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Credit Conditions and Structural Breaks in The Canadian Housing Market: A Cointegration and VECM Approach

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Abstract

This research extends standard econometric house price models in which a housing price model is augmented with an exogenous credit conditions variable and structural breaks. The research entails a modelling exercise; a cointegration approach is undertaken on a demand-side model of Census Metropolitan Area (CMA) house prices in Canada from 1980Q1 to 2016Q1. The research attempts to determine whether the augmented models generate better estimation results and better model fits. New time-series variables are constructed for the analyses, such as an exogenous loan-to-value (LTV) ratio; which we find to be superior to existing measures of credit conditions in Canada. Incorporating single-break unit root and cointegration tests, a stable long-run relationship is detected between CMA real house prices and credit conditions. Evidence of cointegration leads the research to the estimation of a single-equation error correction model (ECM), in order to assess the long-run and short-run behaviour of house prices and credit conditions. The research aims to comment on the effectiveness of Canada's recent tightening of credit conditions as a macroprudential tool in curbing house price growth. In the short-run, lagged changes in the LTV ratio have a significant impact on real house prices – which in turn signifies a role for LTV constraints in Canada's arsenal of macroprudential policies.

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1 Introduction

This paper extends standard econometric house price models in which the proposed model is augmented with an exogenous credit conditions variable and structural breaks. Utilizing a cointegration and error correction approach, the research finds credit conditions to be a significant variable which should not be omitted in econometric house price models; and the inclusion of both credit conditions and structural breaks in a model will often lead to better estimation results and better model fits.

The onset of financial liberalization and innovation – which has eased mortgage lending standards – has often coincided with the large housing booms across advanced countries in the past two decades. Moreover; national and international organizations have often cited credit conditions as one of the main – if not, the main – determinant of housing prices (Schembri, 2015). This points to a clear role for credit conditions in house price dynamics yet; standard econometric house price models often omit proxies for credit conditions. This research attempts to correct for the shortcomings of standard econometric house price models, which often suffer from two omissions: a measure of credit conditions and structural breaks.

The Canadian housing market experienced a shift in its financial regime in the mid-1990's with the onset of financial liberalization; this observation motivates our research and leads us to believe that the inclusion of credit conditions and structural breaks in a house price model will result in better estimation results and better model fits. One aim of the paper entails a modelling exercise; a cointegration and error correction approach is undertaken on a demand-side housing price equation, which is augmented for credit conditions. Then – utilizing single-break cointegration tests, the research further detects and date-stamps break points in the long-run house price equation; which to our surprise has been ignored in the econometric modelling of house prices. Our house price model is further extended to incorporate the estimated break points. We find our extended model to be superior to models that exclude or include credit conditions – but no structural break point – in which our extended model generates more plausible and significant coefficients and better model fits.

A loan-to-value (LTV) series is our selected measure of credit conditions. International house price literatures often have access to a LTV series; such as the LTV ratio for first-time homeowners often utilized in the U.S. literature[1]. However, a LTV series is not available in Canada. To address data limitations within Canada, the research puts forward a novel and straightforward calculation in order to obtain a raw LTV series; we then utilize Duca et al.'s (2011) procedure to obtain an exogenous LTV series. Our estimation results reveal that our constructed exogenous LTV measure often outperforms the existing exogenous measures of credit conditions in Canada.

House prices in Canada's most populous Census Metropolitan Areas (CMAs) have seen unprecedented growth in the past decade in which concerns over fast-growing home prices have been instrumental in the recent implementation of macroprudential policies[2]. This fuels the second aim of the research in which we model via an error correction model the long-run and short-run behaviour of house prices for two major CMAs – Toronto and Vancouver. In light of the emerged interest in macroprudential policies to curb housing prices; the research attempts to measure the speed and extent to which house prices will revert back towards long-run levels in the face of tightened credit conditions, i.e. a lower LTV ratio. We find changes in the LTV ratio to have a significant impact on both the long-run and short-run behaviour of real house prices.

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[1] See Duca et al. (2011) and Bachmaan and Ruth (2016).

[2] For example, macroprudential policies can involve the tightening or loosening of the LTV ratio, or the shortening and lengthening of the amortization period. See Allen et al. (2015, 2017) for a detailed account of historical and current changes in Canada's macroprudential policies.

In the sections that follow; a cointegration and error correction approach are undertaken in the modelling of CMA house prices in Canada from 1980Q1 to 2016Q1. We begin in providing a brief historical and current assessment of the Canadian housing market and the Canadian household credit market, as well as touch on Canada's experience with macroprudential policies. Section 2 discusses the related literatures on housing prices and fundamentals, with an emphasis on research that focuses on the Canadian housing market and/or incorporates credit conditions as a determinant of housing prices. Section 3 is a formulation of the demand-side housing price model, which is utilized within the empirical framework. The selected demand-side fundamentals reflect the attractiveness of homeownership: an affordable housing index, the real mortgage rate, and the LTV ratio. Section 4 is the data section, which provides thorough details on our construction of the affordable housing index and our exogenous credit conditions variable. The remaining sections breakdown the empirical framework into the multiple stages of a cointegration and ECM analysis – which entails standard and single-break unit root and cointegration tests; as well as the econometric modelling of the long-run and short-run behaviour of house prices. When estimating the ECM, we augment and dis-augment the demand-side model with structural break dummies and/or a measure of credit conditions. With the onset of financial liberalization in the mid-1990's in Canada, we suspect that the addition of credit conditions and structural breaks will improve the estimation results of the model.

2 An Overview

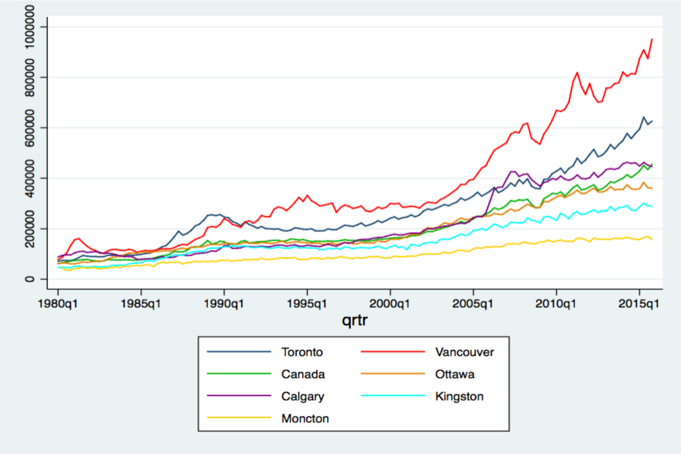
2.1 The Canadian Housing Market

Canada has undergone a housing boom since the 2000's, with home prices doubling in most regions. Table 1 in Appendix A quantifies the growth in house prices throughout the past few decades for a select few of Canada's largest urban regions: Toronto, Vancouver, Ottawa, Calgary, Moncton, and Kingston. Regional house prices have often moved together in Canada; however, in the past decade, there has been regional divergence in Canadian housing prices. Canada's most populous CMAs – Toronto and Vancouver – have undergone unprecedented growth, while the remainder of Canada has seen modest increases in house prices. Both CMAs continue to struggle with intense affordable housing problems, with a high house price growth rate of between 50-60 percent in the past decade; whereas the remainder of Canada sits at a house price growth rate of 10 percent. Figure 1 provides a time series plot of nominal house prices in Canada's largest CMAs; the regional divergence is apparent post-2000's. The stretched overvaluations in Canada's most populous CMAs motivates the research's focus on Toronto and Vancouver; and whether the Government's recent use of macroprudential policies would be an effective tool to ease the recent housing price booms in CMAs.

2.2 The Canadian Household Credit Market

The rise of housing prices is often attributed to Canada's changing financial landscape – such as the relaxation of mortgage lending standards. Canada's financial landscape began to change in the mid 1990's with lower interest rates and financial liberalization and innovation creating favourable credit conditions

Figure 1: House Prices for Canada and Select Cities[a], $1980Q1 - 2016Q1$



[a] House price data sourced from Canadian Real Estate Association (CREA).

for the average homeowner (Schembri, 2015). For instance, the mortgage rate fell from 8.25 percent in 2000 to a present rate of 3.25 percent; whereas, financial innovations – such as government-backed mortgage insurance – further expanded residential mortgage credit (Krznar and Morsink, 2014)[3].

Figure 2 illustrates the path of residential mortgage credit over the past four decades, which has seen an annual growth rate of 8.75 percent since 2000 (Krznar and Morsink, 2014). Also since 2000, household debt – in which 80 percent is often attributed to mortgage loans – has risen 60 percent; and in 2012, debt levels were 163 percent greater than household disposable income (Krznar and Morsink, 2015). In turn, a significant feature of the credit market becomes the Government's influence over mortgage lending practises. Such housing-financing measures are often referred to as macroprudential policies – which act to ease imbalances in the housing market and the financial threats associated with high household debt. For instance, macroprudential policies

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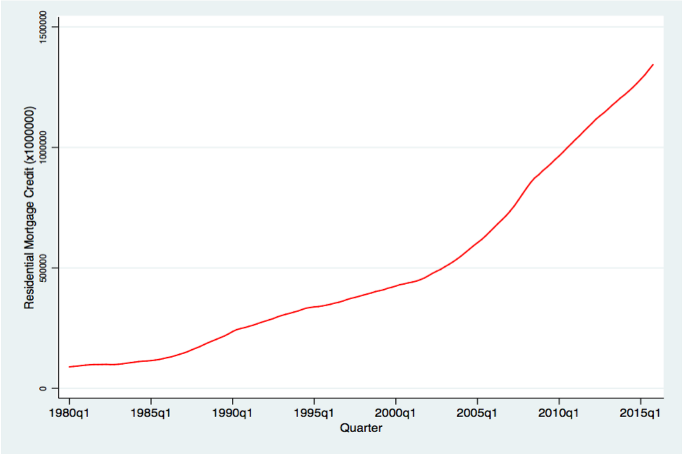
[3] Schembri (2015) and Jason et al.(2017) provide a detailed account of the institutional changes in the Canadian mortgage credit market.

Figure 2: Canada's Residential Mortgage Credit[a], $1980Q1 - 2016Q1$



[a] Credit data sourced from Statistics Canada.

can entail the tightening and loosening of the LTV ratio or the lengthening and shortening of the amortization period. Allen et al. (2016) found that LTV constraints had a significant impact on the Canadian housing market; whereas, constraints on the amortization period had less of an impact. This motivates our focus on the LTV ratio, which has become a well-utilized macroprudential tool in the face of imbalances in the Canadian housing market. The LTV ratio imposes a constraint on the size of the mortgage loan relative to the size of the house,

$$\theta = LTV \leq \frac{Loan}{HouseValue} \tag{1}$$

where θ is the maximum LTV ratio and often fluctuates between 90 and 100 percent in Canada (Allen et al., 2016). A tightening of the constraint discourages potential homeowners from entering the housing market since it requires more financial wealth; while a loosening of the constraint creates the reverse effect (Allen et al., 2016). Below, Table 1 outlines the different periods of tightening and loosening in the LTV ratio for Canada. It is the institutional (exogenous) changes in the LTV ratio – such as the tightening of the maximum LTV ratio from 100 percent to 95 percent in 2006 – which motivates our use of an error correction model in order to explore the long-run and short-run impacts of exogenous changes in the LTV ratio on real house prices.

3 Literature Review

3.1 House Prices and Credit Conditions

Credit conditions are often acknowledged as an omitted variable in econometric housing price models. The growing literatures that include a credit conditions variable reach a clear consensus; augmenting the housing price model with proxies for credit conditions generates better estimation results and better model fits.

The empirical work of Duca et al. (2011) is a leading literature on credit conditions and housing prices; and motivates the empirical undertakings of our own research. The model utilizes data on the average LTV ratio for first-time homeowners in the U.S.; the series is then purged of economic and demographic factors in order to obtain an exogenous measure of credit conditions. That is, the research desired a measure of credit conditions that captured institutional changes in the supply of credit – such as periods of financial innovation or changes in the regulations and policies that govern mortgage lending practises. Duca et al. (2011) incorporated the purged series into an inverted demand model of U.S. housing prices[4]. Based on VECM estimates, the house price model that included the LTV series was superior to the same model that excluded the LTV series – in which the former yielded stable long-run relationships, plausible income and price elasticities, reasonable speeds of adjustment, and improved

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[4] Duca et al.'s (2011) inverted demand model utilized data on national housing prices, housing stock, permanent income, and the real user cost of housing.

model fits.

To our knowledge, Muellbauer et al. (2015) is the sole literature that examines the role of credit conditions within the Canadian housing market. As a measure of credit conditions, the research constructs a non-price credit conditions index (CCI), which captures unobserved structural shifts in credit condition[5]. Three CCI-inclusive equations are estimated, which relate to house prices, debt ,and consumption, in order to examine the transmission mechanism between the household sector variables. However, the estimation results of the CCI-inclusive house price equation are relevant for our research purposes. An inverted demand house price equation is estimated, which is augmented with the CCI. The estimation results indicate significant and plausible speeds of adjustment, as well as a high model fit; the long-run fundamentals – including the credit conditions variable – explain most of the variation in house prices. Akin to Duca et al. (2011), Muellbauer et al. (2015) suggest that standard housing price models that exclude credit conditions will generate weaker empirical results.

Moreover and to our surprise in light of financial liberalization across advanced economies; a small handful of house price models take into account the presence of structural breaks. One approach taken in Duca et al. (2011) involved estimating the house price model over a 'long' sample that spanned from 1983 to 2009; as well as over a 'short' sample that ended before the onset of financial liberalization and the subsequent subprime boom in 2001[6]. When considered, structural breaks often enter the analysis during the estimation of the house price model; however, ignoring the presence of structural breaks in unit root and cointegration tests can bias the conclusions. Few literatures, and none to our knowledge in the housing prices and credit conditions literature, take

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[5] This approach involves the use of a latent interactive variable equation system to model the unobserved structural changes in credit conditions. See Muellbauer et al.(2015) for details.

[6] Duca et al.'s (2011) estimation results found a unique cointegrating relationship for the LTV specification across both the long and short samples; whereas the cointegrating relationship for the non-LTV specification broke down over the long sample.

into account the presence of a structural break throughout the various steps of a cointegration analysis; this becomes a strength of our research.

4 Econometric Models of Housing Prices

A cointegration approach to modelling asset prices was first introduced in Campbell and Shiller (1987). Malpezzi (1999) and Meen (2002), amongst others, later applied the cointegration techniques to models of housing prices. There is a wide consensus on the advantages of a cointegration analysis and error-correction specification, see Malpezzi (1999); however, empirical literatures often diverge on the long-run fundamentals of housing prices.

There are two broad approaches for which housing prices are modelled: the demand and the demand-and-supply models. Empirical works that focus on the Canadian housing market often find it difficult to detect a long-term relationship between housing prices and supply-side fundamentals, see Dupuis and Zheng (2010)[7]. In turn, our model will focus on housing prices and selected demand-side fundamentals.

4.1 Demand Approach: A Simple Affordability Model

Our research opts for a demand-side model, which captures the development of house prices as explained through a set of variables that impact the demand in a housing market. In the short-run, the model takes the supply of housing as fixed. Common demand-side determinants are household disposable income, the interest rate, and borrowing standards – which together, reflects the attractiveness of homeownership (Francke, 2009). Our demand-side model is the following (where subscript t refers to the quarter and superscript i refers to the

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[7] Often a result of data limitations, see Dupuis and Zheng (2010). Housing stock is a common variable in a supply equation of housing prices; however, housing stock is not available at the metropolitan level in Canada.

metropolitan):

$$ln(Rhp_t^i) = ln(Aff_t^i) + ln(Ltv_t^i) + Mrate_t^i + \epsilon_t^i \tag{2}$$

where Rhp_t refers to real house prices, Aff_t to the Bank of Canada's affordable housing index, Ltv_t refers to the loan-to-value ratio, which proxies for changes in credit conditions, $Mrate_t$ refers to the real mortgage rate, and ϵ_t refers to the white noise error.

Our inclusion of an affordable housing index (Aff_t) is intended to serve as a more sophisticated and accurate measure of affordable housing, one that encompasses the range of costs a homeowner faces. As the index is computed as the cost of servicing a house over median household income – the higher the ratio, the less affordable homeownership is in the region. If it becomes less attractive for a consumer to purchase a house (an increase in the index), demand for owner-occupied housing would decrease and in turn house prices would fall, and vice versa. Thus, a negative relationship is expected between the affordable housing index and real house price appreciation.

In our model, the loan-to-value ratio (Ltv_t) proxies for changes in credit conditions. Similar to Duca et al. (2011) and Bachmaan and Ruth (2016), our model treats the LTV ratio as exogenous. After filtering out the effects of expectations about house price appreciation, income growth and interest rates, the LTV series is believed to capture exogenous changes in credit conditions, such as changes in financial innovation or macroprudential policies (i.e. the tightening or loosing of the maximum LTV ratio). A positive relationship is expected between the exogenous LTV ratio and real house price appreciation. The LTV ratio series ranges between 0 and 1, with 1 reflecting no borrowing constraints – the homeowner can obtain a mortgage equal to the value of the home. A tightening or reduction in the maximum LTV ratio leads to tougher mortgage lending on behalf of banks; in turn, demand for home ownership decreases and house prices fall.

The real mortgage rate ($Mrate_t$) captures the cost of financing a mortgage. A negative relationship is expected between real house price appreciation and the real mortgage rate – a rise in the real mortgage rate increases the cost of financing a mortgage, which lowers housing demand and housing prices. However, empirical literatures have often experienced difficulties in finding a meaningful link between real mortgage rates and housing prices (Allen et al., 2007 and Muellbauer and Murphy, 1997).

5 Data Description

The data described here is reported on a quarter-to-quarter basis and covers the time period 1980$Q1$ to 2016$Q4$. Some data series from Statistics Canada were adjusted for seasonal variation; however, for the remaining series, seasonal adjustments were conducted using a procedure similar to X-12-ARIMA, a seasonal adjustment program that various statistical agencies use, such as the U.S. Census Bureau and Statistics Canada. At last, all variables are transformed into natural logarithms in order to interpret the estimates as elasticities.

5.1 CMA Average House Prices

Both Meen and Andrews (1998) and Allen et al. (2009) suggest the use of a disaggregated house price series rather than an aggregated or national series, which tends to mask the regional differences in house price dynamics. The CMA house price data was gathered from the Canadian Real Estate Association (CREA). The series contains the average house price in a CMA in each quarter.

The nominal house price series is transformed into a real house price series using the CMA's consumer price index (CPI), which is available through Statistics Canada.

5.2 An Affordable Housing Index

Econometric models of house prices often incorporate simple proxies of affordable housing, such as the house price-to-rent and house price-to-income ratios. For instance, the latter ratio assumes that an increase in household income makes homeownership more attractive, which fuels demand for homeownership and in turn induces an increase in house prices. However, the simple proxies of affordable housing do not capture the true costs of homeownership, such as the month-to-month expenses relating to mortgage loan payments and utilities. As a contribution of the research, the econometric house price model presented here incorporates a more realistic variable of affordable housing.

It is the Bank of Canada's affordable housing index that motivates our calculation of housing affordability. In particular, the Bank of Canada's housing affordability index estimates the share of disposable income that a representative household puts towards housing-related expenses. The index is a ratio, where the numerator is housing-related expenses and the denominator is average household disposable income. The higher the index, the less affordable it is to purchase a house in the region[8]. The technical details behind the index's calculations are provided in Appendix B.

The affordable housing index series at both the national and CMA levels are plotted in Figure 3. The affordable housing index for Canada are the Bank of Canada's calculations[9]. The national series is useful as a means to evaluate our calculations of the affordable housing indices for the CMAs. It is expected that

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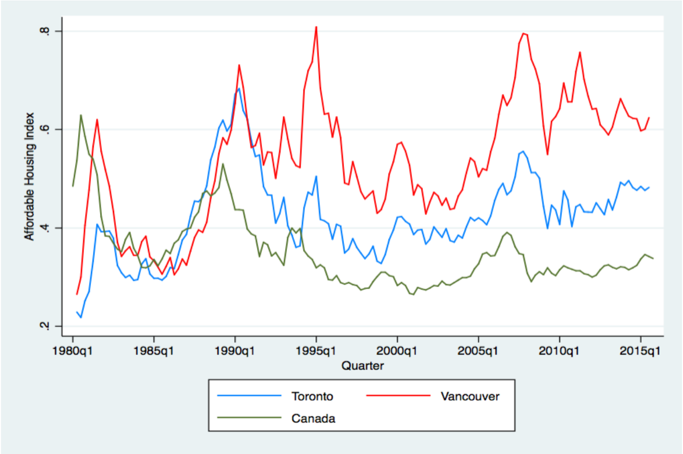
[8] For instance, a reading of 35 percent indicates that homeownership costs – which includes mortgage fees and utilities – take up 35 percent of a household's after-tax income.

[9] The series is available via the Bank of Canada's website.

the national series would exhibit similar trends to the largest CMAs – Toronto and Vancouver – which is indeed the case. As expected, Canada's most populous CMAs are less affordable than the rest of Canada; more stretched conditions are experienced in Toronto and Vancouver, whereas the remainder of Canada experienced more modest conditions.

Figure 3: Affordable Housing Index[a], 1980Q1 – 2016Q1



[a] The national series is the Bank of Canada's Calculation. Vancouver and Toronto Series are the author's calculations.

As a further check on our calculations, the Royal Bank of Canada (RBC) publishes reports on a quarter-to-quarter basis based on its own affordable housing measure, which is calculated at the CMA level[10]. Similar index values and trends were reached across the affordable housing indices for both Toronto and Vancouver. For instance, the RBC reports – which are published from 2010 onwards – indicate a deteriorating trend in affordable housing for 2010 and one that exceeded long-term averages. In particular, in the second quarter of 2010, the RBC reported an affordable housing index value of 74.0 percent for

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[10] Available on the RBC website at: http://www.rbc.com/newsroom/reports/rbc-housing-affordability.html

Vancouver and 50.2 percent for Toronto; both similar in magnitude to our calculated indices. In 2015, the RBC reported that Toronto's affordable housing index reached a '24-year high' of 59.4 percent, in which our calculated affordable housing index also indicates 2015 to be the highest point or least affordable period: see Figure 3. For Vancouver, the RBC reported their measure of affordable housing to be 75.3 percent in 2015, which is again consistent with our calculated index.

5.3 A Loan-to-Value Ratio

Time-series data on credit conditions is limited in Canada, and to a lesser extent in the United States. Duca et al. (2011) and Bachmaan and Ruth (2016) – who both investigate the U.S. housing market – have access to an average LTV series for first-time homeowners; the series is then purged of certain factors that impact mortgage loan *demand* in order to capture an exogenous LTV series, which reflects the *supply* of mortgage loans via banking institutions. However, within Canada – an average LTV series does not exist. As a contribution of the research, a straightforward calculation of a raw LTV series is proposed. Next, similar methods to Duca et al. (2011) and Bachmaan and Ruth (2016) are applied in order to transform the unadjusted series into an adjusted and exogenous one. To our knowledge, Muellbauer et al. (2015) is the sole literature to construct a measure of exogenous credit conditions for Canada[11]. The measure is to be utilized as a benchmark to compare our own constructed exogenous series.

A loan-to-value series is a common measure of credit conditions in the literature[12]. A high ratio indicates that a lender is comfortable with a smaller down-payment in relation to the house's value (i.e. relaxed credit conditions),

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[11] The CCI was obtained in the midst of the research; we utilize the index in the robustness check section in order to determine the effectiveness of our own constructed measure.

[12] See Duca et al (2011, 2012), Bachmaan and Ruth (2016) and Lyons and Muellbauer (2012).

while a lower ratio indicates that a lender requires a large proportion of the house's value as down-payment (i.e. tougher credit conditions). Since it is the exogenous LTV series that lies at the center of the empirical framework, the calculations for the unadjusted (raw) LTV series are provided in Appendix B. Here, the empirical method for transforming the raw series into an exogenous measure of credit conditions is outlined.

5.3.1 An Exogenous LTV Series

The LTV series constructed in Appendix B is referred to as the endogenous or raw series; it captures the institutional changes in the mortgage lending standards of banks, as well as the economic and demographic changes that impact the demand for mortgage loans of borrowers. In following the work of Duca et al. (2011) – and for our own research purposes – an exogenous measure of the LTV ratio is desired, which reflects institutional changes in mortgage lending standards, such as the tightening or loosening of the maximum LTV ratio. To construct an exogenous measure, the raw LTV series is filtered in order to remove the demand shifters of mortgage loans, such as expectations on house price appreciation, income growth, the interest rate, and the unemployment rate. That is, the raw LTV series is regressed on four-period moving averages of the housing-price series, the after-tax income series and the unemployment rate series, as well as the spread between the 10-year and 3-month Treasuries – which proxies for interest rate expectations. Expectations on the interest rate are insignificant for Toronto, while expectations on the unemployment rate are insignificant for Vancouver; the insignificant variables are dropped and the regressions are re-estimated. The results of the regression are provided in Table 1. The negative coefficient on after-tax income reflects the notion that homeowners are comfortable with smaller loans in light of a rise in after-tax income. The residuals of the regression serve as our exogenous or adjusted LTV series.

To smooth the resulting series, a three-period moving-average process is applied to the residuals. Figure 4 illustrates the path of our exogenous LTV series for Toronto and Vancouver.

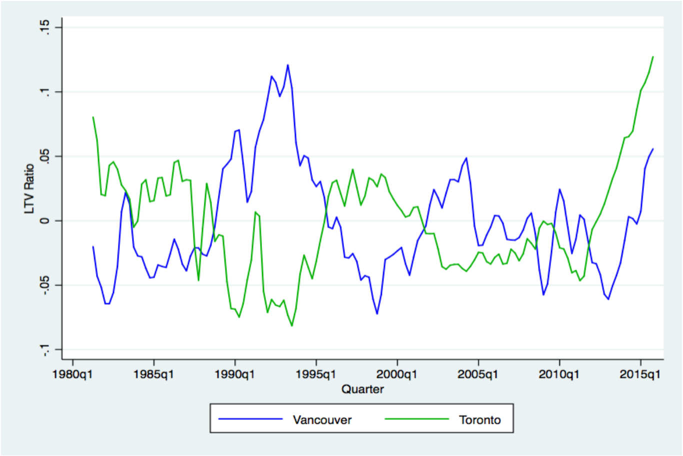
Table 1: Regression Results from the Filtering of LTV Series

Dependent:LTV Series
Time Period: 1980q1-2016q4

Independent	Vancouver	Toronto
$E_{t-1}(y_{t+4} - y_t)$	-0.496^{***}	-0.417^{***}
	(0.000)	(0.001)
$E_{t-1}(hp_{t+4} - hp_t)$	0.078^{***}	0.058^{**}
	(0.000)	(0.043)
$E_{t-1}(i_{t+4} - i_t)$	0.11^{***}	-
	(0.000)	
$E_{t-1}(ue_{t+4} - ue_t)$	-	0.022^{***}
	(0.000)	(0.000)
Constant	4.779	3.762
R^2	0.31	0.23

Notes: *** = 1% significance level, ** = 5% significance level, * = 10% significance level. P-values are shown in parentheses.

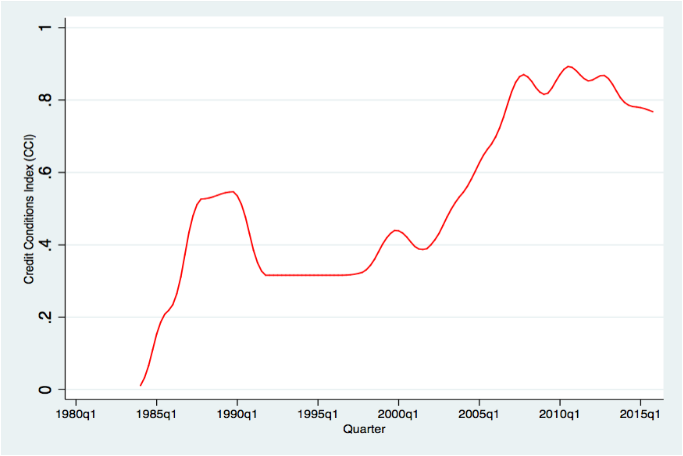
Figure 4: Exogenous LTV Series[a]



[a] Author's calculations.

Another measure of exogenous credit conditions, and which serves as a check on our own exogenous LTV series, is Muellbauer et al.'s (2015) non-price credit conditions index (CCI) for Canada[13]. The calculations behind the CCI are outlined in Muellbauer et al. (2015). Akin to our exogenous LTV series, the CCI measures non-price shifts in a household's access to mortgage credit, after controlling for economic and demographic fundamentals (Muellbauer et al., 2015) The CCI is plotted in Figure 5.

Figure 5: Credit Conditions Index (CCI)[a]



[a] Muellbauer et al.'s (2015) calculations.

Both exogenous measures of credit conditions – the adjusted LTV series and the CCI – reflect institutional changes in mortgage lending standards, such as via financial liberalization and innovation, as well as changes to macroprudential policies (i.e. the tightening or loosening of the maximum LTV ratio). Muellbauer et al. (2015) summarize five distinct periods in the easing and tightening of credit conditions in Canada, which are outlined in Table 2.

At most time periods, our exogenous LTV series coincides with the CCI and the mortgage lending standards of the time. For instance, our exogenous LTV series for Vancouver trails the changes in credit conditions rather well; the clear downwards trend in the late 1980's reflects the period of tightening

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[13] Thanks to David Williams for providing the research with the CCI series.

Table 2: Credit Conditions in Canada[a]

Time Period	Credit Condition
1982-1989	Easing
1989-1992	Tightening
1992-1999	Unclear (Easing Speculated)
2000-mid 2007's	Easing
Since 2007	Tightening

[a] See Muellbauer et al. (2015, 2017) for a detailed account of the events that influenced credit conditions in each time period.

in credit conditions, while the modest upwards trend in the 2000's reflects the relaxed credit conditions at the time. Similar features can be pointed out for the Toronto series. Between 2008 and 2010 a series of tightening measures were implemented; however, the LTV series for both metropolitans indicate an easing of credit conditions during the time period. This suggests that our exogenous LTV series is an imperfect measure of institutional changes in mortgage lending standards, in which our measure continues to be influenced through the economic and demographic fundamentals that drive demand for residual mortgage credit. In the robustness testing, the CCI – which we perceive as a true measure of exogenous credit conditions – is utilized in place of our exogenous LTV series. The estimation results of the CCI-model and the LTV-model are compared; similar results could suggest that our LTV measure is close to exogenous or demand factors have a small impact on the LTV series[14].

6 Empirical Methods and Results

The empirical section of the research has several aims. First, a cointegration approach is undertaken in which we attempt to model a long-run relationship between regional house prices, credit conditions, and a set of other demand-side fundamentals. In line with the empirical work of Duca et al. (2011), our

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[14] Bachman and Ruth (2016) found small changes in the estimation results when an unadjusted LTV measure was replaced with an adjusted LTV measure

empirical framework intends to determine whether the inclusion of exogenous credit conditions in the CMA house price models lead to better estimation results and better model fits. As with a standard cointegration analysis, unit root testing and cointegration testing are undertaken. Moreover, each test is conducted with and without structural breaks in order to comment on whether the estimation results change[15]. To our surprise, structural breaks are often omitted in the empirical housing price literatures; the inclusion of structural breaks in the cointegration analysis is a strength of our empirical framework.

Given the presence of cointegration, the second aim of the empirical section is to model the cointegrating relationship via an error-correction model (ECM), which assesses the long-run and short-run behaviour between regional house prices and its fundamentals. Of interest is the behaviour of real house prices in light of a tightening or loosening of the LTV ratio, which has been proposed as a macroprudential tool in slowing house price growth. At last – and as a robustness check of the model – we impose different measures of exogenous credit conditions, such as Muellbauer et al.'s (2015) credit conditions index (CCI).

6.1 Unit Root Testing

Prior to conducting the cointegration tests, each time-series variable in the proposed cointegration relationship is subjected to unit root testing in order to determine whether the variables are unit root – which implies a stochastic trend in the series – and are integrated of the same order[16]. The unit root tests utilized here are the Augmented Dickey-Fuller (ADF) test and the Dickey-Fuller Generalized Least Squares (DF-GLS) test, as put forward in Elliot et al.

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[15] Certain tests, such as the ADF unit root test, can be misleading if structural breaks are not taken into account. In particular, the ADF test can mistake non-stationary for a structural break in the series: see Joyeux (2007), and Johansen et al. (2000).

[16] The integration process refers to the number of unit roots – or stochastic trends – a variable has, i.e. $I(1)$ signifies one unit root, while $I(0)$ refers to no unit roots (stationarity).

(1996). Both test whether the series is unit root (non-stationary) against the alternative of no unit root (stationary), or put differently – it is a test of $I(1)$ versus $I(0)$. However, a disadvantage of the ADF test is its low power against $I(0)$ alternatives that are close to being $I(1)$, as well as its low power when an unknown mean or trend is present (Elliot et al., 1996). In turn, Elliot et al. (1996), amongst other empirical studies, recommend the DF-GLS test for maximum power. Here, the DF-GLS test results are reported as a complement to the ADF test results.

Unit root tests are conducted on the following time series, and for each metropolitan: real housing prices, the affordable housing index, the exogenous LTV series and the real mortgage rate. A graphical analysis of each series is relied on in order to determine whether or not to include a trend in the unit root test. The metropolitan house price series exhibits a clear upwards trend (see Figure 1), while the real mortgage rate series exhibits a clear downwards trend. The ADF and DF-GLS unit root tests are performed with a trend for the real house price and real mortgage rate series; the remaining series are tested without a trend. Moreover, the unit root tests are conducted on the level and first-difference transformations of each (logged) time series[17].

The results from the unit root tests are presented in Table 8 of Appendix C. The null of both the ADF and DF-GLS tests is the existence of a unit root against the alternative of no unit root. For each first-differenced series, the ADF and DF-GLS unit root tests generate test statistics that are larger than the critical value. The null of a unit root is rejected at the 5 percent significance level for each series, suggesting that each series is integrated of order one and hence, constitutes as potential candidates for inclusion in the cointegration analysis.

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[17] Lag lengths are determined via a range of information criterion: AIC, BIC, and HBIC. The most suggested lag length is the one used – which is often a lag length of four.

6.1.1 Unit Root Testing in the Presence of a Structural Break

A structural break is suspected in both the Toronto and Vancouver house price series. Inspection of the time series plots (see Figure 1) indicate a clear break in the trend of the house price series which is suspected to have occurred at the beginning of the 2000's, a period in which both series began to take on a strong upwards trend. As the presence of a structural break can bias the ADF test, Zivot and Andrew's (1992) endogenous structural break test is utilized – a method which tests for the existence of a unit root while allowing for structural breaks; as well as determines an unknown break point in the series if it exists.

Each series is nonetheless re-tested in order to verify the results from the standard unit root tests, which do not account for break points in the series. The results from the Zivot-Andrews unit root test are provided in Table 9 of Appendix C. The null remains the same as the standard unit root tests, which is the existence of a unit root. For each series, the Zivot-Andrews test was instructed to search for an unknown break point in both the trend and intercept. The null of a unit root was rejected for each differenced series; therefore, upholding the results of the ADF and DF-GLS unit root tests.

Taken together, the ADF, DF-GLS and Zivot-Andrews unit root tests suggest that each time series variable is unit root and integrated of the same order. Each variable constitutes as a potential candidate for inclusion in our cointegration equation.

6.2 Cointegration Testing

Given that two or more series are integrated of the same order, Engle and Granger (1987) suggest that a linear combination of the series could form a stable and common trend, which would indicate a long-run equilibrium relationship amongst the series. That is, cointegration implies that the series will not come apart in the long-run and reverts back to equilibrium levels after short-run fluctuations.

Two approaches to cointegration testing are most utilized in the literature: the two-step Engle-Granger procedure and the Johansson procedure. One disadvantage of the Engle-Granger cointegration test is the potential for small sample bias (Banerjee, 1986)[18]. Another problem is that the Engle-Granger approach assumes a unique cointegrating relationship without taking into account the existence of multiple cointegrating vectors (Drake, 1993 and Brooks, 2008). It becomes the maximum-likelihood (ML) estimation technique developed in Johansson (1998) that establishes the number of cointegrating vectors in a multivariate setting. Nonetheless, both the Engle-Granger and Johansson procedures are applied here in order to contrast the results. The Johansson approach is often noted as the superior cointegration test for it has all the desirable statistical properties; thus, the findings of the Johansson procedure are emphasized over the conclusions drawn in the above Engle-Granger procedure.

6.2.1 Augmented Engle-Granger Cointegration Test

Engle and Granger (1987) proposed a residual-based test for cointegration, which involves two steps. In the first step, the single cointegration equation is estimated in which the log of real housing prices is regressed on the log of the affordable housing index, the log of the exogenous LTV ratio and the real mortgage rate, indexed for both time and metropolitan:

$$ln(rhp_t^i) = \beta_1 + \beta_2 ln(aff_t^i) + \beta_3 ln(ltv_t^i) + rmrate_t + \varepsilon_t \tag{3}$$

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[18] However, our time series at quarter frequencies and spanning four decades provides us with a reasonable amount of observations.

The residuals (ε_t) from the regression are then subjected to unit root testing – i.e. the ADF unit root test – in order to determine whether a linear combination of the four variables generates residuals that are $I(0)$, or stationary. That is, stationary residuals indicate that a combination of the $I(1)$ variables eliminates the stochastic trends in the individual series, which in turn implies that a cointegration relationship exists.

The results of the Engle-Granger procedure are provided in Tables 10 and 11 of Appendix D[19]. The null of the test is unit root residuals, or no cointegration; the alternative is $I(0)$ residuals, or the existence of cointegration. The Engle-Granger test was performed both with and without a trend. At last, in order to determine whether the inclusion of an exogenous credit conditions variable generates a stable long-run relationship, specification (3) is estimated with and without the exogenous LTV series.

Cointegration was detected for two cases. For Toronto, the inclusion of the LTV series led to the rejection of the null at the 10 percent significance level. Opposite findings were found for Vancouver; the exclusion of the LTV series led to the rejection of the null of no-cointegration at the 5 percent significance level.

6.2.2 Johansson Cointegration Test

The Johansson approach to cointegration – i.e. the trace and maximum eigenvalue statistics – is further utilized, which determines the number of cointegrating vectors between the time-series variables. A more thorough discussion of the test is provided in Johansson (1988). To begin, a vector autoregressive model in its VECM form is written out:

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[19] Optimal lag lengths were used, as determined via a range of information criterion (i.e. the AIC and SBIC);

$$\Delta Y_t = \sum_{i=1}^{k-1} \Gamma_i \Delta Y_{t-1} + \alpha\beta^{'} y_{t-1} + \mu + \psi D_t + \epsilon_t \tag{4}$$

where,

Y_t is a (n x 1) time series vector of stochastic I (1) variables
Γ_i is a (n x n) matrix of coefficients
α is (n x r) matrix of error correction coefficients where r is the rank of $\Pi = \alpha\beta^{'}$ or the number of cointegrating vectors. The parameter is referred to as the speed of adjustment
β is a (n x r) matrix of r cointegrating vectors
D_t is a vector of deterministic terms (i.e. constants, trends, and/or seasonal dummies)
ϵ_t is a vector of innovations

The lag length of the VECM is k lags on each variable, which is chosen using a range of information criterion, i.e. the AIC and SBIC. The number of cointegrating vectors coincides with the number of independent rows in the Π-matrix – or in other words, the rank of the matrix. The rank of Π is determined from the number of significant eigenvalues. Johansson (1998) proposes two test statistics: the trace test and the maximum eigenvalue test. The null of the trace test is the null of no cointegration ($H_0 : r = 0$) against the alterative of cointegration ($H_1 : r = 0$). To test the significance of an eigenvalue – which indicates a significant cointegrating vector – the maximum eigenvalue test is utilized. The null of the max test is that the number of cointegrating vectors is equal to r against the alternative of $r + 1$ cointegrating vectors (Johannsson, 1998).

Table 3: Johansson Cointegration Test

Metropolitan:Toronto				
Model	Trace Stat	5% CV	Max Stat	5% CV
With LTV				
$r = 0$	78.6465	47.21	56.8341	27.07
$r = 1$	21.8124*	29.68	13.0187*	20.97
$r = 2$	8.7937	15.41	6.4545	14.07
$r = 3$	2.3392	3.76	2.3392	3.76
$r = 4$	-	-	-	-
Without LTV				
$r = 0$	53.8542	29.68	35.8878	20.97
$r = 1$	17.9663	15.41	17.3253	14.07
$r = 2$	0.6411**	3.76	0.6411**	3.76
$r = 3$	-	-	-	-

Notes: Optimal lag length determined via AIC. *** = 1% significance level, ** = 5% significance level, * = 10% significance level

Table 4: Johansson Cointegration Test

Metropolitan:Vancouver				
Model	Trace Stat	5% CV	Max Stat	5% CV
With LTV				
$r = 0$	90.1598	47.21	67.4229	27.07
$r = 1$	22.7368**	29.68	15.1232**	20.97
$r = 2$	7.6136	15.41	7.6105	14.07
$r = 3$	0.0031	3.76	0.0031	3.76
$r = 4$	-	-	-	-
Without LTV				
$r = 0$	63.9046	29.68	52.6800	20.97
$r = 1$	11.2246**	15.41	9.4908	14.07
$r = 2$	1.7338	3.76	1.7338	3.76
$r = 3$	-	-	-	-

Notes: Optimal lag length determined via AIC. *** = 1% significance level, ** = 5% significance level, * = 10% significance level

Estimation results from the Johansson procedure are provided in Table 3 and Table 4. The test is applied to specification (3) – our LTV model – and a version of the specification which excludes the LTV series. For both metropolitans and both specifications, the null of no cointegration (when r=0) was rejected. In the case of Vancouver – and for both model specifications – one cointegration vector was detected at the 5 percent significance level. Whereas; for Toronto, one cointegration vector was found for the LTV specification and two cointegration vectors were found for the non-LTV specification.

6.3 Testing for Cointegration in the Presence of Structural Breaks

6.3.1 The Gregory-Hansen (1996) Test

In the results of the Engle-Granger test, the null of no cointegration was not rejected for Vancouver's LTV-model nor for Toronto's non-LTV model. However, to neglect to take into account the presence of structural breaks in the long-run relationship can often lead to false conclusions in the cointegration testing procedures, such as the Engle-Granger and Johansson tests outlined above (Gregory and Hansen, 1996). To investigate whether a structural break is the culprit in concluding the lack of cointegration – as well as to substantiate the findings of the Johansson procedure – the residual-based test of Gregory and Hansen (1996) is utilized. In particular, Gregory and Hansen (1996) put forward a test of no cointegration against the alternative of cointegration with a single structural break at an unknown date. Moreover, the technique provides an estimate of the structural break point – which can be utilized in our estimation of the long-run relationship.

The proposed structural test is applied to specification (3), which includes the LTV series, and a version of the specification which excludes the LTV series. The estimation results for both cities are provided in Tables 12 and 13 of Appendix D1. Four cases for which structural change can occur in the cointegrating relationship are considered: a level shift, a level shift with trend, a regime shift, and a regime shift with trend[20].

In the case of Vancouver, the null is rejected and a stable cointegrating relationship with structural breaks is detected in both the LTV and non-LTV specifications. For the LTV model, the results suggest a structural break in the slope of the series at the estimated break point $t = 2001q1$. Break points were suggested in the trend and regime (with trend) for the non-LTV specification at the respective estimated break points, $t = 1998q1$ and $t = 2001q3$. The results are consistent with the Johansson test; but moreover, the results suggest that the presence of a structural break led to the false conclusion of no cointegration for the LTV model in the Engle-Granger test.

For Toronto, the estimation results negate certain findings of the Engle-Granger and Johansson procedures. For the LTV model, a structural break is suggested in both the trend and regime of the cointegrating relationship and at the respective break points, $t = 1988q2$ and $t = 2001q3$. Cointegration was not detected in the non-LTV specification – which is consistent with the Engle-Granger results but inconsistent with Johansson. Again, the results suggest that a disregard for structural breaks can bias the conclusions drawn from conventional cointegration tests.

6.4 Vector Error Correction Model

Engle and Granger (1987) suggested that if a cointegrating relationship exists, then the relationship can be represented in a model as an error correction specification. Having established a cointegrating relationship, the demand-side housing price equation is estimated in its error correction form – which models both the long-run and short-run behaviour of housing prices[21].

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[20] A shift in the level refers to a change in the series intercept, while a shift in the regime refers to a change in the slope of the series.

[21] The lag length of the error correction model is decided based on a range of information criterion, such as the AIC and SBIC – often four lags are included.

6.4.1 Long-Run Equation

Three specifications of the long-run relationship are estimated: a model that excludes credit conditions ($specification$ 1), a model that includes credit conditions ($specification$ 2), and a model that both includes credit conditions and structural break dummies ($specification$ 3). The break points estimated via the G-H test are utilized in the error correction model. The break points are incorporated as dummies, such that:[22]

$$D_t = \begin{cases} 0, & \text{if } t < \lambda \\ 1, & \text{if } t \geq \lambda \end{cases} \tag{5}$$

where λ is the estimated break point.

Estimation results of the cointegration equations for Vancouver – which are normalized on the log of real house prices – are provided in Table 5[23]. It is important to note, due to the normalization process, the signs on the coefficients are reversed. All coefficients in the non-LTV and LTV specifications are significant, except however for the coefficient on the structural break in specification (3). The negative relationship between real house price appreciation and the affordable housing index is consistent with expectations; the higher the index, the less attractive homeownership becomes, reducing the demand and prices of homes. Moreover, all specifications indicate an expected negative relationship between real house price appreciation and the real mortgage rate. In the LTV specification – with and without structural breaks – the coefficient on the LTV series is positive, as one expects.

Of most interest is the change in estimation results when a measure of credit

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[22] This approach to dealing with structural breaks in a VECM is applied in numerous empirical literatures: Nguyen and Wang (2008), Chen and Patel (1998), and Ramirez and Komuves (2013). An alternative method that was considered is estimating the VECM over two samples: a pre-break and post-break sample; however, small sample bias becomes a concern.

[23] Maximum-likelihood estimation techniques were used to estimate the long-run equations.

conditions is included in the specification. No significant changes occur when credit conditions are included in the specification; however, both LTV models generate more plausible coefficients on the affordable housing index – in which existing literatures suggest that affordability measures should be closer to 1 – and on the real mortgage rate (Arestis and Gonzalez, 2013). Canadian literatures suggest that the coefficient on the real mortgage rate should lie around 13.0 (Arestis and Gonzalez, 2013)[24].

Of further interest to the research is the long-run coefficient on the LTV series, which suggests that changes in the LTV ratio have a significant impact on long-run equilibrium house prices. Depending on the specification, a 10 percent reduction in the LTV ratio leads to a 55 to 70 percent decrease in Vancouver's equilibrium house prices. This suggests that the Government's tightening of the LTV ratio has significant and desirable impacts on real house prices in the long-run.

Table 5: Long-Run Relationship, Normalized Coefficients

	Metropolitan:Vancouver Time Period: 1980q1-2016q4		
Cointegrating Equation	(1)	(2)	(3)
Rhp_t	1	1	1
Aff_t	2.1364**	1.1814**	1.1814**
	(0.078)	(0.052)	(0.052)
LTV_t	-	-5.4860^{*}	-7.1569^{*}
		(0.075)	(0.083)
$Mrate_t$	35.2204***	23.7581***	28.6311
	(0.000)	(0.000)	(0.000)
Break Dummy	-	-	.4849957
			(0.260)
Constant	-15.0825	-14.3549	-14.97107

Notes: (1) excludes LTV series, (2) includes LTV series, and (3) includes LTV and break dummy. Optimal lag length determined via AIC. *** = 1% significance level, ** = 5% significance level, * = 10% significance level

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[24] The estimates in Arestis and Gonzalez (2013) were national in scope. We expect the coefficients to be larger in magnitude for Canada's most populous cities

Table 6: Long-Run Relationship, Normalized Coefficients

Metropolitan:Toronto
Time Period: 1980q1-2016q4

Cointegrating Equation	(1)	(2)	(3)
Rhp_t	1	1	1
Aff_t	-7.6638^{***}	$-.5167^{*}$	$.8305^{**}$
	(0.000)	(0.100)	(0.033)
LTV_t	-	-1.6289	-2.330
		(0.303)	(0.169)
$Mrate_t$	-29.3683^{a}	-8.1122^{***}	17.2041^{***}
	(0.000)	(0.000)	(0.000)
Break Dummy	-	-	1.4241^{***}
			(0.000)
Constant	-16.0232	-13.8188	-14.7596

Notes: (1) excludes LTV series, (2) includes LTV series, and (3) includes LTV and break dummy. Optimal lag length determined via AIC. *** = 1% significance level, ** = 5% significance level, * = 10% significance level

The estimation results of the long-run house price equations for Toronto – which are again normalized on logged real house prices – are provided in Table 6. All coefficients in the non-LTV specification are significant, but with the wrong expected sign. The inclusion of credit conditions in specification (2) does not improve the results; however, more promising results emerge with the inclusion of both credit conditions and structural break dummies. Estimation results for specification (3) indicate significant coefficients on all variables, as well as the expected magnitudes and signs on the coefficients. Moreover, and to a lesser extent than Vancouver, the long-run estimates on the LTV series suggest that changes in the LTV ratio have a significant impact on long-run equilibrium house prices; a 10 percent decrease in the LTV ratio leads to a 16-23 percent decrease in Toronto's equilibrium house prices.

6.4.2 Short-Run Dynamics

The residuals generated from the cointegrating equation indicate deviations from long-run equilibrium. In turn, the residuals – hereafter referred to as the error correction term – can be used to model the short-run dynamics of real house price appreciation. Our short-run ECM is as follows,

$$\Delta rhp^i_t = c+\beta_{1j}\Sigma^4_{j=1}\Delta ect_{t-j}+\beta_{1j}\Sigma^4_{j=1}\Delta rhp_{t-j}+\beta_{2j}\Sigma^4_{j=1}\Delta aff^i_{t-j}+\beta_{3j}\Sigma^4_{j=1}\Delta ltv^i_{t-j}+\beta_{4j}\Sigma^4_{j=1}\Delta rmr^i_{t-j} \tag{6}$$

where ecm_{t-j} is the error correction term or the speed of adjustment parameter, and where the coefficients attached to the lagged variables are the short-run elasticities. The error correction term can further serve as a test for cointegration, in which Banerjee et al. (1990) notes it to be more powerful than the residual-based tests[25].

Model (6) is estimated, alongside two versions of it: one that excludes a measure of credit conditions and one that includes both credit conditions and structural break dummies[26]. Each specification is estimated once for Vancouver and then once for Toronto. The short-run estimates are provided in Appendix E[27]. To a large extent, the analysis provided here will focus on the short-run behaviour of real house price appreciation in relation to changes in the LTV ratio for a central aim of the research is to comment on the effectiveness of macroprudential policies in curbing house price growth.

The short-run estimates for Vancouver are provided in Table 14 of Appendix E. The estimated error correction term – which indicates how fast equilibrium is restored – is both significant and negative for each specification. However, the magnitudes of the error correction terms suggest rather slow speeds of adjustment. Depending on the specification, the term ranges from -0.01 to -0.02,

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[25] A negative ECM is expected, which is suggestive of cointegration; real house prices will revert back towards the long-run equilibrium after short-run flunctuations.

[26] Structural break dummies enter the ECM also as lagged variables. See Jiang and Lui (2011) for an application of the ECM with dummies.

[27] Maximum-likelihood (ML) estimation is used to estimate the ECM. OLS is also appropriate for a single equation approach (when r=1). Maximum-likelihood (ML) estimation should be used for multiple cointegrating vectors (when r>1).

which suggests that a 10 percent deviation from long-run equilibrium in the current period will undergo a correction of around 1 to 2 percent in each subsequent period. The inclusion of the LTV series provides a slight improvement to the speed of adjustment. Slow corrections/speeds of adjustment are often common in the Canadian housing price literature[28]; but it also reflects the realities of Canada's largest cities, which have experience prolonged periods of house price growth (see Figure 1). Moreover, the significant and negative error correction term serves as further evidence that cointegration exists in each specification.

Both LTV specifications – with and without structural breaks – explain a higher proportion of the short-run variation in logged real house prices (around 58 percent); whereas, the non-LTV specification explains around 39 percent of the variation. Moreover, the LTV specifications generate more coefficients on the lagged variables that are significant. This suggests that the lagged changes in the model's fundamentals have an impact on real house prices in the short-run. As indicated above, the significant and positive (as expected) coefficient on the lagged LTV ratio is of interest: a 10 percent tightening of the LTV ratio would result in a 6 percent decline in real house prices in the subsequent quarter. Changes in the maximum LTV ratio can thus be seen as an effective macroprudential tool in curbing house price growth. However; the coefficient on the lagged LTV ratio declines as the number of lags increase, which implies that changes in the maximum LTV ratio impose a lesser impact on real house prices with each passing quarter.

The short-run estimates for Toronto are provided in Table 15 in Appendix E. The speed of adjustment in the non-LTV model is -0.0075, which is slow and implausible. The speed of adjustment changes in both LTV specifications of the model, in which the coefficient takes on more realistic speeds of between

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[28] Arestis and Gonzalez (2013) find the speed of adjustment to be around 5 percent for the Canadian housing market

-0.034 and -0.040. Again, the significant and negative error correction terms provide further evidence of cointegration in each of the model specifications. Moreover, the LTV specification that accounts for structural breaks generates a bettter model fit; the model explains around 40 percent of short-run fluctuations in Toronto housing prices, while the remaining two models explain around 20 percent of the variation. At last, the tightening of the LTV ratio generates promising results for Toronto; depending on the specification, a 10 percent rise in the LTV ratio would lead to a 20 to 30 percent decline in real house prices in the next quarter.

6.4.3 Diagnostic Testing

In order to evaluate each model specification, diagnostic tests are conducted. The results of the diagnostic tests can be found in Table 16 of Appendix E1. Maximum likelihood techniques were utilized in the estimation of the error correction model; the technique assumes error terms that are both independent and follow a normal distribution (Engle and Granger, 1987). In turn, the Lagrange multiplier (LM) test for autocorrelation and the Jarque-Bera test for normality are utilized. A well-specified model will have error terms that exhibit no autocorrelation and follow a normal distribution. The null of the LM test is no autocorrelation in the residuals; the null of the Jarque-Bera test is residuals that have a normal distribution. For Toronto, each model specification satisfied both diagnostic tests; however, the number of lags had to be adjusted from four lags to five lags[29]. For Vancouver, each model specification satisfied the LM test of no autocorrelation, but none of the specifications exhibited residuals with a normal distribution.

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[29] Autocorrelation is sensitive to the number of lags

6.5 Robustness check

Choices were made in the construction of the data set that could have impacted the results. For instance, in our construction of an exogenous LTV series, we regressed on select economic and demographic factors that drive the demand for mortgage loans; such as expectations on house price appreciation, income growth, and the interest rate. Of course, various factors could have been candidates in the filtering. To check whether our LTV series is a true exogenous measure – in which it captures changes in the supply of mortgage loans – we utilized Muellbauer et al.'s (2015) credit conditions index (CCI). The CCI captures institutional changes in the supply of mortgage loans, while controlling for economic and demographic influences.

The error correction model was re-estimated using the CCI in place of our exogenous LTV series. The estimation results are provided in Appendix F. Although not included in the appendix – it should be noted that the CCI series was subjected to the same analysis (see Section 6.1: *Unit Root Testing* and Section 6.3 *Cointegration Testing*). The first-difference of the CCI series is integrated of order one and cointegration exists in the CCI specification of the demand-side house price equation. Moreover, the G-H test estimated 2001Q3 and 1991Q4 to be the respective break points for Vancouver and Toronto; both break points are similar to the break points estimated in the LTV specification.

For most estimates, similar and sometimes more or less promising results arouse when the CCI was used in place of our exogenous LTV series. We suspect that some discrepancies are a result of the fact that our LTV series is region-specific and reflects institutional changes in the LTV ratio; whereas, the CCI is national and reflects institutional changes in the credit market as a whole. The long-run estimates are provided in Tables 17 and 18 (Appendix F). Both cities generate coefficients on the CCI that are similar in magnitude and sign to the coefficients on our LTV series. For Vancouver and Toronto, a 10 percent increase in the CCI also leads to respective increases of 60 and 20 percent; however, lower magnitudes arouse when both credit conditions and structural breaks were included in the specification. Akin to our LTV specification, the inclusion of the CCI generates more plausible results. The coefficients on the affordable housing index and the real mortgage rate become more in line with the existing literature; and an expected negative sign arouse on the affordable housing index, which was not the case in our LTV specification.

Similarities arise in the short-run estimates, which are provided in Tables 19 and 20 (Appendix F). Similar speeds of adjustment are found; however, a faster speed of adjustment arises for Toronto when both credit conditions and structural breaks are included. The CCI specification generated insignificant and sometimes negative coefficients on the lagged CCI. Our exogenous LTV specification found the lagged LTV series to have a significant and (expected) positive impact on real house prices. Moreover, similar model fits were found across the two models; although our LTV specification explained more of the variation in Vancouver's housing prices.

While the estimation results are similar across the two specifications, it appears from the short-run estimation results and the better model fit that our constructed LTV series is a reliable and somewhat better measure of credit conditions – especially in modelling the short-run dynamics of house prices.

7 Discussion & Concluding Remarks

Focusing on two major CMA housing markets in Canada from 1980Q1 to 2016Q1; the research extended a standard econometric house price model to include an exogenous LTV series – our selected credit conditions measure – and structural breaks. Utilizing cointegration and an error correction specification, the research assessed whether a house price model augmented with structural breaks and/or credit conditions generated better estimation results and better model fits.

To address data limitations in Canada, the research put forward a novel and straightforward calculation in order to obtain a raw LTV series; Duca et al.'s (2011) procedure was then utilized in order to obtain an exogenous LTV series from the raw series. Estimation results from the robustness checks revealed that our constructed LTV measure often outperformed the existing measures of credit conditions in Canada, such as Muellbauer et al.'s (2015) CCI. When our LTV series was utilized in the specification; changes in the LTV ratio were found to have a significant impact on the long-run and short-run behaviour of real house prices. In the CCI-specification of our house price model, the CCI was found to be significant in the long-run but not in the short-run.

In line with Duca et al. (2011) and Muellbauer et al. (2015), the house price models augmented with credit conditions often generated better estimation results and better model fits. As an extension of the existing literatures; the research further augmented the house price model with both credit conditions and structural breaks. Our research incorporated dummies at the structural break points in order to avoid issues of small sample bias often associated with the conventional practise of sample splitting. Estimation results from cointegration and the ECM revealed the model specification that included credit conditions and structural breaks often generated a stable long-run relationship, reasonable speeds of adjustment, more plausible and significant coefficients, and better model fits.

As a strength of our empirical approach; our research accounts for the presence of a structural break throughout the various steps of the cointegration analysis. We utilized standard and single-break unit root and cointegration tests in which inconsistencies were detected in the conclusions of the two sets of testing procedures. Following the finding of no cointegration in standard cointegration tests, single-break cointegration tests were utilized and evidence of cointegration was found. Existing house price literatures often utilize the standard tests; our research signifies the value in the concurrent use of conventional and single-break testing procedures in which the former can often generate false conclusions in the presence of a structural break.

Utilizing the ECM estimation results from our modelling exercise – the research further commented on the impact of changes in the LTV ratio on real house prices. The estimation results suggested that credit conditions impact both the long-run and short-run behaviour of house prices. Depending on the model specification, a 10 percent reduction in the LTV ratio is associated with a 55 to 70 percent decline in Vancouver's equilibrium house prices and a 6 percent short-run effect in the next quarter. Whereas, for Toronto – a 10 percent reduction in the LTV ratio is associated with a 20 percent decline in Vancouver's equilibrium house prices and a 3 percent short-run effect in the next quarter. The results suggest that changes in the LTV ratio have a large impact on home prices and in turn, tightened LTV ratios can serve as an effective macroprudential tool to curb house price growth.

8 References

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Appendices

A Descriptive Statistics

Table 7: % Change in House Prices, 1980Q1-2016Q1

	Toronto		Vancouver		Calgary	
Year	Price	%Δ	Price	%Δ	Price	%Δ
1980Q1	71,580	-	77,431	-	88,572	-
1990Q1	246,633	244.56	240,335	210.39	133,531	50.76
2000Q1	242,268	-1.77	299,850	24.76	174,910	30.99
2010Q1	428,042	76.68	669,114	123.15	394,463	125.52
2016Q1	675,410	57.79	1,094,936	63.34	450,979	14.33

	Kingston		Moncton		Ottawa	
Year	Price	%Δ	Price	%Δ	Price	%Δ
1980Q1	45,758	-	45,199	-	61,637	-
1990Q1	129,016	181.95	75,120	66.20	142,420	131.06
2000Q1	128,809	-0.16	85,136	13.33	158,335	11.17
2010Q1	233,410	81.21	151,383	77.81	325,339	105.48
2016Q1	289,412	57.79	163,211	7.81	362,499	11.42

Notes: Author's Calculations

B Data Construction

B.1 A Housing Affordability Index

The Bank of Canada's affordable housing index estimates the share of disposable income that a representative household puts towards housing-related expenses. The index is a ratio, where the numerator is housing-related expenses and the denominator is average household disposable income. The higher the index, the less affordable it is to purchase a house in the region. The numerator of the index is based on a series of mortgage payments and utility fees that are calculated as follows,

$$c = \frac{r}{1-(1+r)^{-N}} \bullet M_0 + U \tag{7}$$

where c is the quarterly housing-related costs, r is the five-year fixed mortgage rate, M_0 is the total value of the mortgage, and N is the number of monthly mortgage payments[30]. The total value of a mortgage, M_0, is calculated as a 95 percent loan-to value ratio,

$$M_0 = (0.95) \bullet P_0 \tag{8}$$

where P_0 is a 4-month moving average of the average house price series, which ensures that the measure reflects existing homes. U refers to the utility fees, which are based on the consumer price index for water, fuel, and electricity. The series is transformed into the average dollar amount that a representative household spends on utilities for their principal accommodation, as based on the 2011 Survey of Household Spending. It is important to note, our cost index is not a complete measure of housing-related costs as it does exclude certain household expenses, such as property taxes and housing depreciation; however, we do not believe the exclusion of these expenses will impact our empirical findings. The housing-related cost index is calculated for the regional Canadian cities: Toronto and Vancouver. The denominator of the affordable housing index is medium after-tax household income, which is available on an annual basis from Statistics Canada. As quarterly time series data is desired, linear interpolation is used in order to calculate the estimates between the annual points. A calculated series on average wages and salaries in each quarter is used

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[30] Assumed to be 300 over 25 years.

as a related series in the interpolation in order to approximate the changes in medium disposable household income from quarter to quarter. At last – the cost of serving a house in each quarter is divided by the average after-tax household income in each quarter, in order to obtain the housing affordable index series.

B.2 The Unadjusted (Raw) LTV Series

Residential mortgage credit is available at the national or aggregate level in Canada. To obtain the residential mortgage credit at the metropolitan level, the aggregate series is decomposed in order to obtain the proportion of aggregate credit that can be accredited to the various metropolitan housing markets. Our decomposition of the aggregate residential mortgage credit assumes that changes in the metropolitan's total dollar volume of home sales should be proportional to changes in the metropolitan's residential mortgage credit. That is, the more a region expends on homes, the more residential mortgage credit is demanded in order to finance the home purchases. The total dollar volume of home sales at the national and metropolitan levels were gathered from CREA for our time period of interest. To obtain the total dollar volume of home sales for the cities as a percentage of the aggregate series, the series for each metropolitan is divided by the national series[31]. As indicated above, it is assumed that a metropolitan's percentage of Canada's total dollar home sales in a quarter is equivalent to the region's percentage of Canada's aggregate residential mortgage credit in a quarter. To obtain a metropolitan's residential mortgage credit, the numerator of our constructed loan-to-value ratio, the percentages calculated for each region are multiplied by the aggregate residential mortgage credit. Residential mortgage credit is available through Statistics Canada and for our specified time period; however, the series is available at the national

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[31] For example, the total dollar volume of house sales for Vancouver was divided by the total dollar volume of home sales for Canada.

level which in turn requires the decomposition of the series in order to obtain a metropolitan level credit series.

Next, aggregate mortgage credit for each metropolitan is transformed into the average household mortgage credit through the division of the aggregate series by the number of households in that metropolitan in that quarter. Data on the total number of households in each metropolitan is collected every five years through the Canadian Census Program. Estimates for the total households in a metropolitan area are available for the Census years 1976, 1981, 1986, 1991, 2001, 2006, 2010, and 2016. Linear interpolation is used in order to calculate intercensal estimates between the Census points, in which data on the metropolitan's population size is used to approximate the quarterly change in the number of households[32]. The above calculations provide a measure of average mortgage credit at the metropolitan level. The series is divided by the average housing price in the region in order to obtain an average loan-to-value ratio series, which serves as an endogenous and unadjusted indicator of changes in mortgage lending standards.

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[32] Total population for census metropolitan areas are available through the Labour Force Survey from 1987$Q1$ until 2016$Q4$. Total population for provinces were used in the linear interpolation from 1980Q1 until 1986$Q4$, which is available through Statistics Canada.

C Unit Root Testing Results

Table 8: Unit Root Testing

	ADF			$DF - GLS$		
	Level	1st Difference	Remarks	Level	1st Difference	Remarks
$Vancouver$						
Rhp_t	-2.610	-2.150^{***}	$I(1)$	-3.391	-6.999^{***}	$I(1)$
	(0.275)	(0.000)				
Aff_t	-1.782	-5.922^{***}	$I(1)$	-2.692	-3.251^{**}	$I(1)$
	(0.389)	$(0.000)^{***}$				
$Mrate_t$	-3.182	-5.695^{***}	$I(1)$	-2.839	-4.346^{***}	$I(1)$
	0.088)	0.000)				
LTV_t	-2.471	-14.2721^{***}	$I(1)$	-2.460	-4.355^{***}	$I(1)$
	(0.123)	(0.0000)				
$Toronto$						
Rhp_t	-2.150	-4.434^{***}	$I(1)$	-1.807	-4.355^{***}	$I(1)$
	(0.7261)	(0.0019)				
Aff_t	-2.152	8.8591^{***}	$I(1)$	-1.700	-5.193^{***}	$I(1)$
	(0.224)	(0.000)				
$Mrate_t$	-3.182	-5.695^{***}	$I(1)$	-2.839	-4.346^{***}	$I(1)$
	0.088)	0.000)				
LTV_t	-0.708	-4.753^{***}	$I(1)$	-0.490	-3.813^{***}	$I(1)$
	(0.845)	(0.000)				

Notes: The variables are in logged form. Optimal lag length determined via AIC. *** = 1% significance level, ** = 5% significance level, * = 10% significance level

C.1 Unit Root Tests in the Presence of Structural Breaks

Table 9: Zivot-Andrews Unit Root Test

	At Level			At 1st Difference		
	T-Statistic	Time Break	Remarks	T-Statistic	Time Break	Remarks
$Vancouver$						
Rhp_t	-3.779	1996q4	$I(0)$	-8.195	1990q2	$I(1)$
Aff_t	-4.843	1996q3	$I(0)$	-8.198	1990q3	$I(1)$
$Mrate_t$	-4.852	1987q2	$I(0)$	-6.751	2009q1	$I(1)$
LTV_t	-4.455	1995q2	$I(0)$	-7.821	1993q2	$I(1)$
$Toronto$						
Rhp_t	-3.945	2009q4	$I(0)$	-5.517	1989q2	$I(1)$
Aff_t	-4.737	1991q4	$I(0)$	-7.618	1990q3	$I(1)$
$Mrate_t$	-4.852	1987q2	$I(0)$	-6.751	2009q1	$I(1)$
LTV_t	-3.324	2010q3	$I(0)$	-7.726	1990q2	$I(1)$

Notes: The variables are in logged form. Optimal lag length determined via AIC. *** = 1% significance level, ** = 5% significance level, * = 10% significance level

D Cointegration Testing Results

Table 10: Engle-Granger Cointegration Test

Metropolitan: Vancouver
Null Hypothesis: No Cointegration

Model	T-Statistic	Prob.
With LTV		
Trend	-1.863	0.674
No trend	-1.168	0.687
Without LTV		
Trend	-3.446^{**}	0.045
No Trend	-1.959	0.305

Notes: Optimal lag length determined via AIC. *** = 1% significance level, ** = 5% significance level, * = 10% significance level

Table 11: Engle-Granger Cointegration Test

Metropolitan: Toronto
Null Hypothesis: No Cointegration

Model	Value	Prob.
With LTV		
Trend	-3.126^{*}	0.100
No Trend	-2.766^{*}	0.063
Without LTV		
Trend	-2.452	0.352
No Trend	-1.398	0.583

Notes: Optimal lag length determined via AIC. *** = 1% significance level, ** = 5% significance level, * = 10% significance level

D.1 Cointegration Tests in the Presence of Structural Breaks

Table 12: Gregory-Hansen Structural Break Test

Metropolitan: Vancouver					
Model	ADF	Break Point	Z_t	Z_a	Break Point
With LTV					
Level	-4.58	2008q4	-4.80	-32.08	2008q1
Trend	-5.36^{*}	1997q3	-7.70^{***}	-65.60^{**}	1997q2
Regime	-7.00^{***}	2001q3	-7.16^{***}	-55.66	2000q3
Regime/Trend	-6.81^{***}	1998q3	-9.57^{***}	-85.19^{***}	1998q2
Without LTV					
Level	-3.95	2007q3	-3.80	-20.93	2008q1
Trend	-7.33^{***}	1998q1	-5.53^{*}	-43.55	1998q2
Regime	-5.27^{*}	2001q3	-4.37	-28.36	1994q4
Regime/Trend	-7.63^{***}	1999q1	-5.34	-40.79	1999q3

Notes: The variables are in logged form - except for the real mortgage rate. Optimal lag length determined via AIC. *** = 1% significance level, ** = 5% significance level, * = 10% significance level

Table 13: Gregory-Hansen Structural Break Test

Metropolitan: Toronto					
Model	ADF	Break Point	Z_t	Z_a	Break Point
With LTV					
Level	-4.59	2000q4	-4.32	-34.21	2000q4
Trend	-5.42^{*}	1988q2	-5.15	-43.94	1988q2
Regime	-6.29^{**}	1993q4	-6.05^{**}	-43.94	1993q4
Regime/Trend	-6.25^{*}	1993q4	-5.93	-54.74	1993q4
Without LTV					
Level	-4.18	2009q4	-4.01	-25.12	2009q4
Trend	-4.92	1989q2	-4.63	-32.44	1989q1
Regime	-4.77	1994q2	-4.61	-33.48	1990q1
Regime/Trend	-5.28	1994q4	-5.17	-44.22	1986q1

Notes: The variables are in logged form - except for the real mortgage rate. Optimal lag length determined via AIC. *** = 1% significance level, ** = 5% significance level, * = 10% significance level

E VECM Results

Table 14: Short-Run Dynamics

Metropolitan:Vancouver

Time Period: 1980q1-2016q4

Cointegrating Equation	(1)	(2)	(3)
Ecm_{t-1}	$-.0120^{***}$	$-.0199^{***}$	$-.01154^{***}$
	(0.000)	(0.000)	(0.000)
Rhp_{t-1}	-.0349	$-.1642^{*}$	$-.1779^{*}$
	(0.718)	(0.086)	(0.063)
Rhp_{t-2}	$-.2567^{***}$	$-.1593^{*}$	$-.1719^{*}$
	(0.008)	(0.170)	(0.070)
Rhp_{t-3}	.0189	-.0202	-.02156
	(0.20)	(0.817)	(0.804)
Aff_{t-1}	$.3614^{***}$	$.3138^{***}$	$.3148^{***}$
	(0.000)	(0.000)	(0.000)
Aff_{t-2}	.0254	.1084	.1176
	(0.770)	(0.141)	(0.109)
Aff_{t-3}	$.2004^{***}$	$.2063^{***}$	$.2191^{***}$
	(0.017)	(0.003)	(0.002)
$Mrate_{t-1}$	-2.3727^{***}	-1.5562^{***}	-1.5517^{***}
	(0.000)	(0.003)	(0.003)
$Mrate_{t-2}$	-.7160	-1.2912^{***}	-1.3409^{***}
	(0.152)	(0.003)	(0.002)
$Mrate_{t-3}$	$-.9156^{**}$	$-.8593^{*}$	$-.9058^{**}$
	(0.066)	(0.051)	(0.038)
Ltv_{t-1}	-	$.6359^{***}$	.6614
		(0.000)	(0.000)
Ltv_{t-2}	-	$.4348^{***}$	.4473
		(0.000)	(0.000)
Ltv_{t-3}	-	.2198	.2255
		(0.120)	(0.110)
D_{t-1}	-	-	-.0666
			(0.0.048)
D_{t-2}	-	-	-.0274
			(0.425)
D_{t-3}	-	-	-.0023
			(0.948)
$Constant$	.00052	0022118	.0010
	(0.895)	(0.581)	(0.779)
R^2	0.3915	0.5562	0.5767

Notes: (1) excludes LTV series, (2) includes LTV series, and (3) includes LTV and break dummy. Optimal lag length determined via AIC. Four lags were included in all models. *** = 1% significance level, ** = 5% significance level, * = 10% significance level

Table 15: Short-Run Dynamics

	Metropolitan:Toronto Time Period: 1980q1-2016q4		
Cointegrating Equation	(1)	(2)	(3)
Ecm_{t-1}	$-.0075^{***}$	$-.0342^{***}$	$-.0407^{***}$
	(0.000)	(0.001)	(0.000)
Rhp_{t-1}	-.0506	.0449	-.1025
	(0.561)	(0.610)	(0.240)
Rhp_{t-2}	-.0873	.1410	-.0328
	(0.369)	(0.178)	(0.750)
Rhp_{t-3}	$-.2903^{***}$	-.1615	$-.2489^{**}$
	(0.002)	(0.132)	(0.014)
Aff_{t-1}	$.2647^{***}$	$.1969^{**}$	$.2781^{***}$
	(0.001)	(0.018)	(0.000)
Aff_{t-2}	$.1576^{**}$	.0927	$.1522^{**}$
	(0.049)	(0.237)	(0.038)
Aff_{t-3}	$.2312^{***}$	.1454	$.1638^{**}$
	(0.002)	(0.056)	(0.019)
$Mrate_{t-1}$	-1.3380^{***}	-1.556^{***}	-1.835^{***}
	(0.003)	(0.004)	(0.000)
$Mrate_{t-2}$	-.4319	-.2512	-.2322
	(0.337)	(0.600)	(0.593)
$Mrate_{t-3}$	$-.7871^{**}$	-1.0785^{**}	$-.7977^{**}$
	(0.061)	(0.018)	(0.048)
Ltv_{t-1}	-	$.3505^{*}$	.2126
		(0.055)	(0.217)
Ltv_{t-2}	-	.3388	.2179
		(0.074)	(0.229)
Ltv_{t-3}	-	$-.3497^{**}$	$-.3642^{**}$
		(0.042)	(0.036)
D_{t-1}	-	-	.0036
			(0.926)
D_{t-2}	-	-	.0307
			(0.397)
D_{t-3}	-	-	.01302
			(0.717)
$Constant$	.0025	-.0015	-.0047
	(0.508)	(0.700)	(0.225)
R^2	.2229	.2585	.3843

Notes: (1) excludes LTV series, (2) includes LTV series, and (3) includes LTV and break dummy. Optimal lag length determined via AIC. Four lags were included in all models. *** = 1% significance level, ** = 5% significance level, * = 10% significance level

E.1 Diagnostic Testing Results

Table 16: Diagnostic Testing for VECM

Type of Test	Prob. (1)	(2)	(3)
Vancouver			
Autocorrelation Tests:			
Lagrange Multiplier (LM)	0.41306	0.543	0.845
Normality Tests:			
Jarque-Bera (JB)	0.000***	0.021**	0.007***
Toronto			
Autocorrelation Tests:			
Lagrange Multiplier (LM)	0.234	0.337	0.437
Normality Tests:			
Jarque-Bera (JB)	0.855	0.956	0.941

Notes: (1) excludes LTV series, (2) includes LTV series, and (3) includes LTV and break dummy. *** = 1% significance level, ** = 5% significance level, * = 10% significance level.

F Robustness Checking Results

Table 17: Long-Run Relationship, Normalized Coefficients

	Metropolitan:Vancouver Time Period: 1980q1-2016q4		
Cointegrating Equation	(1)	(2)	(3)
Rhp_t	1	1	1
Aff_t	2.1364**	.7540*	.751583*
	(0.078)	(0.104)	(0.053)
CCI_t	-	-6.5426^{*}	-1.4211^{***}
		(0.014)	(0.001)
$Mrate_t$	35.2204***	14.4194***	14.8496***
	(0.000)	(0.000)	(0.000)
Break Dummy	-	-	.4319
			(0.030)
Constant	-15.0825	-14.35929	-13.0609

Notes: (1) excludes LTV series, (2) includes LTV series, and (3) includes LTV and break dummy. Optimal lag length determined via AIC. Four lags included in both Model's (2) and (3) *** = 1% significance level, ** = 5% significance level, * = 10% significance level

Table 18: Long-Run Relationship, Normalized Coefficients

	Metropolitan:Toronto Time Period: 1980q1-2016q4		
Cointegrating Equation	(1)	(2)	(3)
Rhp_t	1	1	1
Aff_t	$-.7268^{**}$	2.3298**	.6280***
	(0.035)	(0.029)	(0.008)
CCI_t	-	-1.9089	$-.4917^{*}$
		(0.039)	(0.003)
$Mrate_t$	7.8901**	5.6106***	7.7336***
	(0.000)	(0.047)	(0.000)
Break Dummy	-	-	.9165***
			(0.000)
Constant	-16.0232	-10.23907	-15.3124

Notes: (1) excludes LTV series, (2) includes LTV series, and (3) includes LTV and break dummy. Optimal lag length determined via AIC. *** = 1% significance level, ** = 5% significance level, * = 10% significance level

Table 19: Short-Run Dynamics

	Metropolitan:Vancouver Time Period: 1980q1-2016q4		
Cointegrating Equation	(1)	(2)	(3)
Ecm_{t-1}	$-.0120^{***}$	$-.0323^{***}$	$-.0423^{***}$
	(0.000)	(0.001)	(0.000)
Rhp_{t-1}	-.0349	-.1093	-.1128
	(0.718)	(0.294)	(0.279)
Rhp_{t-2}	$-.2567^{***}$	$-.3478^{***}$	$-.3612^{***}$
	(0.008)	(0.001)	(0.001)
Rhp_{t-3}	.0189	-.0467	-.0388
	(0.20)	(0.660)	(0.712)
Aff_{t-1}	$.3614^{***}$	$.5306^{***}$	$.5536^{***}$
	(0.000)	(0.000)	(0.000)
Aff_{t-2}	.0254	.0292	.0503
	(0.770)	(0.801)	(0.663)
Aff_{t-3}	$.2004^{***}$	$.2361^{**}$	$.2483^{**}$
	(0.017)	(0.022)	(0.014)
$Mrate_{t-1}$	-2.3727^{***}	-4.6386^{***}	-4.9219^{***}
	(0.000)	(0.000)	(0.000)
$Mrate_{t-2}$	-.7160	-.3495	-.5198
	(0.152)	(0.767)	(0.658)
$Mrate_{t-3}$	$-.9156^{**}$	-1.3634	-1.4005
	(0.066)	(0.179)	(0.161)
CCI_{t-1}	-	-.2688	-.3485
		(0.793)	(0.729)
CCI_{t-2}	-	.9006	1.0017
		(0.612)	(0.568)
CCI_{t-3}	-	-.6323	-.7154
		(0.523)	(0.466)
D_{t-1}	-	-	-.0651
			(0.106)
D_{t-2}	-	-	.0209
			(0.608)
$Constant$	.00052	.0049	.0128
	(0.895)	(0.304)	(0.758)
R^2	0.3915	0.3218	0.3562

Notes: (1) excludes LTV series, (2) includes LTV series, and (3) includes LTV and break dummy. Optimal lag length determined via AIC. Four lags were included in all Models. *** = 1% significance level, ** = 5% significance level, * = 10% significance level

Table 20: Short-Run Dynamics

	Metropolitan:Toronto Time Period: 1980q1-2016q4		
Cointegrating Equation	(1)	(2)	(3)
Ecm_{t-1}	$-.0120^{***}$	$-.0220^{***}$	$-.1004^{***}$
	(0.000)	(0.000)	(0.000)
Rhp_{t-1}	-.0349	$-.1917^{**}$	$-.1625^{*}$
	(0.718)	(0.029)	(0.065)
Rhp_{t-2}	$-.2567^{***}$	$-.2257^{**}$	$-.1700^{*}$
	(0.008)	(0.028)	(0.093)
Rhp_{t-3}	.0189	$-.3494^{***}$	$-.3030^{***}$
	(0.20)	(0.000)	(0.002)
Aff_{t-1}	$.3614^{***}$	$.3266^{***}$	$.1964^{**}$
	(0.000)	(0.001)	(0.023)
Aff_{t-2}	.0254	$.17488^{*}$	.0560
	(0.770)	(0.055)	(0.504)
Aff_{t-3}	$.2004^{***}$	$.3349^{***}$	$.1985^{**}$
	(0.017)	(0.000)	(0.010)
$Mrate_{t-1}$	-2.3727^{***}	-2.8507^{***}	-.7068
	(0.000)	(0.001)	(0.421)
$Mrate_{t-2}$	-.7160	-.7207	1.0469
	(0.152)	(0.391)	(0.218)
$Mrate_{t-3}$	$-.9156^{**}$	-2.7511^{***}	-1.2590
	(0.066)	(0.000)	(0.109)
CCI_{t-1}	-	2.1959^{**}	1.5908^{*}
		(0.016)	(0.100)
CCI_{t-2}	-	-2.6971^{*}	-1.4896
		(0.080)	(0.368)
CCI_{t-3}	-	1.0803	.1940
		(0.213)	(0.839)
D_{t-1}	-	-	.01709
			(0.671)
D_{t-2}	-	-	.04424
			(0.252)
D_{t-3}	-	-	.0060
			(0.878)
$Constant$	.00052	.0007	-.0043
	(0.895)	(0.866)	(0.312)
R^2	0.2229	0.3870	0.4019

Notes: (1) excludes LTV series, (2) includes LTV series, and (3) includes LTV and break dummy. Optimal lag length determined via AIC. Four lags were included in all Models. *** = 1% significance level, ** = 5% significance level, * = 10% significance level