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The interest rate sensitivity of house prices: International evidence on its state dependence[1]

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Abstract

This paper investigates how house prices have historically responded to interest rates and how their reaction has depended on preexisting conditions. We identify exogenous variations in short-term interest rates for 29 OECD countries relying on international spillovers from US monetary policy. Our results suggest that the average house price reaction is larger and more protracted than most of the previous estimates suggest. Amplitude and speed, however, depend considerably on the specific context. The reaction of house prices is larger and faster when interest rates are low, when their increase occurs during a recession, and when credit conditions are already tight. A preceding boom in house prices slows the price reaction at first but amplifies the decline in the medium term. Based on these results, we estimate how the cyclical conditions prevalent in 2022 typically influenced the house price reaction in our historical sample.

JEL Codes: R21, E51, E32

Keywords: house prices, interest rates, local projection, smooth transition function

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1. Introduction

In many countries, house prices grew rapidly during the 2010s, only to accelerate further during the COVID-19 pandemic. According to the popular narrative (see, e.g., Economist, 2018), this boom was at least partly fuelled by a broad-based decline in interest rates. The trend toward ever-lower interest rates reversed abruptly after mid-2021. Monetary policy in advanced economies tightened at a pace not seen since the 1980s. This raises the questions of how house prices have typically reacted to monetary tightening and to what extent the historical experience is informative for the current context.

From a conceptual perspective, the direction of travel seems clear. The theoretical literature has long highlighted a negative link between interest rates and house prices, relying on two no-arbitrage conditions: (i) between renting and owning (Poterba, 1984; Henderson and Ioannides, 1983) and (ii) between investing in housing rather than in other assets (Case and Shiller 1989, 1990). Both channels suggest that house prices should decrease as a higher interest rate increases the user cost of home ownership.

A significant literature has generally confirmed a negative relationship but also a relatively modest quantitative importance of interest rates compared to other drivers of supply and demand (Andrews, 2010; Duca et al., 2010; Crowe et al., 2011; Hott and Jokipii, 2012; Igan and Loungani, 2012; Cerutti et al., 2017). Most papers have focused on identifying the average effect of monetary policy rates. In some cases, the effect was allowed to evolve over time (e.g., Jordà, et al., 2015), to change with the degree of banking regulation (Andrews, 2010) or to depend on distinct regimes (e.g., Bordo and Landon-Lane, 2013; Goodhart and Hofmann, 2008). Others have investigated how cross-country differences in mortgage market characteristics explain different house price responses (Carstensen et al., 2009; Sà et al., 2011; Calza et al., 2013). Yet, the question of how the effect of interest rates varies with the conditions in the housing market and the broader economy has – to the best of our knowledge – not been investigated systematically. This shortcoming is particularly relevant when considering the recent monetary policy tightening cycle, as economic and mortgage market conditions at its outset were in many cases highly atypical from a historical perspective.

One challenge for the empirical literature has been to identify exogenous variations in interest rates. Most related papers have relied either on recursive VARs (e.g., Calza et al., 2013; Assenmacher-Wesche and Gerlach, 2008; Bordo and Landon-Lane, 2013; Goodhart and Hofmann, 2008) or on the high-frequency identification of monetary policy shocks in individual countries (e.g., Cochrane and Piazzesi, 2002; Gertler and Karadi, 2015; Gürkaynak et al., 2005; Nakamura and Steinsson, 2018; Koeniger et al., 2022). A notable exception is Jordà et al. (2015), who – going back to the 1870s – identify monetary policy shocks for countries with a fixed exchange rate based on the policy trilemma in international macroeconomics (Obstfeld and Taylor, 2004).

The contributions of our paper are twofold. First, we reevaluate the link between interest rates and house prices. We do this by relying on a cross-country panel, which – relative to focusing on the experience of an individual country – allows us to exploit a far larger number of monetary and housing cycles. We follow Jordà et al. (2015) in the use of a local projection instrumental variable model (LP-IV) and in identifying exogenous changes in short-term interest rates based on monetary policy spillovers from the dominant financial center – in our case, the U.S. However, we differ from their approach by focusing on a more recent sample that we believe is better suited to capturing contemporaneous conditions. Since our sample period is better described by an international "policy dilemma" (Rey, 2015) rather than by a "policy trilemma" (Obstfeld and Taylor, 2004), we extend the identification to the increasing number of countries with flexible exchange rates. We also expand their instrumentation strategy by using both the nominal change in the US Federal Funds Rate and exogenous monetary policy shocks (as calculated by Gürkaynak et al. (2005)) as excluded instruments.

Our second contribution is the investigation of how the house price reaction depends on underlying conditions. We can thus relax the linearity assumption prevalent in most studies and allow the effect of a given interest rate shock to change along various dimensions. Potential reasons for such a state contingency include differences in (i) the pass-through from short-term interest rates to effective borrowing costs, (ii) interactions with other drivers of financial conditions, (iii) the health of household balance sheets and income positions, or (iv) preceding house price dynamics. We investigate state contingency with respect to a larger set of factors than the literature has considered and in a way that is more robust than relying on binary regimes. Following the approach popularized by Auerbach and Gorodnichenko (2012), we construct smooth transition functions (STFs) for the initial level of interest rates, the output gap, credit conditions and the state of the housing cycle at the time of the monetary policy shock. Compared to an interaction with dummy variables, this approach avoids discrete jumps in regimes and reduces the sensitivity of the results to outliers. To the best of our knowledge, we are the first to incorporate this approach into an LP-IV setup. Finally, we illustrate how the cyclical conditions prevalent in early 2022 influence the house price reaction to a monetary policy shock.

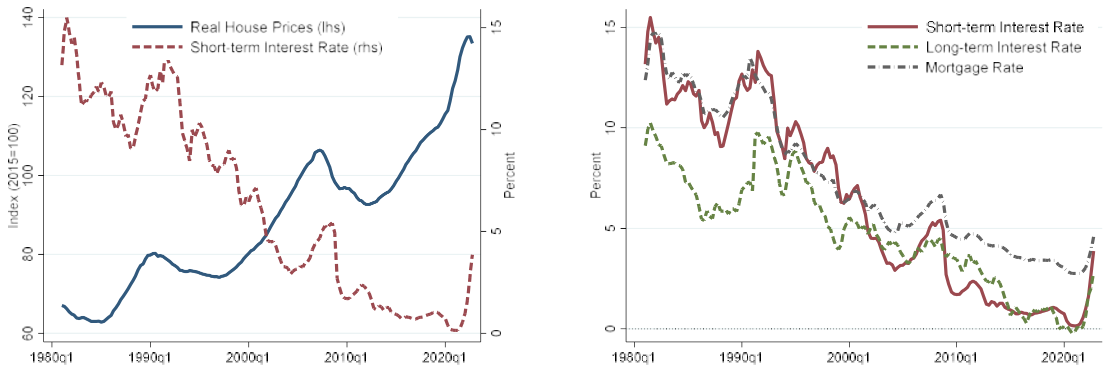
Our key results are as follows. First, we find that following a 1 pp exogenous increase in short-term interest rates, house prices typically fall by up to 8% over a five-year period. Compared to the existing literature, which – according to a meta-study by Ehrenbergerova et al. (2022) – suggest an average peak decline of 1.2% after just two years, the response is substantially larger and more protracted. Second, we find that the effect varies greatly depending on the initial conditions. For example, the response of house prices is substantially larger when interest rates are initially low, and it materializes faster when the increase in interest rates occurs during a recession or when credit conditions are already tight. A preceding house price boom slows the price reaction at first but amplifies the effects in the medium term. Finally, conditions at the onset of the latest monetary tightening cycle have historically led to a stronger house price contraction, particularly in the medium term.

The rest of the paper is structured as follows. Section 2 presents the data and empirical strategy that we use to construct exogenous variations in interest rates. Section 3 sequentially presents

Figure 1: House prices and interest rates

House prices and short-term interest rates
(lhs: 2015=100, rhs: in %)

Interest rates at short and longer horizon
(in %)



Note: Real house prices and long-term interest rate are average indices provided by the OECD with the long-term interest rate being the 10-year government bond yield. Short-term interest rate is calculated as an unweighted average over the money market or Treasury bill rates from the OECD countries in our sample. 1980Q1–2022Q4. The mortgage rate is calculated as unweighted average over the interest rate on new loans to households for home purchases (fixed rate; with 5 to 15 year maturity) from the OECD countries in our sample.

Sources: OECD, various (for details see Appendix A.)

our estimates of the average effect of house prices and the role of initial conditions. Section 4 presents a series of robustness checks, and Section 5 concludes.

2. Data and empirical strategy

This section first illustrates the evolution of our key variables, i.e., house prices and interest rates, before presenting the empirical model, including our identification of exogenous variations in short-term interest rates (STIR). The section concludes by showing how our baseline setup can be extended to study the state contingency of the effect.

2.1. Key variables

At this stage, we focus on introducing and illustrating the variables of interest used in the main analysis. The variables that are specific to the instrumentation or the analysis of state contingency will be introduced in the relevant sections. The definitions and sources of all the variables are summarized in Appendix A.1.

House prices and interest rates

The key variables of interest are real house prices and the short-term interest rate. Figure 1 illustrates their evolution, averaged over the 29 countries in our sample.[1] It suggests an inverse relationship between house prices and short-term interest rates. For example, interest rates

[1] For the list of countries and data sources, we refer the reader to Appendix A.

generally declined during the house price booms in the late 1980s and the mid-2000s as well as during the particularly dynamic house price growth of the last decade. In addition, the two major peaks in global house prices occurred soon after monetary policy entered a tightening cycle. As illustrated in the right-hand panel of Figure 1, the movements in short-term rates were reflected in similar – but at times slightly muted – changes in average mortgage rates and long-term government bond yields.[2] [3]

Economic circumstances

The illustrated comovement of house prices and interest rates does not establish a causal link, as changes in interest rates do not occur exogenously or in isolation. To converge to an empirical setup that allows a causal interpretation of the coefficient, we proceed in two interrelated steps. The first involves accurately reflecting the economic codeterminants of house prices, i.e., the conditions at the time of the monetary tightening. The second step, which will be described in the next subsection, involves distinguishing with an instrumental variable (IV) approach the exogenous changes in the interest rate from their endogenous reaction to the economic circumstances.

The following variables in our system thus serve the double purpose of (i) capturing other determinants of house price developments and (ii) allowing the identification of exogenous changes in short-term interest rates.

- **GDP growth and output gap**: The annual growth rate of real GDP is the key variable capturing economic momentum. We complement it with the output gap (measured as a % of potential GDP) to also capture the distance from the cyclically neutral position. While the two variables are correlated with each other, they can bring complementary information to a monetary policy decision and have independent effects on house prices in practice (as discussed in Section 3.1).
- **Inflation**: Inflation, entered as the difference between actual inflation and the inflation target[4], can affect the relative attractiveness of owner-occupied real estate, given that it delivers real rather than nominal returns. Its inclusion is also essential for interpreting the effect of interest rates in real terms. In the first stage, the deviation of actual inflation from its target helps capture endogenous changes in the short-term interest rate (STIR).

[2] The long-term interest rate is generally defined as the 10-year government bond yield (Source: OECD).

[3] In our empirical analysis, we relate *real* house prices to *nominal* interest rates, following a common practice in the empirical literature (e.g., Calza et al., 2013 or Jordà et al., 2015). The practical reason for this choice is that forward-looking inflation expectations are not consistently available for the countries in our sample and may vary depending on the source (e.g., households, corporates, financial markets) and the horizon. We, however, include both contemporaneous and lagged values of actual CPI inflation as controls (see the next subsection) and propose an IV strategy that identifies exogenous variations in interest rates, which can be interpreted both in nominal and real terms.

[4] For countries or periods where the respective central bank did not have an official target, we use the midpoint of the target range or – if also unavailable – the five-year moving average of actual inflation. To avoid an excessive influence of hyperinflation episodes (e.g., Russia or Poland in the early 1990s), the deviation is curtailed to 5% for advanced economies and 10% for emerging markets (Sources: Oxford economics, national central banks).

- **Private credit:** Credit, scaled by GDP, is used as a proxy for the development of the mortgage market or inversely for the tightness of household borrowing constraints. Easing financing conditions can increase the demand for housing over and above the effect of short-term interest rates (Favara and Imbs, 2015).
- **Domestic share prices.** Developments in the stock market can cause demand for housing to tip in either direction, as they can be a source of exceptional household income (affecting household borrowing constraints) and an alternative investment opportunity. In addition, the inclusion of local share prices supports the validity of our instrumentation strategy, as their inclusion frees us from assuming away the possibility that US monetary policy affects house prices through the prices of financial assets (see also the discussion of the IV strategy in the next section).[5]
- **Long-term interest rates:** Long-term interest rates (LTIR) are used to capture other factors affecting the borrowing costs of households, including the slope of the yield curve. As for share prices, their inclusion relaxes the assumptions regarding the exclusion restrictions associated with our exogenous instruments. To investigate the transmission from short-term interest rates to relevant borrowing costs, we use mortgage rates for a more constrained sample[6].
- **Real rents:** Real rents are included as controls to capture price push factors from the rental market, in line with the no-arbitrage condition mentioned in the introduction.

2.2. Local projection instrumental variable approach

To capture both the scale and dynamics of the effect of an interest rate shock, we rely on a local projection model (Jordà, 2005), in which the intervention variable – the short-term interest rate – is instrumented based on monetary policy spillovers from the US.

We thus model the change in the outcome variable $y_{i,\cdot}$ (i.e., the log of real house prices) between time $t-1$ and $t+h$ as a function of the change in the short-term interest rate at time t ($\Delta STIR_{i,t}$), as described in the following equation, where $\boldsymbol{X}_{i,t}^{p}$ captures up to p lags of controls, which generally also enter contemporaneously[7]:

$$y_{i,t+h} - y_{i,t-1} = \alpha_{i,h} + \beta^{h} \Delta STIR_{i,t} + \gamma_h' \boldsymbol{X}_{i,t}^{p} + \varepsilon_{i,t+h} \tag{1}$$

Estimating Equation (1) with OLS would likely produce biased results due to the endogeneity of $\Delta STIR_{i,t}$. The problem is that interest rates, as set by the central bank, are endogenous to

[5] This does not imply that financial market developments are a target of central banks but that rapid changes in stock prices provide information on the most likely path – and the surrounding uncertainty – of the economy.

[6] Mortgage rates are taken from Oxford Economics and national central banks, and reflect the typical rates at maturity, which ranges from 5 to 15 years, depending on the country. They are likely a closer proxy for the effective mortgage rate. However, as the data coverage for mortgage rates is more limited, we use the LTIR in all specifications where the relevant borrowing costs only feature as a control. We will illustrate in Appendix A.3.2. that this choice is not consequential.

[7] We illustrate in the robustness section that the choice whether a control variable enters contemporaneously or not, has very little impact on the results. In another robustness test, we allow – on top of country fixed effects ($\alpha_{i,h}$) – for country-specific trends, which again does not alter the results.

economic circumstances, which in turn influence present and potentially future house prices. Including observable control variables that capture the economic circumstances is a partial remedy for this issue, yet the scope of omitted variable bias remains. For example, if an interest rate hike merely reflects central banks' anticipation of an overheating economy, it might be associated with a positive house price reaction. The OLS estimate would thus be subject to attenuation bias (i.e., toward a more positive coefficient on $\Delta STIR_{i,t}$).

To address this concern, we follow the emerging literature[8] in combining the local projection (LP) model with an instrumental variable (IV) strategy and estimating our LP-IV model with a 2SLS estimator. We thus model $\Delta STIR_{i,t}$ in the first-stage regression based on the remaining variables of Equation (1) and the excluded instruments $Z_{i,t}$, as outlined in the equation below:

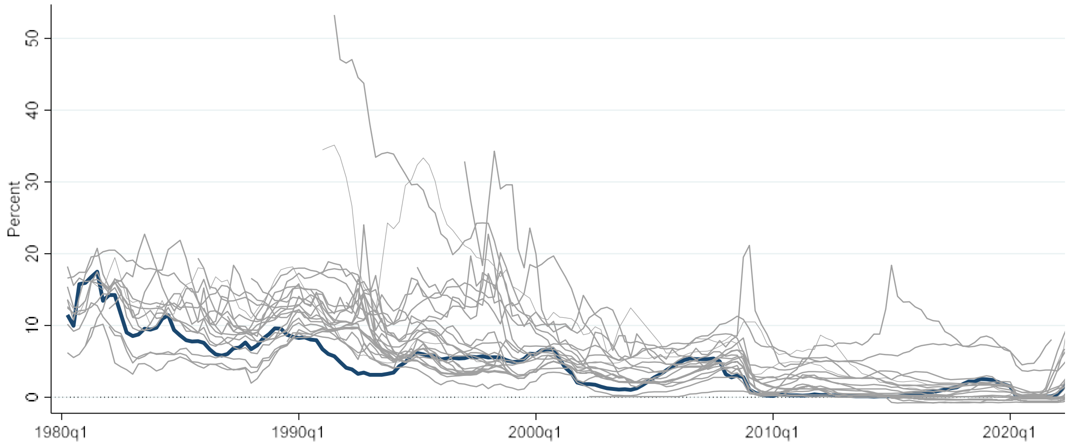
$$\Delta STIR_{i,t}^{IV} = a_i + \theta \boldsymbol{Z}_{i,t} + \rho' \boldsymbol{X}_{i,t}^{p} + e_{i,t} \tag{2}$$

In our choice of the excluded instrument, $\boldsymbol{Z}_{i,t}$, we follow Jordà et al. (2015) in relying on monetary policy spillovers from the global financial center. Jordà et al. (2015), using data going back to the 1870s, identify exogenous variations in interest rates for countries with a pegged exchange rate based on their capital account openness and the prevalent interest rate in the base country (i.e., the country to which the exchange rate is pegged). While this identification is extremely clean, it cannot be applied unadjusted to our more recent sample, as fixed exchange rates have become rather rare.

We thus deviate from the instrumentation strategy of Jordà et al. (2015) in two ways. First, we drop the focus on countries with a pegged exchange rate. This is justified based on the argument that the policy "trilemma" (Obstfeld and Taylor, 1997) of the past has recently become a policy "dilemma" (Rey, 2015, 2013), which means that countries no longer enjoy fully independent monetary policy if the capital account is open, independent of whether their exchange rate is fixed or floating. A significant literature has established the role of US monetary policy in driving global financial cycles (e.g., Miranda-Agrippino and Rey, 2020; Jordà et al., 2019), a pattern that is also illustrated in Figure 2. While particularly in the early parts of the sample, cross-sectional heterogeneity was high, the other countries' interest rates followed those of the US reasonably closely, even if often with a slight lag.

[8] Local projection instrumental variable frameworks have been used by, for example, Jordà et al. (2015), Dedola et al. (2018), Fieldhouse et al. (2018), Ramey and Zubairy (2018), Duval et al. (2020) or Ravn et al., (2020).

Figure 2: The evolution of short-term interest rates



Note: The graph compares the short-term interest rates of the individual countries in our sample with the rate of the US (blue).

Our second deviation is that we use as excluded instruments not only the nominal change in the US short-term interest rate but also its unanticipated component, i.e., US monetary policy shocks, as identified based on the high-frequency event studies around FOMC announcements by Gürkaynak et al. (2005) and Gürkaynak et al. (2022). Accordingly, our vector of excluded instruments $\boldsymbol{Z}_{i,t}$ is given by:

$$\boldsymbol{Z}_{i,t} = \begin{pmatrix} \Delta STIR_t^{US} \; x \; KAO_{i,t} \\ MPS_t^{US} \; x \; KAO_{i,t} \end{pmatrix} \tag{3}$$

It contains two elements: (i) the change in the US short-term interest rate, $\Delta STIR_t^{US}$, and (ii) the US monetary policy shock (MPS_t^{US})[9], each interacted with the country's capital account openness, $KAO_{i,t}$[10]. Adding monetary policy surprises to the set of excluded instruments has the advantage that it contains additional information that can drive monetary policy in other countries and that the instrument is exogenous by construction, an important element of a valid instrumentation strategy[11].

In addition to being exogenous, the excluded instruments need to be (i) correlated with the dependent variable $y_{i,t+h} - y_{i,t-1}$ but (ii) only due to a unidirectional effect through the endogenous variable $\Delta STIR_{i,t}$. A potential concern is that US monetary policy might affect

[9] Gürkaynak et al. (2005) identify high-frequency US monetary policy shocks based on changes in the rate of three-month ahead Federal Funds futures (FF4), within a 30-minute time window around the announcement of the Federal Open Market Committee (FOMC). In so doing, the surprise component of the Federal Funds Target Rate is extracted. Following Gertler and Karadi (2015), monthly and quarterly values are calculated by summing the respective higher frequency values. For our purpose, the extended series are taken from Ilzetzki and Jin (2021) and Gürkaynak et al. (2022).

[10] We measure capital openness with the Chinn-Ito Index (Chinn and Ito, 2006).

[11] We will show in the robustness section that following Jordà et al. (2015) by limiting ourself to the total change in the US short-term interest rate as excluded instrument, i.e., $Z_{it} = \Delta STIR_t^{US} \; x \; KAO_{i,t}$, produces very similar house price reactions, even if slightly less intuitive reactions of the transmission variables.

house prices through channels other than the STIR. After all, global financial markets are highly integrated and quick to react to policy surprises. Yet, this "exclusion restriction" is conditional on the other regressors, in our case $a_i, c_t, \boldsymbol{X}_{i,t}^{p}$. As already mentioned in the data section, for this reason, our set of controls includes financial market variables, such as local share prices or long-term interest rates.

2.3. Smooth Transition Function

Our second methodological extension, relative to a standard OLS LP framework, is to make the house price reaction contingent on the state of the economy or the conditions in the housing market.

Methodologically, we largely follow the literature that has investigated the state contingency of fiscal policy shocks (Auerbach and Gorodnichenko, 2012; Ramey and Zubairy, 2018, building on Granger and Terasvirta, 1993) by relying on regime switching models that allow for a smooth transition between the states, thus avoiding an abrupt and often arbitrary cutoff. This approach involves a *smooth transition function* (F^s) of our state variable $s_{i,t}$, modeled with the following exponential function:

$$F^s(s_{i,t}) = \frac{\exp(-\gamma^s * s_{i,t})}{1 + \exp(-\gamma^s * s_{i,t})} \equiv STF_{i,t}^s \tag{4}$$

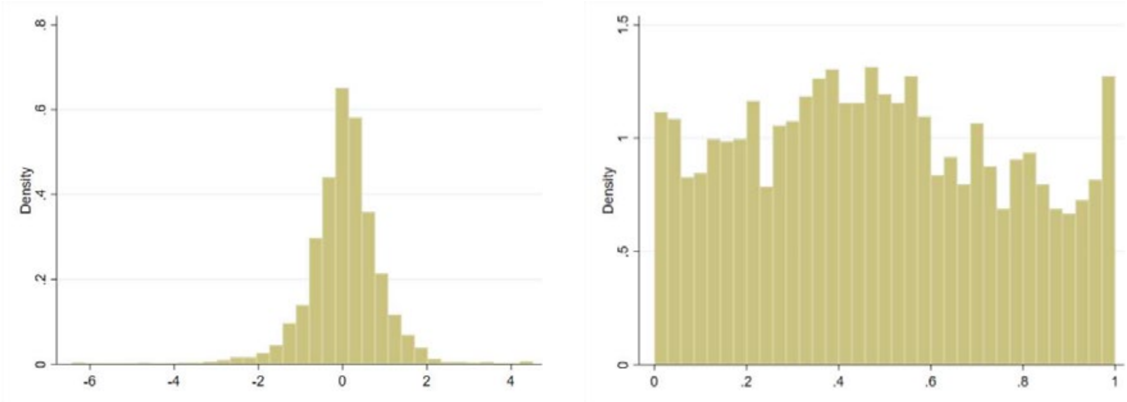
The state variable $s_{i,t}$ is standardized using the mean and variance of the entire distribution in our sample (rather than the country-specific values). This recognizes that not all countries had equally pronounced swings in the conditioning variables (e.g., house prices) and thus implies that countries do not need to be represented in all parts of the distribution of $s_{i,t}$. The scalar γ^s is specific to each conditioning variable and calibrated – consistent with Auerbach and Gorodnichenko (2015) – such that $F^s(s_{i,t})$ exceeds the value of 0.8 twenty percent of the time. To guarantee its *smoothness*, we follow much of the literature[12] by using as $s_{i,t}$ the trailing 7-quarter moving average of the original series.

The function F^s inverses the order of the values, meaning that, e.g., a very low value of $s_{i,t}$ (e.g., a very negative output gap) translates into a relatively high value of the $STF_{i,t}^s$. The function also transforms the distribution of $s_{i,t}$, which is often close to normal, into a distribution of $STF_{i,t}^s$ that is close to uniform and bounded by 0 and 1. This reduces the influence of the most extreme values in driving the interaction coefficient. Figure 3 illustrates the two distributions of $s_{i,t}$ and the corresponding $STF_{i,t}^s$ for the output gap. We also plot the respective time series for the most important conditioning variables for Switzerland in Appendix A.2. .

[12] Auerbach and Gorodnichenko (2015) use a centered 7-quarter MA to ensure the smoothness of the transition. The concern with this approach is that it uses information that may be part of the forthcoming monetary transmission to condition the reaction to the latter, potentially creating a circular relationship. We thus follow Ramey and Zubairy (2018) in using the lagged trailing average instead.

Figure 3: Histograms for output gap

a) Output gap **b)** Smooth transition function of output gap



Note: The histograms show the distribution of the trailing 7-quarter moving average of the output gap (LHS) and its implied smooth transition function (RHS). The output gap is globally standardized.

The conditioning of the effect is implemented with a simple interaction between $\Delta STIR_t$ and $STF_{i,t}^s$, as illustrated in Equation (5), with the caveat that both the contemporaneous short-term interest rate itself ($\Delta STIR_{i,t}$) and its interaction with the smooth transition function $\left(\Delta STIR_{i,t}\ x\ STF_{i,t}^s\right)$ are treated as endogenous.[13]

$$y_{i,t+h} - y_{i,t-1} = \alpha^i + \beta^h\left(\Delta STIR_{i,t}\ x\ STF_{i,t}^s\right) + \gamma_h' \boldsymbol{X}_{i,t}^p + \varepsilon_{i,t+h} \tag{5}$$

In line with the baseline estimation, we instrument the interaction term with the contemporaneous short-term interest rate and the monetary policy shocks from the US as excluded instruments. The state-contingent estimation, however, differs in that the excluded instruments enter both linearly as well as interacted with the $STF_{i,t}^s$. The first-stage regression equation for $STIR_{i,t}^{IV}$ (or equivalently $\Delta STIR_{i,t}^{IV}\ x\ STF_{i,t}^s$) is thus given by:

$$\Delta STIR_{i,t}^{IV} = a_i + \theta \boldsymbol{Z}_{i,t} + \rho'\ \boldsymbol{X}_{i,t}^p + e_{i,t} \tag{6}$$

where

$$\boldsymbol{Z}_{i,t} = STF_{i,t}^s\ x\ \begin{pmatrix} \Delta STIR_t^{US}\ x\ KAO_{i,t} \\ MPS_t^{US}\ x\ KAO_{i,t} \end{pmatrix} \tag{7}$$

To reflect the current state of the countries' housing markets and broader economy, we let $s_{i,t}$ in turn reflect (i) real variables (i.e., the output gap), (ii) monetary variables (i.e., the level of the short-term interest rate), and (iii) financial indicators (i.e., house price growth and credit growth).

[13] The $STF_{i,t}^s$ alone, which is based on the trailing MA of the conditioning variable, is treated as exogenous.

Table 1: First-stage results – Influence of US monetary policy decisions on local STIR

Dependent variable: STIR	
$\Delta STIR_{t}^{US}\ x\ KAO_{i,t}$	0.154***
	(0.025)
$\Delta STIR_{t-1}^{US}\ x\ KAO_{i,t-1}$	–0.036*
	(0.020)
$MPS_{t}^{US}\ x\ KAO_{i,t}$	–0.031
	(0.095)
$MPS_{t-1}^{US}\ x\ KAO_{i,t-1}$	0.251***
	(0.094)
N	2674

Note: The table shows the first-stage result of the 2SLS estimation. The dependent variable is the change in the local short-term interest rates between time $t-1$ and t, as a function of monetary conditions in the US The results for control variables are omitted for readability. Standard errors in parentheses. Star-values: * p<0.10; ** p<0.05; *** p<0.01.

3. Results

We now present the main results. The section starts with the unconditional house price reaction before letting the response vary with underlying conditions. It concludes by illustrating what – based on historical patterns – the typical house price reaction would be when conditions were similar to those at the onset of the most recent tightening cycle.

3.1. The unconditional reaction of house prices

Baseline results

We estimate the unconditional baseline estimation, as shown in Equation (2), by including the contemporaneous value and four lags of the main controls (i.e., output gap, GDP growth, the deviation of inflation from its target, share price growth and the changes in private credit growth as a share of GDP). In addition, we include four lags – but not contemporaneous values – of rents, long-term government bond yields and the variables of interest, i.e., house prices and short-term interest rates. This choice leaves the influence of variables that typically drive monetary policy unconstrained (e.g., inflation, output gap, asset prices[14]) but excludes a contemporaneous link with those variables that are rather associated with monetary policy transmission (e.g., LTIR, rents). Additionally, the lags of the excluded instruments are included

[14] Central banks do not generally target asset prices, but asset prices can influence policy choices if they move abruptly. We thus allow for a contemporaneous effect on house prices.

Table 2: Selected drivers of real house prices

	(1)	(2)	(3)	(4)	(5)	(6)
Dependent variable: Change in real house prices (in %)						
Horizon	h=0	h=1	h=5	h=10	h=15	h=20
STIR shock	–0.298	–0.644	–1.658	–4.926**	–6.930***	–8.147***
	(0.279)	(0.568)	(1.207)	(2.097)	(2.676)	(2.929)
Output gap	0.534***	1.385***	3.927***	2.126	6.453***	5.566**
	(0.206)	(0.396)	(1.154)	(1.360)	(2.018)	(2.230)
GDP growth	0.072**	0.148***	0.475***	1.071***	1.342***	1.742***
	(0.031)	(0.051)	(0.145)	(0.264)	(0.404)	(0.519)
Inflation	–0.341***	–0.476***	–1.069***	–0.896	–0.263	0.125
	(0.084)	(0.155)	(0.356)	(0.621)	(0.816)	(0.960)
Share prices	0.007**	0.015***	0.023	0.021	–0.016	–0.030
	(0.003)	(0.006)	(0.017)	(0.026)	(0.035)	(0.040)
N	2674	2674	2674	2672	2613	2477
R2	0.484	0.532	0.463	0.387	0.369	0.357
Hansen-J p-value	0.375	0.462	0.843	0.791	0.147	0.034
First-stage F stat.	22.447	22.447	22.447	22.446	22.348	22.333

Note: The table shows the second-stage result of the 2SLS estimation. The dependent variable is the change in real house prices between time $t-1$ and $t+h$, focusing on the effect of the changes in the STIR. The results for control variables are omitted for readability. Standard errors in parentheses. Star-values: * p<0.10; ** p<0.05; *** p<0.01.

as controls ($\Delta STIR_{t-1}^{US}\ x\ KAO_{i,t-1}$ and $MPS_{t-1}^{US}\ x\ KAO_{i,t-1}$)[15]. As we will discuss in the robustness section, none of these choices are very consequential for the results.

Error! Reference source not found. presents the first-stage results, focusing on the influence of US monetary policy decisions on short-term interest rates in the rest of the sample. The results for all the other variables (i.e., the controls in the second stage, which naturally also feature in the first stage) are omitted for readability.[16] The table shows that both the expected component of US monetary policy decisions ($\Delta STIR_t^{US}$) and the unexpected component thereof (MPS_t^{US}) influence the STIR in the other countries. For both variables, the sum of the contemporaneous and lagged coefficients is clearly positive and statistically significant. The timing of the effect is, however, slightly distinct. While the influence of the expected

[15] The inclusion of the lagged excluded instruments as controls sharpens the identification, as it implies that only the changes in US monetary policy within a quarter (relative to the preceding quarter) can cause exogenous variations in the STIRs of the other countries.

[16] In our baseline specification, only the contemporaneous values of $\Delta STIR_t^{US}\ x\ KAO_{i,t}$ and $MPS_t^{US}\ x\ KAO_{i,t}$ are actually excluded instruments, whereas their lagged values also feature as controls in the second stage. We choose this specification because the exclusion restriction (i.e., the assumption that US monetary policy decisions do not affect local house prices elsewhere other than through the local short-term interest rate) becomes somewhat less compelling as we increase the time horizon between when the two are captured. We will show in the robustness section that treating the lagged values of $\Delta STIR_t^{US}\ x\ KAO_{i,t}$ and $MPS_t^{US}\ x\ KAO_{i,t}$ as excluded instruments leaves the results qualitatively unchanged.

component of the $\Delta STIR_t^{US}$ materializes contemporaneously, that of the unexpected components generally does so with a one-quarter lag. We interpret this finding as a reflection of the fact that monetary policy meetings are regular but infrequent and that many major central banks have theirs either very close to or even slightly before FOMC meetings, making it less likely that the surprise component of FOMC decisions is immediately reflected in local short-term interest rates.

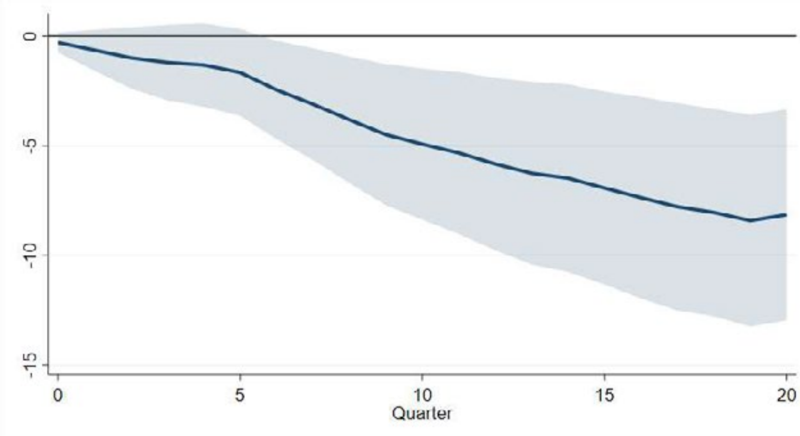
The second-stage results are reported in Table 2. The various summary statistics suggest that the model explains between one-third and half of the variation in real house prices (based on the R2) and that the excluded instruments are indeed relevant determinants of the local $\Delta STIR_{i,t}$ (based on the Kleibergen–Paap Wald rk first-stage F-statistic). We generally fail to reject the Hansen-J overidentification test by a comfortable margin. The associated p-value averages 0.46 over the 20-quarter IRF horizon and remains comfortably above standard significance levels (e.g., p = 0.10), except at the very end of our IRF horizon.

The coefficients further suggest that real house prices are influenced by a wide range of macroeconomic circumstances. We illustrate this in Table 2, where – for readability purposes – we again focus on the STIR shocks and the control variables that enter contemporaneously (omitting their lags). Regarding the latter, we find effects that are intuitive and consistent with the literature (e.g., Andrews, 2010; Duca et al., 2010; Crowe et al., 2011; Hott and Jokipii, 2012; Igan and Loungani, 2012; Cerutti et al., 2017). For example, a positive output gap and faster GDP growth both support future house prices in a statistically significant way, while higher inflation reduces them, at least in real terms. The influence of share prices is positive – consistent with some degree of aribtrage between financial assets and real estate – but quantitatively more limited.

The exogenous variations in STIRs themselves have a pronounced negative effect on real house prices; however, these variations take time to materialize. As shown in Figure 4, the initial reaction is statistically and economically insignificant at first but increases considerably after about 4 quarter. The effect eventually peaks at approximately 8%, about five years after the initial shock. This negative effect on house prices materializes through a persistent transmission to relevant interest rates and a contraction in household credit (as a % of GDP).

The monetary transmission is illustrated in Figure 5. The top-left graph (Figure 5A) shows that the STIR itself increases persistently and even overshoots. This finding is consistent with those of Jordà et al. (2015) and may imply that US monetary policy often leads the global monetary cycle and may thus influence more than one individual policy decision. In the robustness section, we constrain future STIR shocks (i.e., between time t and $t + h$) to zero to illustrate that this overshooting is not driving our result. The reaction of the STIR is mirrored in interest rates more relevant for house purchases. The pass-through to typical mortgage rates (Figure 5B) is almost immediate, broadly complete and highly persistent (i.e., converging back to zero only toward the end of the horizon) and leads to a significant reduction in household credit (as a % of GDP, Figure 5C). Only the reaction of real rents is statistically insignificant (Figure 5D);

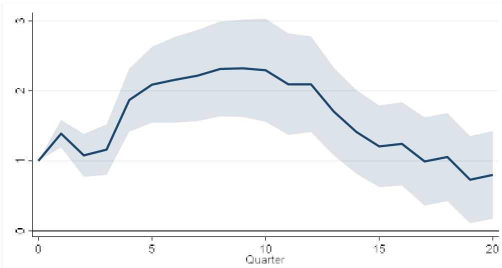
Figure 4: The house price reaction to a monetary policy hike



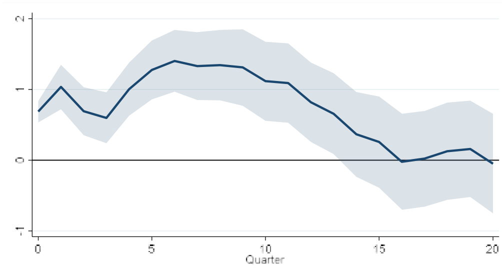
Note: The figure shows the IRFs for real house prices in % to a 1 pp increase in short-term interest rates. The shaded area corresponds to the 90% confidence interval. Robust standard errors are clustered at the country level.

Figure 5 : Monetary policy transmission

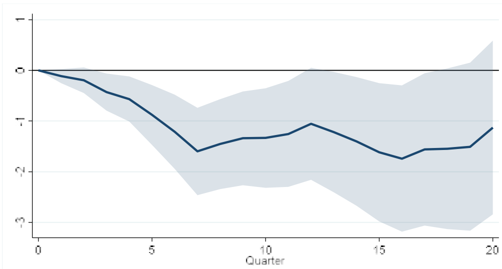
A. Short-term Interest Rate (in pp)



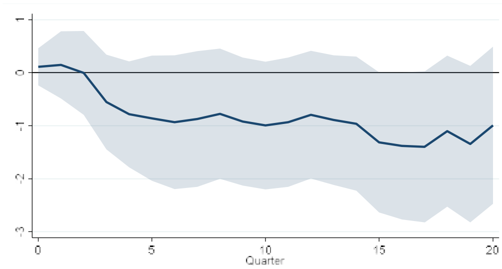
B. Mortgage Rate (in pp)



C. Household credit (as a % of GDP)



D. Real Rents (in %)



Note: The figure shows the IRFs for the short-term interest rate, typical mortgage rates, household credit and real rents to a 1 pp increase in short-term interest rates. The shaded area corresponds to the 90% confidence interval.

the negative point estimates contrast somewhat with the findings of Dias and Duarte (2019), who find a positive effect on both nominal and real rents in the case of the US.[17]

[17] Dias and Duarte (2019) show that an increase in mortgage rates and home ownership costs pushes demand toward rental housing, which depresses homeownership rates and house prices but places upward pressure on rents for up to four years.

The fact that we cannot confirm this result based on our international sample may reflect the influence of structural characteristics on the reactions of rental markets (e.g., size and liquidity, vacancy rates, rent controls).

Comparison with the literature

Our estimated reaction of house prices is toward the upper end of the range found in the literature. For example, among cross-country studies, Jordà et al. (2015) estimate a peak effect after three years of approximately 5%, and Sutton et al. (2017) find a semi-elasticity of house prices that reaches approximately 3% after five years for non-US advanced economies. Crowe et al. (2011) report effects that are even smaller. Based on a panel VAR with 22 countries, they find a semi-elasticity of only 1%. Bordo and Landon-Lane (2013) find effects similar in magnitude but much more short-lived, returning to zero after just seven quarters. Country studies (e.g., Corsetti et al., 2020; Dias and Duarte, 2019) also generally find smaller effects. A meta-analysis by Ehrenbergerova et al. (2022) suggests that the average effect extracted from 37 studies is only 1.2% after just two years. However, our estimate is not exceptionally large. Koeniger et al. (2022), who study the effect of monetary policy on house prices (and related variables) for Germany, Italy and Switzerland, find effects ranging from 5.4% to 24%.

A natural question that arises is where our relatively larger estimates come from. Specifically, to what extent are our results driven by the choice of the estimator and the identification method? To provide a partial answer to this question, we compare our LP-IV estimates with those obtained when estimating the same model with OLS (LP-OLS) or estimating an equivalent model with a panel VAR[18] with recursive identification. The latter approach has been among the most popular empirical strategies in the literature and the dominant approach among the studies used in the meta-analysis by Ehrenbergerova et al. (2022). We broadly attribute the difference between the LP-IV and the LP-OLS to the identification of monetary policy shocks and the difference between the LP-OLS and the panel VAR to the estimator, recognizing that the innovations in the STIR in the two estimators are not exactly identical[19].

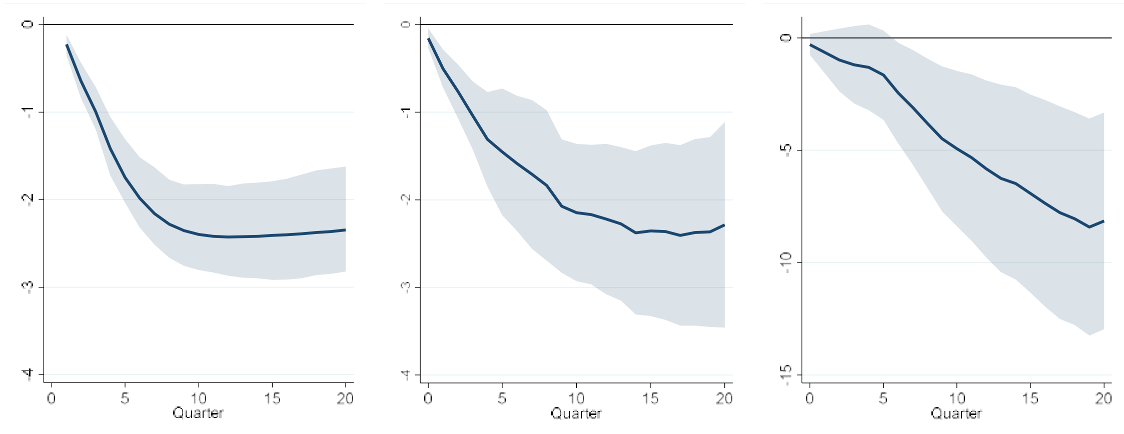
A comparison of the three estimates suggests that the difference in magnitude is largely related to the identification of the monetary policy shock, while the choice of estimator further contributes to the difference in dynamics. In Figure 6, we show the three house price reactions to a 1 pp monetary policy shock. Both the Cholesky panel VAR and the LP-OLS produce peak semi-elasticities that are much smaller than our baseline but comparable between the two, with peak semi-elasticities of 2% and 2.5%, respectively. The smaller effect of LP-OLS is consistent with the previously discussed attenuation bias and the fact that interest rate hikes are often a

[18] We estimate the panel VAR with 4 lags for all variables, ordering the variables in line with the LP-IV specification. This implies that house prices are allowed to react contemporaneously to all variables with the exception of rents and long-term interest rates, while all variables can react instantaneously to monetary policy shocks. Alternative orderings or lag length change the results very little (available on request).

[19] Recursive VARs have been used to identify monetary policy shocks, relying on restrictions on the within-quarter reaction among the variable in the system. The popularity of this choice of identification has faded, given the strong assumptions (e.g., of either a sluggish reaction of asset prices or an outdated information set of monetary policymakers) and often counterintuitive reactions of prices and output. Independent of whether the identified shocks are accurate, they generally differ from the simple change in the STIR.

Figure 6: House price reaction with different estimators

A. Panel VAR B. LP-OLS C. LP-IV



Note: The figure shows the IRFs for real house prices in % to a 1 pp increase in short-term interest rates, when estimated with a recursive VAR (A), a standard LP (estimated with GMM, but without excluded instruments) (B), and with the baseline LP-IV. The shaded area corresponds to the 90% confidence interval. Robust standard errors, clustered at the country level.

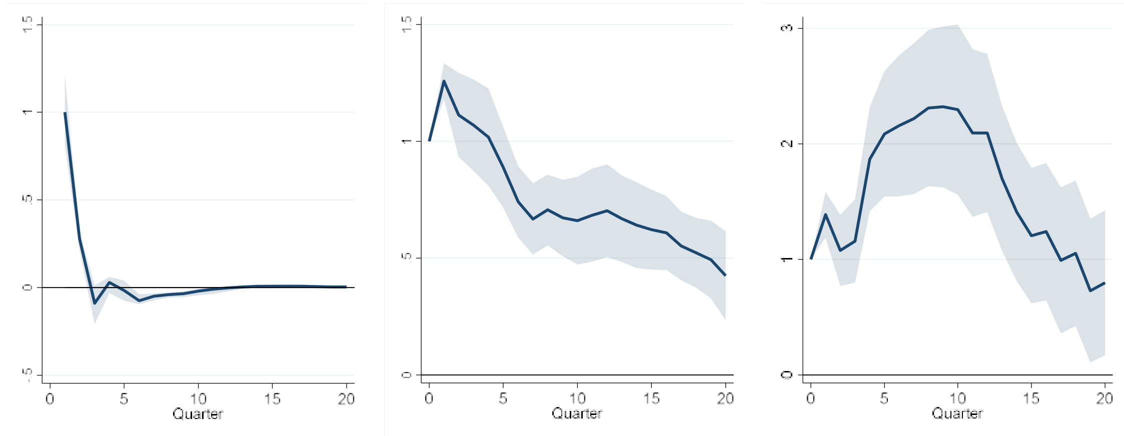
reaction to an overheating economy and are largely anticipated (and thus reflected in a higher longer-term interest rate even before the STIR increased). The fact that a recursive identification produces smaller results is in line with Bjørnland and Jacobsen (2010), who study a similar question for Norway, Sweden and the UK and also find that, compared to the preferred structural VAR with long-run restrictions, a recursive identification produces smaller or even counterintuitive effects.

The difference in terms of dynamics is also affected by the choice of the estimator.[20] In the case of the LP-OLS and the LP-IV, the peak effects are reached after 15 to 20 quarters, compared to about 10 quarters in the case of the panel VAR (Figure 6). This finding suggests that the effect on house prices materializes slightly faster when estimated by the panel VAR than when estimated via local projection. The greater persistence of the effect is in part reflected in the persistence of the monetary policy shocks themselves. The persistent effects of monetary policy shocks on the STIR when estimated with LP-OLS or LP-IV (Figure 7B and C) contrast with the extremely short-lived monetary policy shock identified with the panel VAR (Figure 7A). In this case, the STIR is back to zero (or actually below) already two quarters after the shock occurs.

[20] Plagborg-Møller and Wolf (2021) establish the equivalence in the IRFs at horizon h between a LP and VAR(h). Yet, as shown by Ramey (2016), the two approaches can produce different results in practice. Our findings support both arguments. While we find some differences when the panel VAR is estimated with 4 lags (as discussed), extending the lag length to 20 quarters (available on request) produces a pattern which is very much in line with the LP-OLS results but slightly larger point estimates.

Figure 7: Shock persistence with different estimators

A. Recursive VAR B. LP (OLS) C. LP-IV



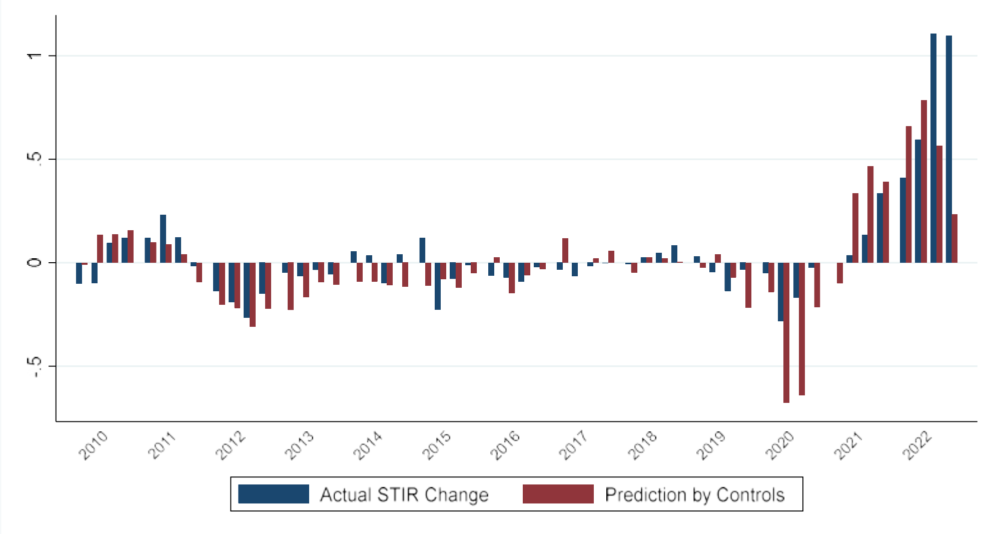
Note: The figure shows the IRFs for the short-term interest rate to a 1 pp increase in short-term interest rate itself, when estimated with a recursive VAR (A), a standard LP (estimated with GMM, but without excluded instruments) (B), and with the baseline LP-IV. The shaded area corresponds to the 90% confidence interval. Robust standard errors, clustered at the country level.

The contrasting dynamics of the STIR raise a larger question, namely, what are the relevant monetary policy movements for house price dynamics? Our setup proposes that significant price movements come from persistent changes in interest rates rather than from marginal surprises on one side or the other, which are reversed very quickly. Given that for most households, house purchases are highly infrequent and associated with administrative delays, we believe this is a more adequate perspective from which to think about the interest rate sensitivity of house prices. Yet, this raises the question of precisely how our results need to be interpreted.

Two additional aspects deserve emphasis when comparing our results to the literature or when applying them to the real world. First, our coefficients show the effect of an exogenous 1 pp shock to the short-term interest rate. Yet, depending on the identification, a large part of a monetary policy decision cannot be considered exogenous. Figure 8 illustrates this for our model. The model compares the predicted $\Delta\widehat{STIR}_{i,t}$ based on the controls in the second stage (i.e., the included instruments) with the actual $\Delta STIR_{i,t}$. We observe that with some exceptions, the predicted changes track the actual changes reasonably well. The exogenous component[21] of $\Delta STIR_{i,t}$ is thus significantly smaller than the observed change in the monetary policy rate or may even have the opposite sign, such as in the early 2020s, when the predicted increase in the

[21] We call the "surprise component" the part of the actual changes in the STIR that goes beyond those predicted by the controls. This is independent of our identified STIR shocks, which are the part of the variation driven by the excluded instruments (i.e., the contemporaneous US monetary policy variables).

Figure 8: Predicted and actual changes in the STIR



Note: The figure compares the averages of the actual changes in the STIR and of the predicted $\Delta\widehat{STIR}_{\imath,t}$, based on the included instruments.

STIR (i.e., the endogenous component) actually outpaced the observed increase until several quarters into the tightening cycle. Second, the estimation coefficient shows the effect of $\Delta STIR_{i,t}$, conditional on the rich dynamics in our model, including those of house prices themselves. This implies that when translating our results to the real world, the identified effect should be interpreted as a deviation from the counterfactual path of house prices and not as a deviation from the level of house prices at time t.

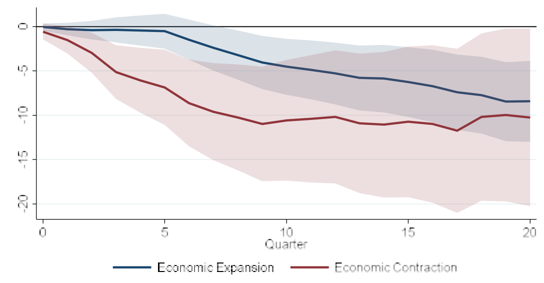
In this subsection, we highlighted that methodological differences go a long way toward explaining our relatively large effects compared to the literature. A final potential driver behind those differences could be the composition of the sample. This hypothesis finds support in analyses, such as Bjørnland and Jacobsen (2010) or Koeniger et al. (2022), that apply the same methodology to different countries only to find considerable differences in the reactions of different housing markets. Yet, rather than focusing on specific countries, the remainder of the section focuses on the role of the specific conditions that are prevalent at the time of the shock.

3.2. The role of initial conditions

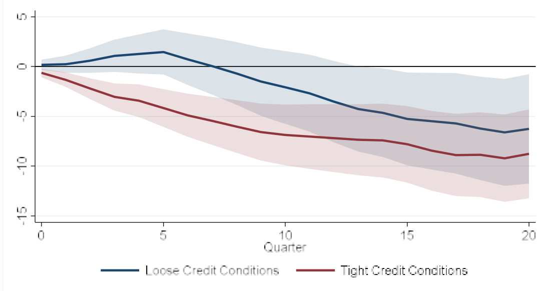
This subsection presents the results related to state contingency. For this, we estimate Equation (5), conditioning the reaction of house prices horizon up to $t + h$ on the initial conditions at time t of the 7-quarter moving average of four different conditioning variables ($s_{i,t}$), namely, the output gap, credit growth, the initial level of the short-term interest rate, and the state of the housing market. Figure 9 compares the house price reactions in low (red) and high (blue) states, corresponding to the 20th and 80th percentiles, respectively, in the distribution of $s_{i,t}$. Generally,

Figure 9: House price reaction depending on cyclical conditions

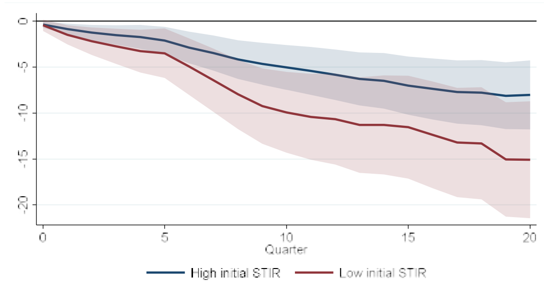
A. Output gap



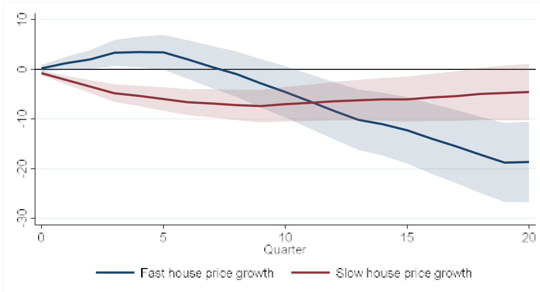
B. Credit growth



C. Level of the short-term interest rate



D. House price growth



Note: The figure shows the IRFs of house prices to a 1 pp increase in short-term interest rates depending on the underlying conditions, captured by the level of the smooth transition function, constructed with trailing 7-quarter moving average of globally standardized variables. The red curve (low state) corresponds to the STF taking a value of 0.8. The blue curve (high state) corresponds to STF=0.2. The shaded area corresponds to the 90% confidence interval.

the results highlight that the reaction of house prices varies greatly depending on initial conditions.

Output gap

Figure 9A compares the house price reaction when the initial output gap is approximately -2% of potential GDP (red line) to that when it is +1% (blue line). The response of house prices materializes significantly faster and is somewhat larger when the hike in the STIR occurs in an environment with a negative output gap. The interaction coefficient (i.e., the difference between the two lines) is, however, no longer statistically significant at standard significance levels (e.g., at p=0.1) after $t + 15$ (see Appendix A.2. for related output tables). This result is consistent with the fact that negative output gaps are often associated with lower income growth and strained household balance sheets, making an increase in the debt financing costs a more binding constraint.

Credit growth

The picture is similar for initial credit conditions (Figure 9B). The house price reaction is again faster if the tightening occurs when credit conditions have already been tightening (e.g., an average decrease of 1.3 pp in the ratio of household credit to GDP, red line). On the other hand, when credit conditions are particularly loose (i.e., an average increase in the household credit-to-GDP ratio of approximately 2 pp, blue line), the reaction of house prices is muted for even longer than in the unconditional baseline. The point estimate of the medium-term decline is also smaller, but the difference is again not statistically significant. The results illustrate that short-term interest rates are not the only factor determining access to debt financing and that financial deepening, for example, due to an easing of regulation (Ortalo-Magné and Rady, 1999), may amplify or offset monetary policy decisions.

Level of the short-term interest rate

The level of the initial STIR also matters but more in terms of scale than for the dynamics. Figure 9C compares the house price reaction when the initial short-term interest rate is approximately 1% (red line) to that when the STIR is initially 7% (blue line). The dynamics of the reaction are very similar, but the magnitude is clearly nonlinear, as it increases by approximately 50%. The larger effect when interest rates are low is intuitive since a 1 pp increase in the interest rate translates into a larger proportional increase in the cost of external financing. The difference between the two curves is, however, only marginally statistically significant, reaching p-values of 0.07 toward the end of the sample (see again Appendix A.2. for the relevant output table).

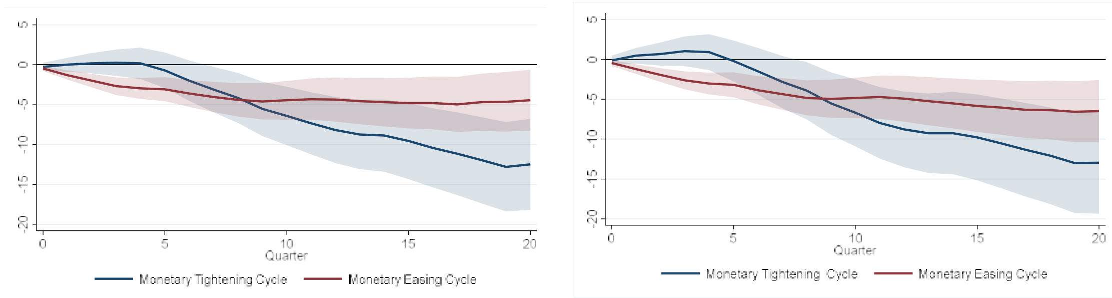
The question that arises is whether the effect of a 1pp increase in the STIR is nonlinear in a roughly proportional way, i.e., it is actually four times larger if the initial interest rate is 1% than if it is 4%. We investigate this by comparing the results in Figure 9C with the results from a specification where interest rates are defined in logs. Given the negative values of the STIR and our desire for symmetry with inflation, our system does not extend naturally to such an exercise. Independent of how we resolve these issues, the results (available on request) suggest that the effect of a 1 pp increase in STIR declines in a less than proportional way with increasing STIR, i.e., it is smaller at low STIR levels and larger at high STIR levels than what a purely log-linear relationship would suggest.

House price growth

The influence of the preceding dynamics in the housing market itself is statistically more pronounced. Figure 9D illustrates this by comparing the effect of an STIR hike when the housing market is booming (an average annual increase of approximately 7% over the preceding 7 quarters, blue line) with that when the housing market is in a slump (declining by 2.3% on average, red line). The results suggest that interest rates affect a fast-growing housing market with a significant time lag. In the medium term, the negative effect is amplified, reaching a semi-elasticity of almost 20% five years after the shock.

Figure 10: The direction of the monetary policy cycle

A. $STF_{i,t}^{\Delta STIR}$ B. Sign($\Delta STIR^{7qMA}$)



Note: The figure shows the IRFs for house prices to a 1 pp increase in short-term interest rates depending on the underlying conditions, captured by the level of the smooth transition function and constructed with trailing 7-quarter moving average of globally standardized variables. Low state = STF value of 0.8. High state = STF value of 0.2. The shaded area corresponds to the 90% confidence interval.

Direction of the monetary policy cycle

Beyond the initial level of the STIR, we follow other contributions (e.g., Tsai 2013, Simo-Kengne et al. 2013; Aastveit and Anundsen, 2022) in investigating whether the reaction of house prices depends on the direction of the monetary cycle, meaning whether monetary policy is tightening or easing. For this purpose, we use two approaches. First, we follow an approach identical to that used for the other conditioning variables. We thus take the 7-quarter MA of the changes in the STIR, obtain $STF_{i,t}^{\Delta STIR}$ and interact it with the shock, as shown in Equation (5). In the second approach, we simply define a dummy variable with the sign of the 7q-moving average of $\Delta STIR$ as the conditioning variable. The advantage of the former is the consistency with the treatment of the other variables and the fact that more pronounced monetary policy cycles (i.e., more extreme values in $STF_{i,t}^{\Delta STIR}$) receive a greater weight. The disadvantage is that average interest rates declined over the entire sample, meaning that the neutral $STF_{i,t}^{\Delta STIR}$ (i.e., the average) is not necessarily equal to zero. As shown in Figure 10, the two approaches produce almost identical results. Both approaches suggest that – conditional on preceeding dynamics and other macroeconomic determinants – the contractionary effect of a monetary tightening materializes more slowly but ends up being larger than the stimulating effect of a monetary easing.[22]

[22] Finally, we also test to what extent the strength of household balance sheets (e.g., measured by leverage), the share of shorter-term mortgages and the degree of rental market regulation affect the house price reaction. However, we were unable to ensure data coverage that is roughly comparable to the baseline results. The results – available on request – are thus not conclusive and generally statistically insignificant.

Discussion

Our results regarding the importance of house price dynamics are consistent with the abundant literature emphasizing momentum (Abraham and Hendershott, 1996; Piazzesi and Schneider, 2009; Guren, 2018) and exuberance (Martínez-García and Grossman, 2020) in real estate markets. This finding is also consistent with earlier evidence that changes in interest rates have a differential effect, e.g., because past house price developments affect the likelihood of obtaining favorable refinancing (Beraja et al., 2019). Yet, the results are only partially consistent with Goodhart and Hofmann (2008). Similarly, their evidence points to a significantly greater degree of price contraction during house price booms. Unlike us, however, they find no difference in the dynamics – that is, the speed with which the effect materializes – between booms and busts.

Regarding the role of the housing cycle, two qualifying comments are needed. First, our model includes rich autoregressive components to control for the typical dynamics. These, however, are not state dependent, which implies that the slight overshooting in the beginning may also reflect differences in the dynamics during the run-up to the monetary policy shock. Alternatively, if housing markets are more prone to overvaluation than to undervaluation, a larger medium-term reaction during a house price boom might not necessarily reflect a larger fundamental interest rate sensitivity of house prices but rather a larger preceding deviation of prices from their fundamental value. While we are not able to decisively refute these possibilities, neither of the two issues find strong support in our data.

3.3. Contemporary vulnerabilities to an interest rate shock

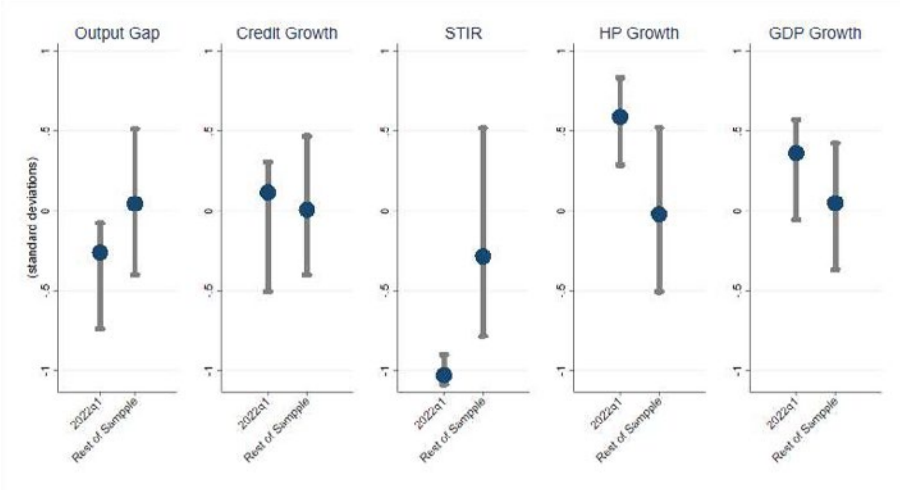
In the previous section, we treated every conditioning variable separately. This ignores the fact that some of these variables are correlated with each other and thus impairs our ability to assess overall housing market vulnerability at a given moment. In this subsection, we attempt to partly overcome this shortcoming by jointly estimating the influence of the four main conditioning variables. This allows us to illustrate how – based on historical patterns – the cyclical conditions in early 2022 (i.e., roughly the beginning of the latest tightening cycle) would have affected the house price reaction to an interest rate shock.

We proceed in two steps. First, we jointly estimate the role of the different conditioning variables. That is, we estimate the following equation:

$$\begin{aligned} y_{i,t+h} - y_{i,t-1} = \; & \alpha^i \\ & + \Delta STIR_{i,t}^{IV} \left[\beta_1^h \, STF_{i,t}^{ogap} + \beta_2^h \, STF_{i,t}^{Credit} + \beta_3^h \, STF_{i,t}^{STIR} + \beta_4^h \, STF_{i,t}^{HP}\right] \\ & + \gamma_h' \boldsymbol{X}_{i,t}^p + \varepsilon_{i,t+h} \end{aligned} \tag{8}$$

We continue to assume that the interactions between the conditioning variables and $\Delta STIR_{i,t}$ are endogenous and thus need to be instrumented in line with Equations (6) and (7). This leads to a total of five endogenous variables and a total of ten excluded instruments. As

Figure 11: The cyclical conditions in 2022-Q1



Note: The figure shows the median and the interquartile range of the 2022-Q1 and the average values of the standardized 7-quarter MA of the output gap, the growth of household credit (as a % of GDP), the level of the short-term interest rate and the growth in real house prices.

we will discuss below, this pushes the instrumentation strategy to its limit, at least for some specifications.

Before showing the results of this expanded specification, we illustrate the cyclical conditions (i.e., the 7-quarter MA of the variable itself) prevalent in 2022-Q1 in Figure 11. For each conditioning variable, the median and the interquartile range of the cross-sectional distribution for 2022-Q1 are compared with the same metrics for the remainder of the sample. The figure suggests that most of the sample still had substantially negative output gaps in early 2022 (Column 1). This is somewhat difficult to reconcile with other economic indicators, e.g., in the labor market[23], which suggest a more neutral cyclical position. Accordingly, and in light of the exceptional uncertainty regarding the output gap in the immediate aftermath of the COVID-19 pandemic, we report in the robustness section an alternative where we condition the reaction on GDP growth instead. The latter metric depicts a cyclical condition that is slightly positive on average (Figure 11, Column 5). The other cyclical variables point to credit growth close to the historic median (Column 2), an exceptionally low level of short-term interest rates (Column 3) and unusually strong growth in house prices (Column 4).

Qualitatively, the influence of the cyclical conditions remains in line with results based on separate estimations, both in terms of statistical significance and direction (bearing in mind that the $STF_{i,t}^{s}$ flips the ordering of the underlying $s_{i,t}$). However, the relative magnitude of the coefficients changes somewhat, in both absolute and relative terms. Table 3 shows that, based

[23] Unemployment rates in major advanced economies reach the lowest levels seen in decades. By Mach 2022, the unemployment rate (BLS) in the USA was 3.6%, just 0.1 pp above the level seen at the beginning of 2020, when it was at the lowest level since late 1960s. In the Euro Area, the unemployment rate fell below 7% for the first time since reporting started (in 2000 for the EA20 by Eurostat or even in 1990 for the EA19 by the OECD).

Table 3: Joint estimation of state dependency

	(1)	(2)	(3)	(4)	(5)	(6)
Dependent variable: Change in real house prices (in %)						
Horizon	**h=0**	**h=1**	**h=5**	**h=10**	**h=15**	**h=20**
Shock	–0.48	–0.73	–4.39**	–10.49***	–14.20***	–18.37***
	(0.40)	(0.68)	(1.91)	(2.75)	(3.58)	(4.34)
Shock X STF(HP)	–1.66*	–3.78**	–12.30***	–2.44	15.42*	26.93**
	(0.98)	(1.66)	(4.70)	(6.79)	(8.80)	(10.70)
Shock X STF(STIR)	–2.83	–4.94	–13.17	–19.65	–21.70	–42.54**
	(2.02)	(3.44)	(9.73)	(14.05)	(17.91)	(21.67)
Shock X STF(o-gap)	–0.38	0.56	–5.42	–10.20	–18.22**	–23.52**
	(1.00)	(1.70)	(4.81)	(6.93)	(8.95)	(11.01)
Shock X STF(Credit)	–1.00	–1.94	–7.26**	–9.57*	–7.40	–11.12
	(0.73)	(1.25)	(3.53)	(5.10)	(6.57)	(7.94)
N	2518	2518	2518	2516	2459	2326
R2	0.436	0.480	0.333	0.432	0.407	0.356
Hansen-J p-value	0.915	0.810	0.211	0.008	0.011	0.039
First-stage F stat.	15.899	15.899	15.899	15.829	15.933	15.190

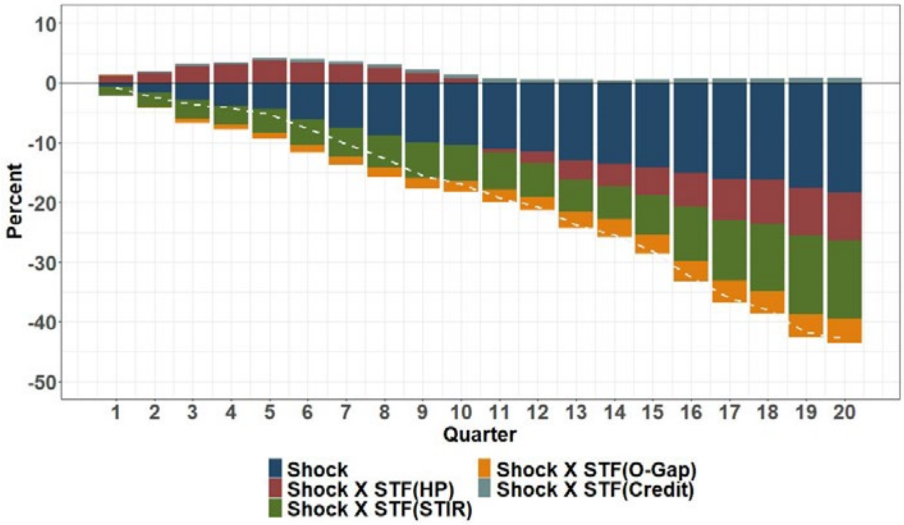
Note: The table shows the second-stage result of the 2SLS estimation for the shock variable itself as well as its interaction with the demeaned STF of the main conditioning variable. The dependent variable is the change in the real house prices between times t-1 and t+h. The results for control variables are omitted for readability. Standard errors in parentheses. Star-values: * p<0.10; ** p<0.05; *** p<0.01.

on the joint estimation, the variable with the most pronounced influence on the reaction of house prices is the level of the STIR (in contrast with the rather muted influence when estimated separately).

We suggest caution when interpreting the absolute magnitude of the coefficients from this joint estimation. The influence of the conditioning variables reported in Table 3 is substantially greater than when these variables are estimated separately (see Figure 9 or Table 7 in Appendix A.2.). The same is true when comparing the unconditional component (i.e., the coefficient on the uninteracted shock variable) with the baseline result reported in **Error! Reference source not found.**. These inflated coefficients may be due to the use of a less clean instrumentation strategy. Notably, the Hansen-J test suggests that the exclusion restrictions are violated over a large share of the IRF horizon. The associated p-value is only 0.14 on average (compared to 0.46 in the baseline) and falls below 0.1 as early as horizon $t + 3$. We show in the robustness section that the alternative specification, which relies on GDP growth to capture the cyclical condition, produces qualitatively similar results but with magnitudes closer to those in the baseline as well as more reassuring Hansen-J statistics. The other summary statistics still show the strong explanatory power of the model itself (the R2) and of the excluded instruments in the first stage (the F-statistic).

Figure 12: The semi-elasticities of house prices in 2022-Q1

Using the output gap as proxy for cyclical condition



Note: The figure shows the average model-implied semi-elasticity of house prices to a 1 pp increase in short-term interest rates given the cyclical conditions of 2022-Q1, captured by the level of the smooth transition function of output gap, credit growth, the level of the short-term interest rate, and the past house price growth. The shaded area corresponds to the 90% confidence interval.

As a second step, we combine the results from this joint estimation with the $STF_{i,t}^{s}$ values of 2022-Q1 to condition the house price reaction to the circumstance prevalent at the onset of the latest tightening cycle. The contribution of the cyclical conditions is calculated as the sum of the unconditional coefficient and the respective products of the median 2022-Q1-value of the corresponding $STF_{med,t}^{s}$ and the coefficient associated with the $\Delta STIR_{i,t}^{IV}\ x\ STF_{i,t}^{s}$ interaction, i.e., $\beta_{med,2022Q1}^{h} = \beta^{h} + \sum_{n=1}^{4} \beta_{n}^{h} * STF_{med,2022Q1}^{n}$.

Figure 12 shows the median contributions of the cyclical conditions. Overall, these findings suggest that the sensitivity of house prices was amplified, particularly in the medium term, but at times with offsetting contributions from different cyclical conditions. An amplifying contribution over the entire horizon comes from the low level of the initial STIR (shown in green) and the below-average output gap (in orange). The contribution of household credit was also broadly constant but minimal, in line with a measure of credit conditions, which was close to average in 2022-Q1. Finally, the figure suggests that the very dynamic state of the housing market normally contributes to a muted price effect at first but amplifies it in the medium term.

The main take-aways from this section are thus (i) that house prices react slowly but significantly to increases in short-term interest rates, (ii) that the reaction of house prices depends substantially on the prevalent conditions at the time of the monetary tightening and (iii) that the conditions in 2022-Q1 have historically been associated with an amplified house price reaction, particularly in the medium-term.

Table 4: The unconditional reaction with alternative specifications

Dependent variable: Change in real house prices over 20 quarters (in %)

	(A) original	(B) all contemp.	(C) no contemp.	(D) 8 lags	(E) 12 lags	(F) Cou spec. trends
shock	–8.147***	–8.506**	–8.137***	–10.253***	–7.389**	–11.141***
	(2.929)	(3.663)	(2.987)	(3.525)	(3.076)	(3.036)
N	2477	2475	2477	2350	2231	2477
R2	0.313	0.317	0.306	0.323	0.382	0.412
Hansen–J p–value	0.031	0.026	0.035	0.034	0.058	0.013
First–stage F stat	20.355	15.409	21.191	21.811	31.995	49.286

Note: The table shows the estimated impact of a STIR shock on real house prices at the horizon t+20 depending on the specification. The results for control variables are omitted for readability. Standard errors in parentheses. Star–values: * p<0.10; ** p<0.05; *** p<0.01.

4. Robustness

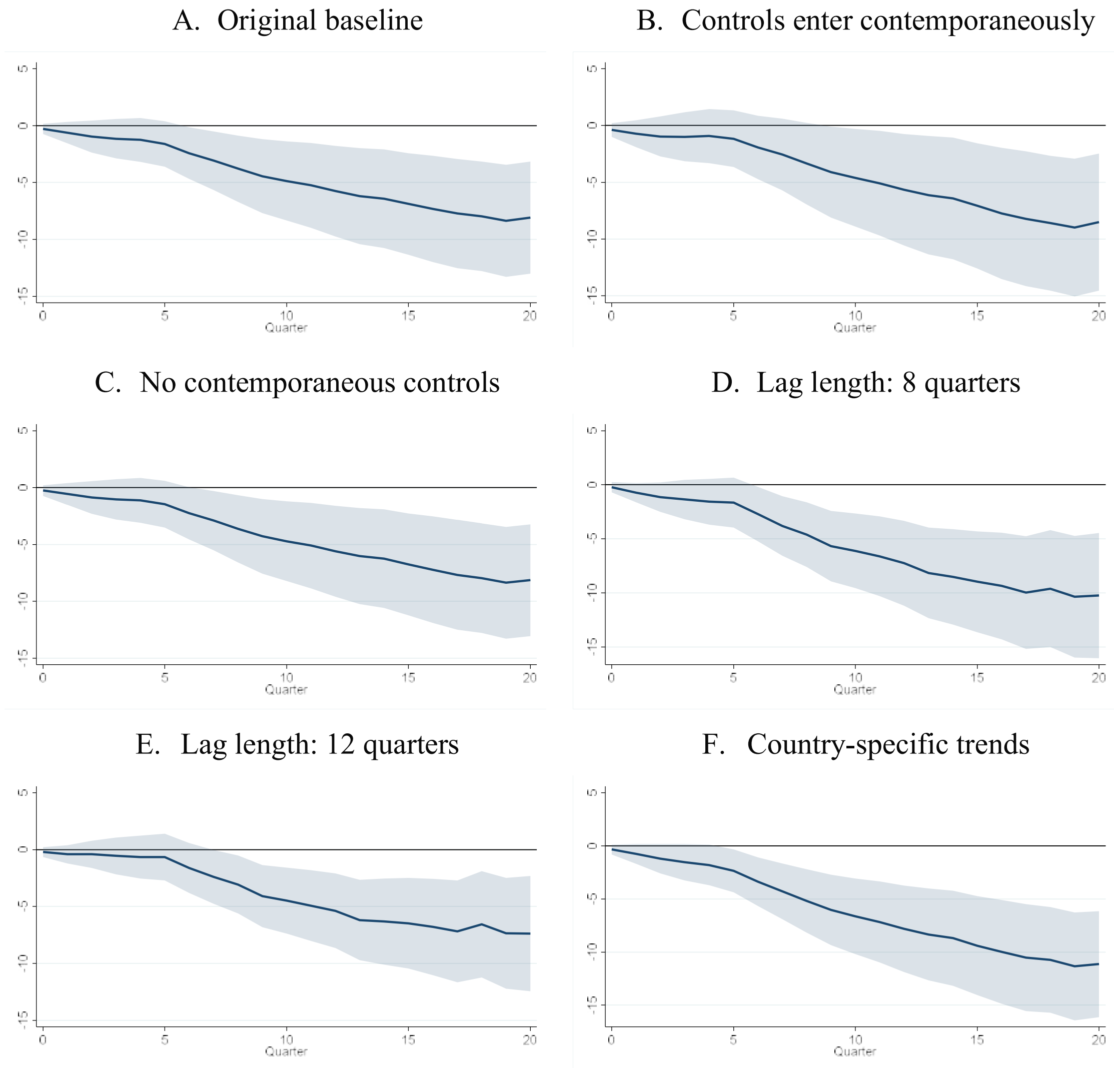
When we presented the main results, we only briefly discussed the relevance of the chosen specifications. We do this now in the robustness section. Sequentially, it explores the sensitivity of the unconditional reaction of house prices to different choices regarding the control variables, the excluded instruments and the treatment of "future shocks", i.e., changes in the STIR that occur between t and $t + h$. Finally, we will show how the joint estimation and the influence of the cyclical conditions in 2022-Q1 change when GDP growth, rather than the output gap, is used as a proxy for real economic conditions.

4.1. The relevance of controls for the unconditional reaction

The first robustness check examines the relevance of how the control variables are included in our 2SLS estimation. In the baseline specification, we allowed the variables that plausibly influence monetary policy choices such as inflation, the output gap, credit growth and share prices to enter contemporaneously but excluded a contemporaneous effect of the variables we considered more related to the monetary transmission, such as longer-term interest rates or rents. We included four lags for all control variables but no country-specific trends. Here, we illustrate to what extent these choices are consequential.

We run the IV estimation of Equation (2) in five additional specifications, which we report in Table 4 (Column A again shows the baseline estimation for comparison). First, we allow all control variables to affect house prices – and the STIR in the first stage – contemporarily (Column B). We then go in the opposite direction and exclude a contemporaneous impact for all controls (C). We increase the lag length to 8 quarters (D) and 12 quarters (E; using the original ordering of the variables). Eventually, we add – in addition to country fixed effects –

Figure 13: **Robustness of the unconditional reaction to different specifications**

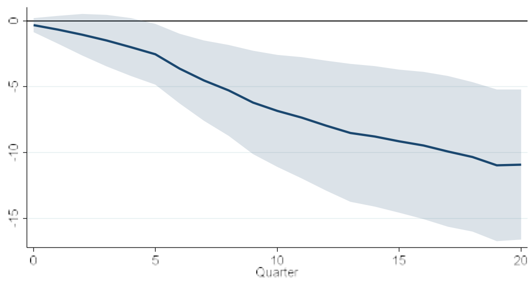


Note: The figure shows the reaction of real house prices to a STIR shock depending on the precise specification. A: original baseline; B: all controls enter contemporaneously; C: all controls enter with a 1-quarter lag; D: the lag length is extended to 8 quarters; E: the lag length is extended to 12 quarters; and F: country-specific trends. The shaded area corresponds to the 90% confidence interval. Robust standard errors, clustered at the country level.

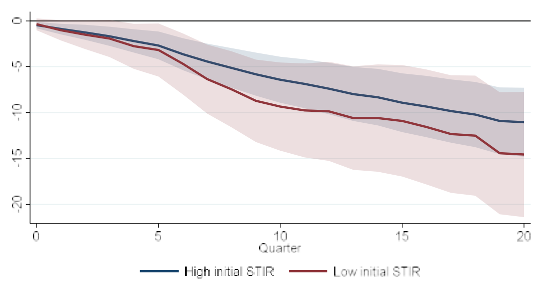
country-specific trends (F). As a complement to Table 4, which focuses on the magnitude of the medium-term impact (i.e., 20 quarters after the shock), Figure 13 plots the corresponding house price reactions over the usual 20-quarter horizon.

Figure 14: Robustness to using the mortgage rate as control

A. Unconditional reaction of HP



B. HP reaction conditional on STIR



Note: The figure shows the unconditional reaction of real house prices to a STIR shock (A), as well as that conditional on the level of the STIR (B), when mortgage rates are used as a control instead of the LTIR. The shaded area corresponds to the 90% confidence interval. Robust standard errors are clustered at the country level.

Two things stand out: First, both the magnitude of the medium-term effect and the associated standard errors vary little. Only the specifications with 8 lags (Column D) and with country-specific trends (Column F) produce a slightly larger point estimate; however, this trend is reversed if the lag length is extended further (Column E)[24]. Second, the pattern over the IRF horizon remains almost unchanged. This remarkable robustness extends to the state-contingent house price reaction. The relevant results for more consequential specification changes – the specifications used for Columns (D) and (F) – are shown in Appendix A.3.1. The results for the remaining specifications are available on request.

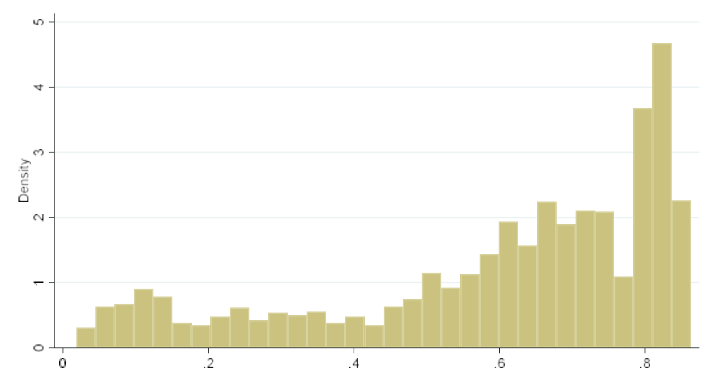
4.2. Mortgage interest rates vs. long-term government yields

In our baseline specification, we use the 10-year government bond yield as a control. Compared to the mortgage rate, it has the advantages of (i) being available for a broader sample and (ii) being more consistent across countries. Nevertheless, it is an imperfect proxy for typical mortgage rates, as mortgage market characteristics (e.g., popular maturities) vary considerably across countries.

Here, we investigate whether our main results also hold when we use the mortgage rate (and its lags) instead of the LTIR as a control. This decreases the sample by approximately 20%. Our unconditional results are qualitatively unchanged, but the point estimate does increase somewhat (i.e., peaking at just above 10% at the end of the horizon; Figure 14A). The robustness of the results extends to the variables of transmission as well as most conditional reactions (shown in Appendix A.3.2.). The only exception is the difference between the high- and low-STIR regimes, which becomes statistically insignificant (Figure 14B). In part, this may

[24] The results remain robust even if the lag length is extended to an implausible 20 quarters.

Figure 15: **The distribution of $STF_{i,t}^{STIR}$ in the $\Delta \boldsymbol{MR_{i,t}}$ sample**



Note: The figure shows the distribution of $STF_{i,t}^{STIR}$ in the constrained sample (at h=20).

be because shrinking the sample further leads to a more skewed distribution of the relevant $STF_{i,t}^{s}$ (as illustrated in Figure 15).

4.3. Robustness to alternative specifications for excluded instruments

Having shown that the way we handle our control variable, i.e., the included instruments, is largely irrelevant to the results, we now turn to the excluded instruments. For this purpose, we check how our estimates change if we either reduce or increase the set of excluded instruments while remaining close to the broader instrumentation strategy.

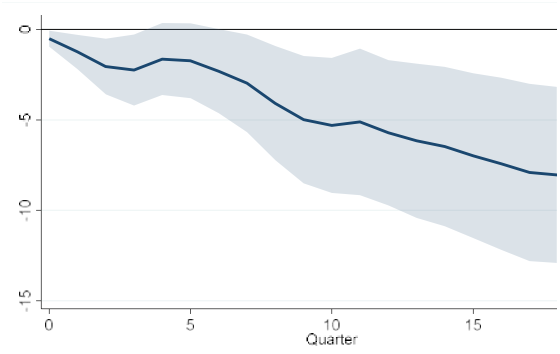
To reduce the set of excluded instruments, we drop the unexpected component of US monetary policy decisions (MPS_t^{US}) and focus only on the actual changes in the US STIR ($\Delta STIR_t^{US}$). This approach brings our identification strategy closer to that of Jordà et al. (2015) but neglects relevant information that also supports the exogeneity of the instruments. To increase the set of excluded instruments, we also add to the contemporaneous values the lags of the US monetary policy variables (of both the $\Delta STIR_t^{US}$and the MPS_t^{US}). This does not alter the first stage – since the lags of the US monetary policy variables were already included as standard controls – but omits them from the second stage.

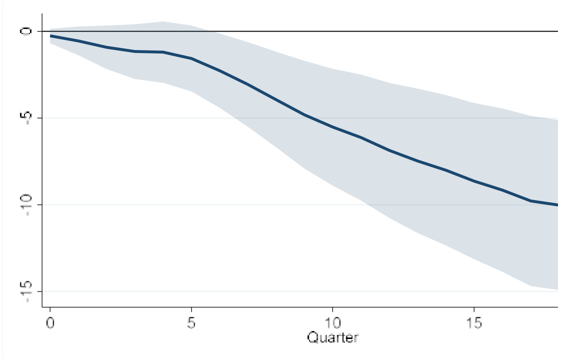
Figure 16 compares the house price reactions under these two alternatives. The picture again remains largely unchanged, although also including the lags of the US monetary policy variables as excluded instruments slightly increases the estimated effects. The unconditional reaction of the transmission variables (corresponding to Figure 5) as well as the house price reaction conditional on the cyclical factor (corresponding to Figure 10) are shown in Appendix A.3.3. Also in these cases, the results remain broadly unchanged, though slightly less convincing. In particular, dropping the MPS_t^{US} makes some results related to the transmission channels more erratic. On the other hand, including lagged US monetary policy variables as excluded instruments accentuates the influence of the housing cycle somewhat (Figure 23D)

Figure 16: Robustness to the choice of excluded instruments

A. Only $\Delta STIR_t^{US}$

B. Lagged US monetary policy variables are also excluded instruments





Note: The figure shows the reaction of real house prices to a STIR shock depending on the precise treatment of the excluded instruments. A: only the nominal changes in the US STIR are the excluded instrument; B: the lags of the nominal and unexpected component of $\Delta STIR_t^{US}$ are also treated as excluded instruments (rather than being part of the control vector). The shaded area corresponds to the 90% confidence interval. Robust standard errors are clustered at the country level.

but attenuates that of the initial level of the STIR (Figure 23C). It also further accentuates the overshooting of the STIR itself (Figure 22A). We turn to this issue next.

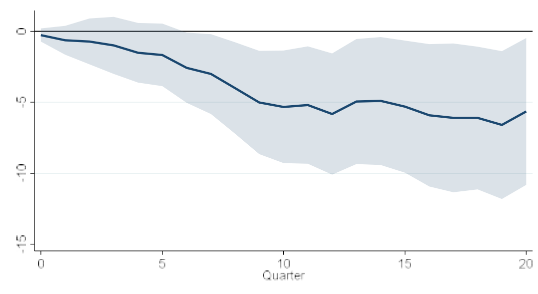
4.4. Controlling for future changes in STIR

Our baseline specification leaves future changes in the STIR unconstrained, consistent with Jordà (2005) and most of the related literature. In our setup, this results in an IRF for the STIR that starts at 1 (by construction) but continues to grow over roughly two years before receding over the medium term. This seems to be in line with monetary policy cycles, which typically consist of several interest rate hikes in the same direction but sharply contrast how monetary policy shocks are analyzed in more theoretical setups. To attenuate this potential shortcoming, we constrain the STIR shock to be equal to 1pp in $t-1$ but 0 thereafter; i.e., we control for any $\Delta STIR_{i,t}$ that occurs between t and $t+h$.

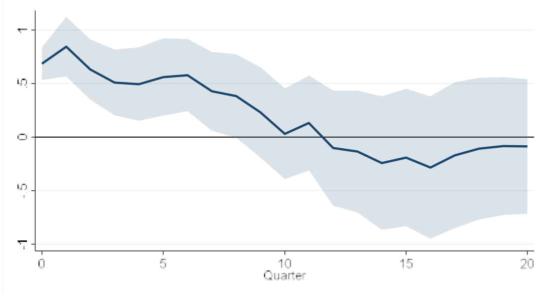
Figure 17 plots the resulting reaction of house prices and of the other transmission variables. It omits the IRF of the STIR itself, since it is by construction a flat line at value 1. The other IRFs are surprisingly similar to our baseline. Although the effect on the mortgage rate is more short-lived than in Figure 5 (gradually returning to zero over a period of approximately 3 years), the effect on private credit is only slightly less persistent and very similar in magnitude (peaking at –1.5 pp seven quarters after the shock). The reaction of house prices is also similar. The semi-elasticity again peaks roughly five years after the shock but at approximately 6.5%, rather than at the 8% in our baseline. The robustness of the results extends to the state contingency, as the

Figure 17 : Baseline results controlling for "forward shocks"

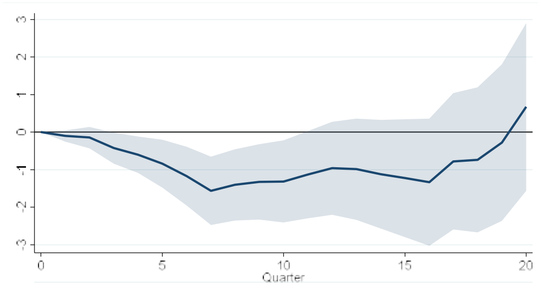
A. Real house prices



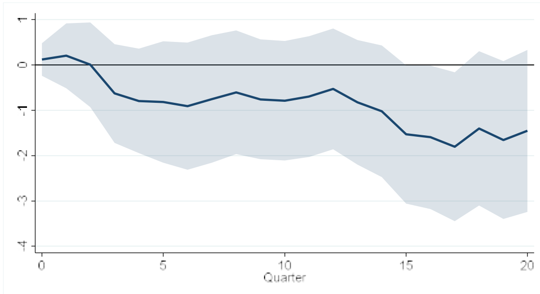
B. Mortgage rates



C. Household credit (as a % of GDP)



D. Real rents



Note: The figure shows the IRFs for the real house prices, typical mortgage rates, household credit and real rents to a 1 pp increase in short-term interest rates when changes in the STIR between t and $t + h$ are controlled for. The shaded area corresponds to the 90% confidence interval.

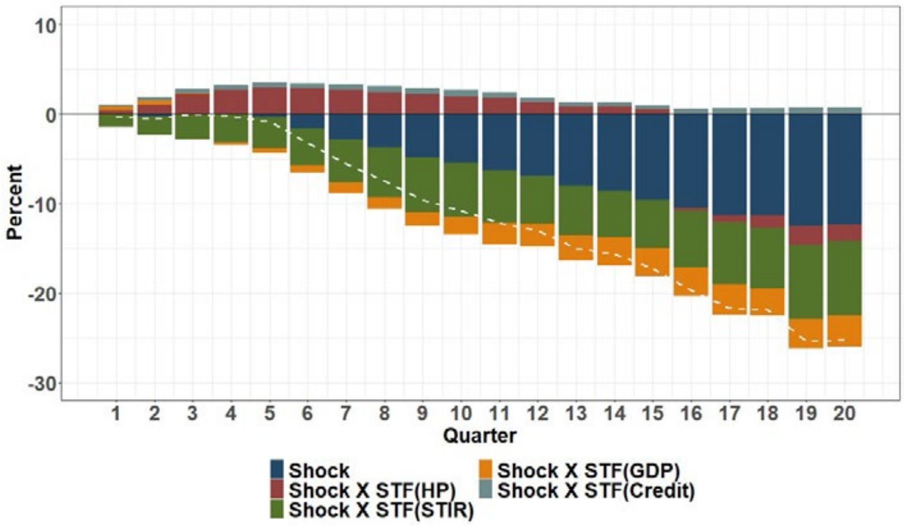
inclusion of forward shocks does not result in any meaningful differences in the IRFs when conditioning on the usual cyclical conditions (shown in Appendix A.3.4.).

4.5. GDP growth as an alternative proxy for cyclical conditions

We used the output gap as the standard proxy for economic activity. Relative to GDP growth, it has the advantage of being a more direct measure of economic slack and of not being affected by base effects. However, the variable is estimated, which can pose a challenge when the structure of the economy, i.e., the supply side, is subject to rapid transformation. This was notably the case during and immediately after the COVID-19 pandemic. We thus explore in this robustness check how the influence of the 2022-Q1 conditions changes if we use the annual growth rate of real GDP as an alternative measure of economic activity. In addition to the change in one of the $STF_{i,t}^{s}$, we follow the same process as outlined in Section 3.3.

Figure 18 depicts the corresponding contributions (with more details reported in Appendix A.3.5.). The shape is very similar to that in Figure 12. We again observe a pronounced negative contribution from the low level of the STIR, an almost negligible contribution from credit growth and a contribution from past house price growth, which first attenuates and then amplifies the effect. However, there are two differences. First, the contribution from economic

Figure 18: The semi-elasticities of house prices in 2022-Q1



Note: The figure shows the average model-implied semi-elasticity of house prices to a 1 pp increase in short-term interest rates given the cyclical conditions of 2022-Q1, captured by the level of the smooth transition function GDP growth, credit growth, the level of the short-term interest rate, and the past house price growth. The shaded area corresponds to the 90% confidence interval.

activity goes from amplifying to attenuating, in line with the differences in the underlying variable (Figure 11). Second, all the contributions are slightly smaller and more in line with the effects estimated in the baseline. This is reassuring and may be related to the fact that the associated Hansen-J tests (reported in Table 8 in the Appendix A.3.5.) comfortably fail to reject H0 over the entire IRF horizon (with an average p-value of 0.31). This suggests that while the magnitude of the coefficients from the joint estimation (reported in Section 3.3. may be exaggerated (e.g., by a weakness in the instrumentation), the qualitative conclusion remains robust.

We conclude from this section that our results are robust to various alternative specifications regarding the control variables, the instrumentation and the treatment of changes in the STIR.

5. Conclusion

This paper investigates the transmission of short-term interest rates to house prices in a cross-country sample of mostly advanced economies. We follow previous studies in relying on local projections to estimate the dynamics of the effects and in identifying exogenous changes in interest rates based on monetary policy decisions in the US. Yet, we allow the effects of interest rates to vary over a rich set of cyclical conditions, which characterize the domestic housing market and the broader economy. Compared to Jordà et al. (2015), the closest existing paper to ours, we also rely on a more recent sample that is more suitable for informing us about current vulnerabilities.

Our key finding is that interest rates have a larger and more protracted effect on house prices than suggested by many of the preexisting studies. On average, an exogenous 1 pp increase in the short-term interest rate depresses house prices by approximately 8% over a period of up to five years. However, the effect is nonlinear and highly dependent on preexisting conditions. For example, the reaction of house prices materializes significantly faster when their increase occurs in a recession or when credit conditions are tight to start with; they are also larger when initial interest rates are low. A preceding boom in house prices slows the house price reaction at first but amplifies the price decrease in the medium term. We show that cyclical conditions in early 2022 – the year with the fastest monetary tightening in decades – typically amplified the effect on house prices, particularly in the medium term.

This paper has important policy implications. It highlights that a correction in house prices may take a considerable amount of time and that existing vulnerabilities in the housing sector may be greater than a simple – i.e., an unconditional – analysis would suggest. Even if the exogenous component of the recent increase in short-term rates is relatively small compared with the total change observed, it is still large enough – should interest rates be equally persistent as in the past – to lead to a significant decline in house prices in many countries.

The findings also have implications for monetary policy, for which housing markets are an important transmission channel. Swings in house prices affect economic activity either through construction activity or through the implications that housing wealth and the tightness of credit constraints have for household spending and saving decisions (e.g., Eugster, 2024). By implication, state dependence in the reaction of house prices can also help explain why the effect of a monetary tightening depends on underlying circumstances, a topic that has been the subject of an important nascent literature (e.g., Tenreyro, and Thwaites, 2016; Barnichon and Matthes, 2018; Debortoli et al. 2020, Boissay et al. 2023).

The paper has academic implications as well, as it highlights the relevance of state dependence in areas where this topic has traditionally been underappreciated. Even with regard to the link between interest rates and house prices, room for further research remains substantial. While we have been able to demonstrate the empirical relevance of state dependence, our work does not provide a coherent theoretical framework or a structural investigation that would allow a clearer identification of relevant mechanisms. In addition, a similar analysis focusing on different elements of mortgage contracts is left for further research.

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A. Appendix

A.1. Variable description and countries

Table 5: Variable definition and sources

VARIABLE	NAME	DESCRIPTION	SOURCE
Dependent variables			
Real house prices	HP	Real house price index (2015 = 100)	OECD
Real rents	RENTS	Real rents index (2015 = 100)	OECD
Mortgage rate	MR	Interest rate on new loans to household for home purchase, fixed rate and with 5-to-15-year maturity	Oxford Economics, ECB, SNB
Long-term interest rate	LTIR	10-year government bond yield	OECD
Short-term interest rate	STIR	Money market rate or Treasury bill rate	OECD
IVs			
US short-term interest rate	$\Delta STIR^{US}$	First instrument that represents changes in the US short-term interest rate	OECD
US monetary policy shock	MPS	Second instrument that captures changes in the three-month ahead rate of Federal Funds futures (FF4) within a 30-minute time window around FOMC announcements; it identifies the surprise component of changes in the Federal Funds Target Rate. Quarterly values are obtained by summing daily surprises within the same quarter, following Gertler and Karadi (2015).	Ilzetzki and Jin (2021); Gürkaynak, Karasoy-Can and Lee (2022)
Capital account openness	KAO	The degree of capital account openness is measured by the Chinn-Ito index. It is bounded between 0 and 1. A higher value indicates more restrictions on cross-border capital transactions.	Chinn and Ito (2006)
Control and Conditioning Variables			
Output gap	OGAP	Deviation of actual GDP from potential GDP as percent of potential GDP	IMF, Oxford Economics, Datastream/OECD
GDP	GDP	Gross domestic product at constant prices, seasonally adjusted	OECD
Inflation differential	INF	The inflation differential is defined as the deviation of total inflation from the inflation target. The target is capped at 5% for advanced and 10% for emerging economies.	OECD, Oxford, National Central Banks, Ehrmann (2021)
Private credit	CREDIT	Credit to households and NPISHs from all sectors at market value, percentage of GDP	BIS
Domestic share price	SHARE PRICE	Share price index (2015 = 100)	OECD
Rent control	RENT LAWS	Rent control is measured by a composite (average) index of six binary indicators defined by Weber (2017), including rent freeze (real and nominal), rent level control, rent decontrol (intertenancy and other specific), and specific rent recontrol. A higher index indicates more limitations on rents.	Kholodilin (2020)

Table 6: Countries

ADVANCED ECONOMIES			EMERGING ECONOMIES	
Australia	Germany	Italy	Chile	South Africa
Austria	Great Britain	Norway	China	
Belgium	Greece	Portugal	Columbia	
Canada	Ireland	South Korea	Hungary	
Czech Republic	Israel	Spain	India	
Denmark	Japan	Sweden	Indonesia	
Finland	Netherlands	Switzerland	Mexico	
France	New Zealand	(USA)	Poland	

A.2. Additional tables and figures

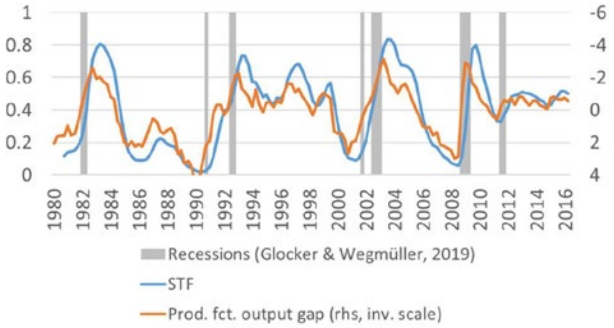
Table 7 : Influence of cyclical conditions

	(1)	(2)	(3)	(4)	(5)	(6)
Dependent variable: Change in real house prices (in pp)						
	h=0	h=1	h=5	h=10	h=15	h=20
(A) Conditioning on the output gap						
$\Delta STIR_{i,t}^{IV}$	–0.327	–0.922	–3.796**	–7.653***	–8.548**	–9.349**
	(0.353)	(0.608)	(1.670)	(2.686)	(3.333)	(3.874)
$\Delta STIR_{i,t}^{IV}\ x\ STF_{i,t}^{OGap}$	–0.882	–2.076	–10.742***	–10.251	–7.550	–3.023
	(0.826)	(1.421)	(3.907)	(6.283)	(7.798)	(9.113)
N	2644	2644	2644	2642	2583	2447
R2	0.478	0.515	0.382	0.328	0.345	0.349
Hansen-J p-value	0.613	0.518	0.974	0.956	0.219	0.051
First-stage F stat	43.371	43.371	43.371	43.312	42.851	40.761
(B) Conditioning on credit growth						
$\Delta STIR_{i,t}^{IV}$	–0.253	–0.582	–1.502	–4.609***	–6.629***	–7.642***
	(0.233)	(0.399)	(1.048)	(1.686)	(2.140)	(2.505)
$\Delta STIR_{i,t}^{IV}\ x\ STF_{i,t}^{Cred}$	–1.207***	–2.270***	–8.176***	–6.933**	–3.720	–3.665
	(0.462)	(0.790)	(2.076)	(3.340)	(4.228)	(4.931)
N	2642	2642	2642	2640	2581	2445
R2	0.483	0.526	0.447	0.397	0.389	0.381
Hansen-J p-value	0.675	0.843	0.968	0.456	0.136	0.035
First-stage F stat	108.707	108.707	108.707	108.620	106.822	101.842
(C) Conditioning on the level of STIRs						
$\Delta STIR_{i,t}^{IV}$	–0.411*	–1.047***	–2.509***	–6.443***	–8.389***	–10.354***
	(0.226)	(0.380)	(0.973)	(1.589)	(2.056)	(2.390)
$\Delta STIR_{i,t}^{IV}\ x\ STF_{i,t}^{STIR}$	–0.197	–1.663	–3.668	–12.860**	–11.749	–18.233**
	(0.863)	(1.455)	(3.726)	(6.082)	(7.770)	(8.999)
N	2641	2641	2641	2639	2582	2449
R2	0.495	0.548	0.493	0.436	0.407	0.394
Hansen-J p-value	0.655	0.979	0.773	0.341	0.130	0.014
First-stage F stat	74.992	74.992	74.992	74.911	74.238	70.866
(D) Conditioning on past house price growth						
$\Delta STIR_{i,t}^{IV}$	–0.331	–0.575	–1.573	–5.856***	–8.978***	–11.325***
	(0.246)	(0.446)	(1.214)	(1.777)	(2.291)	(2.789)
$\Delta STIR_{i,t}^{IV}\ x\ STF_{i,t}^{HP}$	–1.564*	–5.563***	–15.549***	–4.052	10.269	22.512**
	(0.896)	(1.627)	(4.428)	(6.482)	(8.349)	(10.162)
N	2630	2630	2630	2628	2569	2433
R2	0.465	0.443	0.343	0.417	0.390	0.326
Hansen-J p-value	0.917	0.578	0.636	0.284	0.210	0.063
First-stage F stat	50.162	50.162	50.162	50.094	49.168	47.408

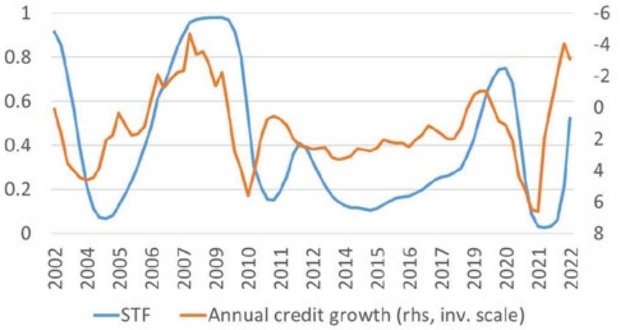
Note: The table shows the second-stage result of the 2SLS estimation when the house price reaction is conditioned on (A) the output gap, (B) the change in household credit, as a % of GDP, (C) the initial level of the STIR, and (D) past house price growth. The dependent variable is the change in the real house prices between times t-1 and t+h, focusing on the effect of the changes in the STIR. The results for control variables are omitted for readability. Standard errors in parentheses. Star-values: * p<0.10; ** p<0.05; *** p<0.01.

Figure 19: Smooth Transition Functions - Switzerland

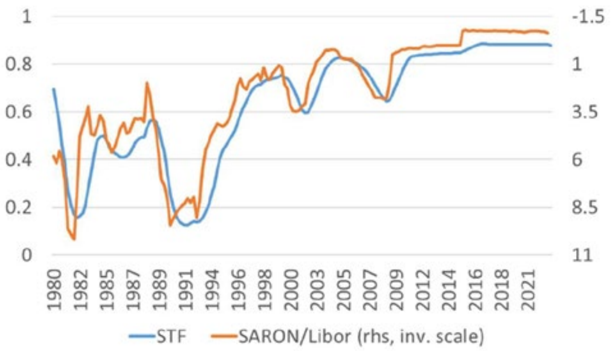
1. Output gap



2. Credit growth



3. Short-term interest rate



4. Real house price growth

Note: The figures plot the smooth transition function (blue, LHS) and its underlying variable, constructed as the globally standardized trailing 7-quarter moving average: output gap, credit growth, short-term rate and house price growth (orange, RHS, inverted scale).

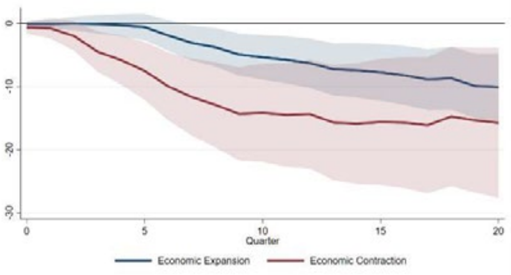
A.3. Robustness checks

A.3.1. Robustness to lag lengths and country-specific trends

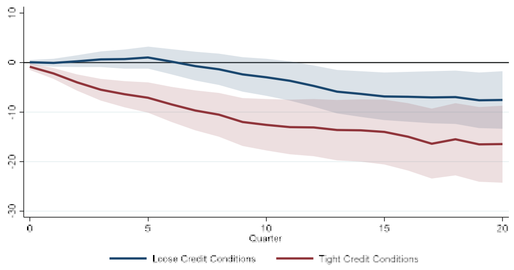
Figure 20: Conditional HP reaction with different specifications

A. 8 lags

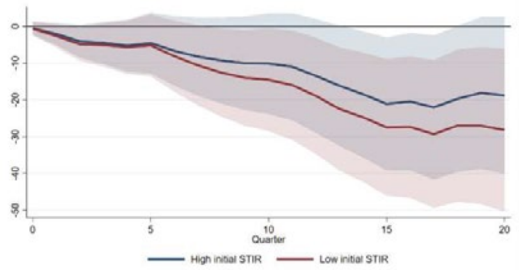
1. Output gap



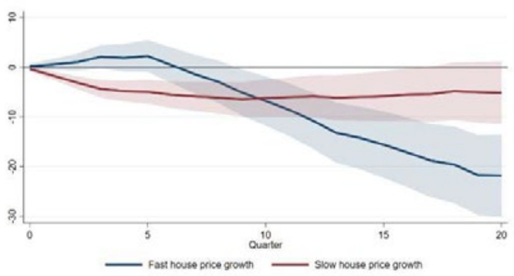
2. Credit growth



3. Level of the short-term interest rate

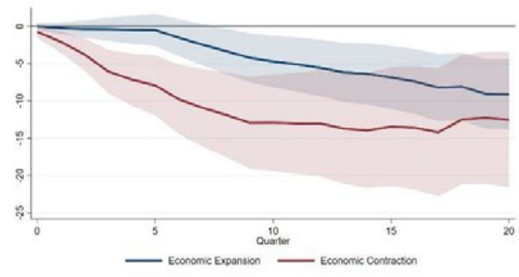


4. House price growth

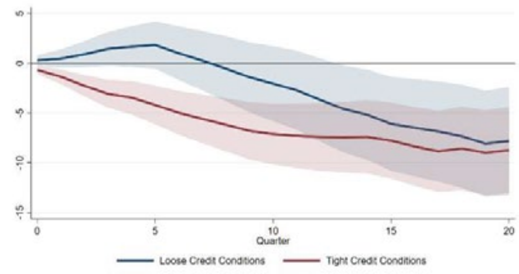


B. Country-specific trends

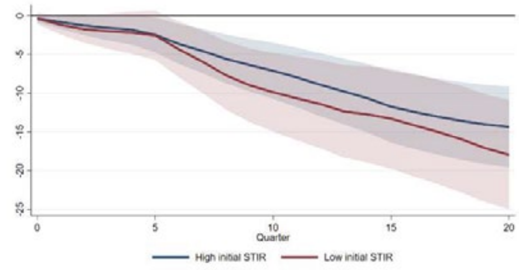
1. Output gap



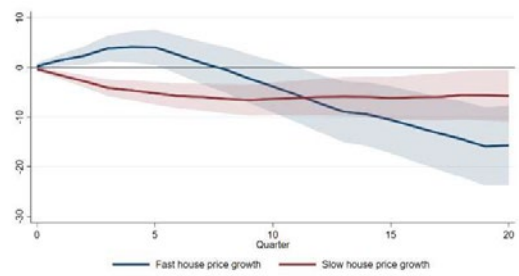
2. Credit growth



3. Level of the short-term interest rate



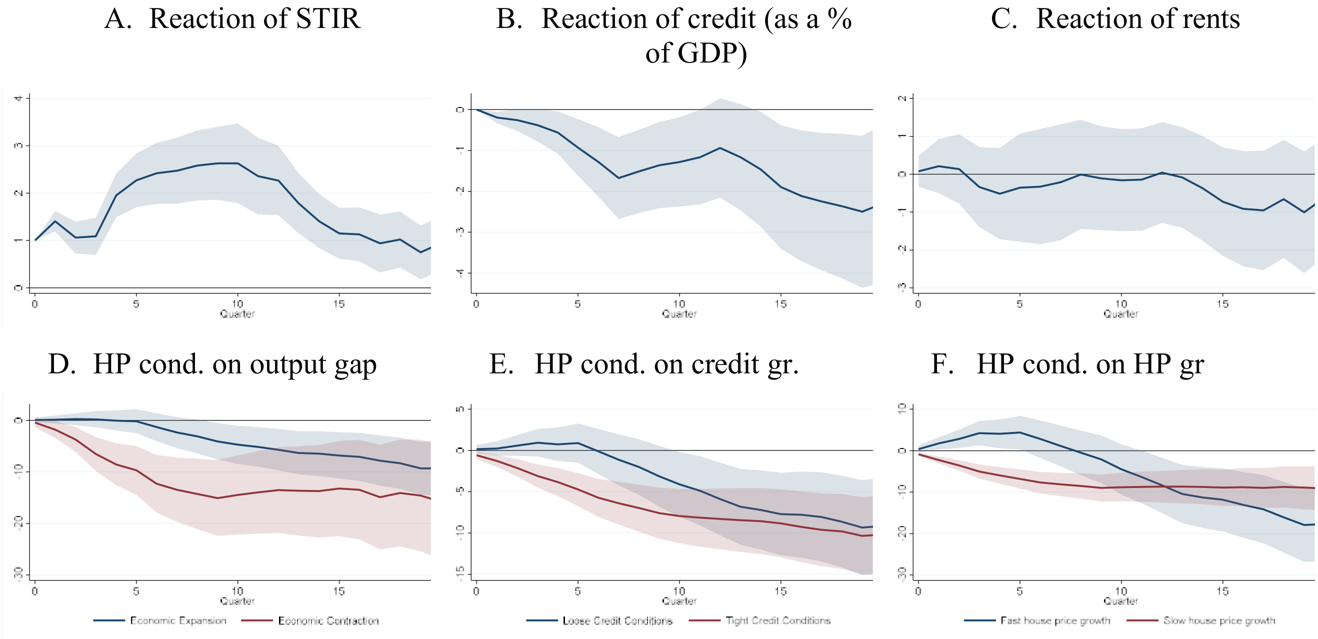
4. House price growth



Note: The figure shows the transmission of a STIR shock depending on the precise treatment of the excluded instruments. A: only the nominal changes in the US STIR are the excluded instrument; B: the lags of the nominal and unexpected component of $\Delta STIR_t^{US}$are also treated as excluded instrument (rather than being part of the control vector). The shaded area corresponds to the 90% confidence interval. Robust standard errors are clustered at the country level.

A.3.2. Robustness to the use of mortgage interest rates

Figure 21: Additional results with mortgage rates as controls



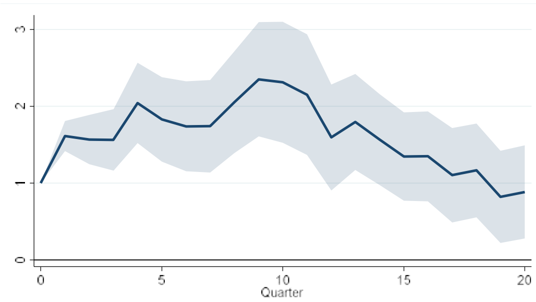
Note: The figure shows the transmission of a STIR shock when the mortgage rate is used rather than the LTIR to the STIR itself (A), household credit (as a % of GDP) (B) and real rents (C) as well as the reaction of real house prices when conditioned on the output gap (D), credit growth (E) and past house price growth (F). The shaded area corresponds to the 90% confidence interval. Robust standard errors are clustered at the country level.

A.3.3. Robustness to excluded instruments

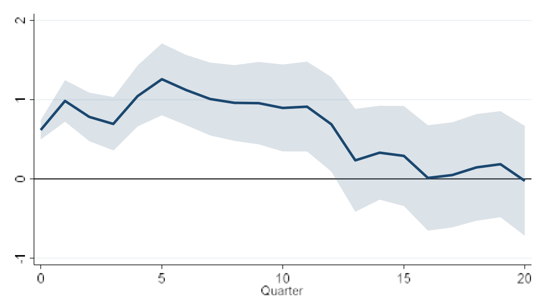
Figure 22: Monetary policy transmission with different excluded instruments

A. Only $\Delta STIR_t^{US}$

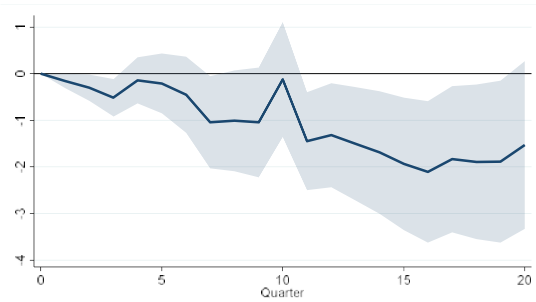
A. Short-term interest rate



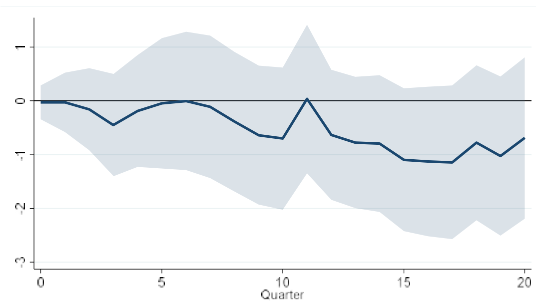
B. Mortgage rate



C. Household credit (as a % of GDP)

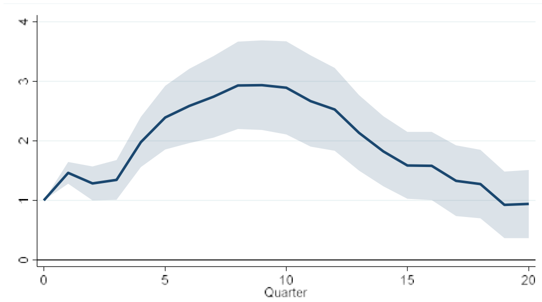


D. Real rents

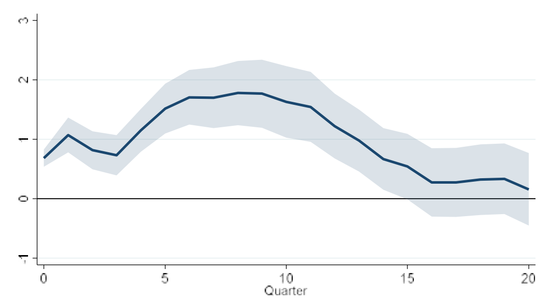


B. Lagged US monetary policy variables are also excluded instruments

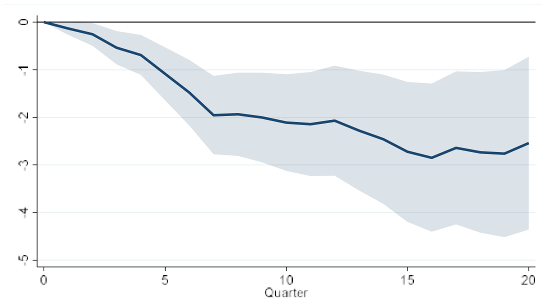
A. Short-term interest rate



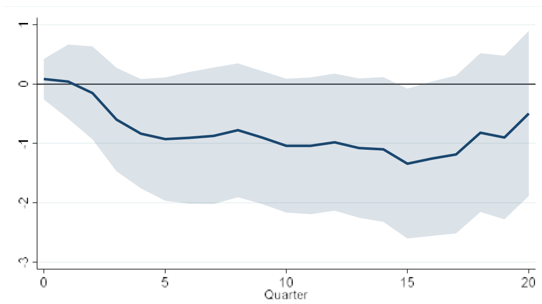
B. Mortgage rate



C. Household credit (as a % of GDP)



D. Real rents

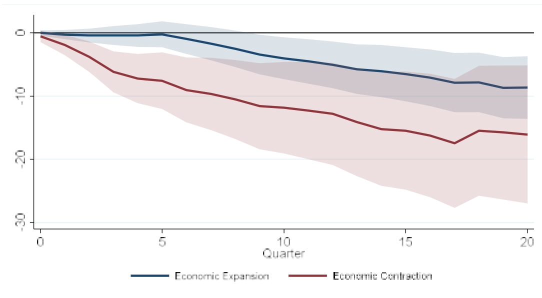


Note: The figure shows the transmission of a STIR shock depending on the precise treatment of the excluded instruments. A: Only the nominal changes in the US STIR are the excluded instrument; B: the lags of the nominal and unexpected component of $\Delta STIR_t^{US}$ are also treated as an excluded instrument (rather than being part of the control vector). The shaded area corresponds to the 90% confidence interval. Robust standard errors are clustered at the country level.

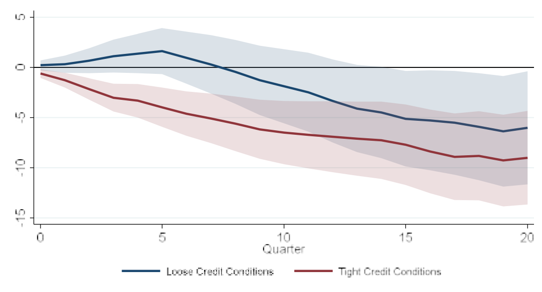
Figure 23: Conditional HP reaction with different excluded instruments

A. Only $\Delta STIR_t^{US}$

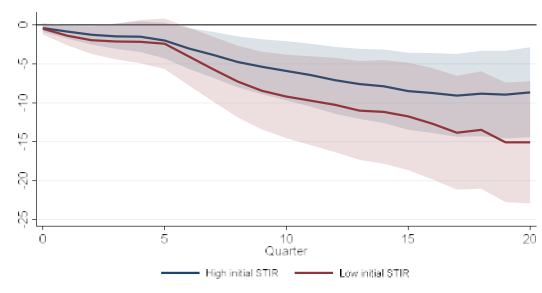
A. Output gap



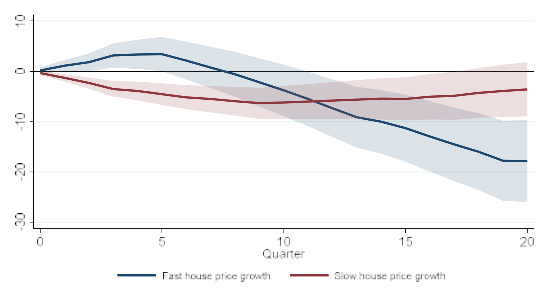
B. Credit growth



C. Level of the short-term interest rate

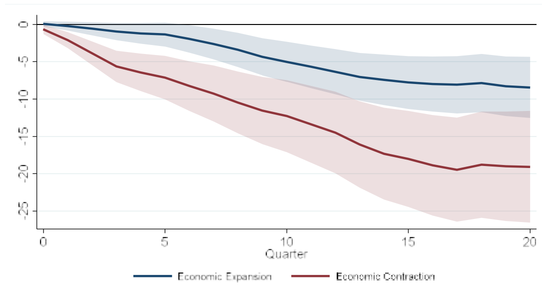


D. House price growth

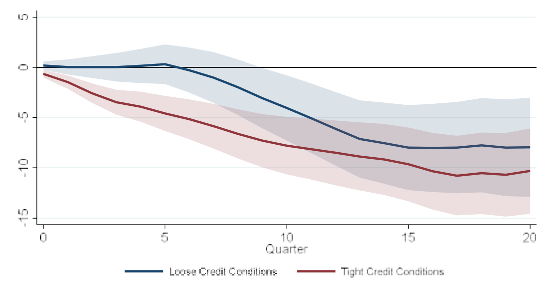


B. Lagged US monetary policy variables are also excluded instruments

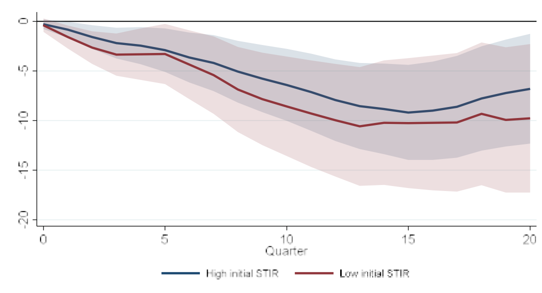
A. Output gap



B. Credit growth



C. Level of the short-term interest rate



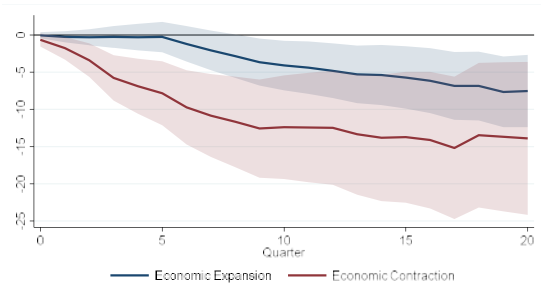
D. House price growth

Note: The figure shows the transmission of a STIR shock depending on the precise treatment of the excluded instruments. A: Only the nominal changes in the US STIR are the excluded instrument; B: the lags of the nominal and unexpected component of $\Delta STIR_t^{US}$ are also treated as an excluded instrument (rather than being part of the control vector). The shaded area corresponds to the 90% confidence interval. Robust standard errors are clustered at the country level.

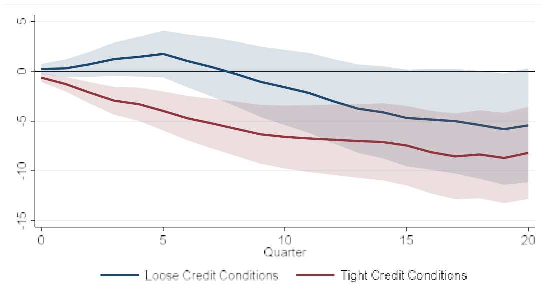
A.3.4. Robustness to forward shocks

Figure 24: Conditional house price reaction with "forward shocks"

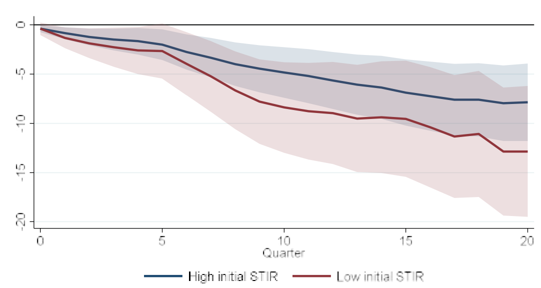
A. Output gap



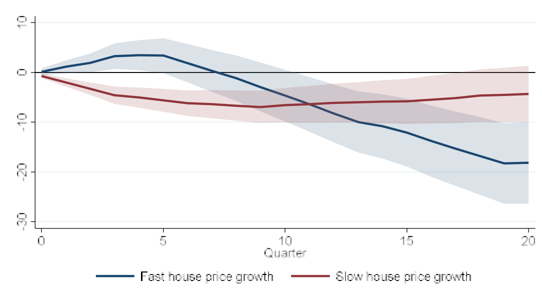
B. Credit growth



C. Level of the short-term interest rate



D. House price growth



Note: The figure shows the IRFs for house prices to a 1 pp increase in short-term interest rates depending on the underlying conditions when changes in the STIR between t and $t + h$ are controlled for. The shaded area corresponds to the 90% confidence interval.

A.3.5. Robustness of joint estimation to the use of GDP growth as a proxy for economic activity

Table 8: Joint estimation with GDP growth to proxy for economic activity

Dependent variable: Change in real house prices (in pp)[1]

	h=0	h=1	h=5	h=10	h=15	h=20
Shock	0.05	–0.09	–0.30	–5.45**	–9.63***	–12.34***
	(0.33)	(0.59)	(1.61)	(2.39)	(3.06)	(3.66)
Shock X STF(HP)	–0.29	–1.22	–9.94**	–6.66	–1.53	6.26
	(0.94)	(1.68)	(4.64)	(6.88)	(8.76)	(10.46)
Shock X STF(STIR)	–1.90*	–4.26**	–11.42**	–19.93***	–17.63*	–27.21**
	(1.02)	(1.82)	(5.02)	(7.46)	(9.46)	(11.16)
Shock X STF(GDP growth)	–0.53	–2.41*	2.49	8.76	14.12**	16.07**
	(0.73)	(1.31)	(3.59)	(5.33)	(6.80)	(8.18)
Shock X STF(Credit)	–1.46**	–2.73**	–8.62***	–9.69**	–6.80	–11.34
	(0.63)	(1.12)	(3.10)	(4.60)	(5.84)	(6.93)
N	2562	2562	2562	2560	2503	2370
R2	0.544	0.533	0.417	0.477	0.480	0.449
Hansen-J p-value	0.977	0.723	0.459	0.118	0.259	0.234

Note: The table shows the second-stage result of the 2SLS estimation for the shock variable itself as well as its interaction with the STF of the main conditioning variable. The dependent variable is the change in the real house prices between times t-1 and t+h. The results for control variables are omitted for readability. Standard errors in parentheses. Star-values: * p<0.10; ** p<0.05; *** p<0.01.

[1] The table omits the weak instrument test, as critical values for the Stock-Yogo weak ID test are not reported for a system of 5 endogenous regressors and a total of 10 excluded instruments. The Sanderson-Windmeijer multivariate F tests for the excluded instruments for the individual endogenous regressors are statistically significant by wide margins and available on request.

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