

Housing markets and unconventional monetary policy

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Highlights

- We create cross-country monthly and quarterly databases of housing markets
- We estimate various PVAR models identified with zero and sign restrictions
- We show a positive, persistent response of house prices and residential investment
- The response of house prices peaks between one and two years following a policy shock
- The results are robust to a range of specifications and across frequencies.

ACCEPTED MANUSCRIPT

Housing markets and unconventional monetary policy

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Abstract

While the role of housing markets in the run up to the recent financial crisis is well documented, we consider how housing markets have since responded to unconventional monetary policy shocks in the form of innovations in total assets and the monetary base. We build quarterly and monthly housing market datasets for eight OECD countries, estimating a range of specifications in panel vector autoregressions identified through a combination of zero and sign restrictions across both frequencies. Despite a minor amount of individual cross-country heterogeneity, our mean group panel estimators show a positive, persistent response of house prices which peaks at between one and two years following a policy shock. Residential investment responds more strongly than house prices, but takes longer to peak, consistent with the conveyancing procedures involved in construction. Mortgage rates are shown to initially decrease by between five and six basis points following a 3% balance sheet shock.

Keywords: VAR; PVAR; Unconventional Monetary Policy; Housing Markets; Sign Restrictions.

JEL Classification: R00, R30, C50

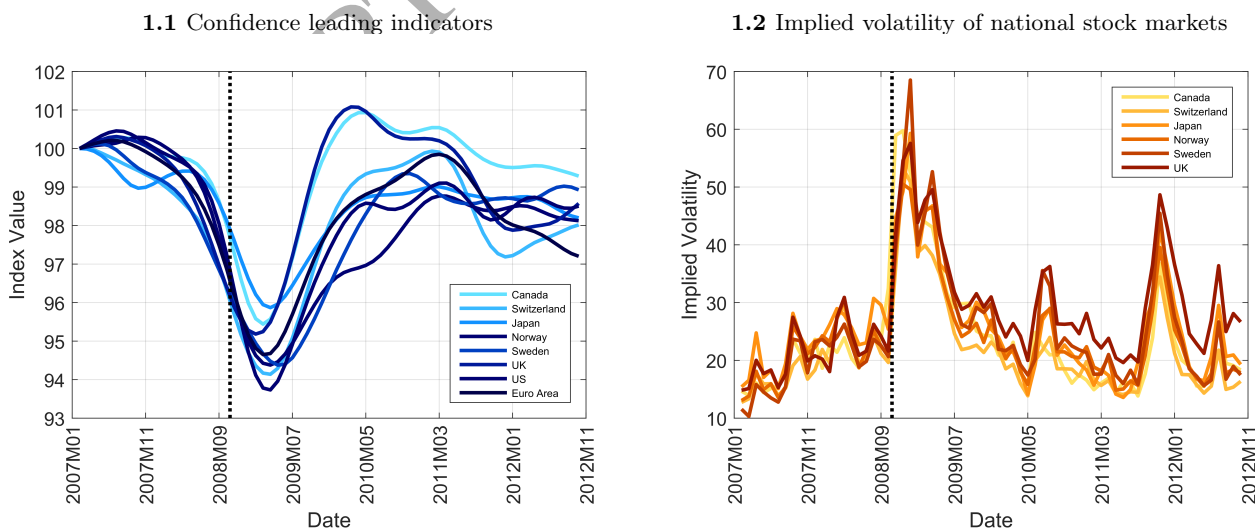
*The corresponding information has been redacted for anonymity.

1 Introduction and policy background

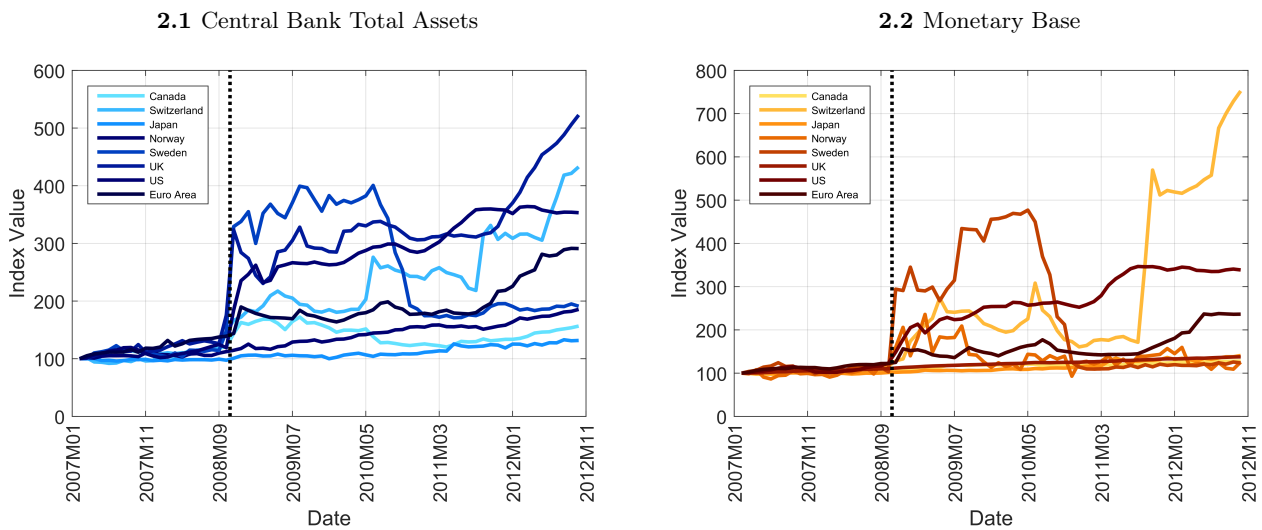
The recent financial crisis, developing out of the faltering United States mortgage market and two collapsed Bear Sterns hedge funds, began its trajectory as early as March 2007. With the threat of global financial and economic instability looming large in the world's most developed economies, governments and central banks began to pursue unorthodox policies in the face of recessionary and deflationary fears in order to prevent a collapse akin to the Great Depression of 1929. While most countries have pursued a mix of monetary and fiscal policies, some actions taken by central banks in response to the crisis have often been termed 'unconventional'. Such policies quickly became the primary monetary policy tool after interest rates began their descent to the zero lower bound (ZLB). Following the collapse of Lehman Brothers Holdings Inc. (15th September, 2008), formerly the fourth largest investment bank in the United States, economic confidence indicators fell and implied stock market volatility rose dramatically (Figure 1). While malfunctioning residential markets are well accepted as one of the primary originators of the crisis, this paper analyzes their response to the unconventional policy measures undertaken since.

The role of housing is vital in the transmission mechanism of monetary policy. The first potential channel - the contentious housing wealth effect - has a significant body of literature in its own right, with varied empirical findings. There is also the closely related potential for a substitution effect, specifically concerned with the relative price of housing to other goods and services. It is also possible that turnover in housing markets creates aggregate demand in the form of transaction costs associated with high housing turnover, such as surveying fees, fixtures and furnishings, or a transaction related tax. Academic models postulate that house prices are integral to determining the magnitude of residential investment (and, in particular, housing starts - [Leamer \(2007\)](#)) which can subsequently stimulate the supply side of an economy and create real activity. Another mechanism by which monetary policy may affect housing markets is through the credit channel by means of collateral values, as described in the model outlined in [Iacoviello \(2005\)](#). An

Figure 1: Economic indicators during the 'Great Recession'



Source: OECD and volatility indices, dashed - collapse of Lehman Brothers Inc

Figure 2: Central Bank Responses to the Crisis

important example of this channel is provided by [Fuster & Willen \(2010\)](#) who show that large reductions on agency mortgage-backed security rates around the 25th of November 2008 were quickly followed by large reductions in residential mortgage rates offered by lenders to households, something also considered in this paper. Unconventional monetary policy can reduce real interest rates, reducing the user cost of housing, and therefore increasing the demand for (and price of) houses.

Following the financial crisis, it has never been more important to estimate the impact of policies on the value of residential assets. Any asset whose value is linked to residential real estate is an essential component of the aggregate portfolio of financial intermediaries, and therefore significant for the wider economy. The need for this study can also be identified throughout the early literature on quantitative easing stemming from the crisis, where it is claimed: 'Analysis suggests that the purchases have had a significant impact on financial markets and particularly gilt yields, but there is clearly more to learn about the transmission of those effects to the wider economy' ([Joyce et al. 2011](#), p.4). However, because of the nature of the crisis and the policies involved (due to the presence of the ZLB), standard econometric tools which would have otherwise included estimation across a pre-crisis period are not appropriate. We create a dataset for both monthly and quarterly housing variables across the crisis period, informed by pre-crisis studies such as [Goodhart & Hofmann \(2008\)](#) and [Assenmacher-Wesche & Gerlach \(2008\)](#) which consider the response of house prices to *conventional* monetary policy shocks in PVAR models. We use this dataset (and variants of the baseline specification) to analyze the response of housing markets following an unconventional monetary policy shock.

Figure 2 shows the time paths of central bank total assets and the monetary base. While there has been a strong cross-country correlation in the rise of central bank total assets as a policy tool, with the balance sheets of the Federal Reserve and the European Central Bank tripling, the size of the balance sheet of the Bank of England rose more than fivefold. The central banks of smaller economies, such as the Swedish Riksbank, the Swiss National Bank, and, to a lesser extent, the Bank of Canada also expanded their balance sheets sharply

after September 2008 (and such actions guide our sample selection in the remainder of the paper). However, such policies have been predominantly heterogeneous in the ways they were undertaken. The transmission of such policies to housing markets is also likely to be strongly characterized by the institutional structure regarding how mortgage finance is provided. In general, the countries in our sample are those which have experienced faster and deeper innovations in mortgage markets, such as the United Kingdom, the United States, Canada and the Nordic countries, and tend to have a higher stock of mortgage debt as a ratio to GDP, compared to the international averages. This heterogeneity helps to drive our research design.

As argued for in both the theoretical and empirical literature (Section 2), countries with a larger stock of mortgages may be expected to experience stronger effects of monetary policy shocks. This will not only depend on the proportion of owner-occupiers, but the amount of debt outstanding per residence. Areas with a higher proportion of variable (as opposed to fixed) rate mortgages may be more sensitive, and variation in loan-to-value (LTV) ratios may cause a heterogeneous degree of pass-through, magnified by variations in mortgage/credit market efficiency. The remainder of this paper is structured as follows. We next discuss the literature along four inter-related paths (Sections 2.1 to 2.4). Following this, we detail the intricate construction of our monthly and quarterly housing market datasets across eight OECD countries in Section 3. In Section 4 we discuss the estimation method and identification scheme. In Section 5 we document our results and finally, Section 6 concludes.

2 Existing Literature

2.1 Housing in general equilibrium models

While not explicitly the focus here, a number of recent studies worth mentioning have emerged within a general equilibrium framework which emphasize the necessity of researching relationships between monetary policy, house prices and other macroeconomic variables. Of particular interest is the work by Rubio (2014), which uses a two-country new Keynesian general equilibrium model with housing and collateral constraints to show that consumption reacts more strongly to a monetary policy shock in countries with high LTV ratios, a higher proportion of borrowers and a higher proportion of variable-rate mortgages. Aoki et al. (2004) consider a general equilibrium model with frictions in credit markets which are used by households, where houses provide services and themselves serve as collateral to reduce the cost of debt. Their result is that this effect amplifies and propagates the effect of monetary policy shocks on housing prices, housing investment and consumption.

2.2 Unconventional Monetary Policy Shocks

In related work along the unconventional monetary policy dimension, Boeckx et al. (2014) also estimates the effects of exogenous innovations to central bank (ECB) total assets within a (single country) structural VAR framework with zero and sign restrictions, also identifying the same monetary policy shock as used in this paper. They find that an expansion leads to a significant, albeit temporary rise in output and prices, with results similar to those found in the literature for conventional policy rate innovations. With interesting

implications for our study, they find smaller effects in countries within the ECB where the banking system is less well-capitalized. In one of the first studies on the subject, [Peersman \(2011\)](#) estimates an SVAR model (with sign restrictions lasting up to four months) for the euro area between 1999M1-2009M12, also finding ‘similar macroeconomic consequences’ when comparing unconventional policy shocks with traditional interest rate innovations. As mentioned in Section 1, of particular inspiration is the paper by [Gambacorta et al. \(2014\)](#), where the authors estimate a PVAR with monthly data across the eight aforementioned countries using exogenous increases to the central bank balance sheets (total assets and monetary base) as policy shocks.¹ In accordance with the two previous aforementioned studies in this subsection, their conclusion is that unconventional policies have similar effects to policy rate shocks, and that the impact on the price level is weaker and less persistent than the impact on output.

2.3 Single country VAR models of housing

The most relevant paper from a conceptual perspective is that of [Gabriel & Lutz \(2014\)](#), who use a structural FAVAR model (with factors extracted from daily US series) to show, amongst other things, that ‘the estimated effects (on housing markets) are generally large in magnitude and similar in size to those found for equity markets’. A number of papers estimate single country SVAR models for housing markets. For the UK, the most relevant is [Elbourne \(2008\)](#), which takes a one-step approach to analyzing two questions using an eight-variable model. They find a predictable role for housing wealth in the transmission mechanism, albeit less than suggested by other authors. [Aoki et al. \(2002\)](#) estimate a small (‘core five variable’) single country SVAR for the UK to consider how house prices react to a 50 basis point short-term interest rate shock, concluding that the peak decline of house prices occurs after five quarters (0.8%).

[Giuliodori \(2004\)](#) considers monetary policy shocks across Europe by estimating nine individual country-specific VAR models over the period preceding the European Monetary Union. The identification scheme is standard in that the policy variable is ordered last, however, they also augment the baseline with mortgage market variables and exchange rates. The study finds evidence of a stronger credit channel in countries with more developed housing and mortgage markets. [Vargas-Silva \(2008b\)](#) estimates regional VAR models for the United States using the sign restriction methodology proposed by [Uhlig \(2005\)](#), comparing the results with a standard Cholesky decomposition, and [Vargas-Silva \(2008a\)](#) and [Gupta & Kabundi \(2010\)](#) use standard FAVAR methodology to answer similar questions. It is this difference between the two identification procedures which is especially interesting, as within their sign restricted models, the response of housing market activity to a monetary policy shock is not only smaller, but also lasts for a shorter period.

[Iacoviello \(2002\)](#) estimates an SVAR for six countries. After considering the co-integrating relationships in the quarterly model, they show that countries with low transaction costs, high LTV ratios, a large owner-occupied ratio and a large proportion of variable-rate mortgages experience a higher sensitivity to monetary policy shocks. Using a similar methodology, [Iacoviello & Minetti \(2008\)](#) use short and long-run restrictions in four different VAR models across four countries, each time with a different variable such as the ‘mix’ (the fraction of housing loans by non-bank institutions), showing a clear relationship between the credit channel

¹We follow a similar identification strategy to this paper, and this is discussed in Section 4.

and the efficiency of housing finance. [Jarocinski & Smets \(2008\)](#) show that while developments in U.S. GDP alone cannot explain developments in housing markets, adding a policy variable to the information set can. Finally, considering synthetic euro area data for the period 1980-1998, [Smets & Peersman \(2001\)](#) analyze the impulse responses from an area-wide shock to monetary policy on house prices, finding (as may have been expected due to the frictions present in housing markets) that they respond more sluggishly than share prices.

2.4 Panel VAR models of housing

Despite the extensive work that has gone into the subject, individual country VAR models tend to produce estimates and forecasts which can often be easily improved, both in terms of their precision and efficiency. [Sá et al. \(2011\)](#) consider not only the effect of monetary policy on housing booms, but also the role of capital in-flows and financial innovation combined with lax regulation. They use a PVAR with sign restrictions, splitting their sample according to the 2008 International Monetary Fund index of high and low mortgage market development. They find a result similar to that of [Iacoviello \(2002\)](#) – that economies with more developed housing and mortgage markets are more responsive to interest rate shocks. In the research most similar in methodology to the current paper, [Goodhart & Hofmann \(2008\)](#) uses a quarterly fixed effects PVAR in the pre-crisis period for 17 countries to show a strong link between house prices and monetary variables, especially in a more recent sub-sample (1985-2006: after mortgage market deregulation following the highly variable inflation rates of the early 1980s). Augmenting their PVAR with dummy variables, they also find evidence that money and credit growth are useful indicators of house price booms.

[Assenmacher-Wesche & Gerlach \(2008\)](#) use a quarterly pre-crisis (1986-2006) PVAR to consider the effect of monetary policy on asset (housing and equity) prices across countries using the mean group estimator. While the paper predictably finds a noticeable effect of monetary policy on asset prices, one of the main contributions of this paper to the literature is to analyze spillover effects, showing the significance of US monetary policy shocks internationally (but not housing market shocks). [Carstensen et al. \(2009\)](#) use a pre-crisis (1996-2006) model split across European countries, dependent on how pronounced the response of house prices is to a monetary policy shock. They find that where there is a stronger transmission of the shock through housing, there is also a stronger transmission to other macroeconomic variables.

3 Data

As indicated in Section 1, one of the key contributions of this paper is the creation of two unique balanced panels of quarterly and monthly macroeconomic time series from 2007M1 to 2014M09. Their construction arises from the need to undertake research on housing markets in an international, cross-country context, and are subsequently used in the remainder of this chapter. Despite the fact that house prices are not always directly comparable across countries, due to both the definition of residential property and data collection methodologies, we attempt to harmonize the data used in estimation.² One key insight to appreciate is

²Unless otherwise specified, series are collected from Datastream, and a list of the appropriate identifiers accompanies the replication files for this paper.

that in all of our quarterly and monthly specifications, we attempt to use equivalent representations. Where a series is available only in a naturally occurring monthly frequency, we convert using the third monthly observation of the quarter to construct a quarterly representation (as opposed to a summation across all three quarters, given that we only have ‘stock’ variables of this type, such as total assets and the monetary base). Where a series is available in only quarterly frequency, we obtain its monthly representation using the [Chow & Lin \(1971\)](#) procedure and one or two ‘related series’ as discussed in Section 3.2 below.³ All series are adjusted using the X-13 ARIMA-SEATS Seasonal Adjustment algorithm. Our sample contains data on Canada (CA), Switzerland (CH), Japan (JP), Norway (NO), Sweden (SE), United Kingdom (UK), United States (US) and the euro area (XM), and where required, an index is re-based (2007M1=100).

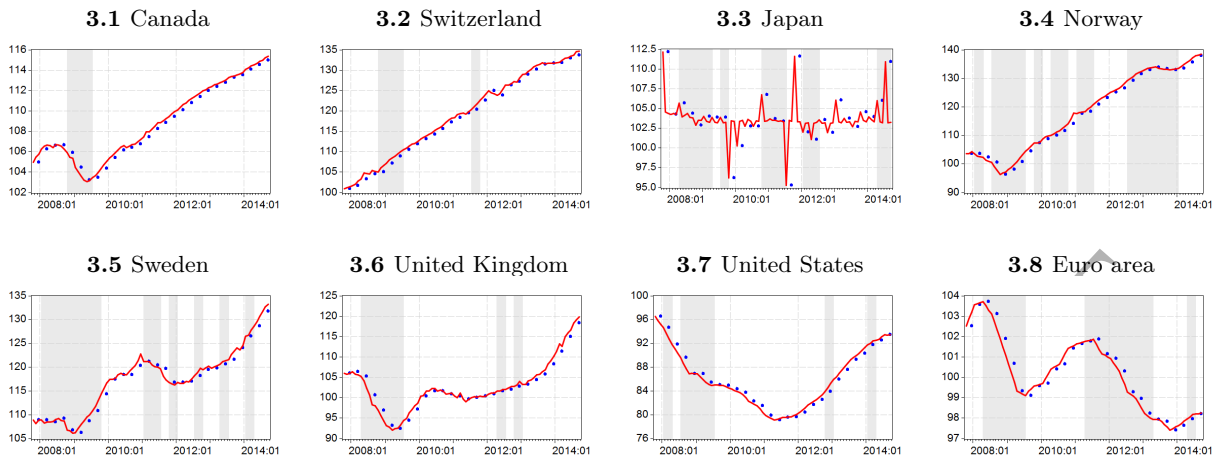
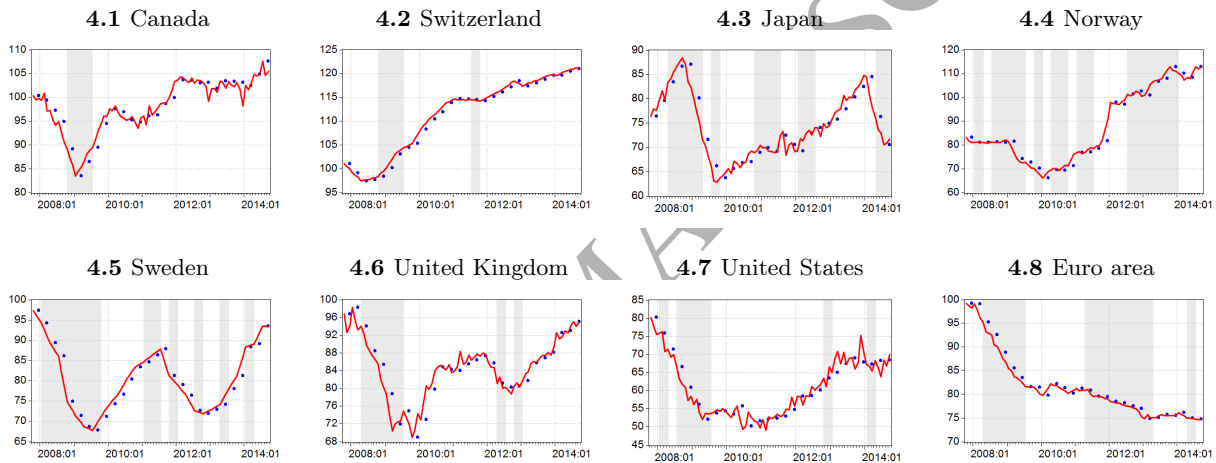
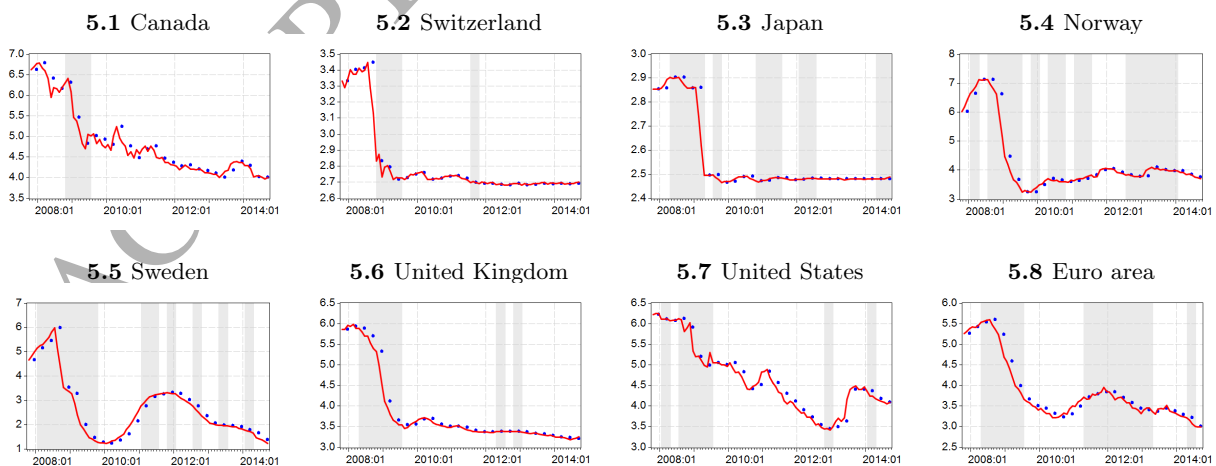
3.1 Quarterly Dataset

For all specifications containing ‘GDP’, we use real gross domestic product from the OECD database. In Model Two and Three, we use the final monthly observation of retail sales and industrial production, discussed below. For our quarterly house price specifications, we use indices provided by Oxford Economics. Quarterly residential investment comes from OECD series on investment in private dwellings, measured in constant values other than Norway (due to availability), which is a series for gross fixed capital formation for construction. For mortgage rates, we use data from Oxford Economics, apart from the euro area where we use an arithmetic average of all available European countries from the euro area (France, Italy, Spain, Germany and Ireland), Norway, where we use an average of mortgage companies (provided by Statistics Norway) and an average of different variable mortgage rates for Switzerland (provided by the Swiss National Bank). For central bank total assets and the monetary base, we use the final monthly (or seldom weekly) observation of the quarter, discussed below.

3.2 Monthly Dataset

The monthly series for GDP are interpolated using both retail sales and industrial production as related series, common in the macroeconometrics literature. Industrial production series are volume indexes of total production excluding construction (from the OECD MEI series), apart from Switzerland, where no appropriate series could be found for the required frequency, so a quarterly series was created with cubic spline interpolation. Retail sales are measured as total retail sales in volume, also from the OECD MEI series. The series which are used to interpolate quarterly house price indexes are in the majority country specific indexes (which are usually constructed in different ways, motivating the interpolation of the standardized Oxford Economics series, as opposed to using a monthly series alone) such as the ONS National House Price Index in the UK or the Valueguard, HOX Housing index in Sweden. Residential investment is interpolated using a somewhat heterogeneous range of series as housing starts or building permits granted (or for the UK, a volume index of building production, or for Switzerland, a monthly index on building composite materials imported into the country) from a range of national statistical offices, wholly dependent on availability. For

³Our replication files which accompany this paper also generate ‘Denton’ and ‘Litterman’ interpolations, although the created series do not materially differ, and nor do any of the generated impulse responses.

Figure 3: Quarterly and Monthly House Prices**Figure 4: Quarterly and Monthly Residential Investment****Figure 5: Quarterly and Monthly Mortgage Rates**

Shaded regions: quarters of country-specific negative GDP growth. Lines represent monthly, symbols represent quarterly data.

monthly mortgage related series, we typically use private sector mortgage market indicators (such as the US conventional home fixed mortgage rate on 30 year products) apart from Sweden, Japan and Norway, where no such series is available, so we use 10 year government bond yields to capture movements in capital markets. For our fifth model (discussed below), we use monthly CPI ‘All Items’ series from the OECD. Of critical importance are our two policy variables, both of which are predominantly located on central bank websites and reconstructed from backdated balance sheets. In Figures 3 to 5 we show the close relation between our monthly and quarterly housing market series.

4 Methodology

Proposed as an alternative to traditional large-scale macroeconomic models, structural VARs have rapidly become the workhorse of macroeconomic research. Studies which focus on the effects of an identified monetary policy shock, such as Uhlig (2005) in a sign restricted context, are a primary focus of attention.

4.1 Model Specification

We estimate five specifications each containing five variables revolving around a core housing market orientated⁴ VAR model. The variations are summarized in Table 1, and include changing the measure of economic activity between GDP, industrial production (IP) and retail sales (RS - as in Elbourne (2008)), changing our measure of monetary policy from central bank total assets (TA) to the monetary base (MB - as done in Gambacorta et al. (2014)) and incorporating a measure of inflation. We appreciate the importance of a credible identification scheme, and for this reason, the fifth specification acts a robustness check in this regard. Given that the VAR in this context, is, in essence a reduced-form monetary policy rule, we include CPI given that each of the central banks in our sample are focused on targeting (officially or unofficially) inflation. CPI is therefore interchanged with residential investment in Model Five, in order to show only a negligible difference in the response of other variables. Given that we are following the estimation approach of Gambacorta et al. (2014), we also follow their deterministic specification also, including a constant in all of our models.

Table 1 also describes the ordering of the variables where the measure of economic activity is ordered first, followed by house prices, housing supply (or CPI), mortgage rates, and finally, the policy variable is ordered last (as per the majority of the macroeconometric literature). All of our VAR models described above are estimated from 2007M10/2007Q4 through to 2014M9/2014Q3. At this point, it is important to note that although standard unit root tests indicate some variables are non-stationary, we estimate the system in levels.⁵ Estimating each of the specifications in a series of single country models for both monthly and quarterly data indicates that conventional information criteria indicate a preference for one, or (for monthly data) at most two lags. For this reason, we estimate our monthly and quarterly model sets (which

⁴For four of the five specifications we include house prices, residential investment and mortgage rates as per the ‘lens of fundamentals’ of Gattini & Hiebert (2010) and other papers discussed in Section 2.3 and 2.4

⁵Sims et al. (1990) show that even if co-integration exists, the dynamics of the system are consistently estimated with a VAR in levels, whereas first differencing may discard relevant information. Regardless, we are prohibited from an explicit consideration of the long-run behavior due to our short sample.

Table 1: Overview of the five model specifications

	GDP	RS	IP	HP	RInv	CPI	Mort	TA	MB	Constant
Model One	✓	×	×	✓	✓	×	✓	✓	×	✓
Model Two	×	✓	×	✓	✓	×	✓	✓	×	✓
Model Three	×	×	✓	✓	✓	×	✓	✓	×	✓
Model Four	✓	×	×	✓	✓	×	✓	×	✓	✓
Model Five	✓	×	×	✓	×	✓	✓	✓	×	✓

are equivalent between frequency) with the lag length set to one, and we also re-estimate our monthly models (where the number of observations is larger) for two lags also, discussing the results (which are shown to be robust to lag length choice) for both in Section 5.

4.2 Estimation and identification Strategy

Early pioneers proposed that structural inference using VARs might be based solely upon hypotheses about the signs of the impacts of some specific shocks in the system, and this approach has been adopted in numerous applied studies in various contexts thereafter (see [Fry & Pagan \(2011\)](#) for a review of the various economic sub-disciplines that sign-restricted techniques have been utilized within). We tailor the method used in [Gambacorta et al. \(2014\)](#) discussed above, reporting the median individual country⁶ and the distribution of mean group responses. Panel techniques allow a substantially more efficient estimate compared to country-specific SVAR models through the exploitation of the cross sectional dimension. The mean group panel VAR is estimated in several steps. In order to increase efficiency, each equation of the VAR is estimated for each country to take into account the correlation between the residuals of the same endogenous variables. This is undertaken using feasible generalized least squares (FGLS), which helps to capture information about common dynamic relationships which would have been lost by OLS estimation. The greater the correlation from common global shocks which are not captured in domestic mortgage markets, the greater the efficiency gain from using FGLS. We then bootstrap the system of equations having grouped each variable together across countries. As in [Gambacorta et al. \(2014\)](#), we use the mean group estimator as opposed to the fixed effects estimator, as it allows for the cross country heterogeneity, without the imposition that the dynamics of each economy are the same.

To identify a structural re-parameterization of the system, we use a mix of zero and sign restrictions. While combinations of zero and sign restrictions have previously been used in papers such as [Peersman \(2011\)](#), [Gambacorta et al. \(2014\)](#) claim that the imposition of additional zero restrictions reduces the number of permissible models, ‘sharpening’ the identification. We start with a Cholesky decomposition of the country-specific covariance matrices, with a recursive ordering of variables as discussed above. We generate new estimated shocks to specific variables. It is the fact that this combination of shocks has an identical covariance matrix, yet a different impact upon our endogenous variables which gives us the ‘ability to create a large number of candidate shocks that is the basis of sign restriction methods’ ([Fry & Pagan 2011](#),

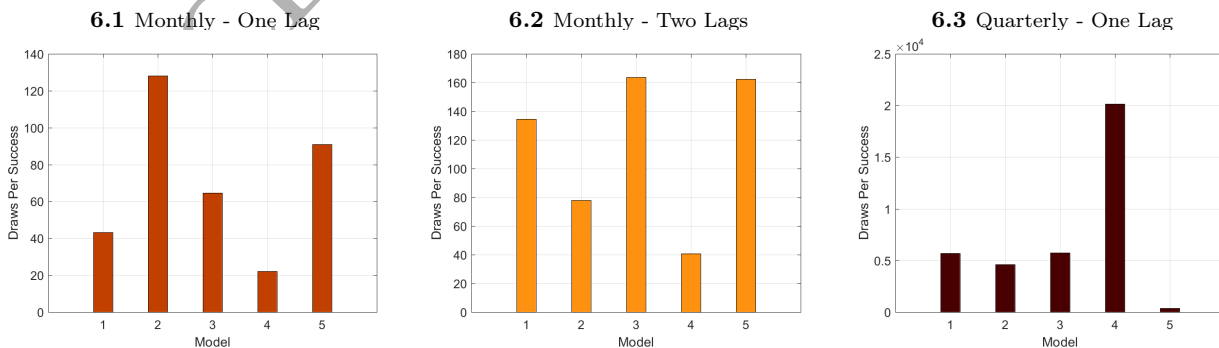
⁶Simple modifications to the program files easily would allow the reporting of the 16th and 84th percentiles of these responses, as is common in the literature, although we leave them unreported due to the comparative nature of our approach.

Table 2: Identification of an Unconventional Monetary Policy Shock

Economic Activity	House Prices	Supply	Mortgage Rate	Total Assets
0	0	0	≤ 0	> 0

p.6), and it is from here that we generate impulse responses which we use for our identification scheme based on economic theory. The responses of the fourth and fifth variables are treated as candidates for satisfying the sign restrictions.

As in the papers discussed in Section 2, we assume that policy shocks have only a lagged impact on residential supply, economic activity and house prices. The valuation, negotiation and conveyancing procedures involved in housing transactions justify such a restriction. However, we also impose the restriction that mortgage rates must not increase in response to a positive policy shock to reflect the way that lenders may instantly adjust their lending rates following general economic theory and as in more structural papers such as Garriga et al. (2013). From this follows the ‘complementary’ restriction that total assets increase in response to the mortgage rate rising - a fact resembled in the reaction of central banks to mounting financial uncertainty. Utilizing the fact that the policy variable is the most endogenous of all, with policymakers reacting to information on all other variables in the system when determining how to optimally react, we order central bank total assets last, giving us the ordering in Table 1 and sign restrictions as in Table 2 (where the restrictions are imposed for six months or two quarters, depending on which frequency we are considering). The imposition of the sign, as opposed to a zero restriction on mortgage market rate allows monetary policy interventions to immediately influence mortgage markets. We argue that conditioning on the mortgage rate is able to ‘disentangle exogenous innovations to central bank balance sheets from endogenous responses to financial market risk perceptions’, as per (Gambacorta et al. 2014, p.623), although we acknowledge it to be a weaker indicator than in their study. Crucially, if a draw does not satisfy the imposed restrictions for all countries simultaneously, it is discarded, and we repeat until we have 1,000 satisfactory responses.⁷ Figure 6 shows the number of draws required per successful identification of each model across each of the lag lengths

Figure 6: Draws Required Per Model

⁷Unreported experiments to redraw 10,000 accepted responses show no qualitative difference (with differences occurring at the fifth decimal place only).

and frequencies, and while the number of draws required for a model with either one or two lags is almost equivalent, considerably more draws are required for the shorter quarterly sample.⁸

5 Results

5.1 Monthly Data

First we consider the median country level individual impulse response functions generated by the five models with monthly data and one lag. These are shown in Figure 7, and in all of the figures which follow, the shaded area represents the period for which the sign restriction holds (either six months or two quarters, as appropriate). The first thing to note from all plots is the general congruence of each of the specifications, with all five models generating very similar median responses for each variable for each country. The shape of the response of house prices is almost identical across each of the eight countries (with the exception of the euro area), taking between one and three years to peak. Two of the largest responses for house prices occur in the two economies with the most developed shadow banking sectors – the United States and the United Kingdom, indicating a relationship between the credit channel and the efficiency of housing finance. The smallest responses come in the Euro area and Japan. Residential investment responds more strongly than house prices, but takes longer to peak, consistent with the conveyancing procedures involved in construction.⁹ There is a minor heterogeneity in the response (lower in magnitude) of Model Four for the U.K. and Switzerland which we attribute to the variables used to create the series. Considering the third column of responses, almost none of the single country median responses return immediately to zero following the imposition of the six month sign restriction on mortgage rates.

We next compare the response of the same set of models estimated with two lags seen in Figure 8. The responses are extremely similar in shape to those shown in Figure 7, indicating the robustness of our models to lag length specification. The response of some variables are marginally larger for some models (for example - the response of House Prices in Model Four for Norway), and marginally smaller for some other models (for example - the response of House prices in Model Two for the United States). At this point, we can evaluate whether including CPI as one of the variables in one of the models in the model set affects the time paths of the responses. With the exception of the median response of the two lag model for the United States, no discernible difference is noticeable.

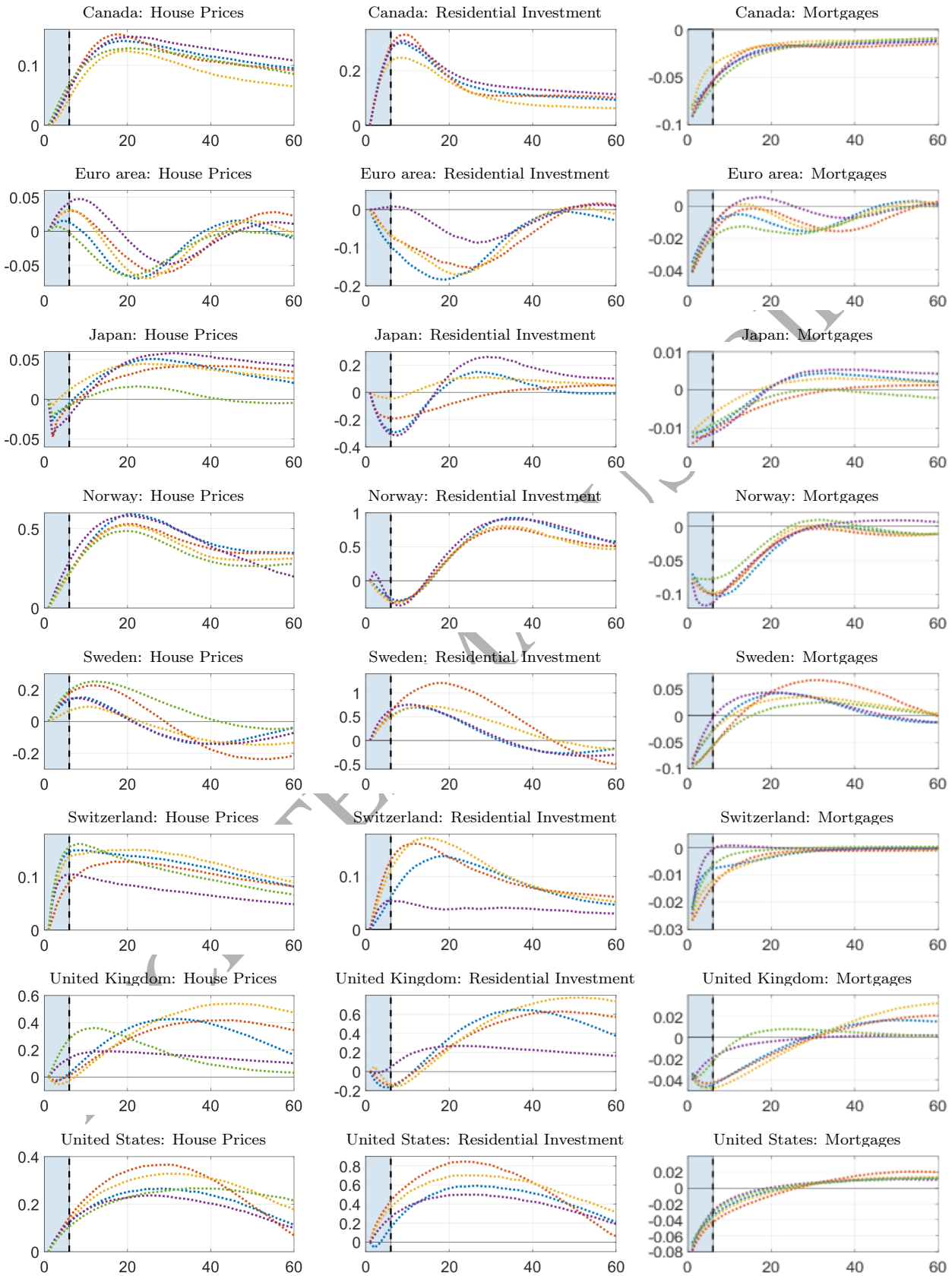
Figures 9 and 10 show the mean group responses of each variable for Model One when estimated with one and two lags respectively. The unreported (median) impulse responses for this model indicate that the shock is characterized by an increase in the central bank balance sheet of 3.328% and 3.032% for one and two lag models respectively, fading out after about six to twelve months.¹⁰ In these plots (and also in Figure

⁸While the technical details regarding the mechanics of the process are omitted here, interested readers are directed towards Sections 2.1 to 2.3 in [Gambacorta et al. \(2014\)](#)

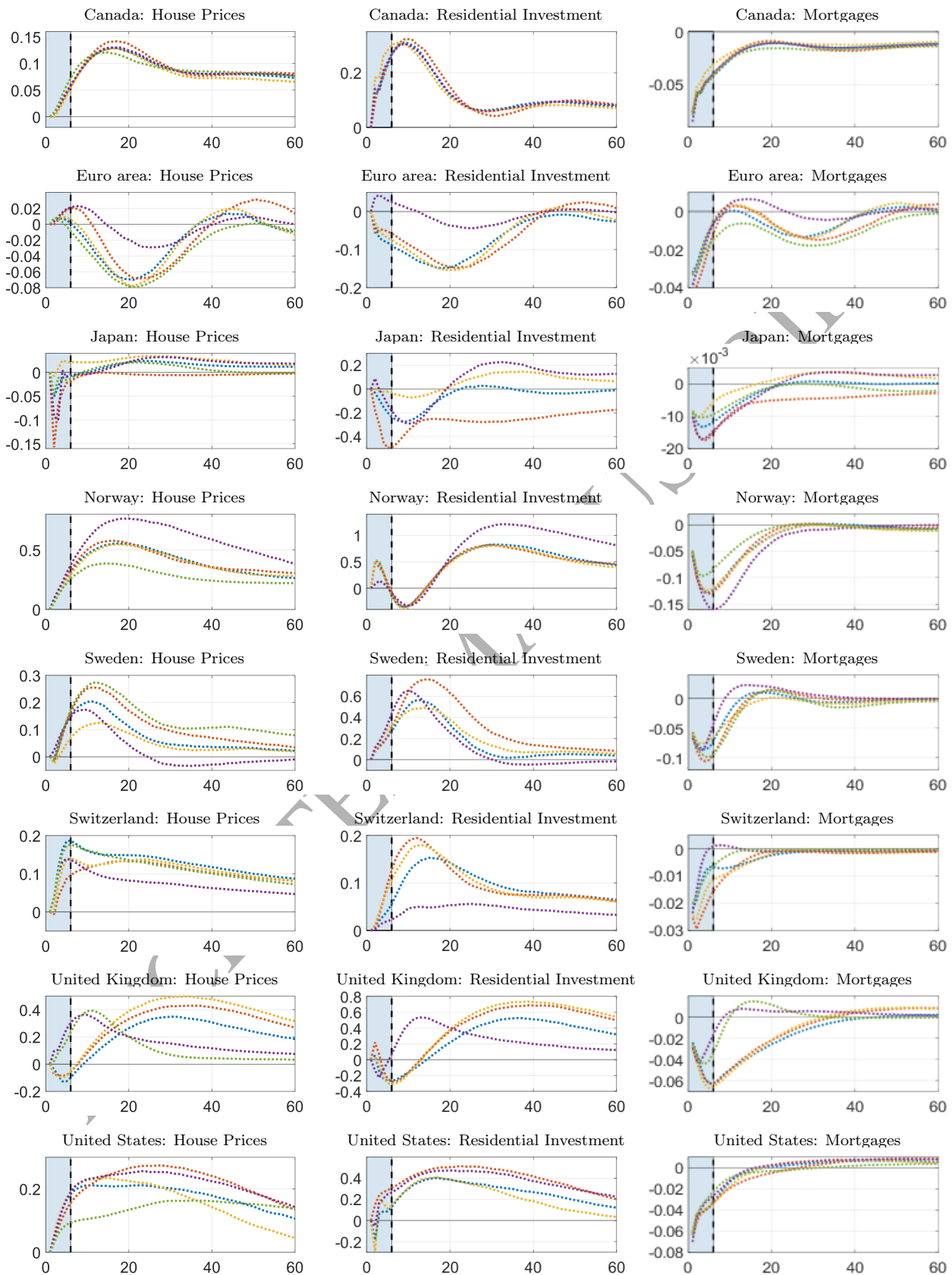
⁹We have omitted the response of the third variable – CPI – for Model Five, and for this reason, the middle column of plots only contain four median responses.

¹⁰This information, along with the fact that central banks typically increased their balance sheets by 100% in total over the crisis period can be used to construct ‘back of the envelope’ calculations as in [Gambacorta et al. \(2014\)](#) relating to the total effect of quantitative easing.

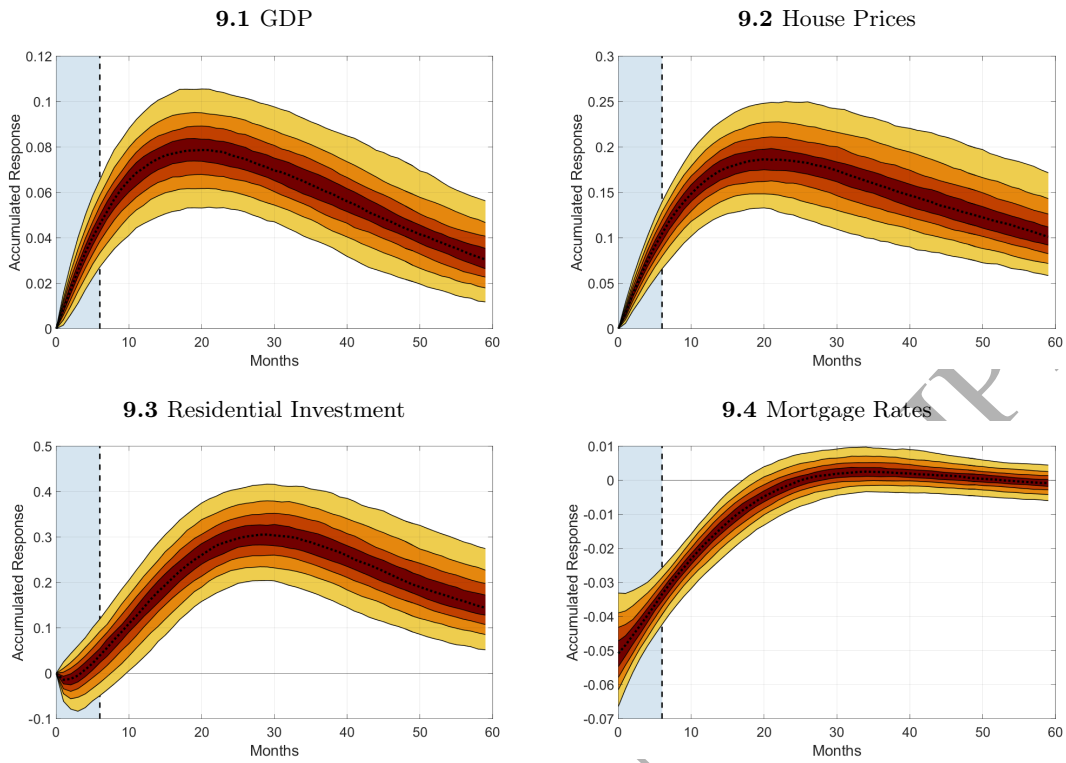
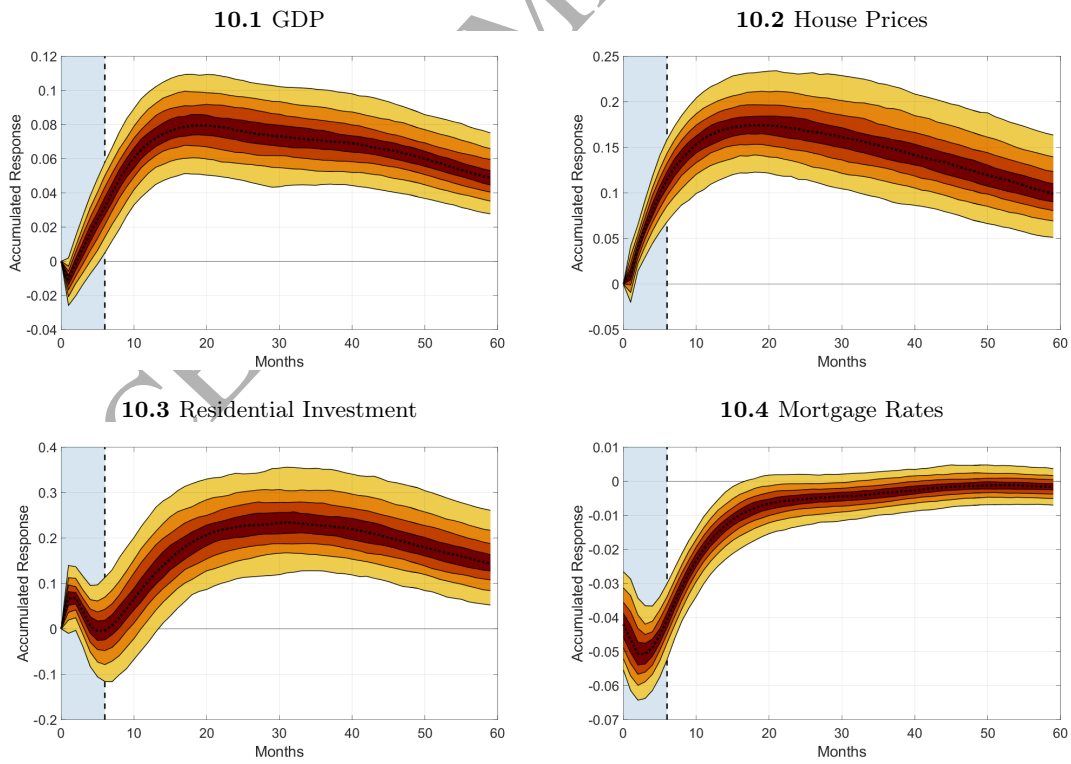
Figure 7: Monthly Single Country Median Impulse Responses: One Lag



Blue: Model One, Red: Model Two, Yellow: Model Three, Purple: Model Four, Green: Model Five. X-axis: horizon, Y-axis: accumulated response.

Figure 8: Monthly Single Country Median Impulse Responses: Two Lags

Blue: Model One, Red: Model Two, Yellow: Model Three, Purple: Model Four, Green: Model Five. X-axis: horizon, Y-axis: accumulated response.

Figure 9: Monthly mean group responses for Model One: One Lag**Figure 10:** Monthly mean group responses for Model One: Two Lags

11), the figures show the distribution of the impulse responses (‘firemap’) across 8 deciles (80% probability bands), with the median (dashed black line) in the middle. The plots suggest that the response of house prices peaks after 24 months, and after 31 months for Residential Investment, and that the effect is nearly double in magnitude for the latter. The response of GDP is included for comparison with [Gambacorta et al. \(2014\)](#), and the longer delay until the peak of the response in comparison to is natural and expected, given the bureaucratic intricacies involved in the planning, financing and conveyancing of the construction of residential developments in the majority of our OECD countries. The range of the distribution at the peak however is almost equivalent, despite the longer sample period which we employ. The first period is the most negative in magnitude for the response of mortgage rates (which are constrained to be negative for six periods under this identification scheme) which shows that following the shock, they do not decline further.

5.2 Quarterly Data

Turning to quarterly data, the mean group responses of house prices are qualitatively similar in shape to the monthly results, albeit larger in absolute magnitude. This increase in magnitude is wholly expected given the temporal aggregation over the frequencies. The shape of the responses of the mean group estimators however, albeit slightly more ‘peaked’, is almost exactly equivalent to both of the monthly specifications,

Figure 11: Quarterly mean group responses for Model One: One Lag

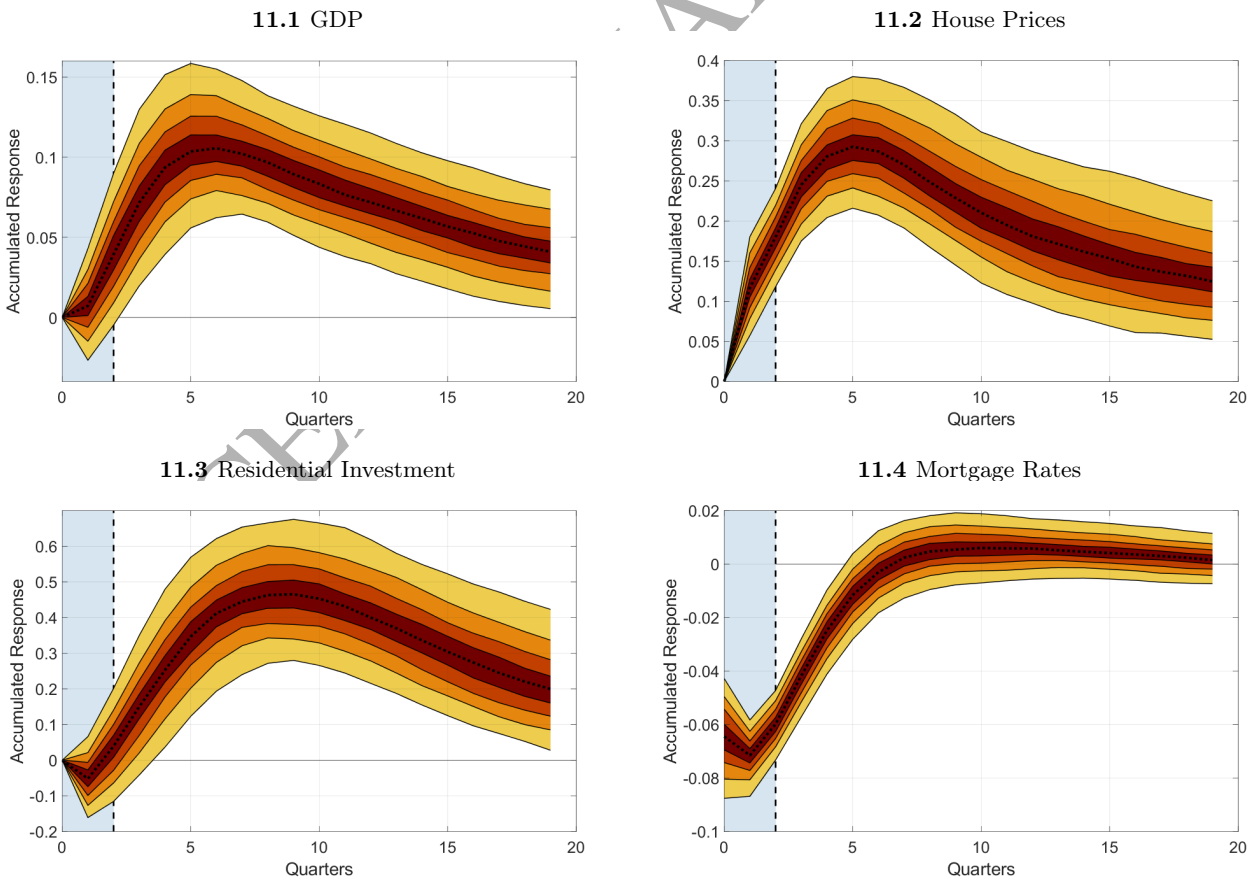
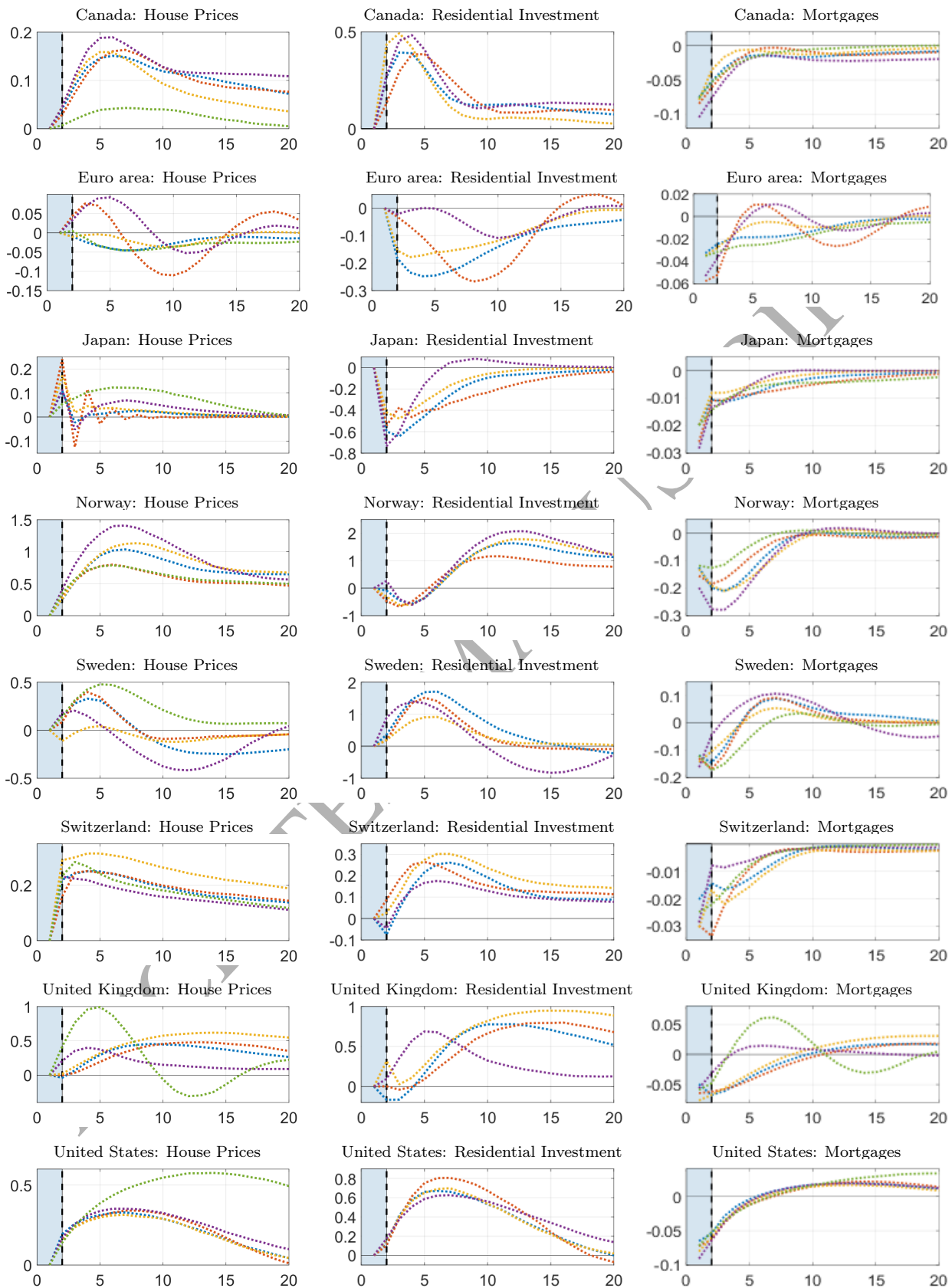


Figure 12: Quarterly Single Country Median Impulse Responses: One Lag

Blue: Model One, Red: Model Two, Yellow: Model Three, Purple: Model Four, Green: Model Five. X-axis: horizon, Y-axis: accumulated response.

where the unreported responses for this model indicates that the shock is characterized by an increase in the central bank balance sheet of 4.091%, again fading between two and four quarters (six and twelve months as above). At a country level, we see a similar congruence in results between the different specifications, and again observe that the response of house prices is smallest in Japan and the euro area. We again see a more delayed, but larger response of residential investment when compared to house prices. On a comparative note, the response of house prices to a ‘money shock’ is in general smaller than in [Goodhart & Hofmann \(2008\)](#), which reports results for a sample split dependent on the rate of house price growth (Figure 7 in their paper), and is similar in absolute magnitude, albeit slightly smaller (but necessarily opposite in sign) than [Vargas-Silva \(2008b\)](#), which shows a 0.5% decrease at the peak in response to a contractionary one standard deviation shock in conventional policy rates.

6 Conclusion

The empirical results above provide strong evidence in favor of the intuitive economic theory that an unconventional monetary policy shock, in the form of an increase of central bank total assets, has an effect not only on house prices, but also residential supply and mortgage markets. Despite the varied undertaking of policy measures and heterogeneous institutional mortgage market structures, the results appear to be relatively consistent across countries. The results are also consistent across lag length choice, model specification and data frequency employed.

There are a number of wide-ranging policy implications from the results of this work. The first is to recognize that when undertaking any form of monetary policy, conventional or otherwise, central banks must learn more about the precise ways in which their policies are transmitted into the wider economy (such as through housing markets). These considerations are especially important when policy-makers are combining both monetary and fiscal policy, or using some specific policies focused upon one area of economy, when multiple interactions between different policy measures may already be in effect. This is especially relevant when considering the recovery period following the recent financial crisis when expansionary monetary policy has been paired with contractionary fiscal policy. Policymakers must also consider the effect of lower financing costs and higher aggregate demand for housing on not only wealth effects associated with housing, but also the effects of a potentially higher turnover for housing (and the associated increase in transaction taxes for example).

Another implication is that when estimating models of this kind, the underlying structure of institutions in place can drive any effects of unconventional monetary policy, and as such, requires explicit consideration, shown by the heterogeneous magnitudes in response across countries. For example, the response of house prices is larger in the U.K. and the U.S., where shadow banking and mortgage markets are more developed, in Norway where there is a larger proportion of owner-occupiers (up to 85% according to some sources), and Sweden which has high typical LTV ratios.

Further research in this sub-discipline may involve model averaging or other incorporation of likelihoods, or to incorporate further methods of response analysis, such as considering the joint distribution of admissible models as per [Inoue & Kilian \(2013\)](#). Other avenues for potential research might focus on how housing

markets are affected by different types of changes in the composition of central bank balance sheets. It would be an interesting advancement to incorporate methodology from the recent factor literature (although data availability currently constrains us from including factors into our panel-based research design), or to consider time-varying parameters. However, the main implication of this study is that more research is required to focus upon the transmission of unconventional policies to other assets, with a particular regard to real estate markets, in addition to the already considered bond yields, output and prices.

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