ANALYSIS
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Moody's Analytics RPS Canadian Home Price Forecast Methodology

INTRODUCTION

Moody's Analytics uses a structural econometric model approach to forecast house prices at the national and regional levels in Canada. The forecast is generated by a two-step error-correction model that relies on long-term and cyclical economic drivers of the housing market. The approach for the RPS house price indexes is based on a structural model of housing demand and supply that allows for serial correlation and mean reversion.

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BY ABHILASHA SINGH

Moody's Analytics uses a structural econometric model approach to forecast house prices at the national and regional levels in Canada. The forecast is generated by a two-step error-correction model that relies on long-term and cyclical economic drivers of the housing market. The approach for the RPS house price indexes is based on a structural model of housing demand and supply that allows for serial correlation and mean reversion.

The model that Moody's Analytics has developed is a tool for identifying the forces driving house prices, and for assessing to what degree house prices can be explained by fundamental, persistent factors and to what degree they are explained by more cyclical factors.

The structural econometric model used in this study can determine whether housing markets are overvalued or undervalued, the degree to which overvaluation or undervaluation exists, and how these markets will ultimately adjust toward a long-run equilibrium.

The model, in conjunction with forecasts of the economic, demographic and financial drivers that the Moody's Analytics regional and macroeconomic forecast models generate within each housing market, also produces explicit house price index forecasts. It can also generate alternative forecast scenarios that match different macroeconomic outlook assumptions.

Model selection

Several classes of models may be considered to study the dynamics of, and produce forecasts for, house prices. Pure time series models such as vector autoregressions can provide insight but are highly dependent on history. For this reason, they tend to be less accurate in times of significant shifts in behavior than a structural model that considers market fundamentals.

Another approach is the leading indicator, which econometrically identifies variables that have historically led changes in housing values. The information provided by a structural model is richer than that provided by a leading indicator, including the magnitude and timing of a change in house price in addition to the direction of that change, but it also has clear disadvantages. Most importantly, a structural model cannot predict events that have never occurred historically and may not fully reflect the myriad factors that affect housing demand, supply and prices. Moreover, the forecasts produced by such a model are only as accurate as the forecasts of the drivers. Fundamentally, however, the leading indicator and structural model approaches are complements rather than substitutes, as they provide different types of information about the future of house prices.

The general approach of Moody's Analytics is to rely primarily on the results of a fully specified structural model. Information from leading indicators and other models as well as forward-looking changes in housing policy, mortgage markets and consumer preferences are used infrequently to re-estimate the model-based forecasts.

In addition to striving for theoretical rigor in the model development process, Moody's Analytics is mindful of other desirable model properties such as equations that behave well under commonly used stress scenarios and consistency of house price forecasts across geographic regions and across different measures of house prices. The theoretical basis for the structural model, choice of house price index to model, its estimation, and validation follow.

Historical data and their sources

RPS uses an extensive national housing database containing information about millions of unique residential property transactions across Canada. This database is refreshed and populated with hundreds of thousands of records on an annual basis. The methodology used in calculating prices and indexes is different from the Canadian Real Estate Association/MLS house price index, which uses a hedonic measure of home values obtained from a narrower multiple listing service dataset, and from the Teranet-National Bank of Canada house price index, which uses a standard repeat-sales methodology on public registry data.

By contrast, the RPS indexes and house price values use Bayesian filtering techniques wherein the first step is to group similar types of homes in the same geography and then to remove outlier transaction prices, which usually results in less data loss than a repeat-sales procedure. For price levels, the Bayesian filtering procedure allows RPS to come up with a central measure of prices for each housing category that is as straightforward as the median of the filtered observations. For the 13 large census metro areas that make up the RPS 13-metro composite index, RPS also calculates a transactions-weighted value measure that differs only slightly from the median-value measure.

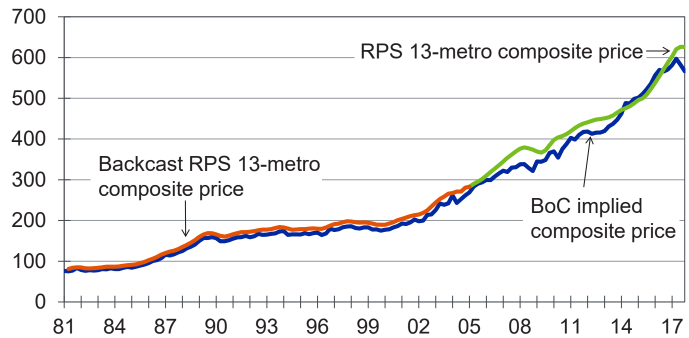
The Moody's Analytics forecast model covers all of the value and index series in the RPS Enterprise Risk Solutions product, including national measures, 10 provinces, 33 census metropolitan areas, 100 census agglomerations, 1,000 census subdivisions, and 1,500 forward sortation areas. Moody's Analytics forecasts four types of values and their associated indexes: median composite, median detached single-family home, median condo apartment, and aggregate transactions-weighted composite. Though the main econometric model is for the seasonally adjusted indexes and values, Moody's Analytics also forecasts the not seasonally adjusted series by calculating the average quarterly seasonal-adjustment factor for the entire historical dataset.

The full set of historical data used in the model is shown in Table 1. With only four exceptions, the economic data used to obtain house price forecasts come primarily from Statistics Canada. The exceptions being the national housing affordability index calculated by the BoC; the residential completions—used to estimate national regional housing stocks—and the five-year adjustable mortgage rate, which come from Canada Mortgage & Housing Corp.; and the S&P/TSX Composite Stock Share Price Index, provided by SIX Financial Information, which is used as a proxy for national wealth.

Data that are derived from Statistics Canada generally come from the CANSIM II database, with the exception of households, which are obtained from a combination of the quinquennial census and annual population estimates, and annual regional personal income estimates. Moody's Analytics does a significant amount of work converting annual province and census metropolitan area series into quarterly estimates at seasonally adjusted annual rates in order to provide a basis for a forecast model. Last, the native frequency of the RPS house price series is monthly but the forecast series frequency is quarterly, since the regional personal income drivers are quarterly in frequency.

Chart 1: Implied BoC Price Fits With RPS

Composite home values, C$ ths



Sources: RPS, Bank of Canada, Statistics Canada, Moody's Analytics

Backcasting home values

The RPS house price series goes back only to 2005, as do the CREA MLS house price indexes, while the Teranet house price series goes back only a few more years. None of the house price index series in Canada goes back much more than two decades. Fortunately, there are ways to extend the home value series backward, with the proviso that the main purpose of such backcasting is to establish a long-term house price trend and a corresponding mean-reversion relationship rather than to use the backcast series as inputs into an econometric forecast model. For the national home value, a composite series can be derived indirectly from the BoC's housing affordability index. The BoC calculates its affordability index using the formula:

$$HAI = HC / Y_{dh}$$

Where HAI is the housing affordability measured as a proportion, HC is average homeownership costs, and Ydh is average household disposable income. Average homeownership costs are obtained from the equation:

$$\mathrm{HC} = \left(\frac{\mathrm{r}}{1-(1+\mathrm{r})^{-\mathrm{N}}}\right) * 0.95\mathrm{P} + \mathrm{U}$$

Where r is the weighted average of the effective five-, three- and one-year mortgage rates, N is total number of interest payments (assumed to be 300 over 25 years), P is the price of the home (described by the BoC as the average multiple listing service composite price), and U is the cost of utilities and waste removal; it is assumed that the loan-to-value ratio for the initial mortgage is 0.95.

Moody's Analytics has extended national time series data for the BoC housing affordability index, disposable personal income, households, and mortgage rates. With two further assumptions—that the weights used to calculate the average effective mortgage rate are fixed and that annual utility costs are approximately 0.6% of the cost of a home—an average composite price going back to 1981 is obtained from the above equation. This extended composite price fits well with the RPS 13-metro composite price (see Chart 1).

Moody's Analytics forecasts this extended house price using the cointegrating regression shown in Table 2 and uses the resulting backcast (see Chart 1). Since the regression assumes that the two series are cointegrating, Table 2 also shows the results of a Hansen test for cointegration, which indicate that the null hypothesis of cointegration between the RPS 13-metro composite price and the implied BoC composite price cannot be rejected.

Error-correction model

As with nearly all Moody's Analytics forecast models, the house price model employs the structural approach, which specifies, estimates and then solves equations that mirror the structural workings of Canadian housing markets.[1] Structural macroeconomic models such as the Moody's Analytics Canada model excel in exploring the economywide implications of alternative assumptions about the future, including those used in stress-testing exercises. This approach is also well suited to extrapolate implications for specific regions.

1 By comparison, VAR models provide good short-term forecast accuracy but lack any causal explanation for such forecasts that can be applied to simulations, while dynamic stochastic general equilibrium models require highly restrictive assumptions about household behavior and about the causal relationship between individual actions and macroeconomic aggregates.

The structural econometric model of housing demand, supply and price employed by Moody's Analytics is a standard approach that allows for both serial correlation and mean reversion in the housing market.[2] Mean reversion implies that in the long run, housing markets move toward equilibrium values based on fundamental supply and demand factors. In each geographic area k and each period t, it is assumed that there is a long-run equilibrium value for the unit price of housing space that is determined by:

$$P^*_{t,k} = \alpha_k + f(x_{t,k}) \qquad (1)$$

Where P* is the real equilibrium house value, α_k is a constant specific to the geography k, and x_{tk} is a vector of explanatory variables affecting either supply or demand and that are relatively insensitive to business cycles.

The explanatory variables in the equilibrium equation can include factors that influence the long-run demand for housing such as real household income, real household non-housing wealth, population growth, and the long-run risk-adjusted return to housing and other household assets. Long-run supply-side factors such as construction costs can also be included in the equation. Moody's Analytics postulates that construction costs are important in areas where housing supply is not constrained either by geographic boundaries or by zoning or regulatory constraint.

The specification of an equilibrium or trend home value does not deny that home values can drift away from such an equilibrium. Indeed, a look at post-2010 RPS house price data would seem to indicate that house prices are likely overvalued for Toronto and Vancouver (see Chart 2). Nor does such a specification guarantee that there will be perceptible mean-reversion effects, especially if the historical dataset for a particular geography is insufficiently long.

Short-run fluctuations around the equilibrium house price are determined by:

$$\Delta P_{t,k} = a_k \Delta P_{t-1,k} + b_k\left(P^*_{t-1,k} - P_{t-1,k}\right) + c_k \Delta P^*_{tk} + D_{t,k} \qquad (2)$$

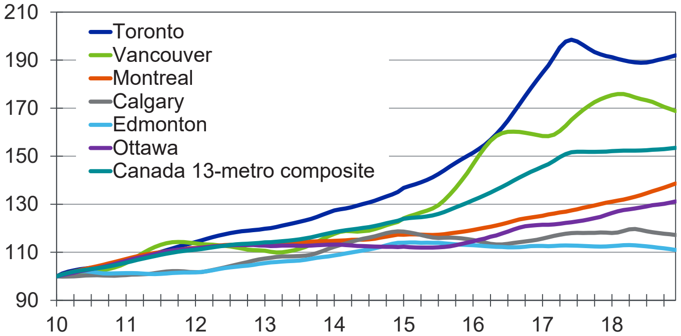
The first set of terms in Equation (2) captures serial correlation, where ak is the serial correlation coefficient, bk is the rate of mean reversion, and ck captures the immediate adjustment to changing fundamentals. The vector Dtk includes various business-cycle factors—such as unemployment, relative scarcity of housing, and mortgage rate-determined costs of homeownership—that affect changes in house prices around their long-run equilibrium. Supply-side and policy factors such as housing inventory buildup, regulatory conditions, permitting requirements, and structural changes in lenders' underwriting standards can be included in the adjustment equation.

It is important to note that Equation (2) can be written as a difference equation so its dynamic properties can be examined. The parameters ak and bk determine whether house prices exhibit oscillatory or damped behavior, and convergent or divergent behavior.[3] In particular, the bk term denoting the magnitude of mean-reversion effects takes in a host of real-world housing market dynamics that may not have extensive data. For example, overvaluation leading to excessive construction, declining mortgage debt performance and foreclosures, and even policy measures intended to act as a brake on purchase demand all fall under the mean-reversion rubric. The same applies to reduced construction and opportunistic purchases that take place in any geography with undervalued markets.

Moody's Analytics applies the model described by Equations (1) and (2) to house price index determination at the national, provincial and metro area levels. Empirical analysis, however, determines the functional form and variables that the model equations will ultimately include. For some geographies, it may not be possible to establish significant mean-reversion effects (coefficient bk). Statistical tests will guide the final specification for the equilibrium and adjustment equations.

Chart 2: Toronto, Vancouver Overvalued?

RPS transactions-weighted composite indexes, Jan 2010=100



Sources: RPS, Moody's Analytics

National RPS indexes

The first series that is chosen to be modelled is the seasonally adjusted[4] RPS 13-metro composite price index. This index is chosen because media focus more on the national index than on its corresponding composite price level. The first step in forecasting the national RPS 13-metro composite price index is to choose contemporaneous economic drivers and then show that there is a cointegrating relationship between the RPS national index and these contemporaneous drivers. That is, that they have a long-run equilibrium relationship. If the data confirm a cointegration relationship, any correlation established by the long-run equilibrium regression is unlikely to be spurious, and thus the two-step error-correction specification in Equations (1) and (2) is desirable.

The chosen drivers are the Canada new house and land price index and real median family income interacting with the national population.[5] This latter driver requires explanation. Median family income is a plausible choice for an income driver precisely because it is a median while the RPS composite price measure is much closer to a median than to an average. However, since 2010 at least, national house price appreciation has easily outpaced median household income growth

2 The main academic antecedent to this modeling approach is Capozza, Dennis R.; Hendershott, Patric H.; Mack, Charlotte, "An Anatomy of Price Dynamics in Illiquid Markets: Analysis and Evidence from Local Housing Markets," *Real Estate Economics (*March 2004).

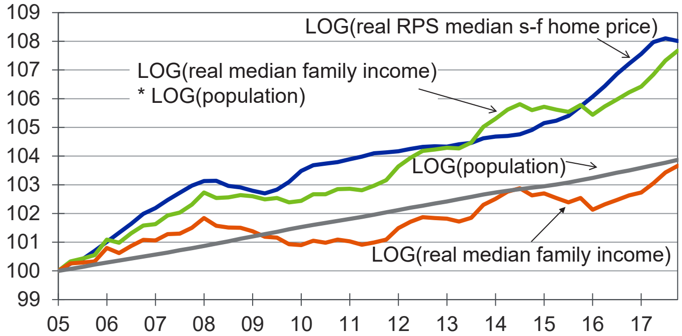
3 Capozza et al., 2004, calculate the dynamic properties of Equation (2) under the simplifying assumption that P*tk = P*k, a constant.

4 All the house price series provided by RPS are seasonally adjusted by Moody's Analytics.

5 In all regressions that use economic drivers, house price and income measures are first deflated by the consumer expenditure deflator.

Chart 3: Population Growth Matters

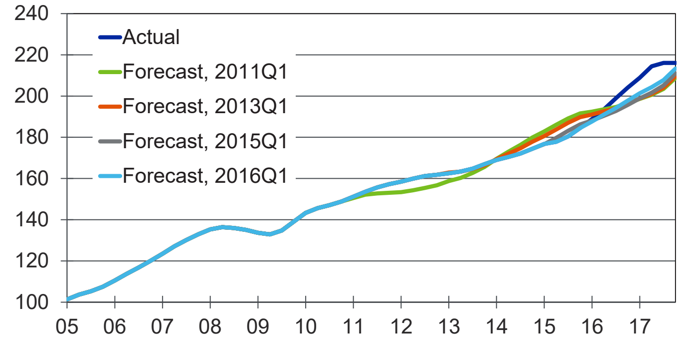
Canada, 2005Q1=100



Sources: RPS, Statistics Canada, Moody's Analytics

Chart 4: In-Sample Back-Test Validations

RPS house price index, composite (Jan 2005=100, SA), Canada



Sources: RPS, Moody's Analytics

(see Chart 3). Median income multiplied by population grows at a rate approximating house price appreciation, so population would seem to be a logical inclusion in the house price drivers.

Demonstrating a cointegrating relationship requires first showing that both series are nonstationary (in technical terms, that they both have a unit root). Table 3 shows the augmented Dickey-Fuller tests for nonstationarity. None of the tests reject the null hypothesis of a unit root, even for the new house and land price index. Table 4 shows the results of a Johansen cointegration test for the three series. The null hypothesis of no cointegration is rejected in favor of the alternative of at least one cointegrating equation.

With cointegration shown to be a strong possibility, an equilibrium trend for the RPS 13-metro composite index is forecast using a LOG-LOG regression; the regression is shown in Table 5.[6] The fitted values from this regression form a long-term price trend from 1981 through the end of the forecast horizon.

The regression in Table 6, using only 2005-2017 data, generates the actual forecast. The drivers include the constant, dependent variable lagged one and two quarters in order to generate persistence effects, and the appreciation rate of the equilibrium price level in order to proxy the effects of contemporaneous increases in median family income and new home or land prices. The mean-reversion term is perceptible and statistically significant. Last, changes in the five-year mortgage rate and the unemployment rate versus the nonaccelerating inflation rate of unemployment gap are also included, though the former usually has stronger effects in most house price models, this regression being no exception. The mortgage rate is lagged two quarters because of the time gap between the decision to purchase a home and the actual recording of the closed transaction.

In order to evaluate the model performance, Moody's Analytics conducts in-sample and out-of-sample validation tests for house prices by calculating the normalized root-mean-square error for selected subperiods of the forecast.[7] The in-sample and out-of-sample back-testing forecasts and the NRMSEs for the national house price model indicate that the national model behaves well. Four tests are conducted, with forecasts starting in 2011Q1, 2013Q1, 2015Q1 and 2016Q1, respectively. The end point is 2017Q4 for all cases; this was the last quarter of historical data at the time these tests were conducted. Charts 4 and 5 demonstrate that for both in-sample and out-of-sample validations, the national house price model's predictions are very close to the actual values of the RPS house price. NRMSEs for the in-sample validation are all very small, ranging from 0.030 to 0.034. The out-of-sample validations also have reasonably small NRMSEs, ranging from 0.030 to 0.065.

The regressions in Tables 5 and 6 are not the final step in deriving the national house price forecast. Quite often, the national analyst has to take into account difficult-to-quantify factors, including policy interventions such as transfer taxes, vacant property taxes, and resale restrictions in Toronto and Vancouver as well as successive moves by the Office of the Superintendent of Financial Institutions to restrict mortgage lending by making the requirements for mortgage insurance more stringent. Because of this, the forecasts generated in Tables 5 and 6 are a starting point but can be subject to significant adjustment in order to take into account nonquantifiable housing market factors such as policy restrictions.

The forecast for the RPS 13-metro composite price index is the core house price forecast for the Canada resale market in the macro model and is published with the macroeconomic forecast as well as with the RPS index forecasts. All the remaining RPS national indexes are forecast in a series of equations shown in Table 7. The individual series equations are shown as columns in the table; each equation column is recursively dependent on the equation column to its left, with the leftmost column dependent on the RPS 13-metro composite index forecast in Table 5.

In left-to-right order, the RPS 13-metro composite price level is driven by the corresponding price index as well as a moving average MA(1) term, as its growth rate does not match 100% with the growth rate of the index.

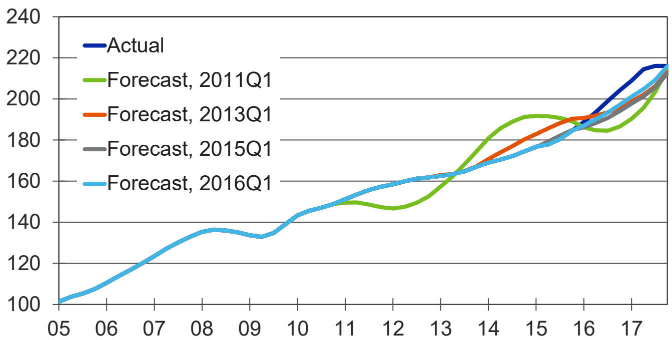
Then in the second and third columns, the RPS national median composite price is forecast

6 The regression is restricted to 2017 because median family income data are not available for post-2017.

7 The in-sample tests use parameters estimated from all historical data and compare the predicted value to the actual value for subperiods. The out-of-sample tests hold out some historical data, and use parameters estimated from the remaining period to predict values in the hold-out period and compare the fitted values with the actual ones. Also note that the out-of-sample validation tests here are ex post (they use actual historical data for drivers rather than forecasts).

Chart 5: Out-Sample Back-Test Validations

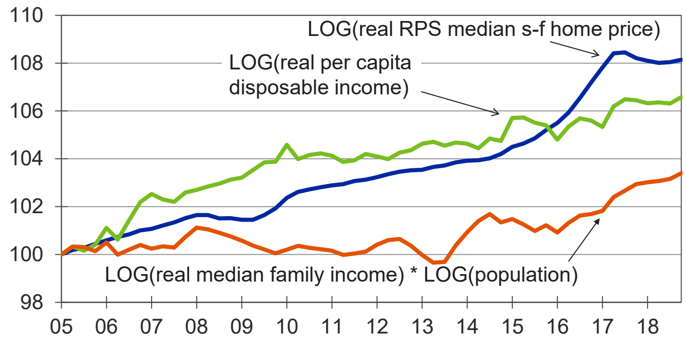
RPS house price index, composite (Jan 2005=100, SA), Canada



Sources: RPS, Moody's Analytics

Chart 6: Net Income Fits Better for Ontario…

Ontario, 2005Q1=100



Sources: RPS, Statistics Canada, Moody's Analytics

in a two-step error-correction process. In the first step, a trend national median composite price is obtained by being regressed on the 13-metro composite price level. In the second step, the national composite price level is obtained using both persistence and mean-reversion drivers in addition to the effect of the 13-metro composite index appreciation rate.

In the fourth column, household formation net of single-family completions, and scaled to total households, is used to drive a wedge between the growth rates of the national median composite price level and the national detached single-family house price level.

And in the fifth column, an autoregressive AR(1) term and the growth rate of the median detached single-family house price are used to forecast the ratio of the national condo apartment appreciation rate to the national composite price appreciation rate, from which a forecast for the median national condo apartment price level can be calculated.[8]

Last, indexes for the national median composite, detached single-family, and condo apartment price levels appreciate one-for-one with these price levels, so their forecasts are obtained using the growth rates of the price levels forecast in Table 6.

Provincial RPS median price

Forecasting the national RPS house price levels and indexes is a necessary first step before forecasting the provincial house and condo price levels, as the provincial forecasts have to be calibrated to the national forecasts in order to maintain geographic consistency.

The next important decision in the forecast process is to select the primary cointegrating driver for each median house price forecast. The chosen drivers are the real per capita disposable income and deflated S&P/TSX stock price index—a proxy for national financial wealth. For the provinces, a single measure of income did not provide a particularly good long-term fit (see Charts 6 and 7). House price appreciation outpaced median family income multiplied with population growth in Ontario, British Columbia, Alberta, Manitoba, Nova Scotia and Quebec, while per capita disposable income grows at a rate approximating house price appreciation in Ontario, British Columbia, Alberta and Manitoba. This lack of uniformity is most likely because housing markets can be strongly different from one another. Real per capita disposable income is chosen as the model performed better than median family income multiplied with population.[9] Table 8 results indicate that RPS median detached single-family house prices, RPS median condo apartment prices, real per capita disposable income, and the deflated S&P/TSX stock price index are nonstationary at the provincial level, which is the first necessary assumption for cointegration testing. Table 9 shows the results of the corresponding Johansen Fisher panel tests for cointegration. For detached single-family homes and condo apartments, the tests reject the null hypothesis of no cointegration in favor of alternative hypotheses of at least one cointegrating equation. With cointegration shown to be a strong possibility, an equilibrium trend for the RPS median detached single-family house price and RPS median condo apartment price is forecast in a similar framework as in the national model.[10]

To further allow for geographic differences in the relationship between house and condo prices and explanatory variables—such as different price elasticity of income for different areas, different correction speed, different magnitude of persistence in house price changes, or different sensitivity to the unemployment rate or mortgage rate—the 10 provinces are divided into five groups: Atlantic, Prairie, British Columbia, Ontario and Quebec. The regional dummy variables for these five groups interact with the explanatory variables; therefore, areas in different groups can have different regression coefficients, but geographies within the same group have the same coefficients. Table 10 lists the grouping for the provinces. The areas are divided based on their housing market similarity and geographic proximity. British Columbia is the western-most province of Canada and has the most expensive housing market, so it forms its own group. Ontario and Quebec are in central Canada, but these two provinces form separate groups, as Ontario is Canada's financial and manufacturing hub with the second-most expensive housing market. The rest of the provinces are divided

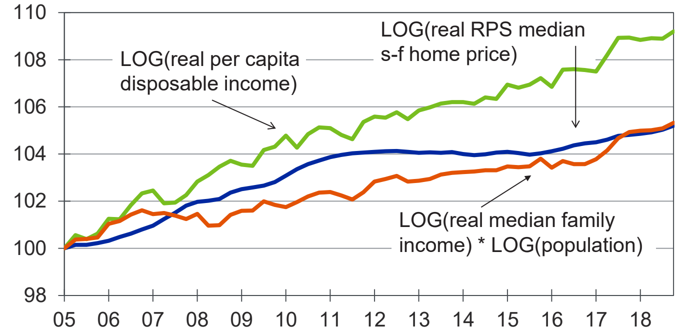
8 The last two columns in Table 6 show that intercept terms are not used in the regressions, so that the adjusted R-squared statistic is therefore not a valid measure of closeness of fit.

9 In-sample and out-of-sample results were better for the model with real per capita disposable income.

10 In order to evaluate the model performance, Moody's Analytics conducted in-sample and out-of-sample validation tests for house prices by calculating the normalized root-mean-square error for selected subperiods of the forecast. Validation test results are available upon request.

Chart 7: …But Not for Quebec

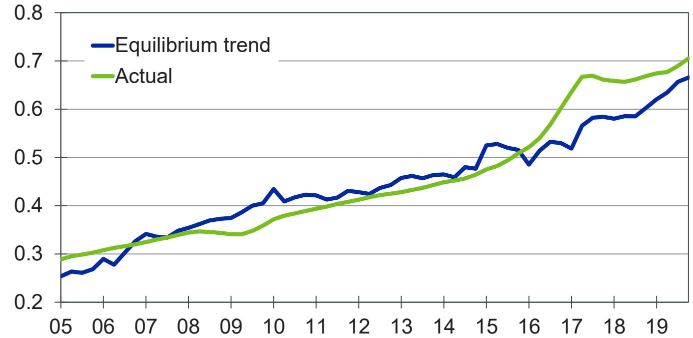
Quebec, 2005Q1=100



Sources: RPS, Statistics Canada, Moody's Analytics

Chart 8: Ontario Is Overvalued…

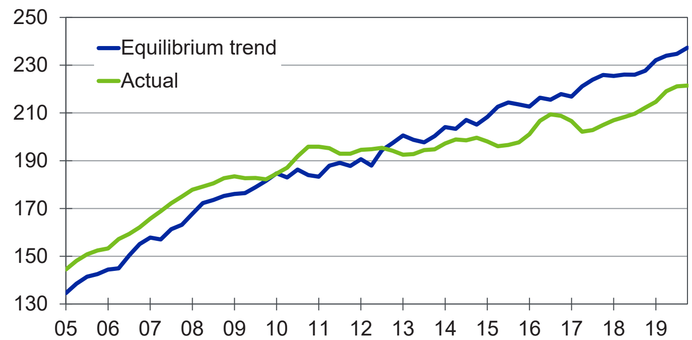
Ontario median single-family house price, C$ mil



Sources: RPS, Moody's Analytics

Chart 9: …But Not New Brunswick

New Brunswick median single-family house price, C$ ths



Sources: RPS, Moody's Analytics

into two groups: Atlantic and Prairies, based on geographic location and similarity in housing markets.

Tables 11 and 12 show the equilibrium regression results corresponding to Equation (1).[11] The long-run equilibrium trend for both price series is estimated in a panel regression with cross-sectional fixed effects and with cross-sectional weighting to reduce heteroscedasticity. The fixed effects in the trend equation capture geographic differences in house prices that do not change over time. The regressions are done using actual data starting from 2005 to establish a long-term price trend.[12] Both house price and income series are deflated by the Canada consumer spending deflator, so that house prices trend at the rate of consumer price inflation even if all other drivers are unchanged. As indicated in Tables 8 and 9, the main fundamentals driver for each province is real disposable income as a determinant of the detached single-family house and condo apartment price trend.

However, the deflated S&P/TSX stock price index is also included to ensure that individual metro areas did not diverge too radically from the national index price trend and reacted in a perceptible way to local income trends. A common coefficient instead of a group-specific coefficient is used for this driver because of highly insignificant coefficients for some groups.

It should be noted that the regressions in Table 10 and 11 are in levels rather than difference terms to generate a price trend with a lot of autocorrelation, allowing a significant departure of the actual house price series from the fitted values, which would correspond to housing market over- or undervaluation. Charts 8 and 9 show the difference between actual median detached single-family house prices and the trend values generated by the Table 12 regressions for Ontario and New Brunswick. Ontario is clearly overvalued despite recent provincial government efforts to restrict wealth-driven demand and increase supply. By contrast, New Brunswick appears to be undervalued. British Columbia and Ontario are significantly overvalued, most likely as a result of wealth inflows boosting housing demand.

The Table 11 and 12 regressions that correspond to Equation (1) establish a long-term price trend, but the actual house price forecasts have to be established using dynamic equations similar to Equation (2), which may or may not show significant persistence or trend-reversion effects. Tables 13 and 14 show the resulting adjustment regressions for provinces, again divided into five groups.

The provincial price level is obtained using both persistence, the effect of trend house price appreciation, and mean-reversion drivers. The regression tables show the persistence effects (that is, lagged dependent variable effects). As expected for a stable price series such as the RPS median prices, they are positive for the first lagged quarter and tend to be negative for the second lagged quarter.

The use of persistence terms involves a potential trade-off. In normal housing markets, the use of persistence drivers stabilizes the forecast and improves forecast accuracy. But if housing market circumstances are not ordinary, the use of persistence terms increases the likelihood that the forecast will miss significant market turning points, such as when the market becomes oversupplied or distress sales become a significant part of the market. This is all the more reason to make sure that the other independent variables in the regressions have strong effects.

The coefficients of the effect of trend house price appreciation—that is, the contemporaneous effect of all the long-term drivers that go into the Table 11 and 12 regressions—are all positive, though they vary in intensity. The coefficients on mean-rever-

11 The regression is restricted to 2018 because income data are not available for post-2018.

12 Actual data instead of a backcast series were used, as the model performed better with actual data.

sion effects, as proxied by the lagged difference of the actual price to the trend price estimated in Tables 11 and 12, are negative.

With a few exceptions, mean-reversion effects turn out to be perceptible and statistically significant, but the exceptions turn out to be important. In Ontario, single-family house prices have diverged from trend since 2010 and have not reverted, so it is no surprise that the mean-reversion effects were not significant for Ontario; the same applies for the Ontario condo apartment markets. In effect, the lack of mean reversion is caused both by the short length of the historical time series and by the lack of data that quantify capital inflows into the Ontario housing markets.

The mortgage rate is one of the largest and most variable determinants of the costs of homeownership, so the five-year mortgage rate is also included as a regression driver for both home types and demonstrates negative effects on appreciation.[13] Changes in the unemployment rate have weaker effects, but this driver is included as well because it usually comes out with the correct sign and because it is the main indicator of local business cycle conditions.

Deriving the median composite price level for provinces is not as straightforward. The first reason is that only a fraction of a geography's multifamily housing stock is used for condo ownership, with the rest being rented out.

The second reason is that the composite price level also includes smaller housing categories such as semidetached, townhouse/rowhouse, and plex homes that are not part of the price forecast process. For this reason, the "weights" for detached single-family and condo apartment prices in the composite indexes are determined in the pooled regressions themselves. These regressions are shown in Table 15.

Furthermore, New Brunswick and Prince Edward Island are kept in a separate pool because of a lack of condo apartment prices. The coefficients for each driver are in effect the estimated weight of each housing type used to determine the appreciation rate of the composite price. That the weights do not add up to 1 is attributable to the housing types that are missing as independent variables in the regression.

Metro area RPS median price

Forecasting the provincial RPS house and condo price levels and indexes is a necessary first step before forecasting the metro area house and condo price levels, as the metro area forecasts have to be calibrated to the provincial forecasts in order to maintain geographic consistency.

The primary cointegrating drivers for each median house price forecast are the real per capita disposable income and deflated S&P/TSX stock price index. Table 16 results indicate that RPS median detached single-family house prices, RPS median condo apartment prices, real per capita disposable income, and the deflated S&P/TSX stock price index are nonstationary at the metro area level. Table 17 shows the results of the corresponding Johansen Fisher panel tests for cointegration. For detached single-family homes and condo apartments, the tests reject the null hypothesis of no cointegration in favor of alternative hypotheses of at least one cointegrating equation.

An equilibrium trend for the RPS median detached single-family house price and RPS median condo apartment price is forecast in a similar framework as in the provincial model. All the metro areas are divided into five groups: Atlantic, Prairie, British Columbia, Ontario and Quebec. Table 10 lists the grouping for the metro area. Tables 18 and 19 show the equilibrium regression results corresponding to Equation (1).[14] The regressions are done using actual data starting from 2005 to establish a long-term price trend.[15] As indicated in Tables 16 and 17, the main fundamentals driver for each province is real per capita disposable income along with the deflated S&P/TSX stock price index as a determinant of the detached single-family house and condo apartment price trend. A common coefficient instead of a group-specific coefficient is used for this driver because of highly insignificant coefficients for some groups.

Tables 20 and 21 show the resulting adjustment regressions for metro areas. The metro price level is obtained using persistence, the effect of trend house price appreciation, mean-reversion drivers, the mortgage rate, and the unemployment rate. A common coefficient was used instead of group-specific coefficients if the coefficients were highly insignificant or had the wrong sign.

The approach used to derive the median composite price level for each metro area is similar to provinces. These regressions are shown in Table 22. The metro areas are grouped into two pools; the first group consists of metro areas with both house and condo prices and the second group consists of metro areas with only house prices.

Province and metro area index and NSA forecasts

All of the RPS home value forecasts discussed so far have been for prices because prices are better than index numbers at establishing the gap between actual and long-term values.

But index forecasts follow almost automatically out of price-level forecasts. For the non-transactions-weighted price levels, the historical index growth rates are exactly the same as the price-level growth rates, so the index forecasts are simply the index history grown out by the growth rate of the price-level forecasts.

For the 13 metro area transactions-weighted composite indexes, the growth rates between prices do not correspond 100%, but DLOG-DLOG regressions (not shown) indicate that the coefficient of the transactions-weighted price level is almost equal to 1 at five significant digits, so the transactions-weighted index forecasts are also grown out by the growth rate of the transactions-weighted price.

All of the house price value and index forecasts discussed thus far had been seasonally adjusted. To obtain not seasonally adjusted forecasts, we run pooled regressions in which the log-ratio of the NSA to the SA forecast for each geography is compared with four dummy variables—one for each quarter of the year.

The estimated coefficient for each quarterly dummy variable is then added to the log of the SA forecast in order to obtain an NSA forecast that fluctuates around its SA

13 The mortgage rate difference is lagged by two quarters to account for reaction times by prospective buyers as well as offer-to-closing time gaps in recording purchases.

14 The regression is restricted to 2018 because income data are not available for post-2018.

15 Actual data instead of a backcast series were used, as the model performed better with actual data.

trend. In order to avoid showing a plethora of province and metro area coefficients, the tables are not shown.[16] Because of the short length of the RPS time series, all of the historical data are used to estimate the average seasonal adjustment factors, but as more data are added it may be possible to restrict the sample to more recent observations, for example, by using breakpoint regression methods.

Forecast calibration

All of the metro area and province forecasts previously estimated are in a sense preliminary since they have not been calibrated to maintain consistency with the national index forecasts.

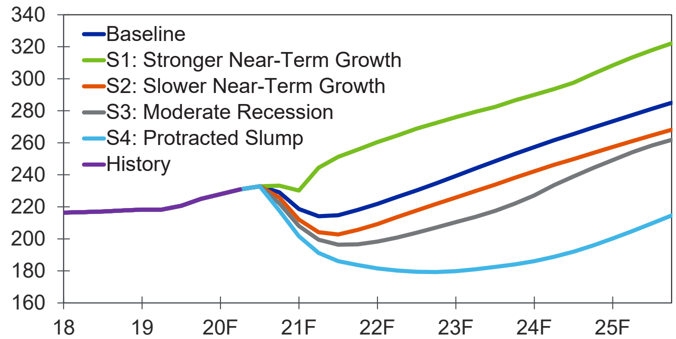
Calibration is a straightforward procedure. Using housing stock forecasts, the weighted-average growth rates of all province house price levels and house price indexes are calculated and compared with the growth rate of the national house price levels and house price indexes. The gap between the two growth rates is then used to adjust the provincial forecasts up or down as needed so that their weighted-average growth rate is the same as the national price or index growth rate.

The metro area forecasts are calibrated in the same manner, as are the 13 metro area transactions-weighted price and index forecasts, though the latter are calibrated to the 13-metro composite values rather than to the national price or index.[17] Use of the housing stock estimates rather than households or population to set weights is also slightly more flexible, as it allows weights for condo apartment price calibration to be determined by the more unevenly distributed multifamily housing stock.

It is worth noting that for normal forecasts including the baseline that this calibration is small in magnitude, but it can be larger in forecasts where the national economy is subject to severe downward shocks that generate financial feedback effects such as credit restrictions and foreclosures that are not captured in the regional forecast models.

Chart 10: Standard Alternative Scenarios

RPS house price index, composite (Jan 2005=100, SA), Canada



Sources: RPS, Moody's Analytics

Sub-metro area forecast

The house price forecasts at the national, provincial and metro level are generated by a two-step error-correction model that relies on long-term and cyclical economic drivers of the housing market. We use a similar framework to forecast house prices at the sub-metro level. The biggest challenge in using this framework was unavailability of economic drivers in the sub-metro area. To overcome this problem, we use the house price of a higher-level geography as a proxy for the economic condition in the area. For example, we use the house price forecast of Ontario as a proxy economic driver for Brockville—a census agglomeration in Ontario.

All the census agglomerations are divided into five groups: Atlantic, Prairie, British Columbia, Ontario and Quebec. Tables 23 and 24 show the equilibrium regression and adjustment regression results corresponding to Equation (1) and Equation (2) for census agglomeration within Ontario. As indicated in Tables 23 and 24, the main fundamentals driver for each census agglomeration is house price of a higher-level geography; it is house price of Ontario for these equations.

We use the same framework to forecast census subdivisions and forward sortation area. The house price forecast of a metro area or census agglomeration is used as the economic driver for a census subdivision. If any census subdivision is not part of any metro area or census agglomeration, then we use the house price of the province as the driver. In case of forward sortation area, we use the house price of census subdivision as a proxy economic driver.

Alternative scenarios

The Moody's Analytics forecast model for RPS house prices is rerun regularly as new historical data come in.

The procedure for rerunning is chronologically sequential. The Canada macroeconomic forecast model is run, then the provinces economic forecast model, followed by the metro area forecast model. It is only once these economic inputs are in place that the RPS forecast model is run.

Moody's Analytics does not just run a baseline forecast; its models also have the capability of forecasting the effects of alternative macroeconomic assumptions.

Along with the regular baseline forecast, Moody's Analytics runs seven standard alternative scenarios, four of which relate directly to the severity of the business cycle.

Chart 10 shows the baseline scenario forecast and these four business cycle scenarios for the Montreal metro area, where scenarios tend to have somewhat less variability than Toronto and Vancouver because Montreal is not heavily overvalued. In general, the flexibility of the Canada macroeconomic model allows Moody's Analytics to run a wide range of assumptions through its national and regional forecast models.

16 Tables can be provided upon request.

17 An alternative procedure is to first calibrate the province forecasts to the national forecasts, and then to calibrate the metro area forecasts to their corresponding province forecasts. But since the initial province forecasts were derived mainly from weighted averages of their corresponding metro area forecasts, this alternative yields essentially the same result.

Table 1: Data Sources for RPS House Price Index Forecast Model

Series	Source
House price indexes and median values, transactions-weighted composite	RPS Real Property Solutions, public database
House price indexes and median values	RPS Real Property Solutions, Enterprise Solutions database
Housing affordability index	Bank of Canada
Housing completions	Canada Mortgage & Housing Corp. (CMHC)
Mortgage interest rate, adjustable, 5-yr	Canada Mortgage & Housing Corp. (CMHC)
Chartered bank conventional mortgage, 1-yr	Statistics Canada
Chartered bank conventional mortgage, 3-yr	Statistics Canada
Chartered bank conventional mortgage, 5-yr	Statistics Canada
S&P/TSX Composite Stock Share Price Index	SIX Financial Information
Housing permits and starts	Statistics Canada
New house and land price index	Statistics Canada
Consumer price index: Homeowners' replacement cost	Statistics Canada
Private consumption spending deflator	Statistics Canada
Total personal income	Statistics Canada
Household disposable income	Statistics Canada
Median family income	Statistics Canada
Population	Statistics Canada
Households	Statistics Canada
Unemployment rate	Statistics Canada

Note: All Statistics Canada series are from the CANSIM II database except the following:

Population and households	Census and annual estimates
Personal income	Income and sector accounts tables

Source: Moody's Analytics

Table 2: Canada RPS 13-Metro Composite Price Index, Backcast Regression

Dependent variable: LOG(RPS 13-metro transactions-weighted composite price)
Method: Dynamic Least Squares (DOLS)
Sample: 2005Q1-2017Q4
Included observations: 52
No cointegrating equation deterministics
Automatic leads and lags specification (lead=0 and lag=1 based on SIC criterion, max=10)
Long-run variance estimate (Bartlett kernel, Newey-West fixed bandwidth = 4.0000)

Variable	Coefficient	Std. Error	t-Statistic	Prob.
@MOVAVC(LOG(FHPIX_M_ICAN),3)	1.008	0.004	237.691	0.000
R-squared	0.949	Mean dependent var		5.019
Adjusted R-squared	0.947	S.D. dependent var		0.201
S.E. of regression	0.046	Sum squared resid		0.104
Long-run variance	0.008			

Cointegration Test - Hansen Parameter Instability

Lc statistic	Stochastic Trends (m)	Deterministic Trends (k)	Excluded Trends (p2)	Prob.*
0.005	1	0	0	> 0.2

*Hansen (1992b) Lc(m2=1, k=0) p-values, where m2=m-p2 is the number of stochastic trends in the asymptotic distribution

Sources: RPS Real Property Solutions Inc., Moody's Analytics

Table 3: Unit Root Test Results, Extended and RPS 13-Metro Composite House Price Index and Determinants

RPS 13-metro composite house price index
Null hypothesis: LOG(Extended real RPS 13-metro composite house price index) has a unit root
Exogenous: Constant
Lag length: 1 (Automatic - based on SIC, maxlag=10)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-0.036	0.953
Test critical values:	1% level	-3.476	
	5% level	-2.881	
	10% level	-2.577	
*MacKinnon (1996) one-sided p-values			

Median family income, interacting with population growth
Null hypothesis: LOG(Real median family income)*LOG(Population) has a unit root
Exogenous: Constant
Lag length: 1 (Automatic - based on SIC, maxlag=10)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		1.459	0.9992
Test critical values:	1% level	-3.476	
	5% level	-2.881	
	10% level	-2.577	

*MacKinnon (1996) one-sided p-values

New house and land price index
Null hypothesis: LOG(Real Canada new house and land price index) has a unit root
Exogenous: Constant
Lag length: 1 (Automatic - based on SIC, maxlag=10)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-2.289	0.177
Test critical values:	1% level	-3.476	
	5% level	-2.881	
	10% level	-2.577	

*MacKinnon (1996) one-sided p-values

Sources: RPS Real Property Solutions Inc., Moody's Analytics

Table 4: Cointegration Test Results, Extended RPS House Price Index and Determinants

Johansen Cointegration Test
Sample (adjusted): 1982Q3-2017Q4
Included observations: 142 after adjustments
Trend assumption: No deterministic trend (restricted constant)
Series: LOG(Extended real RPS 13-metro composite house price index),
LOG(Real median family income)*LOG(population),
LOG(Real Canada new house and land price index)
Lags interval (in first differences): 1 to 4

Unrestricted Cointegration Rank Test (Trace)

Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	0.050 Critical Value	Prob.**
None*	0.288	69.246	35.193	0.000
At most 1	0.091	20.935	20.262	0.040
At most 2	0.051	7.451	9.165	0.105

Trace test indicates 1 cointegrating eqn(s) at the 0.05 level
*Denotes rejection of the hypothesis at the 0.05 level
**MacKinnon-Haug-Michelis (1999) p-values

Sources: RPS Real Property Solutions Inc., Moody's Analytics

Table 5: Canada RPS National House Price Index, Equilibrium Regression

Dependent variable: DLOG(RPS 13-metro composite transactions-weighted index, seasonally adjusted)
Method: Least squares
Sample (adjusted): 1981Q2-2015Q4
Included observations: 139 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-6.747	0.196	-34.440	0.000
LOG(Real median family income)*LOG(Population)	0.501	0.013	37.244	0.000
LOG(Real Canada new house and land price index)	0.442	0.071	6.187	0.000

R-squared	0.962	Mean dependent var	0.003
Adjusted R-squared	0.962	S.D. dependent var	0.355
S.E. of regression	0.069	Akaike info criterion	-2.477
Sum squared resid	0.694	Schwarz criterion	-2.416
Log likelihood	185.076	Hannan-Quinn criter.	-2.452
F-statistic	1836.971	Durbin-Watson stat	0.066
Prob(F-statistic)	0.000		

Sources: RPS Real Property Solutions Inc., Moody's Analytics

Table 6: Canada RPS National House Price Index, Adjustment Regression

Dependent variable: DLOG(Real RPS 13-metro composite transactions-weighted price index)
Method: Least squares
Sample (adjusted): 2006Q1-2017Q4
Included observations: 49 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
DLOG(Real RPS 13-metro composite transactions-weighted price index), lagged 1 qtr	0.954	0.139	6.884	0.000
DLOG(Real RPS 13-metro composite transactions-weighted price index), lagged 2 qtr	-0.204	0.138	-1.478	0.147
DLOG(Equilibrium real RPS 13-metro composite transactions-weighted price index)	0.127	0.066	1.930	0.060
LOG(Real RPS 13-metro composite price index, lagged 1 qtr/Equilibrium real RPS 13-metro composite price index, lagged 1 qtr), 2-qtr MA	-0.061	0.031	-1.978	0.055
Difference(5-yr mortgage rate/100, lagged 2 qtr)	-0.987	0.370	-2.667	0.011
Difference(Unemployment rate/100 - NAIRU/100)	-0.471	0.381	-1.238	0.222

R-squared	0.659	Mean dependent var	0.011
Adjusted R-squared	0.618	S.D. dependent var	0.011
S.E. of regression	0.006	Akaike info criterion	-7.122
Sum squared resid	0.002	Schwarz criterion	-6.888
Log likelihood	176.920	Hannan-Quinn criter.	-7.033
Durbin-Watson stat	1.904		

Sources: RPS Real Property Solutions Inc., Moody's Analytics

Table 7: Remaining RPS National House Price Regressions

Method: Least squares
t-Statistics are in parentheses

Drivers	Dependent variable DLOG(RPS 13-metro composite transactions-weighted price)	LOG (RPS median composite price)	DLOG (RPS median composite price)	DLOG(RPS median detached single-family home price level/RPS median composite price)	DLOG(RPS median condo apartment price/ RPS median composite price)
Constant	--	0.931 (14.539)**	--	--	--
DLOG(RPS 13-metro composite transactions-weighted price index)	1.063 (61.034)**	--	--	--	--
LOG(RPS 13-metro median composite price)	--	0.904 (185.241)**	--	--	--
DLOG(RPS median composite price, lagged 1 qtr)	--	--	0.079 (3.090)**	--	--
DLOG(RPS median composite price trend)	--	--	0.952 (36.422)**	--	--
LOG(RPS median composite price, lagged 1 qtr/ RPS median composite price trend, lagged 1 qtr)	--	--	-0.062 (-1.987)	--	--
Household formation net of single-family completions, % of households lagged 1 qtr	--	--	--	0.501 (3.022)**	--
DLOG(RPS median detached single-family home price)	--	--	--	--	-0.110 (-2.134)*
AR(1)	--	--	--	--	0.508 (3.181)**
MA(1)	0.676 (4.842)**	--	--	--	--
Sample	**2005Q2-2016Q2**	**2005Q1-2016Q2**	**2005Q3-2016Q2**	**2005Q2-2016Q2**	**2005Q2-2016Q2**
Observations	45	46	44	45	45
Adjusted R-squared	0.981	0.999	0.970	0.047	0.136
Log-likelihood	226.469	171.863	219.239	229.768	182.893
Schwarz information criterion	-9.812	-7.306	-9.621	-10.127	-7.875

*Statistically significant at the 5% confidence level
**Statistically significant at the 1% confidence level

Sources: RPS Real Property Solutions Inc., Moody's Analytics

Table 8: Province Unit Root Test Results

RPS median condo apartment prices
Null hypothesis: Unit root (individual unit root process)
Exogenous variables: Individual effects, individual linear trends
Automatic selection of maximum lags
Automatic lag length selection based on SIC: 1 to 2
Total number of observations: 428
Cross-sections included: 8

Method	Statistic	Prob.**
Im, Pesaran and Shin W-stat	0.7065	0.76

**Probabilities are computed assuming asymptotic normality

RPS median detached single-family house prices
Null hypothesis: Unit root (individual unit root process)
Exogenous variables: Individual effects, individual linear trends
Automatic selection of maximum lags
Automatic lag length selection based on SIC: 0 to 4
Total number of observations: 535
Cross-sections included: 10

Method	Statistic	Prob.**
Im, Pesaran and Shin W-stat	-0.5813	0.2805

**Probabilities are computed assuming asymptotic normality

Deflated S&P/TSX stock price index
Null hypothesis: Unit root (individual unit root process)
Exogenous variables: Individual effects
Automatic selection of maximum lags
Automatic lag length selection based on SIC: 1
Total (balanced) observations: 1360

Method	Statistic	Prob.**
Im, Pesaran and Shin W-stat	-0.1054	0.458

**Probabilities are computed assuming asymptotic normality

Real per capita disposable income
Null hypothesis: Unit root (individual unit root process)
Exogenous variables: Individual effects, individual linear trends
Automatic selection of maximum lags
Automatic lag length selection based on SIC: 0
Total (balanced) observations: 1710
Cross-sections included: 10

Method	Statistic	Prob.**
Im, Pesaran and Shin W-stat	2.3026	0.9893

**Probabilities are computed assuming asymptotic normality

Sources: RPS Real Property Solutions Inc., Moody's Analytics

Table 9: Province Johansen Fisher Panel Cointegration Test

Series: RPS house price, real disposable income, deflated stock index
Included observations: 196
Trend assumption: Linear deterministic trend
Lags interval (in first differences): 1 4

Unrestricted Cointegration Rank Test (Trace and Maximum Eigenvalue)

Hypothesized No. of CE(s)	Fisher Stat.* (trace)	Prob.	Fisher Stat.* (max-eigen)	Prob.
None	61.150	0.000	43.740	0.000
At most 1	33.180	0.007	25.080	0.068
At most 2	34.870	0.004	34.870	0.004

Series: RPS condo price, real disposable income, deflated stock index
Included observations: 196
Trend assumption: Linear deterministic trend
Lags interval (in first differences): 1 4

Unrestricted Cointegration Rank Test (Trace and Maximum Eigenvalue)

Hypothesized No. of CE(s)	Fisher Stat.* (trace)	Prob.	Fisher Stat.* (max-eigen)	Prob.
None	106.400	0.000	81.370	0.000
At most 1	49.000	0.000	38.920	0.007
At most 2	42.540	0.002	42.540	0.002

*Probabilities are computed using asymptotic Chi-square distribution

Sources: RPS Real Property Solutions Inc., Moody's Analytics

Table 10: Province and Metro Area Grouping

	Province	Metro area
Group 1 - Atlantic	Prince Edward Island	Moncton
	New Brunswick	Saint John
	Nova Scotia	St. John's
	Newfoundland and Labrador	Halifax
Group 2 - Prairie	Alberta	Calgary
	Manitoba	Edmonton
	Saskatchewan	Winnipeg
		Regina
		Saskatoon
		Thunder Bay
Group 3 - West Coast	British Columbia	Abbotsford
		Kelowna
		Vancouver
		Victoria
Group 4 - Central 1	Ontario	Toronto
		Ottawa-Gatineau (f.k.a.Ottawa-Hull)
		Hamilton
		Kitchener
		London
		St. Catharines-Niagara
		Oshawa
		Windsor
		Barrie
		Kingston
		Greater Sudbury
		Guelph
		Brantford
		Peterborough
Group 5 - Central 2	Quebec	Saguenay (f.k.a. Chicoutimi-Jonquière)
		Montréal
		Québec
		Sherbrooke
		Trois-Rivières

Source: Moody's Analytics

Table 11: Province RPS Median Condo Price, Equilibrium Regression

Dependent variable: LOG(RPS real median condo price, seasonally adjusted)
Method: Pooled EGLS (Cross-section weights)
Sample: 2005Q1-2018Q4
Included observations: 56
Cross-sections included: 8
Linear estimation after one-step weighting matrix

Variable	Coefficient	Std. Error	t-Statistic	Prob.
Constant	2.011	0.142	14.131	0.000
British Columbia*LOG(real per capita disposable income)	1.641	0.186	8.845	0.000
Prairie*LOG(real per capita disposable income)	1.635	0.083	19.614	0.000
Ontario*LOG(real per capita disposable income)	2.811	0.174	16.172	0.000
Quebec*LOG(real per capita disposable income)	1.181	0.079	14.881	0.000
Atlantic*LOG(real per capita disposable income)	1.481	0.090	16.409	0.000
LOG(deflated S&P/TSX stock price index, MA of 16 quarters)	0.047	0.044	1.074	0.283
Fixed Effects coefficients are available on request				

Weighted statistics			
R-squared	0.931	Mean dependent var	9.900
Adjusted R-squared	0.929	S.D. dependent var	4.613
S.E. of regression	0.079	Sum squared resid	2.725
F-statistic	450.332	Durbin-Watson stat	0.199
Prob(F-statistic)	0.000		

Unweighted statistics			
R-squared	0.908	Mean dependent var	7.862
Sum squared resid	2.889	Durbin-Watson stat	0.153

Sources: RPS Real Property Solutions Inc., Moody's Analytics

Table 12: Province RPS Median House Price, Equilibrium Regression

Dependent variable: LOG(RPS real median house price, seasonally adjusted)
Method: Pooled EGLS (Cross-section weights)
Sample: 2005Q1-2018Q4
Included observations: 56
Cross-sections included: 10
Linear estimation after one-step weighting matrix

Variable	Coefficient	Std. Error	t-Statistic	Prob.
Constant	2.073	0.107	19.320	0.000
British Columbia*LOG(real per capita disposable income)	2.945	0.134	22.046	0.000
Prairie*LOG(real per capita disposable income)	1.846	0.050	36.804	0.000
Ontario*LOG(real per capita disposable income)	3.115	0.220	14.137	0.000
Quebec*LOG(real per capita disposable income)	1.366	0.067	20.275	0.000
Atlantic*LOG(real per capita disposable income)	1.023	0.044	23.132	0.000
LOG(deflated S&P/TSX stock price index, MA of 12 quarters)	0.051	0.028	1.851	0.065
Fixed Effects coefficients are available on request				

Weighted statistics			
R-squared	0.979	Mean dependent var	9.958
Adjusted R-squared	0.978	S.D. dependent var	4.410
S.E. of regression	0.062	Sum squared resid	2.063
F-statistic	1676.422	Durbin-Watson stat	0.254
Prob(F-statistic)	0.000		

Unweighted statistics			
R-squared	0.977	Mean dependent var	7.987
Sum squared resid	2.166	Durbin-Watson stat	0.197

Sources: RPS Real Property Solutions Inc., Moody's Analytics

Table 13: Province RPS Median Condo Price, Adjustment Regression

Dependent variable: DLOG(Real RPS median condo price)
Method: Pooled EGLS (Cross-section weights)
Sample (adjusted): 2005Q4-2019Q4
Included observations: 57 after adjustments
Cross-sections included: 8
Linear estimation after one-step weighting matrix

Variable	Coefficient	Std. Error	t-Statistic	Prob.
British Columbia*LOG(Real RPS median condo price, lagged 1 qtr)-LOG(Equilibrium real RPS median condo price, lagged 1 qtr)	-0.023	0.017	-1.367	0.173
Prairie*LOG(Real RPS median condo price, lagged 1 qtr)-LOG(Equilibrium real RPS median condo price, lagged 1 qtr)	-0.039	0.013	-2.941	0.004
Ontario*LOG(Real RPS median condo price, lagged 1 qtr)-LOG(Equilibrium real RPS median condo price, lagged 1 qtr)	-0.007	0.019	-0.384	0.701
Quebec*LOG(Real RPS median condo price, lagged 1 qtr)-LOG(Equilibrium real RPS median condo price, lagged 1 qtr)	-0.084	0.030	-2.817	0.005
Atlantic*LOG(Real RPS median condo price, lagged 1 qtr)-LOG(Equilibrium real RPS median condo price, lagged 1 qtr)	-0.016	0.017	-0.936	0.350
British Columbia*DLOG(Real RPS median condo price), lagged 1 qtr	1.018	0.118	8.619	0.000
Prairie*DLOG(Real RPS median condo price), lagged 1 qtr	0.896	0.074	12.137	0.000
Ontario*DLOG(Real RPS median condo price), lagged 1 qtr	0.888	0.124	7.163	0.000
Quebec*DLOG(Real RPS median condo price), lagged 1 qtr	0.817	0.122	6.672	0.000
Atlantic*DLOG(Real RPS median condo price), lagged 1 qtr	0.748	0.092	8.120	0.000
British Columbia*DLOG(Real RPS median condo price), lagged 2 qtrs	-0.233	0.120	-1.945	0.053
Prairie*DLOG(Real RPS median condo price), lagged 2 qtrs	-0.110	0.076	-1.434	0.152
Ontario*DLOG(Real RPS median condo price), lagged 2 qtrs	-0.103	0.128	-0.809	0.419
Quebec*DLOG(Real RPS median condo price), lagged 2 qtrs	-0.190	0.120	-1.586	0.114
Atlantic*DLOG(Real RPS median condo price), lagged 2 qtrs	-0.097	0.098	-0.985	0.325
DLOG(DLOG(Equilibrium real RPS median condo price))	0.099	0.023	4.297	0.000
D(5-yr mortgage rate/100, lagged 2 qtrs)	-0.810	0.215	-3.759	0.000
D(Unemployment rate/100)	-0.323	0.143	-2.256	0.025

Weighted statistics			
R-squared	0.614	Mean dependent var	0.010
Adjusted R-squared	0.599	S.D. dependent var	0.026
S.E. of regression	0.016	Sum squared resid	0.113
Durbin-Watson stat	1.998		

Unweighted statistics			
R-squared	0.527	Mean dependent var	0.007
Sum squared resid	0.116	Durbin-Watson stat	2.119

Sources: RPS Real Property Solutions Inc., Moody's Analytics

Table 14: Province RPS Median House Price, Adjustment Regression

Dependent variable: DLOG(Real RPS median house price)
Method: Pooled EGLS (Cross-section weights)
Sample (adjusted): 2005Q4-2019Q4
Included observations: 57 after adjustments
Cross-sections included: 10
Linear estimation after one-step weighting matrix

Variable	Coefficient	Std. Error	t-Statistic	Prob.
British Columbia*LOG(Real RPS median house price, lagged 1 qtr)-LOG(Equilibrium real RPS median house price, lagged 1 qtr)	-0.053	0.024	-2.176	0.030
Prairie*LOG(Real RPS median house price, lagged 1 qtr)-LOG(Equilibrium real RPS median house price, lagged 1 qtr)	-0.052	0.011	-4.825	0.000
Ontario*LOG(Real RPS median house price, lagged 1 qtr)-LOG(Equilibrium real RPS median house price, lagged 1 qtr)	-0.011	0.015	-0.704	0.482
Quebec*LOG(Real RPS median house price, lagged 1 qtr)-LOG(Equilibrium real RPS median house price, lagged 1 qtr)	-0.048	0.018	-2.702	0.007
Atlantic*LOG(Real RPS median house price, lagged 1 qtr)-LOG(Equilibrium real RPS median house price, lagged 1 qtr)	-0.040	0.012	-3.302	0.001
British Columbia*DLOG(Real RPS median house price), lagged 1 qtr	0.941	0.069	13.716	0.000
Prairie*DLOG(Real RPS median house price), lagged 1 qtr	0.990	0.047	21.154	0.000
Ontario*DLOG(Real RPS median house price), lagged 1 qtr	0.923	0.075	12.341	0.000
Quebec*DLOG(Real RPS median house price), lagged 1 qtr	0.934	0.068	13.667	0.000
Atlantic*DLOG(Real RPS median house price), lagged 1 qtr	0.776	0.055	14.196	0.000
DLOG(Real RPS median house price), lagged 2 qtrs	-0.121	0.040	-3.031	0.003
DLOG(Equilibrium real RPS median house price)	0.074	0.015	4.954	0.000
British Columbia*D(5-yr mortgage rate/100, lagged 2 qtrs)	-1.555	0.602	-2.582	0.010
Prairie*D(5-yr mortgage rate/100, lagged 2 qtrs)	-0.698	0.268	-2.604	0.010
Ontario*D(5-yr mortgage rate/100, lagged 2 qtrs)	-0.665	0.530	-1.255	0.210
Quebec*D(5-yr mortgage rate/100, lagged 2 qtrs)	-0.545	0.245	-2.222	0.027
Atlantic*D(5-yr mortgage rate/100, lagged 2 qtrs)	-0.299	0.252	-1.187	0.236
D(Unemployment rate/100)	-0.096	0.085	-1.130	0.259

Weighted statistics			
R-squared	0.7078	Mean dependent var	0.0099
Adjusted R-squared	0.6988	S.D. dependent var	0.0195
S.E. of regression	0.0106	Sum squared resid	0.0619
Durbin-Watson stat	1.9318		

Unweighted statistics			
R-squared	0.6412	Mean dependent var	0.0082
Sum squared resid	0.0637	Durbin-Watson stat	2.0442

Sources: RPS Real Property Solutions Inc., Moody's Analytics

Table 15: Province Median Composite Price

Dependent variable: DLOG(Real RPS median composite price)

Method: Pooled EGLS (Cross-section weights)
Sample: 2005Q2-2019Q4
t-Statistics are in parentheses

	Province †						
Driver	**British Columbia**	**Prairie**	**Ontario**	**Quebec**	**Nova Scotia and Newfoundland and Labrador**	**New Brunswick**	**Prince Edward Island**
DLOG(Real RPS median detached single-family home price)	0.818 (37.172)**	0.935 (89.548)**	0.899 (45.614)**	0.829 (36.441)**	0.975 (44.417)**	0.795 (15.503) **	0.508 (5.530) **
DLOG(Real RPS median condo apartment price)	0.145 (5.497)**	0.047 (5.258)**	0.050 (2.490)**	0.125 5.070)**	0.020 (1.856)		
Cross-sections included					8		2
Total pool (balanced) observations					472		59
Adjusted R-squared					0.987		0.495

† New Brunswick and Prince Edward Island have no condo apartment price series

*Statistically significant at the 5% confidence level
**Statistically significant at the 1% confidence level

Sources: RPS Real Property Solutions Inc., Moody's Analytics

Table 16: Metro Area Unit Root Test Results

RPS median condo apartment prices
Null hypothesis: Unit root (individual unit root process)
Exogenous variables: Individual effects, individual linear trends
Automatic selection of maximum lags
Automatic lag length selection based on SIC: 1 to 4
Total number of observations: 1120
Cross-sections included: 21

Method	Statistic	Prob.*
Im, Pesaran and Shin W-stat	1.162	0.877

*Probabilities are computed assuming asympotic normality

RPS median detached single-family house prices
Null hypothesis: Unit root (individual unit root process)
Exogenous variables: Individual effects, individual linear trends
Automatic selection of maximum lags
Automatic lag length selection based on SIC: 0 to 5
Total number of observations: 1768
Cross-sections included: 33

Method	Statistic	Prob.*
Im, Pesaran and Shin W-stat	1.346	0.911

*Probabilities are computed assuming asympotic normality

Real per capita disposable income
Null hypothesis: Unit root (individual unit root process)
Exogenous variables: Individual effects, individual linear trends
Automatic selection of maximum lags
Automatic lag length selection based on SIC: 0
Total number of observations: 5550
Cross-sections included: 33

Method	Statistic	Prob.*
Im, Pesaran and Shin W-stat	1.505	0.934

*Probabilities are computed assuming asymptotic normality

Sources: RPS Real Property Solutions Inc., Moody's Analytics

Table 17: Metro Area Johansen Fisher Panel Cointegration Test

Series: RPS house price, real disposable income, deflated stock index
Included observations: 196
Trend assumption: Linear deterministic trend
Lags interval (in first differences): 1 4

Series: RPS condo price, real disposable income, deflated stock index
Included observations: 196
Trend assumption: Linear deterministic trend
Lags interval (in first differences): 1 4

Unrestricted Cointegration Rank Test (Trace and Maximum Eigenvalue)

Hypothesized No. of CE(s)	**Fisher Stat.* (trace)**	**Prob.**	**Fisher Stat.* (max-eigen)**	**Prob.**	**Hypothesized No. of CE(s)**	**Fisher Stat.* (trace)**	**Prob.**	**Fisher Stat.* (max-eigen)**	**Prob.**
None	160.800	0.000	118.900	0.000	None	224.100	0.000	170.200	0.000
At most 1	84.720	0.000	72.220	0.003	At most 1	112.400	0.000	88.890	0.032
At most 2	67.860	0.007	67.860	0.007	At most 2	118.300	0.000	118.300	0.000

*Probabilities are computed using asymptotic Chi-square distribution

Adjusted R-squared	0.9544	S.D. dependent var	4.3013
S.E. of regression	0.0996	Sum squared resid	16.6368
F-statistic	945.1966	Durbin-Watson stat	0.1466
Prob(F-statistic)	0		

	Unweighted Statistics		
R-squared	0.9399	Mean dependent var	8.0276
Sum squared resid	17.5801	Durbin-Watson stat	0.0910

Sources: RPS Real Property Solutions Inc., Moody's Analytics

Table 18: Metro Area RPS Median Condo Price, Equilibrium Regression

Dependent variable: LOG(Real median condo price)
Method: Pooled EGLS (Cross-section weights)
Sample: 2005Q1-2017Q4
Included observations: 52
Cross-sections included: 21
Total pool (balanced) observations: 1092
Linear estimation after one-step weighting matrix

Variable	Coefficient	Std. Error	t-Statistic	Prob.
Constant	4.783	0.124	38.717	0.000
British Columbia*LOG(real per capita disposable income)	0.106	0.086	1.224	0.221
Prairie*LOG(real per capita disposable income)	0.903	0.069	13.137	0.000
Ontario*LOG(real per capita disposable income)	0.923	0.037	24.705	0.000
Quebec*LOG(real per capita disposable income)	1.153	0.059	19.634	0.000
Atlantic*LOG(real per capita disposable income)	0.936	0.035	26.973	0.000
LOG(deflated S&P/TSX stock price index)	0.070	0.021	3.311	0.001
Fixed Effects coefficients are available on request				

Weighted statistics			
R-squared	0.902	Mean dependent var	10.021
Adjusted R-squared	0.900	S.D. dependent var	4.437
S.E. of regression	0.108	Sum squared resid	12.455
F-statistic	378.901	Durbin-Watson stat	0.195
Prob(F-statistic)	0.000		

Unweighted statistics			
R-squared	0.867	Mean dependent var	7.776
Sum squared resid	12.966	Durbin-Watson stat	0.127

Sources: RPS Real Property Solutions Inc., Moody's Analytics

Table 19: Metro Area RPS Median House Price, Equilibrium Regression

Dependent variable: LOG(Real median house price)
Method: Pooled EGLS (Cross-section weights)
Sample: 2005Q1-2017Q4
Included observations: 52
Cross-sections included: 33
Linear estimation after one-step weighting matrix

Variable	Coefficient	Std. Error	t-Statistic	Prob.
Constant	4.592	0.091	50.402	0.000
British Columbia*LOG(real per capita disposable income)	0.911	0.098	9.253	0.000
Prairie*LOG(real per capita disposable income)	1.153	0.051	22.475	0.000
Ontario*LOG(real per capita disposable income)	0.695	0.026	27.214	0.000
Quebec*LOG(real per capita disposable income)	0.974	0.040	24.504	0.000
Atlantic*LOG(real per capita disposable income)	0.658	0.028	23.687	0.000
LOG(deflated S&P/TSX stock price index)	0.132	0.016	8.127	0.000
Fixed Effects coefficients are available on request				

Weighted statistics			
R-squared	0.952	Mean dependent var	10.371
Adjusted R-squared	0.951	S.D. dependent var	4.551
S.E. of regression	0.106	Sum squared resid	18.851
F-statistic	877.327	Durbin-Watson stat	0.157
Prob(F-statistic)	0.000		

Unweighted statistics			
R-squared	0.929	Mean dependent var	8.030
Sum squared resid	19.973	Durbin-Watson stat	0.091

Sources: RPS Real Property Solutions Inc., Moody's Analytics

Table 20: Metro RPS Median Condo Price, Adjustment Regression

Dependent variable: DLOG(FHPLBKAPTQ_?/FPDICQ_ICAN)
Method: Pooled EGLS (Cross-section weights)
Sample (adjusted): 2005Q4-2019Q4
Included observations: 57 after adjustments
Cross-sections included: 21
Linear estimation after one-step weighting matrix

Variable	Coefficient	Std. Error	t-Statistic	Prob.
LOG(Real RPS median condo price, lagged 1 qtr)-LOG(Equilibrium real RPS median condo price, lagged 1 qtr)	-0.023	0.005	-4.363	0.000
British Columbia*DLOG(Real RPS median condo price), lagged 1 qtr	0.824	0.065	12.747	0.000
Prairie*DLOG(Real RPS median condo price), lagged 1 qtr	0.917	0.055	16.543	0.000
Ontario*DLOG(Real RPS median condo price), lagged 1 qtr	0.660	0.048	13.829	0.000
Quebec*DLOG(Real RPS median condo price), lagged 1 qtr	0.819	0.090	9.056	0.000
Atlantic*DLOG(Real RPS median condo price), lagged 1 qtr	0.766	0.090	8.500	0.000
British Columbia*DLOG(Real RPS median condo price), lagged 2 qtrs	-0.187	0.064	-2.923	0.004
Prairie*DLOG(Real RPS median condo price), lagged 2 qtrs	-0.207	0.056	-3.718	0.000
Ontario*DLOG(Real RPS median condo price), lagged 2 qtrs	-0.137	0.048	-2.844	0.005
Quebec*DLOG(Real RPS median condo price), lagged 2 qtrs	-0.189	0.091	-2.084	0.037
Atlantic*DLOG(Real RPS median condo price), lagged 2 qtrs	-0.112	0.092	-1.222	0.222
DLOG(DLOG(Equilibrium real RPS median condo price))	0.067	0.022	3.115	0.002
British Columbia*D(5-yr mortgage rate/100, lagged 2 qtrs)	-1.069	0.560	-1.908	0.057
Prairie*D(5-yr mortgage rate/100, lagged 2 qtrs)	-1.113	0.497	-2.237	0.026
Ontario*D(5-yr mortgage rate/100, lagged 2 qtrs)	-0.417	0.381	-1.095	0.274
Quebec*D(5-yr mortgage rate/100, lagged 2 qtrs)	-0.174	0.328	-0.530	0.596
Atlantic*D(5-yr mortgage rate/100, lagged 2 qtrs)	-0.150	0.737	-0.203	0.839
D(Unemployment rate/100)	-0.056	0.075	-0.746	0.456

Weighted statistics			
R-squared	0.442	Mean dependent var	0.009
Adjusted R-squared	0.434	S.D. dependent var	0.032
S.E. of regression	0.024	Sum squared resid	0.687
Durbin-Watson stat	1.949		

Unweighted statistics			
R-squared	0.367	Mean dependent var	0.007
Sum squared resid	0.710	Durbin-Watson stat	2.015

Source: Moody's Antaltics

Table 21: Metro Area RPS Median House Price, Adjustment Regression

Dependent variable: DLOG(FHPLBKHOUQ_?/FPDICQ_ICAN)
Method: Pooled EGLS (Cross-section weights)
Sample (adjusted): 2005Q4-2019Q4
Included observations: 57 after adjustments
Cross-sections included: 33
Linear estimation after one-step weighting matrix

Variable	Coefficient	Std. Error	t-Statistic	Prob.
LOG(Real RPS median house price, lagged 1 qtr)-LOG(Equilibrium real RPS median house price, lagged 1 qtr)	-0.010	0.002	-4.149	0.000
British Columbia*DLOG(Real RPS median house price), lagged 1 qtr	0.898	0.040	22.345	0.000
Prairie*DLOG(Real RPS median house price), lagged 1 qtr	0.905	0.033	27.084	0.000
Ontario*DLOG(Real RPS median house price), lagged 1 qtr	0.864	0.029	30.138	0.000
Quebec*DLOG(Real RPS median house price), lagged 1 qtr	0.792	0.044	18.072	0.000
Atlantic*DLOG(Real RPS median house price), lagged 1 qtr	0.687	0.054	12.758	0.000
DLOG(Real RPS median house price), lagged 2 qtr	-0.072	0.023	-3.111	0.002
British Columbia*DLOG(Equilibrium real RPS median house price)	0.032	0.025	1.251	0.211
Prairie*DLOG(Equilibrium real RPS median house price)	0.067	0.021	3.134	0.002
Ontario*DLOG(Equilibrium real RPS median house price)	0.057	0.018	3.191	0.001
Quebec*DLOG(Equilibrium real RPS median house price)	0.033	0.020	1.626	0.104
Atlantic*DLOG(Equilibrium real RPS median house price)	0.040	0.032	1.251	0.211
British Columbia*D(5-yr mortgage rate/100, lagged 2 qtrs)	-1.187	0.358	-3.320	0.001
Prairie*D(5-yr mortgage rate/100, lagged 2 qtrs)	-0.619	0.243	-2.550	0.011
Ontario*D(5-yr mortgage rate/100, lagged 2 qtrs)	-0.568	0.158	-3.600	0.000
Quebec*D(5-yr mortgage rate/100, lagged 2 qtrs)	-0.633	0.210	-3.007	0.003
Atlantic*D(5-yr mortgage rate/100, lagged 2 qtrs)	-0.321	0.321	-0.999	0.318
D(Unemployment rate/100, lagged 1qtr)	0.007	0.034	0.211	0.833

Unweighted statistics			
R-squared	0.571	Mean dependent var	0.010
Adjusted R-squared	0.567	S.D. dependent var	0.019
S.E. of regression	0.012	Sum squared resid	0.283
Durbin-Watson stat	1.959		

Unweighted statistics			
R-squared	0.548	Mean dependent var	0.009
Sum squared resid	0.286	Durbin-Watson stat	2.014

Source: Moody's Analytics

Table 22: Metro Area Median Composite Price

Dependent variable: DLOG(Real RPS median composite price)
Method: Pooled EGLS (Cross-section weights)
Sample: 2005Q2-2019Q4
t-Statistics are in parentheses

Driver	British Columbia metros	Prairie metros with condo prices	Ontario metros with condo prices	Quebec metros with condo prices	Atlantic metros with condo prices	Prairie metros w/o condo prices	Ontario metros w/o condo prices	Quebec metros w/o condo prices	Atlantic metros w/o condo prices
DLOG(Real RPS median detached single-family home price)	0.907 (77.289)**	0.925 (121.026)**	0.924 (135.147)**	0.859 (58.504)**	0.956 (54.308)**	0.944 (41.466) **	0.990 (138.187) **	0.845 (31.937) **	0.828 (22.771) **
DLOG(Real RPS median condo apartment price)	0.046 (5.472)**	0.062 (9.646)**	0.038 (8.393)**	0.073 (5.246)**	0.025 (2.295)*				
Cross-sections included					21				12
Total pool (balanced) observations					1239				708
Adjusted R-squared					0.983				0.950

*Statistically significant at the 5% confidence level
**Statistically significant at the 1% confidence level

Sources: RPS Real Property Solutions Inc., Moody's Analytics

Table 23: Ontario's Census Agglomeration RPS Median House Price, Equilibrium Regression

Dependent variable: LOG(House price)
Method: Pooled EGLS (Cross-section weights)
Sample: 2005Q1 2018Q4
Included observations: 56
Cross-sections included: 27
Total pool (balanced) observations: 1512
Linear estimation after one-step weighting matrix

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	4.185	0.071	58.698	0.000
LOG(House price of Ontario)	0.629	0.006	114.207	0.000
Fixed effects coefficients are available on request				
	Weighted statistics			
R-squared	0.955	Mean dependent var		15.647
Adjusted R-squared	0.954	S.D. dependent var		7.228
S.E. of regression	0.075	Sum squared resid		8.352
F-statistic	1159.458	Durbin-Watson stat		0.140
Prob(F-statistic)	0.000			
	Unweighted statistics			
R-squared	0.918	Mean dependent var		12.325
Sum squared resid	8.377	Durbin-Watson stat		0.116

Sources: RPS Real Property Solutions Inc., Moody's Analytics

Table 24: Ontario's Census Agglomeration RPS Median House Price, Adjustment Regression

Dependent variable: DLOG(FHPLBKHOU_?)
Method: Pooled EGLS (Cross-section weights)
Sample (adjusted): 2005Q2 2018Q4
Included observations: 55 after adjustments
Cross-sections included: 27
Total pool (balanced) observations: 1485
Linear estimation after one-step weighting matrix

Variable	Coefficient	Std. Error	t-Statistic	Prob.
DLOG(FHPLBKHOU_P_?)	0.585	0.025	23.559	0.000
LOG(FHPLBKHOU_?(-1))-LOG(FHPLBKHOU_?_EQ(-1))	-0.037	0.008	-4.446	0.000
	Weighted statistics			
R-squared	0.090	Mean dependent var		0.014
Adjusted R-squared	0.089	S.D. dependent var		0.026
S.E. of regression	0.025	Sum squared resid		0.929
Durbin-Watson stat	1.033			
	Unweighted statistics			
R-squared	0.073	Mean dependent var		0.011
Sum squared resid	0.933	Durbin-Watson stat		1.004

Sources: RPS Real Property Solutions Inc., Moody's Analytics

About the Author

Abhilasha Singh is an economist at Moody's Analytics, where she leads model development, validation, and forecasting for global subnational economies. She is responsible for coverage of emerging markets as well as U.S. and metropolitan area economies. She is also a regular contributor to Economic View. Abhilasha completed her PhD in economics at the University of Houston, where she taught microeconomics. She holds a master's degree in finance from Pune University in India.

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