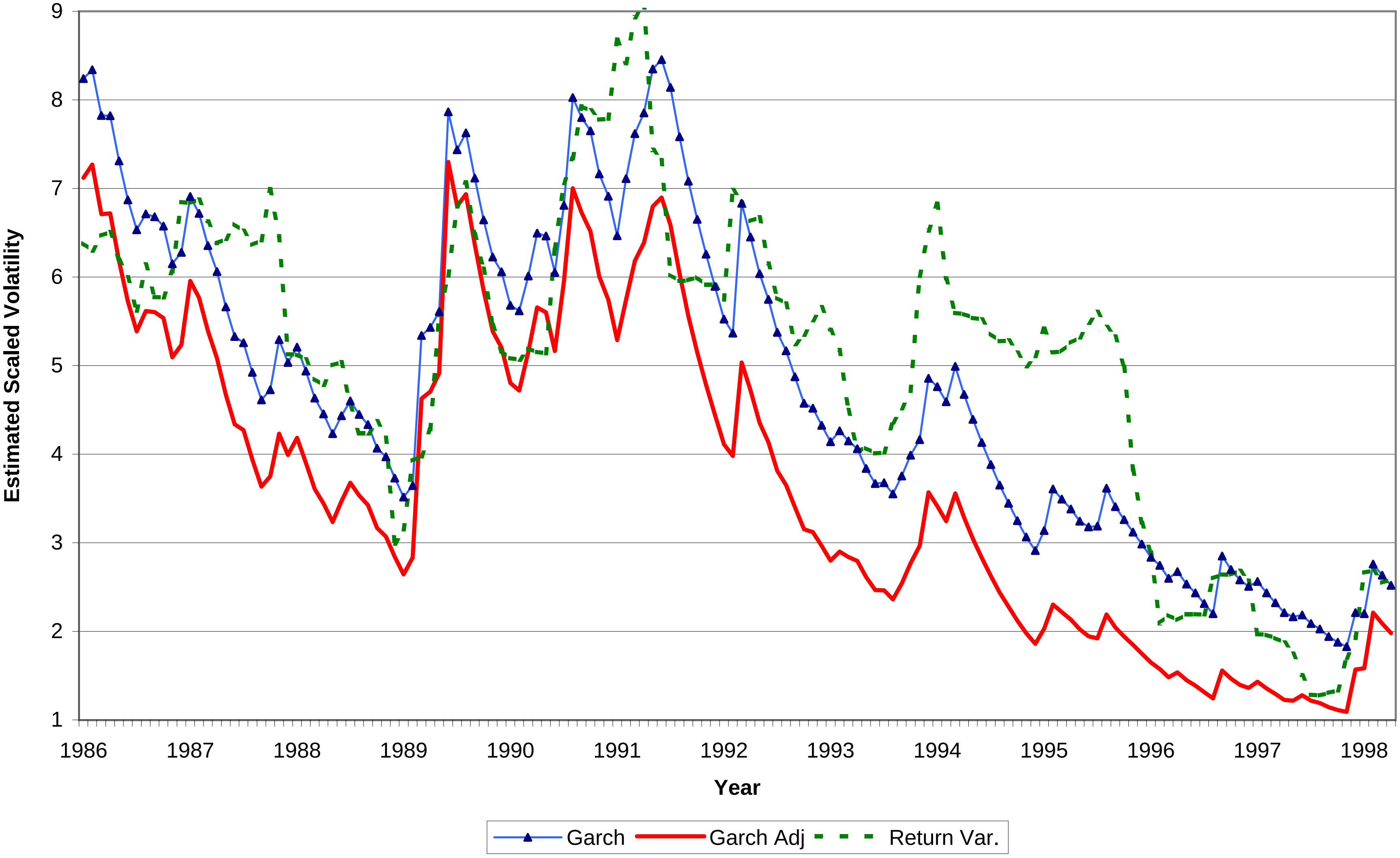


Figure 4 - Non-parametric Beta Vancouver Condos vs TSE300