Moody's Analytics

RPS Real Property Solutions

METHODOLOGY

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RPS - Moody's Analytics Canadian House Price Forecast Methodology

Introduction

Moody's Analytics has developed an econometric model for the RPS Real Property Solutions house price indexes at the Canada national, province and census metropolitan area levels. The forecast model covers three house types and four indexes as well as their not seasonally adjusted versions. The model that Moody's Analytics has developed is a tool for identifying the forces driving house prices and 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 modeling approach is a structural model of housing demand and supply that allows for serial correlation and mean reversion, though mean reversion effects will not be uniform across regions. The forecast model also adapts for important regional housing market differences by using separate province pools for all census metro areas and varying the functional form of the forecast model for each province pool as needed to explain regional house price variation.

Moody's Analytics Canada RPS Index Forecast Methodology

BY ANDRES CARBACHO-BURGOS

To forecast housing values at national and regional levels for most countries, Moody's Analytics uses a structural econometric model approach that relies on long-term and cyclical economic fundamentals. The approach used to forecast the RPS Real Property Solutions house price indexes is of this type, but also adapts to the highly different housing market characteristics between regions within Canada. 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 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 important, 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 geographical 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 Canada Real Estate Association 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 first 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, and all 33 census metropolitan 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. While 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 first exception is the national housing affordability index calculated by the Bank of Canada. The second and third exceptions are residential completions—used to estimate national regional housing stocks—and the five-year adjustable mortgage rate, which come from the Canadian Mortgage and Housing Corp. Lastly, the S&P/TSX Composite Stock Share Price Index, provided by SIX Financial Information, 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. Lastly, 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.

Backcasting home values

Before describing the procedure for error correction models that are the primary approach Moody's Analytics uses for forecasting house price values, one important difficulty has to be overcome, which is the relatively short length of the Canada resale market house price series available. The RPS house price series go 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. Without lengthy time series for national and regional home values, it is difficult to accurately establish long-term house price trends necessary to use error-correction forecast models.

Fortunately, there are ways to extend the home value series backward, with the proviso that the main purpose of such backcasting is

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 and Housing Corp. (CMHC)
Mortgage interest rate, adjustable 5-yr	Canada Mortgage and Housing Corp. (CMHC)
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
Total wage and salary income	Statistics Canada
Household disposable income	Statistics Canada
Median family income	Statistics Canada
Population	Statistics Canada
Households	Statistics Canada
Total employment	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

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 (adjusted): 2005Q1 2017Q1
Included observations: 49 after adjustments
No cointegrating equation deterministics
Automatic leads and lags specification (lead=0 and lag=2 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.
LOG(BoC implied composite price index), 3-qtr centered moving avg	1.012	0.005	193.045	0.000
R-squared	0.947	Mean dependent var		5.002
Adjusted R-squared	0.943	S.D. dependent var		0.188
S.E. of regression	0.045	Sum squared resid		0.090
Long-run variance	0.007			

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

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

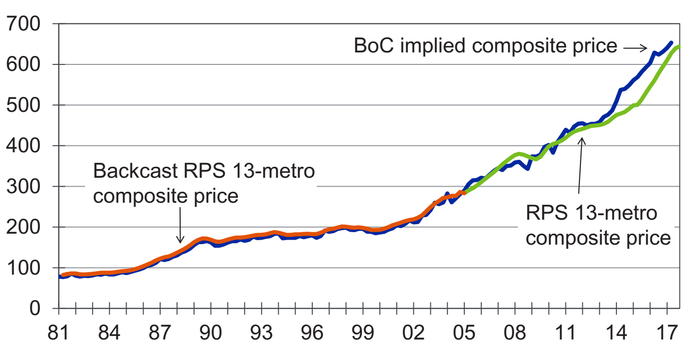
$$\mathrm{HC} = \left(\frac{\mathrm{r}}{1-(1+\mathrm{r})^{-\mathrm{N}}}\right) * 0.95\mathrm{P} + \mathrm{U}$$

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 only 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, and is shown in Chart 1. This national house price series also fits well with the CREA's composite benchmark house price.

Chart 1: Implied BoC Price Fits With RPS

Composite home values, C$ ths



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

Moody's Analytics forecasts this extended house price using the cointegrating regression shown in Table 2 and uses the resulting backcast (also shown in 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 BPC composite price cannot be rejected.

That leaves province and census metro area RPS house prices, which are also backcast in order to better establish mean-reversion effects. In addition to persistence as proxied by one- and two-quarter lagged appreciation rates, the province and metro area backcasts were driven by the national extended composite house price and by the local new house and land price index.[1] For both the province and metro area pooled

1 For smaller metro areas without an individual house and land price index, the corresponding province new house and land price was used.

regressions, the strongest effect was persistence, with the local new house and land price index and national composite price index having smaller coefficients. This means that pre-2005 values for each index had growth rates that were not hugely different from the 2005-2006 growth rates of the RPS indexes, with the local new house and land price providing some variation. As a result of these two pooled regressions, province and metro area RPS indexes were estimated back to 1981. As emphasized, the pre-2005 data are used to establish a long-term house price trend and associated mean reversion, but not to obtain coefficients for short-term economic drivers of the forecast.

Error correction: A primer

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.[2] Structural macroeconomic models such as the Moody's Analytics Canada model excel in exploring the economy-wide 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.

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.[3] Mean reversion implies that in the long run, housing markets move toward equilibrium values based on fundamental supply and demand factors. In each geographical 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:

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

where P* is the real equilibrium house value in the metro area, 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 local business cycles. Equation (1) can be thought of as the reduced form of a long-run housing supply and demand relationship.[4]

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 geographical boundaries or by zoning or regulatory constraint.

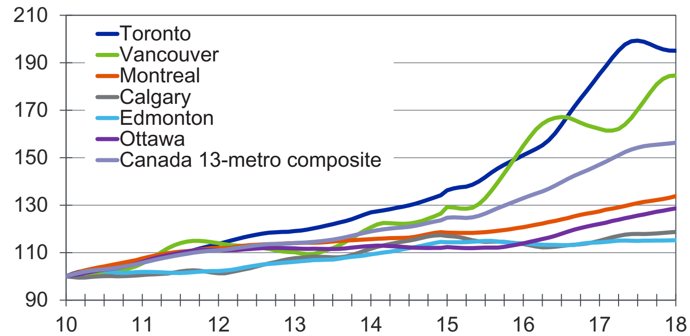
The specification of an equilibrium or trend home value does not deny that home values can drift away from such an equilibrium. Indeed, a look at post-2010 RPS house price data would seem to indicate that house prices are likely overvalued for Toronto and Vancouver (see Chart 2). Nor does such a specification 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:

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

Chart 2: A Toronto-Vancouver Bubble?

RPS transactions-weighted composite indexes, Jan 2010=100



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

The first set of terms in Equation (2) captures serial correlation, where a_k is the serial correlation coefficient, b_k is the rate of mean reversion, and c_k captures the immediate adjustment to changing fundamentals. The vector D_{tk} 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 its 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 in difference equation form and its dynamic properties examined. The parameters a_k and b_k determine whether house prices exhibit oscillatory or damped behavior, and convergent or divergent behavior.[5] In particular, the b_k 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 pur-

2 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.

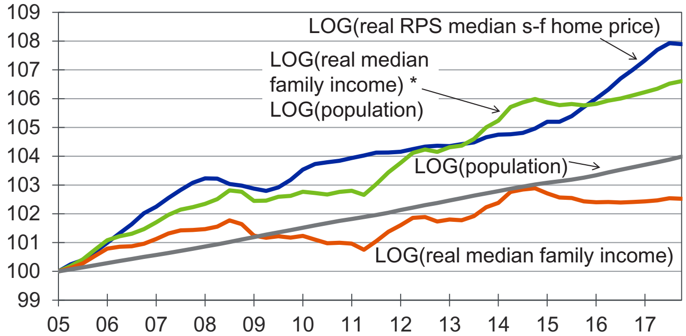
3 The main academic antecedent to this modeling approach is Capozza, Dennis R.; Hendershott, Patric H.; Mack, Charlotte, "An Anatomy of Price Dynamics in Illiquid Markets: Analysis and Evidence from Local Housing Markets," *Real Estate Economics* (March 2004).

4 It can also be derived from urban theory. See Capozza, Dennis; Helsley, R., "The Fundamentals of Land Prices and Urban Growth," *Journal of Urban Economics* 26 (1989), 295-306.

5 Capozza et al, 2004, calculate the dynamic properties of equation (2) under the simplifying assumption that $P^*_{tk} = P^*_k$, a constant.

Chart 3: Population Growth Matters

2005Q1=100



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

chases 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 b_k). Statistical tests will guide the final specification for the equilibrium and adjustment equations.

National RPS indexes

The first step in forecasting the national RPS house price indexes is to choose contemporaneous economic drivers and then show that there is a cointegrating relationship between one of the RPS national indexes and these contemporaneous drivers, so that a long-term house price trend can be established. The chosen RPS national series is the seasonally adjusted, transactions-weighted 13-metro composite index. This index is chosen because media focus more on the national index than on its corresponding composite price level. The chosen drivers are the Canada new house and land price index and real median family income interacting with the national population.[6] This latter driver requires explanation. Median family income is the most 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, as shown in Chart 3. But when looking at a smaller than national scale, the regions where house prices have grown most strongly are those which combine large median incomes with growth dynamism, which can be proxied by population growth. 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 non-stationary (in technical terms, that they both have a unit root) so that their average rate of change is not uniform over time. Table 3 shows the augmented Dickey-Fuller tests for non-stationarity. None of the tests are able to reject the null hypothesis of

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

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

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		0.458	0.985
Test critical values:	1% level	-3.476	
	5% level	-2.882	
	10% level	-2.578	

* 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=13)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		0.512	0.987
Test critical values:	1% level	-3.478	
	5% level	-2.882	
	10% level	-2.578	

* 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=13)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-2.371	0.152
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

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

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

Johansen Cointegration Test
Sample (adjusted): 1982Q3-2015Q4
Included observations: 134 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		Trace	0.050	
No. of CE(s)	**Eigenvalue**	**Statistic**	**Critical Value**	**Prob.****
None *	0.286	63.868	35.193	0.000
At most 1	0.080	18.747	20.262	0.080
At most 2	0.055	7.576	9.165	0.099

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	-6.620	0.208	-31.863	0.000
LOG(Real median family income)*LOG(Population)	0.485	0.014	34.562	0.000
LOG(Real Canada new house and land price index)	0.417	0.073	5.711	0.000

R-squared	0.951	Mean dependent var	-0.083
Adjusted R-squared	0.950	S.D. dependent var	0.320
S.E. of regression	0.071	Akaike info criterion	-2.426
Sum squared resid	0.689	Schwarz criterion	-2.363
Log likelihood	171.626	Hannan-Quinn criter.	-2.401
F-statistic	1323.481	Durbin-Watson stat	0.054
Prob(F-statistic)	0.000		

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

a unit root, even for the more variable new house and land price index.

Once non-stationarity is assumed, it must be shown that the two series are cointegrated: That they tend to move towards each other more often than not. 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.[7] Although the coefficients for the two drivers look the same, the interaction of median family income with population has a significantly larger magnitude, so that this is the stronger determinant of the trend. The fitted values from this regression form a long-term price trend from 1981 through the end of the forecast horizon.

Lastly, the regression in Table 6, using only 2005-2017 data, generates the actual forecast. The drivers include the 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 for the effects of contemporaneous increases in median family income and new home or land prices. The mean reversion term is shown in the fourth row and is perceptible and statistically significant. Lastly, 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

7 Here also, the regression is restricted to 2015 because population data are not yet available for 2017 and median family income data are not available for 2016-2017.

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): 2005Q4-2017Q4
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	0.883	0.135	6.554	0.000
DLOG(Real RPS 13-metro composite transactions-weighted price index), lagged 2 qtr	-0.111	0.144	-0.771	0.445
DLOG(Equilibrium real RPS 13-metro composite transactions-weighted price index)	0.195	0.083	2.350	0.024
LOG(Real RPS 13-metro composite price index, lagged 1 qtr/ Equilibrium real RPS 13-metro composite price index, lagged 1 qtr), 2-qtr moving avg	-0.059	0.027	-2.139	0.038
Difference(5-yr mortgage rate/100, lagged 2 qtr)	-1.115	0.387	-2.882	0.006
Difference(Unemployment rate/100 - NAIRU/100)	-0.383	0.416	-0.921	0.362

R-squared	0.634	Mean dependent var	0.012
Adjusted R-squared	0.591	S.D. dependent var	0.011
S.E. of regression	0.007	Akaike info criterion	-7.047
Sum squared resid	0.002	Schwarz criterion	-6.815
Log likelihood	178.641	Hannan-Quinn criter.	-6.959
Durbin-Watson stat	1.961		

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

time gap between the decision to purchase a home and the actual recording of the closed transaction.

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. Most recently these policy interventions include transfer taxes, vacant property taxes, and resale restrictions in Toronto and Vancouver as well 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. The remaining RPS national series 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 left-most column dependent on the RPS 13-metro composite index forecast in Table 5.

In brief 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, the RPS national median composite price is forecast 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.[8] 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.[9]

Lastly 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.

Regional RPS price trends

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

The first important decision in the process is to make the census metro areas the basic unit of the forecast. With only 10 provinces, there is a significant risk that a pooled province regression would not have enough observations to create statistically significant coefficients, especially if such a pooled

8 An observation-specific dummy variable for 2009Q3 is also included in order to reduce the leverage effect of this quarter, which had a large DFFITS leverage statistic in the regression.

9 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.

Table 7: Remaining RPS National House Price Regressions

Method: Least squares
t-statistics are in parentheses

	Dependent variable				
Drivers	**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	--	1.057 (11.090)**	--	--	--
DLOG(RPS 13-metro composite transactions-weighted price index)	1.063 (61.034)**	--	--	--	--
LOG(RPS 13-metro median composite price)	--	0.904 (122.280)**	--	--	--
DLOG(RPS median composite price, lagged 1 qtr)	--	--	0.279 (5.537) **	--	--
DLOG(RPS median composite price trend)	--	--	0.712 (14.013)**	--	--
LOG(RPS median composite price, lagged 1 qtr/RPS median composite price trend, lagged 1 qtr)	--	--	-0.051 (-1.386)	--	--
Household formation net of single-family completions, % of households lagged 1 qtr	--	--	--	0.501 (3.022)**	--
DLOG(RPS median detached single-familiy home price)	--	--	--	--	-0.110 (-2.134)*
2009Q3 dummy	--	--	0.006 (2.740)**	--	
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	0.997	0.970	0.047	0.136
Log-likelihood	226.469	154.182	219.239	229.768	182.893
Schwarz information criterion	-9.812	-6.537	-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

regression also contains regional interactions. The 33 census metro areas plus Prince Edward Island provide a larger dataset for modeling regional interactions.[10]

The second important decision in the forecast process is to select the primary cointegrating driver for each median house price forecast. Just as with the national equilibrium price equation, a single measure of income such as median family income or per capita income did not provide a particularly good long-term fit even with the backcast price series. This lack of uniformity is most likely because metro area housing markets can be strongly different from each other even within the same province, so it is necessary to bring in an additional interacting driver. Population seems to interact much better in combination with some measure of income.

10 Prince Edward Island is treated as a metro area rather than a province, as it lacks metro areas of its own and therefore cannot have an index forecast that is an aggregated metro area forecast.

Table 8: Metro Area Unit Root Test Results

Median detached single-family home price
Null hypothesis: Unit root (individual unit root process)
Series: LOG(Real RPS median detached single-family home price, extended series)
Sample: 1981Q1-2017Q4
Exogenous variables: Individual effects
Automatic selection of maximum lags
Automatic lag length selection based on SIC: 1 to 6
Total number of observations: 4,883
Cross sections included: 34

Method	Statistic	Prob.**
Im, Pesaran and Shin W-stat	7.303	1.000

**Probabilities are computed assuming asymptotic normality

Median family income, interacting with population
Null hypothesis: Unit root (individual unit root process)
Series: LOG(Real median family income)*LOG(Population)
Sample: 1976Q1-2015Q4
Exogenous variables: Individual effects
Automatic selection of maximum lags
Automatic lag length selection based on SIC: 0 to 5
Total number of observations: 4,800
Cross sections included: 34

Method	Statistic	Prob.**
Im, Pesaran and Shin W-stat	0.736	0.769

**Probabilities are computed assuming asymptotic normality

Median condo apartment home price
Null hypothesis: Unit root (individual unit root process)
Series: LOG(Real RPS median condo apartment price, extended series)
Sample: 1981Q1-2017Q4
Exogenous variables: Individual effects
Automatic selection of maximum lags
Automatic lag length selection based on SIC: 1 to 10
Total number of observations: 3,026
Cross sections included: 21

Method	Statistic	Prob.**
Im, Pesaran and Shin W-stat	4.681	1.000

**Probabilities are computed assuming asymptotic normality

Per capita disposable income, interacting with population
Null hypothesis: Unit root (individual unit root process)
Series: LOG(Real per capita disposable income)*LOG(Population)
Sample: 1976Q1-2015Q4
Exogenous variables: Individual effects
Automatic selection of maximum lags
Automatic lag length selection based on SIC: 0 to 4
Total number of observations: 2,987
Cross sections included: 21

Method	Statistic	Prob.**
Im, Pesaran and Shin W-stat	5.732	1.000

**Probabilities are computed assuming asymptotic normality

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

The first step in the regional forecasts is establishing that the error correction model described in equations (1) and (2) broadly fits the Canada data. For this step all 34 cross sections are subjected to unit root and cointegration tests. Table 8 shows the unit root tests for RPS median detached single-family house prices, RPS median condo apartment prices, real median family income interacting with population, and real per capita disposable income interacting with population.

These two different measures were chosen because of the different demographics of the two housing markets. Detached single-family homes tend to be purchased almost entirely by families rather than singles or unrelated individuals, so median family income would seem to be the logical income driver for the median price. In comparison, condo apartments tend to have a significantly larger share of purchasers who are either single or who are purchasing the apartment as a second home, so that an average measure such as per capita income might be a better measure of underlying demand.

The Table 7 results indicate that both price series and the interacting income-population drivers are broadly non-stationary at the metro-area level, which is the first necessary assumption for cointegration testing. Table 9 shows the results of the corresponding panel augmented Dickey-Fuller tests for cointegration. For both detached single-family homes and condo apartments, the tests reject the null hypothesis of no cointegration in favor of alternative hypotheses of a common AR coefficient or more realistically, individual AR coefficients for the house price vs. income-population correlation.

A warning here is in order: Though the Table 7 and 8 results indicate broad metro area cointegration and thus indicate the use of an error–correction model with mean-reversion effects, such effects will not be visible in the historical data for all metro areas. Since 2010, Vancouver and a few Ontario metro areas, Toronto most visibly, have recorded house price appreciation rates since 2010 that seem to move steadily away from income and population fundamentals and belie mean-reversion effects. This is all the more reason for the third important decision in the metro model specification, which is to have separate regressions by province pools rather a single panel regression. The use of separate province pools for the metro area regressions allow for more leeway in specification, whereas it is likely that the needed number of regional interactions for a single pooled regression would make the regression results unwieldly.

Tables 10 and 11 show the equilibrium regressions results corresponding to equa-

Table 9: Metro Area Cointegration Test Results

Median single-family house price vs. median family income, interacting with population

Pedroni Residual Cointegration Test
Series: LOG(Real median family income)*LOG(Population), LOG(Real RPS median detached s-f home price)
Sample: 1981Q1-2015Q4
Included observations: 140
Cross sections included: 34
Null hypothesis: No cointegration
Trend assumption: No deterministic trend
Use d.f. corrected Dickey-Fuller residual variances
User-specified lag length: 1
Newey-West automatic bandwidth selection and Bartlett kernel

Alternative hypothesis: common AR coefs. (within-dimension)

	Statistic	Prob.	Weighted Statistic	Prob.
Panel ADF-Statistic	-6.801	0.000	-5.286	0.000

Alternative hypothesis: individual AR coefs. (between-dimension)

	Statistic	Prob.
Group ADF-Statistic	-6.583	0.000

Median condo apartment price vs. real per capita income, interacting with population

Pedroni Residual Cointegration Test
Series: LOG(Real per capita disposable income)*LOG(Population), LOG(Real RPS median condo apartment price)
Sample: 1981Q1-2015Q4
Included observations: 140
Cross-sections included: 21
Null hypothesis: No cointegration
Trend assumption: No deterministic trend
Use d.f. corrected Dickey-Fuller residual variances
Automatic lag length selection based on SIC with lags from 12 to 13
Newey-West automatic bandwidth selection and Bartlett kernel

Alternative hypothesis: common AR coefs. (within-dimension)

	Statistic	Prob.	Weighted Statistic	Prob.
Panel ADF-Statistic	-4.755	0.000	-4.630	0.000

Alternative hypothesis: individual AR coefs. (between-dimension)

	Statistic	Prob.
Group ADF-Statistic	-4.329	0.000

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

tion (1).[11] These regressions are done on the backcast metro area price series in order to establish a long-term price trend. 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 metro area is real median family income interacting with population as a determinant of the detached single-family house price trend, and real disposable per capita income interacting with population as a determinant of the condo apartment price trend.

However, other drivers were included in order to ensure that individual metro areas did not diverge too radically from the national index price trend or reacted in a perceptible way to local income trends. The first such secondary driver is the national new house and land price index, which acts as a proxy for the national supply side of the housing market, including land and construction costs. The second secondary driver is the deflated S&P/TSX stock price index interact-

11 The regressions are limited to data through 2015 because that is when historical estimates for metro area income currently come to an end. Also, the regressions sample starts in 1996 because the old metro area time series for population used to start in 1996. Recently, the quarterly metro area historical data was extended to the 1970s, which indicates that a re-estimation of the model should be done in the near term.

Table 10: Metro Area Equilibrium Median Single-Family House Price Regressions

Dependent variable: LOG(Real RPS median detached single-family home price)
Method: Pooled EGLS (Cross-section weights, fixed effects)
Linear estimation after one-step weighting matrix
t-statistics are in parentheses

	Province †								
Driver	Alberta	British Columbia	Manitoba	New Brunswick	New-foundland	Nova Scotia	Ontario	Quebec	Saskatchewan
Constant	-2.297 (-7.161)**	-2.818 (-23.139)**	-2.671 (-8.183)**	0.691 (4.693)**	0.523 (0.808)	0.109 (0.527)	-1.335 (-12.696)**	2.159 (7.777)**	-3.352 (-7.712)**
LOG(Real median family income)*LOG(Population)	0.096 (12.453)**	0.039 (3.607)**	--	0.033 (2.498) *	0.210 (13.556)**	0.115 (5.868)**	0.099 (20.053)**	0.215 (17.799)**	--
LOG(Real per capita income)	--	--	0.861 (3.380)*	--	--	--	--	--	--
LOG(Real median family income)	--	--	--	--	--	--	--	--	1.748 (14.589)**
LOG(Real national new house and land price index)	1.713 (14.967)**	2.359 (37.588)**	1.664 (7.379)**	1.370 (24.342)**	0.554 (2.879)*	1.108 (10.378)**	1.533 (69.869)**	--	--
LOG(Real Canada stock price index)*LOG(Population/Population lagged 4 qtr)	--	-0.446 (-2.376)*	--	1.274 (6.370)**	1.977 (4.927)**	--	1.566 (16.189)**	7.167 (16.289)**	--
LOG (Real Canada stock price index)	--	--	--	--	--	--	--	--	0.768 (8.752)**
Sample	1993Q1 - 2015Q4	1996Q2 - 2015Q4	1996Q2 - 2015Q4	1996Q2 - 2015Q4	1998Q1 - 2015Q4	1996Q2 - 2015Q4	1996Q2- 2015Q4	1996Q2 - 2015Q4	1998Q1 - 2015Q4
Cross sections ‡	2	4	1	3	1	1	15	5	2
Observations	184	316	79	237	72	79	1178	388	144
Adj. R-squared	0.944	0.973	0.930	0.941	0.951	0.945	0.945	0.886	0.825

† Prince Edward Island is treated as a metro area in the New Brunswick pool
‡ Census metropolitan areas plus Prince Edward Island
* Statistically significant at the 5% confidence level
** Statistically significant at the 1% confidence level

Note: Fixed effects coefficients for cross sections available upon request

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

ing with population growth. This driver not only is a proxy for national financial wealth, but also interacts with population growth as a way of underlining that national financial wealth is more likely to affect housing markets in metro areas that are showing substantial growth as opposed to those where growth is slow or static. The coefficient for this driver does not necessarily have to be positive.

Tables 9 and 10 show negative coefficients for British Columbia, which are most likely determined by the Vancouver housing market. This market depends significantly on foreign wealth inflows, so that house prices might be increasing at a fast clip even when the national stock market is correcting. At the other end of the spectrum, the Montreal-led single-family home market in Quebec seems to be mainly wealth and population-driven, resulting in a large coefficient for this driver relative to real median family income.

Additional changes were made to ensure that some of the smaller housing market price trends responded to some measure of income. For Manitoba, detached single-family house prices seem to trend more in line with disposable per capita income rather than median family income. For Saskatchewan, interacting median family income and stock prices with population growth did not seem to work for determining a long-term price trend, so these drivers were used without population interactions. Lastly, the Alberta condo apartment prices reacted only sluggishly to per capita disposable income growth, so an additional driver in the form of the wage share of personal income was

Table 11: Metro Area Equilibrium Median Condo Apartment Price Regressions

Dependent variable: LOG(Real RPS median condo apartment home price)
Method: Pooled EGLS (Cross-section weights, fixed effects)
Linear estimation after one-step weighting matrix
t-statistics are in parentheses

	Province †							
Driver	**Alberta**	**British Columbia**	**Manitoba**	**New-foundland**	**Nova Scotia**	**Ontario**	**Quebec**	**Saskatchewan**
Constant	-0.798 (-1.332)	-2.515 (-8.652)*	-0.481 (-1.637)	0.610 (1.002)	3.143 (11.583)*	0.141 (0.898)	-0.242 (-1.229)	-5.003 (-9.782)*
LOG(Real disposable per capita income)*LOG(Population)	0.137 (17.901)*	0.045 (3.075)*	0.067 (2.923)*	0.137 (14.885)*	0.138 (12.846)*	0.078 (13.282)*	0.121 (14.883)*	0.032 (3.471)*
LOG(Real national new house and land price index)	0.737 (5.571)*	2.187 (18.402)*	1.431 (10.248)*	1.070 (6.690)*	0.472 (4.677)*	1.319 (25.168)*	1.157 (17.537)*	2.682 (20.902)*
LOG(Real Canada stock price index)*LOG(Population/population lagged 4 qtr)	--	-0.844 (-2.664)*	3.567 (8.194)*	0.654 (1.980)	--	0.494 (3.254)*	0.184 (0.426)	1.115 (3.605)*
Wage share of personal income	2.443 (6.127)*	--	--	--	--	--	--	
Sample	1990Q1 - 2015Q4	1996Q2 - 2015Q4	1996Q2 - 2015Q4	1996Q2 - 2015Q4	1996Q2 - 2015Q4	1996Q2 - 2015Q4	1996Q2 - 2015Q4	1996Q2 - 2015Q4
Cross sections ‡	2	4	1	1	1	8	2	2
Observations	208	316	79	79	79	632	158	158
Adj. R-squared	0.909	0.910	0.974	0.964	0.960	0.923	0.968	0.964

† No condo apartment price are available for New Brunswick or Prince Edward Island
‡ Census metropolitan areas
* Statistically significant at the 1% confidence level

Note: Fixed effects coefficients for cross sections available upon request

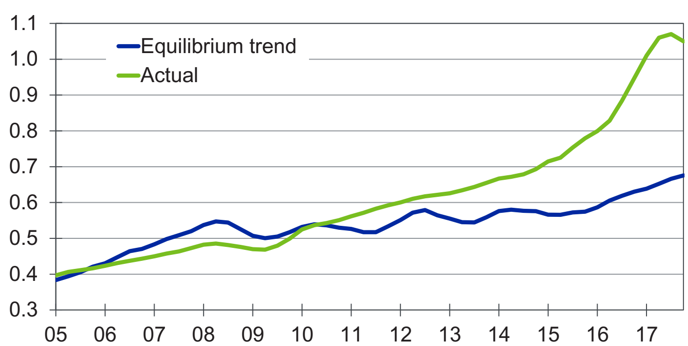
Sources: RPS Real Property Solutions Inc., Moody's Analytics

added, which underlines the greater dependence of housing demand in Alberta on wage income rather than property income or wealth inflows.

It should be noted that the Table 10 and 11 regressions are in level rather than difference terms precisely in order to generate an extended price trend with a lot of autocorrelation, and thus to allow a significant departure of the actual house price series from the fitted values, which would correspond to housing market over- or undervaluation. Charts 4 through 6

Chart 4: Toronto Is Seriously Overvalued…

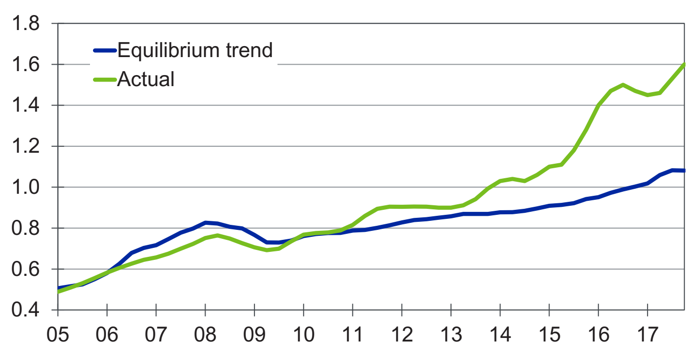
Toronto median detached single-family house price, C$ mil



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

Chart 5: …As Is Vancouver…

Vancouver median detached single-family house price, C$ mil



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

Table 12: Metro Area Adjustment Median Single-Family House Price Regressions

Dependent variable: DLOG(Real RPS median detached single-family home price)
Method: Pooled EGLS (Cross-section weights)
Linear estimation after one-step weighting matrix
Sample: 2005Q4-2017Q4
t-statistics are in parentheses

					Province †				
Driver	**Alberta**	**British Columbia**	**Manitoba**	**New Brunswick**	**New-foundland**	**Nova Scotia**	**Ontario**	**Quebec**	**Saskatchewan**
DLOG(Real RPS median detached single-family home price, lagged 1 qtr)	1.182	0.889	0.869	0.640	0.586	0.294	0.729	0.625	0.941
	(13.979)**	(13.598)**	(5.620)**	(8.369)**	(3.817)**	(2.184)*	(19.364)**	(9.737)**	(9.713)**
DLOG(Real RPS median detached single-family home price, lagged 2 qtr)	-0.400	-0.334	-0.214	-0.229	0.098	-0.038	-0.079	-0.002	-0.112
	(-4.857)**	(-5.109)**	(-1.388)	(-2.931)**	(0.706)	(-0.290)	(-2.090)*	(-0.037)	(-1.149)
DLOG(Equilibrium RPS median detached single-family home price)	0.184	0.230	0.107	0.290	0.034	0.284	0.148	0.026	0.108
	(4.181)**	(5.754)**	(1.279)	(3.236)**	(0.908)	(3.295)**	(7.044)**	(1.674)	(2.292)*
LOG(RPS median detached single-family home price, lagged one qtr./ Equilibrium median s-f home price, lagged 1 qtr)	-0.012	--	-0.028	-0.066	-0.054	-0.093	--	-0.006	-0.043
	(-0.938)		(-1.559)	(-2.306)*	(-2.476)*	(-2.370)*		(-1.510)	(-3.480)**
Difference(Adjustable 5-yr mortgage rate/100, lagged 2 qtr)	-1.838	-0.982	-0.377	-0.040	-0.470	-0.221	-0.618	-0.608	-1.698
	(-4.143)**	(-2.353)*	(-0.659)	(-0.075)	(-0.777)	(-0.375)	(-3.659)**	(-2.252)*	(-2.513)*
Unemployment rate/100 lagged 1 qtr, 8-qtr moving avg minus unemployment rate/100 lagged 9 qtr, 8-qtr moving avg	-0.120	-0.116	--	-0.060	-0.359	--	-0.119	-0.214	-0.003
	(-1.683)	(-1.578)		(-0.322)	(-1.611)		(-3.036)**	(-2.329)*	(-0.018)
DLOG(Single-family housing stock, lagged 1 qtr) - DLOG(Households, lagged 1 qtr)	--	-1.186	-0.530	--	--	--	-1.182	-0.615	-0.305
		(-1.410)	(-0.458)				(-3.398)**	(-1.151)	(-0.366)
Cross sections ‡	2	4	1	3	1	1	15	5	2
Observations	98	196	49	147	49	49	735	245	98
Adj. R-squared	0.867	0.664	0.330	0.421	0.641	0.184	0.496	0.322	0.733

† Prince Edward Island is treated as a metro area in the New Brunswick pool
‡ Census metropolitan areas plus Prince Edward Island
* Statistically significant at the 5% confidence level
** Statistically significant at the 1% confidence level

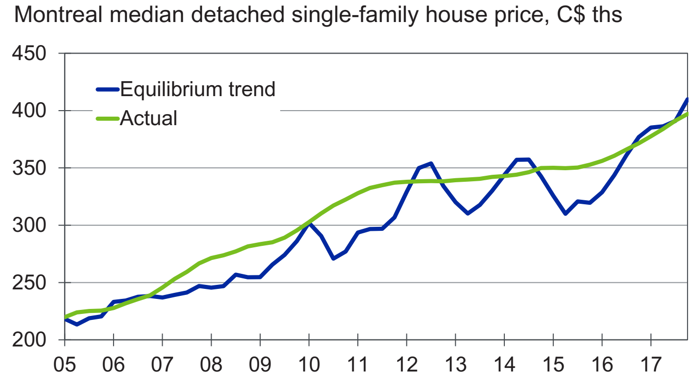
Sources: RPS Real Property Solutions Inc., Moody's Analytics

show the difference between actual median detached single-family house prices and the trend values generated by the Table 9 regressions for the three largest Canada metro areas. Toronto and Vancouver are clearly overvalued despite recent province government efforts to restrict wealth-driven demand and increase supply. By contrast Montreal seems to be fairly valued so far even though the greater sensitivity to population growth and national wealth makes the trend house price series more volatile.

The use of an average measure of income as opposed to a median makes it harder for condo apartment markets to become overvalued and indeed, most metro area condo apartment markets are currently fairly valued or even slightly undervalued according to the Table 10 metrics. However, Chart 7 indicates that Toronto and Vancouver are again the major exceptions, being significantly overvalued most likely as a result of wealth inflows boosting housing demand.

Chart 6: …But Not Montreal

Montreal median detached single-family house price, C$ ths



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

Table 13: Metro Area Adjustment Median Condo Apartment Price Regressions

Dependent variable: DLOG(Real RPS median condo apartment price)
Method: Pooled EGLS (Cross-section weights)
Linear estimation after one-step weighting matrix
Sample: 2005Q4-2017Q4
t-statistics are in parentheses

	Province †							
Driver	**Alberta**	**British Columbia**	**Manitoba**	**Newfound-land**	**Nova Scotia**	**Ontario**	**Quebec**	**Saskatchewan**
DLOG(Real RPS median condo apartment price, lagged 1 qtr)	0.998 (10.679)**	0.781 (11.698)**	0.295 (2.012)*	0.816 (5.641)**	0.602 (4.552)**	0.617 (12.685)**	0.732 (7.805)**	0.780 (8.848)**
DLOG(Real RPS median condo apartment price, lagged 2 qtr)	-0.305 (-3.438)**	-0.216 (-3.165)**	0.144 (1.006)	-0.100 (-0.712)	-0.052 (-0.362)	-0.242 (-4.947)**	-0.251 (-2.688)**	-0.357 (-3.918)**
DLOG(Equilibrium RPS median condo apartment price)	0.228 (4.136)**	0.276 (3.893)**	0.224 (1.187)	-0.036 (-0.435)	0.043 (0.351)	0.298 (5.050)**	0.108 (2.158)*	0.291 (2.578)*
LOG(RPS median condo apartment price, lagged 1 qtr/Equilibrium median s-f home price, lagged 1 qtr)	-0.017 (-1.182)	-0.050 (-3.033)**	-0.162 (-2.481)*	--	-0.183 (-3.415)**	--	-0.055 (-2.704)**	-0.101 (-3.393)**
Difference(Adjustable 5-yr mortgage rate/100, lagged 2 qtr)	-1.335 (-1.930)	-1.662 (-2.911)**	-0.407 (-0.281)	-0.119 (-0.109)	-0.052 (-0.061)	-0.949 (-2.314)*	-0.368 (-0.866)	-2.652 (-2.253)*
Unemployment rate/100 lagged 1 qtr, 8-qtr moving avg minus unemployment rate/100 lagged 9 qtr, 8-qtr moving avg	-0.228 (-1.983)	-0.191 (-1.932)	-0.553 (-0.698)	--	--	-0.148 (-1.602)	--	-1.184 (-3.562)**
DLOG(Multifamily housing stock, lagged 1 qtr) - DLOG(Households, lagged 1 qtr)	--	--	-0.902 (-0.327)	--	-0.905 (-0.969)	--	-0.670 (-1.202)	--
Cross sections ‡	2	4	1	1	1	8	2	2
Observations	98	196	49	49	49	392	98	98
Adj. R-squared	0.778	0.507	0.117	0.458	0.292	0.249	0.342	0.602

† No condo apartment price are available for New Brunswick or Prince Edward Island
‡ Census metropolitan areas
* Statistically significant at the 5% confidence level
** Statistically significant at the 1% confidence level

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

Regional RPS price adjustment

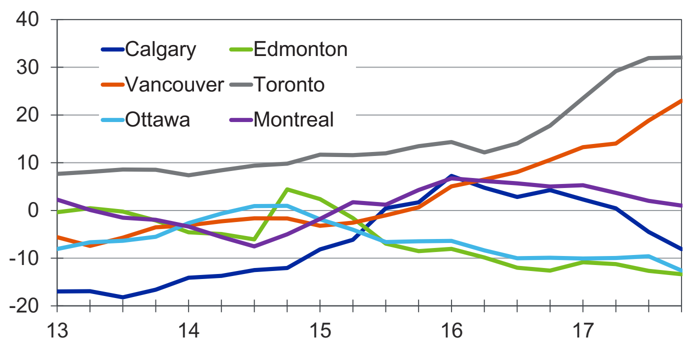
The Table 10 and 11 regressions that correspond to equation (1) establish a long-term price trend, but the actual house price forecasts have to be established using dynamic equations similar to equation (2), which may or may not show significant persistence or trend-reversion effects. Tables 12 and 13 show the resulting adjustment regressions for census metro areas, again divided up into provincial pools. Since the purpose of these regressions is to generate the actual forecast rather than a long-term price trend, only available data from 2005-2017 are used.

The first two rows in these regression tables show the persistence effects (That is, lagged dependent variable effects), which as expected for stable price series such as the RPS median prices, are positive for the first lagged quarter and tend to be negative for the second lagged quarter, though there are exceptions such as Manitoba and Newfoundland for the latter case.[12] As is well known, the use of persistence terms involves a potential trade-off. In normal

12 Because lagged dependent variables are included in the regressions, the standard Durbin-Watson statistic to test for autocorrelation is not valid and is not shown in the tables.

Chart 7: …And Their Condos as Well

RPS median condo apartment price, % deviation from trend



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

Table 14: Derivation of Province Median Detached Single-Family House Price Forecasts

Dependent variable: DLOG(Real RPS median detached single-family home price)
Method: Least squares
Sample: 2005Q2-2017Q4
t-statistics are in parentheses

	Province †								
Driver	Alberta	British Columbia	Manitoba	New Brunswick	New-foundland	Nova Scotia	Ontario	Quebec	Saskatchewan
Constant	0.001 (2.486)*	0.0005 (1.273)	0.001 (1.689)	0.002 (1.735)	0.002 (3.250)**	0.004 (4.403)**	-0.0004 (-1.633)**	0.0007 (2.711)**	0.001 (1.872)
DLOG(Weighted avg of metro area median s-f home prices)	0.894 (84.624)**	0.935 (75.110)**	0.924 (42.516)**	0.668 (7.756)**	0.828 (34.295)**	0.465 (6.976)**	1.050 (82.774)**	0.871 (46.419)**	0.917 (49.503)**
DLOG(Province new house and land price) - DLOG(Weighted avg of metro area new house and land prices)	--	--	0.844 (1.842)	--	0.301 (0.614)	0.190 (0.257)	0.113 (0.675)	--	0.239 (0.622)
Observations	51	51	51	51	51	51	51	51	51
Adjusted R-squared	0.993	0.991	0.973	0.542	0.961	0.483	0.994	0.977	0.984
Schwarz information criterion	-9.408	-9.448	-9.561	-6.620	-8.777	-7.608	-10.614	-10.587	-8.248

† Prince Edward Island excluded; its forecast is obtained from Table 7
* Statistically significant at the 5% confidence level
** Statistically significant at the 1% confidence level

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

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 third row in each table shows the effect of trend house price appreciation. That is, the contemporaneous effect of all the long-term drivers that go into the Table 9 and 10 regressions. As expected, the coefficients are all positive, though they vary in intensity. The fourth row in each table shows the mean-reversion effects, as proxied by the lagged ratio of the actual price to the trend price estimated in Tables 9 and 10. With a few exceptions, mean-reversion effects turn out to be perceptible and statistically significant, but the exceptions turn out to be important. In Vancouver and the region of Toronto and its smaller nearby metro areas, single-family house prices have diverged from trend since 2010 and have not reverted, so it is no surprise that for the British Columbia and Ontario pools, mean-reversion effects were not significant and were left out of the equation; 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 unquantifiable degree of capital inflows into the Toronto and Vancouver housing markets, where the only contrary push so far has been from government policy measures that are still starting to take effect.

Three other drivers to the adjustment regressions simulate local and national business cycle and supply-side effects that can influence 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 included as a regression driver for both home types and demonstrates negative effects on appreciation across all province pools.[13] Changes in the unemployment rate have generally weaker effects that can be perceived only with lags of several quarters, but this driver is included because it usually comes out with the correct sign and because it is the main indicator of local business cycle conditions. Supply-side conditions were also taken into account by adding in the difference between either single-family or multifamily construction and household formation, though the reaction between provinces was uneven. Also, in the regional forecast process care has to be taken that the forecast for household formation does not diverge too radically from the forecast for residential construction.

Expanding the forecast model

The Table 10, 11, 12 and 13 regressions generate what could be thought of as the core house price forecast at the regional

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

Table 15: Derivation of Province Median Condo Apartment Price Forecasts

Dependent variable: DLOG(Real RPS median condo apartment price)
Method: Least squares
Sample: 2005Q2-2017Q4
t-statistics are in parentheses

	Province †							
Driver	**Alberta**	**British Columbia**	**Manitoba ‡**	**New-foundland ‡**	**Nova Scotia ‡**	**Ontario**	**Quebec**	**Saskatchewan**
Constant	-0.0005 (-0.130)	0.0008 (1.169)	0	0	0	-0.002 (-2.133)*	0.0008 (1.966)	-0.0003 (-0.486)
DLOG(Weighted avg of metro area median condo apartment prices)	0.981 (90.604)**	0.985 (32.741)**	1.000 (NA)	1.000 (NA)	1.000 (NA)	1.157 (23.765)**	0.915 (34.032)**	1.014 (73.023)**
DLOG(Province new house and land price) - DLOG(Weighted avg of metro area new house and land prices)	1.181 (6.284)**	--	--	--	--	1.432 (2.671)*	0.250 (0.942)	0.587 (1.690)
Observations	51	51	51	51	51	51	51	51
Adjusted R-squared	0.994	0.955	1.000	1.000	1.000	0.926	0.959	0.992
Schwarz information criterion	-9.022	-7.985	NA	NA	NA	-8.137	-9.435	-8.369

† New Brunswick and Prince Edward Island have no condo apartment price series
‡ The Manitoba, Newfoundland, and Nova Scotia median apartment prices are set equal to those of their metro areas in the historical data.
* Statistically significant at the 5% confidence level
** Statistically significant at the 1% confidence level

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

level, with other series being produced by a combination of aggregation or distributed growth from the core forecast. Province single-family house price and condo apartment price forecasts are determined mainly by the housing-stock weighted average of their metro area forecasts. Single-family and multifamily housing stocks are estimated and forecast using both national data and regional completions data from CMHC.

Tables 14 and 15 summarize the single-equation results of the province-level regressions. The main driver is the housing-stock weighted average of metro area prices (single-family stock weights for detached single-family prices and multifamily stock weights for condo apartment prices). In some provinces, the difference between the provincial and the weighted average of metro new house and land prices is also used as a wedge between province and metro area prices, but as expected the effects did not turn out to be significant. Also, no fewer than three province condo apartment median prices—for Manitoba, Newfoundland and Nova Scotia—are identical to their metro area condo apartment price, and this is shown in the single-equation regressions in Table 14.

Deriving the median composite price level for each geography is not as straightforward as using housing-stock weighted averages of detached single-family and condo apartment prices. 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 semi-detached, 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 16, where each pool consists of metro areas within each province and the provinces themselves. Furthermore, the Ontario and Quebec pools are divided into metro areas with and without 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.

There remain the aggregate transactions-weighted composite prices for the 13 metro areas used to calculate the RPS 13-metro composite index. There are almost all very close in magnitude to the median composite price for each metro area, so it is very tempting to forecast the aggregate transactions-weighted composite prices simply by growing them out with the growth rates of the median composite prices. But the transactions-weighted composite price series are not completely equal to the median composite price series and actually show significant

Table 16: Derivation of Province and Metro Area Median Composite Price

Dependent variable: DLOG(Real RPS median composite price)
Method: Pooled EGLS (Cross-section weights)
Linear estimation after one-step weighting matrix
Sample: 2005Q2-2017Q4
t-statistics are in parentheses

	Province †										
Driver	Alberta	British Columbia	Manitoba	New Brunswick	New-foundland	Nova Scotia	Ontario metro areas w/o condo prices	Ontario, with condo prices	Quebec metro areas w/o condo prices	Quebec, with condo prices	Saskat-chewan
DLOG(Real RPS median detached single-family home price)	0.902 (51.640)*	0.918 (68.166)*	0.880 (37.103)*	0.558 (14.166)*	0.881 (32.534)*	0.923 (28.618)**	0.955 (73.731)*	0.916 (96.190)*	0.751 (22.974)*	0.851 (50.047)*	0.911 (62.613)**
DLOG(Real RPS median condo apartment price)	0.078 (5.227)*	0.038 (3.614)*	0.081 (5.423)*	--	0.102 (5.289)*	0.022 (1.070)	--	0.048 (7.353)*	--	0.073 (4.801)*	0.064 (5.608)*
Cross sections ‡	3	5	2	4	2	2	7	9	3	3	3
Observations	153	255	102	204	102	102	357	459	153	153	153
Adj. R-squared	0.993	0.939	0.897	0.324	0.914	0.808	0.901	0.933	0.629	0.900	0.975

† Prince Edward Island is treated as a metro area in the New Brunswick pool
‡ Census metropolitan areas and provinces
* Statistically significant at the 1% confidence level

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

divergence for one metro area—Hamilton, Ontario. As a result, it is safer if less expedient to forecast these composites using error correction models in order to take into account the possibility of divergence, even though the two prices will often be almost on top of each other and will thus generate extreme regression coefficients.

Table 17 shows the results of unit root and cointegration tests needed as the first step in using error-correction equations. With only 13 metro areas it is harder to establish nonstationarity, but even so the Im, Pesaran and Shin statistic fails to reject the null hypothesis of individual unit root processes. Given that the metro area series are so close to each other, the panel cointegration rejects the null hypothesis of no cointegration at much less than a 1% confidence level.

Table 18 shows the results of the LOG-LOG equilibrium trend results, where for the sake of consistency the metro areas have also been divided into province pools. With one exception, the constant terms are close to 0 and the coefficients for the median composite price driver are almost equal to 1. The exception is Ontario, where the divergence between the Hamilton transactions-weighted composite and median composite prices causes the coefficient to be slightly higher than 1.

The same logic applies to the adjustment equation results shown in Table 19. The persistence drivers all have coefficients close to 0, but this is mainly because the trend composite price level estimated in Table 17 provides all of the needed change: Its coefficients are all almost equal to 1 except for Ontario, where the price divergence for Hamilton again causes the forecast growth rate to be slightly below the median composite price level forecast. The mean-reversion terms also indicate that even though the two indexes are almost on top of each other, the forecast tends to overshoot by small amounts when reverting to trend. Hamilton and Ontario are again the only exception.

Index and NSA forecasts

All of the RPS home values forecast so far have been prices, for the main reason that 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 values and indexes forecast so far have already 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 to four dummy

Table 17: Unit Root and Cointegration Test Results for Transactions-Weighted Metro Area Indexes

Unit Root Test
Im, Pesaran and Shin Unit Root Test
Series: LOG(RPS transactions-weighted composite price)
Null hypothesis: Unit root (individual unit root process)
Sample: 2005Q1-2017Q4
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: 638
Cross sections included: 13

Method	Statistic	Probability **
Im, Pesaran and Shin W-stat	-0.634	0.263

**Probabilities are computed assuming asympotic normality

Cointegration Test
Johansen Fisher Panel Cointegration Test
Series: LOG(RPS transactions-weighted composite price), LOG(RPS median composite price)
Sample: 2005Q1-2017Q4
Included observations: 52
Trend assumption: Linear deterministic trend
Lags interval (in first differences): 1 to 4

Unrestricted Cointegration Rank Test (Trace and Maximum Eigenvalue)

Hypothesized No. of CE(s)	Fisher Statistic* (from trace test)	Prob.	Fisher Statistic* (from max-eigen test)	Prob.
None	129.2	0.000	81.2	0.000
At most 1	107.7	0.000	107.7	0.000

* Probabilities are computed using asymptotic Chi-square distribution

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

Table 18: Metro Area Equilibrium Transactions-Weighted Composite Price Regressions

Dependent variable: LOG(RPS transactions-weighted composite price)
Method: Pooled EGLS (Cross-section weights)
Linear estimation after one-step weighting matrix
Sample: 2005Q1-2017Q4
t-statistics are in parentheses

	Province †						
Driver	Alberta	British Columbia	Manitoba	Nova Scotia	Ontario	Quebec	Saskatchewan
Constant	3.77E-05 (0.475)	4.01E-06 (0.270)	-7.32E-05 (-1.414)	0.0001 (1.464)	-0.615 (-3.170)*	5.95E-05 (1.161)	4.80E-06 (0.180)
LOG(RPS median composite price)	0.9999 (162378.7)*	1.000 (895621.8)*	1.000 (238853.9)*	1.000 (149635.1)	1.045 (69.263)*	1.000 (244700.3)*	1.000 (470429.1)*
Cross sections (metro areas)	2	2	1	1	3	2	2
Observations	104	104	52	52	156	104	104
Adjusted R-squared ‡	1.000	1.000	1.000	1.000	0.969	1.000	1.000

† New Brunswick, Newfoundland and Prince Edward Island have no metro areas with transactions-weighted prices
‡ Except for Ontario, adjusted R-squared values differed from 1 at less than six significant digits
* Statistically significant at the 1% confidence level

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

Table 19: Metro Area Transactions-Weighted Composite Price Adjustment Regressions

Dependent variable: DLOG(RPS transactions-weighted composite price)
Method: Pooled EGLS (Cross-section weights)
Linear estimation after one-step weighting matrix
Sample: 2005Q4-2017Q4
t-statistics are in parentheses

Driver	Alberta	British Columbia	Manitoba	Province † Nova Scotia	Ontario	Quebec	Saskatchewan
DLOG(RPS transactions-weighted composite price, lagged 1 qtr)	9.64E-05 (0.874)	3.53E-05 (1.220)	5.80E-05 (0.335)	9.46E-05 (0.843)	0.0004 (0.095)	6.11E-05 (0.330)	3.61E-05 (0.640)
DLOG(RPS transactions-weighted composite price, lagged 2 qtr)	-5.07E-05 (-0.776)	-4.56E-06 (-0.238)	-5.39E-05 (-0.452)	-2.91E-05 (-0.279)	0.0002 (0.060)	-4.65E-05 (-0.370)	1.01E-05 (0.271)
DLOG(Equilibrium RPS transactions-weighted composite price)	1.000 (15161.89)*	1.000 (52145.69)*	1.000 (8271.073)*	1.000 (9580.698)*	0.957 (360.663)*	1.000 (7649.089)*	1.000 (27101.56)*
LOG(RPS transactions-weighted composite price, lagged 1 qtr/Equilibrium RPS transactions-weighted composite price, lagged 1 qtr)	-1.379 (-14.497)*	-1.092 (-10.874)*	-1.118 (-7.458)*	-1.150 (-7.943)*	-9.76E-05 (-0.185)	-1.242 (-12.396)*	-1.129 (-10.996)*
Cross sections (metro areas)	2	2	1	1	3	2	2
Observations	98	98	49	49	147	98	98
Adjusted R-squared ‡	1.000	1.000	1.000	1.000	0.999	1.000	1.000

† New Brunswick, Newfoundland and Prince Edward Island have no metro areas with transactions-weighted prices
‡ Except for Ontario, adjusted R-squared values differed from 1 at less than six significant digits
* Statistically significant at the 1% confidence level

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

variables, one for each quarter of the year. The estimated coefficient for each quarterly dummy variable are then added to the log of the SA forecast in order to obtain an NSA forecast that fluctuates around its SA trend. In order to avoid showing a plethora of metro area coefficients, Table 20 shows only the estimated coefficients for the Toronto metro area. 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 will also 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 the same housing stock forecasts that were used to compute metro area weights for obtaining province forecasts, the weighted average growth rates of all metro area 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 metro area 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 province forecasts are calibrated in the same manner, as are the 13 metro 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.[14] 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 should be mentioned that for normal forecasts including the baseline 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.

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, then the metro area forecast model.

14 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 in this case.

Table 20: Sample Not Seasonally Adjusted Forecast, Toronto Census Metropolitan Area

Dependent variable: LOG(Not seasonally adjusted RPS median detached s-f home price/Seasonally adjusted RPS median detached s-f home price)
Method: Pooled least squares
Sample (adjusted): 2005Q1-2017Q4
Included observations: 52 after adjustments

	Coefficient	t-statistic	Probability
First quarter	-0.006	-5.517	0.000
Second quarter	0.003	2.327	0.020
Third quarter	0.006	5.001	0.000
Fourth quarter	-0.002	-1.888	0.059
Adjusted R-squared	0.641		
Log likelihood	3434.548		
Schwarz information criterion	-7.739		

Coefficients for other metro areas in the pooled regression are available on request

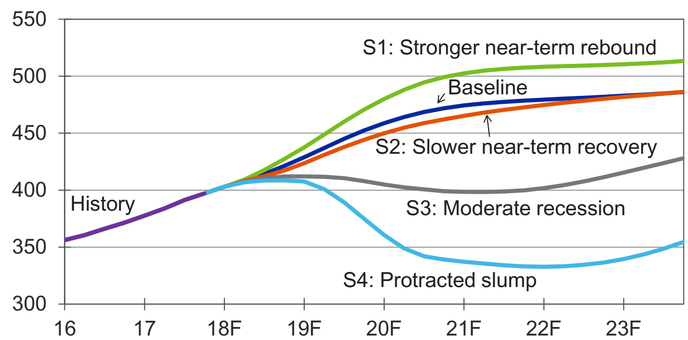
Sources: RPS Real Property Solutions Inc., Moody's Analytics

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 8 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. But in general the flexibility of the Canada macroeconomic model allows Moody's Analytics to run a very wide range of assumptions through its national and regional forecast models.

Chart 8: Standard Alternative Scenarios

RPS single-family median home price level, C$ ths, Montreal



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

About the Author

Andres Carbacho-Burgos is an economist at the West Chester office of Moody's Analytics. He covers the U.S. housing market, residential construction, and U.S. regional economies. Before joining Moody's Analytics, he taught economics at Texas State University, where he also researched open-economy macroeconomics and income inequality. Born in Chile, he obtained his PhD and master's in economics from the University of Massachusetts at Amherst and his BA in economics from Carleton College.

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RPS Real Property Solutions is a leading Canadian provider of outsourced appraisal management, mortgage-related services, and real estate business intelligence to financial institutions, real estate professionals, and consumers. The company's expertise in network management and real estate valuation, together with its innovative technologies and services, has established RPS as the trusted source for residential real estate valuation services.

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The RPS – Moody's Analytics House Price Forecasts are based on fully specified regional econometric models that account for both housing supply-demand dynamics and long-term influences on house prices such as unemployment and changes in mortgage rates. Updated monthly and providing a 10-year forward-time horizon, the forecasts are available for the nation overall, its 10 provinces and for 33 metropolitan areas, and cover three property style categories, comprising single-family detached, condominium apartments and aggregate, in a number of scenarios: a baseline house price scenario, reflecting the most likely outcome, and six alternative scenarios.

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