Effects of cost of mortgage on house prices: the role of the maturity structure of mortgage contracts[*†]

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Abstract

This paper examines the implications of the maturity structure of mortgage contracts for the effects of the cost of mortgage on house prices. Theoretical results indicate that economies with larger shares of variable interest rate mortgage contracts present faster responses of house prices to changes in the cost of mortgage, as well as higher interest rate sensitivities of cost of mortgage and house prices. Lower mortgage rate levels, higher loan-to-value ratio, and higher effects of cost of mortgage on house prices also increase these sensitivities. Empirical results validate the theoretical ones. Local projections estimated for the US, UK, Sweden, Canada, Finland and France show negative and significant responses of house prices to shocks on the cost of mortgage, with responses being faster in economies with larger shares of variable interest rate mortgage contracts. Estimates of the interest rate sensitivity of the cost of mortgage are also in line with theory and increase as the mortgage rate declines. This sensitivity is attenuated when the central bank shifts its focus of monetary policy towards longer-term rates or when the effective lower bound is perceived to be lower.

Keywords: mortgage interest rate; cost of mortgage; house prices; monetary policy; interest rate sensitivity; mortgage market.

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1. Introduction

How changes in mortgage rates and the costs related to mortgage payments affect house prices have, for long, attracted considerable attention from market participants, policy makers and academic researchers. At a first glance, this attention is explained by the noticeable decline in mortgage rates over the past decades in conjunction with the increase in property prices and household indebtedness in several industrialized countries. Or by the ups and downs in mortgage rates and mortgage payments, with opposing movements in house prices. However, one important aspect of how mortgage rates and mortgage costs affect house prices that has not yet been studied in detail is the role of certain characteristics of mortgage markets, such as the maturity structure of mortgage contracts.

In this paper, I present both theoretical and empirical results supporting the argument that economies which experience a larger share of homes financed with variable interest rate mortgage contracts present faster responses of house prices to changes in mortgage rates and the cost of mortgage. The argument is that, as mortgage rates decline and drive the cost of mortgage down, households become more willing to purchase homes using newly created mortgages, which help to boost house prices and mortgage debt. Conversely, when mortgage rates rise, the cost of mortgage increases for the share of mortgage contracts with variable interest rates (or newly created contracts), making households more willing to move to cheaper homes, driving house prices down. The overall effect of changes in the cost of mortgage on house prices is larger in markets with a larger share of home ownership using mortgages with variable interest rate contracts.

The theoretical findings in this paper support this argument. I show that mortgage costs are more sensitive to changes in mortgage rates the larger the share of variable interest rate mortgage contracts, and the lower the mortgage interest rate. Regarding house prices, I show that house prices become more sensitive to changes in mortgage rates the larger the effects of the cost of mortgage on house prices, the higher the loan-to-value ratio, and the larger the share of variable interest rate mortgage contracts in the economy. These results indicate the importance of maturity structure of mortgage contracts in determining the speed of adjustment of house prices to changes in mortgage rates and the cost of mortgage.

The theoretical results are also tested empirically. To do so, I first estimate local projection regressions (Jordà 2005) that measure the impulse responses of house prices to shocks in the cost of mortgage, where one should expect negative effects. The speed of adjustment in the local projections' impulse responses, i.e. their lag structure, works as a measure of the share of variable interest rate mortgage contracts in the economy, with faster responses corresponding to larger shares. The impulse responses also measure the magnitudes of the effects of the cost of mortgage on house prices. As a second exercise, I estimate the interest rate sensitivities of the cost of mortgage and house prices. To do so, I use a nonparametric regression method where time-varying coefficients are estimated with local linear least-squares and kernel estimators. The coefficients in the regression models work as time-varying measures of the interest rate sensitivities derived theoretically.

To carry the empirical exercise, I use data for the US, UK, Sweden, Canada, Finland and France, which have well established mortgage markets in terms of size and importance within their own economies, but differ in terms of the share of variable interest rate mortgage contracts in their own mortgage markets. For instance, according to statistics collected for 2018, in the US, the UK and Canada, variable interest rate mortgage contracts account for 18%, 10% and 30% of the total, respectively, while in Finland and Sweden this number is considerably larger, 96% and 70% respectively. According to statistics of 2021, this number is 3% in France, which rather shows a large share of mortgage contracts with short-term fixed maturities (one- to five-years), 97%. The maturity of mortgage contracts in Finland and Sweden are mostly very short-term, up to one year, while in the UK they are spread across maturities and are mostly concentrated in the segments of one- to five-years and five- to ten-years. This characterization suggests that Finland and Sweden should experience the fastest reactions of house prices to changes in mortgage rates and the cost of mortgage, followed by France, Canada, the US, and the UK.

Empirical results are as expected, and in line with theory. The impulse responses are negative and significant for all economies. Effects are also lagged, with the maximum negative effects happening after twelve quarters for the US, twenty quarters for the UK, four quarters for Sweden, eleven quarters for Canada, three quarters for Finland and six quarters for France. This is in line with the idea that the speed of adjustment of house prices to shocks in the cost of mortgage described by the lag structure of the impulse responses is closely connected to the share of variable interest rate mortgage contracts in these economies, where Finland and Sweden show the fastest responses, followed by France, Canada, the US, and the UK. Following the theory, empirical results also indicate that the estimated interest rate sensitivity of the cost of mortgage increases as the mortgage interest rate declines. Moreover, the estimated values track closely the theoretical result based on the data only, confirming the ability of the empirical model with time-varying coefficients to replicate the data.

The results above have at least two key implications for how monetary policy affects house prices. First, as interest rates have shown a declining trend over the past decades, the interest rate sensitivity of the cost of mortgage has increased, making the cost of mortgage more subject to sudden rises when monetary policy is contracted. As a result, the recent monetary contraction induced by several central banks to fight inflation caused the cost of mortgage to rise sharply and house prices to react negatively in several economies, with the speed of reaction being correspondent to the share of variable interest rate mortgage contracts in the respective economy, and with the magnitude of the reaction increasing with the loan-to-value ratio. For instance, following this argument, the data analyzed in this study indicates stronger house price declines in Finland, Sweden and Canada more recently. Another key implication is that the increase seen in the interest rate sensitivity of cost of mortgage can be attenuated when the constraints imposed by the zero-lower bound on the mortgage rate are softened. This happens when the central bank shifts its focus towards changing longer-term interest rates through unconventional monetary policies, or when the central bank and market participants perceive the effective lower bound as being lower or negative. Finally, results have also key implication for real estate investments. As house prices commonly react with lags, sharp rises in the cost of mortgage may suggest future house price declines. Under this scenario, it might be wise that real estate investors pull out their funds from highly risky markets and redirect them to more favorable ones. I devote one section to discuss these.

This study is related to a large strand of the literature that discusses the effects of interest rates on house prices. Himmelberg et al. (2005) discuss that house prices become more sensitive to changes in interest rates when rates are already low. Calza et al. (2013) studied the role of housing finance for the transmission of monetary policy, and find that residential investment, consumption, and house prices are more responsive to monetary policy shocks in countries with more developed and flexible mortgage markets, and that the prevailing interest rate structure of mortgage contracts is an important factor for consumption. Glaeser et al. (2013) document that the interest rate elasticity of house prices is negative and, all other factors constant, increases when the interest rate decreases. Sherlund (2020) finds that house prices are more sensitive to changes in interest rates in areas with less land available for development, in areas with more land-use regulation, and in areas with more inelastic housing supply. Kuttner (2012) finds evidence of modest impact of interest rates on house prices. More recently, Svensson (2024) discusses that rising mortgage rates have contributed to increasing the cost of housing for Swedish homeowners in 2022-2023. Regarding the effects of cost of mortgage on house prices, Adelino et al. (2012) use the conforming loan limit as an instrument for easier access to home finance and cost of credit measurement and find that it significantly affects house prices. Regarding mortgage debt, Jordà et al. (2015) find that mortgage debt to asset and income ratios have raised substantially over the period 1870-2011 and have been an important determinant of financial instabilities and business cycle dynamics in advanced economies. This paper supports previous findings that interest rate changes affect house prices. However, this is the first paper to establish the finding that the maturity structure of mortgage contracts is a key determinant of the speed of adjustment of house prices to changes in mortgage rates and the cost of mortgage, and to estimate that speed of adjustment as well as the time-varying interest rate sensitivities of cost of mortgage and house prices. This is also the first paper to provide insights on how the interest rate sensitivity of cost of mortgage can be attenuated by lowering the effective lower bound on interest rates.

This paper is organized as follows. The following section introduces the theoretical arguments around the relationship between cost of mortgage and house prices including the interest rate sensitivities of cost of mortgage and house prices, as well as a brief characterization of housing markets in the US, UK, Canada and Sweden. The third section introduces the econometric methods used in the empirical analyses of this study. The fourth section introduces the data used in the paper and describes some stylized facts. The fifth section shows the empirical results, and implications for house prices and policy. Finally, the seventh section concludes.

2. The relationship between cost of mortgage and house prices

2.1. A theoretical foundation

The starting point for studying the relationship between the cost of mortgage and house prices is the expression of cost of mortgage (K_M) itself, which represents the yearly mortgage cost of the homeowner as a function of the yearly mortgage interest rate (r), the mortgage debt level (M), as well as the interest rate tax relief (τ_r),

$$K_M = r(1 - \tau_r)M \qquad (1)$$

In many countries the interest rate tax relief is zero $(\tau_r = 0)$, so to facilitate the exposition I proceed by assuming that $\tau_r = 0$, $K_M = rM$. This last expression tells us that the cost of mortgage increases with the mortgage rate and mortgage debt level.

Based on the user cost approach (Hendershott and Slemrod, 1983; Poterba, 1984; DiPasquale and Wheaton, 1996; Svensson, 2025) I can also consider the house price (P) as a negative function of the cost of mortgage in addition to other fixed variables such as the maturity level of the mortgage market, and costs with relocation, operation, maintenance, repair, depreciation and property tax, which may affect P and are jointly denoted by c.[3] Therefore, the below follows.

$$P = f(K_M, c),\ f' < 0 \qquad (2)$$

[3] Although I acknowledge that rents may affect house prices according to the user cost approach, these are not directly included in the model. However, rents may affect house prices in relation to the cost of mortgage, that is, considering all else constant, higher rents in relation to the cost of mortgage may increase house prices due to higher demand for houses.

Notice that the exact functional form of $f(K_M, c)$ is unknown. In the rest of the paper, I assume c to be constant over time and $f(\cdot)$ to be linear in K_M and c, implying the following,

$$P = a + \kappa K_M + \gamma c, \ \kappa, \gamma < 0 \qquad (3)$$

Based on the above, one can also obtain the expression of by how much the cost of mortgage changes with the mortgage interest rate by taking the derivative of K_M with respect to r. To do that, I acknowledge that only a share η of the mortgage debt level that uses variable interest rate contracts can have its cost contemporaneously affected by changes in the mortgage interest rate. Therefore, we have the following,

$$\frac{\partial K_M}{\partial r} = \eta M \qquad (4)$$

which implies that the interest rate sensitivity of the cost of mortgage rises with the mortgage debt level itself and with the share $0 \leq \eta \leq 1$ of variable mortgage interest rate contracts. Similarly, one can obtain the percentage derivative of the cost of mortgage with respect to the mortgage interest rate as below,

$$\frac{\partial ln(K_M)}{\partial r} = \frac{\frac{\partial K_M}{K_M}}{\partial r} = \frac{\eta M}{K_M} = \frac{\eta}{r} \qquad (5)$$

This last expression implies that the interest rate sensitivity of the cost of mortgage (in percentage terms) rises as the mortgage interest rate declines and the share η of variable mortgage interest rate contracts increases. More than that, the relationship is nonlinear, implying that as the interest rate approaches zero, the interest rate sensitivity of the cost of mortgage increases towards infinite, so small rises in interest rates have large positive effects on the cost of mortgage itself. Obviously, effects are larger, the larger the share η of variable mortgage interest rate contracts. Graphically, the relationship above is illustrated by Figure 1(a) when $\eta = 1$, and can be obtained directly using mortgage interest rate data.

Following a similar approach, one can also obtain the interest rate sensitivity of the house price (in percentage terms),

$$\frac{\partial ln(P)}{\partial r} = \frac{\frac{\partial P}{P}}{\partial r} = f'(K_M, c)\eta LTV = \kappa \eta LTV, \ LTV = \frac{M}{P} \qquad (6)$$

where I used the linear form assumed for $f(\cdot)$ in the last part of the equality. LTV is the loan-to-value ratio, or mortgage-to-value ratio. The implications of the expression above are twofold. First, because $\kappa < 0$, house prices shall decline as the mortgage rate rises, with the declining effects increasing with κ, implying that the sensitivity above shall be mostly negative. Second, the higher the loan-to-value ratio and the share of variable mortgage interest rate contracts, the more sensitive the house price (in percentage terms) is in relation to interest rates. Also notice that, differently from the expression of the interest rate sensitivity of the cost of mortgage, the interest rate sensitivity of the house price cannot be obtained directly, as $f(K_M, c)$ is unknown. One alternative it to *estimate* it instead, by estimating κ, or the whole expression.

Importantly, notice also that because the share η of the mortgage debt level that uses variable interest rate contracts is contemporaneously affected by changes in the mortgage rate, the interest rate sensitivity above measures the *instantaneous* percentage change in the house price given a change in the mortgage rate. However, mortgage contracts can also be set with fixed term interest rates (the share $1 - \eta$) and, therefore, changes in mortgage rates may affect house prices through the cost of mortgage with lags. One way to capture this is to setup a lagged version of the expression of the house price as a function of the cost of mortgage and the other fixed variables/costs,

$$P = a^h + \kappa^h K_{M,h} + \gamma c, \;\; \kappa^h, \gamma < 0 \qquad (7)$$

where h is the lag of K_M in relation to P, and $\gamma c = \gamma^h c_h$ given that c is time-invariant. The lag structure on K_M embedded in κ^h indicates the speed at which changes in the cost of mortgage affect house prices and works as an indication of the fraction of variable interest rate mortgage contracts in the economy, with that fraction approaching one as the lag h approaches zero. This would imply a quick reaction of house prices to changes in the mortgage rate.

2.2. Mortgage market characterization

I study the effects of cost of mortgage on house prices in six economies: US, UK, Sweden, Canada, Finland and France. These countries have well established mortgage markets in the world, both in size and importance within their own economies. As can be seen in Figure 2, mortgages are largely used in home ownership in these six economies. In the US, about 68% of households own their homes, with about 46% of total homes owned using mortgages. In the UK, home ownership accounts for 71%, where 32% of the total homes use mortgages. In Sweden, the percentage of home ownership is slightly smaller, about 64%, but mortgages are largely used, with 51% of the total owned homes done through mortgages. In Finland, about 70% of households own their homes, with about 40% using mortgages. Finally, in France, home ownership represents 65% of the total, with 31% using mortgages. Importantly, however, the percentage of variable interest rate mortgage loans vary substantially across countries. According to the statistics of 2018, in the US, the UK and Canada, variable interest rate loans account for 18%, 10% and 30% of the total, respectively, while in Finland and Sweden this number is considerably larger, 96% and 70%, respectively. According to the statistics of 2021, this number is 3% in France, which rather shows a large share of mortgage contracts with short-term fixed maturities (one- to five-years), 97%. The maturity of mortgage contracts in Finland and Sweden are mostly very short-term, up to one year, while in the UK they are spread across maturities, but are mostly concentrated in the segments of one- to five-years and five- to ten-years.[4]

The statistics above have at least two main implications. First, as mortgages are largely used in home ownership in the six economies, changes in the cost of mortgage are likely to affect house prices. Second, the responses of house prices to changes in cost of mortgage are expected to be faster in economies with a high percentage of mortgage contracts with variable or short-term fixed interest rates. Given that, and considering the six economies above, Finland and Sweden are likely to have the fastest responsiveness, followed by France, Canada, US and the UK.

3. Econometric framework

3.1. Estimation of the effects of cost of mortgage on the house price

To estimate the effects of the cost of mortgage on the house price I assume that $f(K_M, c)$ is approximated using a linear regression. As house prices increase with time (show an upward trend), at least during the period studied in this paper, and the cost of mortgage moves with the interest rate and credit cycles, I detrend both variables using Exponentially Weighted Moving Average (EWMA) filters with parameter α.[5] More specifically,

[4] Unfortunately, I do not have this statistic for the US and Canada. The data shown in Figure 2 are obtained from various sources: homeownership data is from the OECD (https://www.oecd.org/housing/data/affordable-housing-database/), the share of variable interest rate mortgage contract and the maturity of mortgage contracts are from reports by the European Mortgage Federation (EMF Hypostat, https://hypo.org/emf/publications/hypostat/) and from Hoenselaar et al. (2019).

[5] Several studies have sustained the use of the EWMA filter to model the dynamics of house prices, their expectations and household debt. Based on data from the Michigan Survey of Consumers, Piazzesi and Schneider (2009) report that "starting in 2004, more and more households became optimistic after having watched house prices increase for several years." Regarding housing investor expectations from 2002 to 2008, Case et al. (2012) conclude that "1-year expectations [of future house prices changes] are fairly well described as attenuated versions of lagged actual 1-year price changes". Jurgilas and Lansing (2013) show that the balance of Norwegian households expecting a house price increase over the next year is strongly correlated with nominal house price growth over the preceding year, which suggests a moving-average type of forecast rule. Gelain and Lansing (2014) model expectations of the price-to-rent ratio using a EWMA process. Gelain et al. (2013) introduce EWMA forecast rules for households in a DSGE model and verify that the model is able to better match the volatility of house prices and household debt seen in the data. Granziera and Kozicki (2012) and Gelain and Lansing (2014) show that simple Lucas-type asset-pricing models with either extrapolative or moving-average type expectations can help account for numerous quantitative and qualitative features of US house-price data. Furthermore, the EWMA filter shows several advantages in trend estimation,

$$\bar{P}_t = \alpha_P P_t + (1 - \alpha_P)\bar{P}_{t-1} \qquad (8)$$

$$\bar{K}_{M,t} = \alpha_K K_{M,t} + (1 - \alpha_K)\bar{K}_{M,t-1} \qquad (9)$$

where $\bar{P}$ and $\bar{K}_M$ are long-term (EWMA) trends. The parameters α_P and α_K are estimated using integrated moving average processes, IMA(1,1). Notice that this is possible, as any EWMA filter has an IMA(1,1) representation, with or without constant. To see this, consider the EWMA for housing prices. Since $\bar{P}_{t+1}$ may be viewed as the forecast of P at time *t+1,* one can write the EWMA filter as,

$$\bar{P}_{t+1} = \alpha_P P_t + (1 - \alpha_P)\bar{P}_t \qquad (10)$$

Alternatively, one can have the IMA(1,1) representation of $\bar{P}$ as below,

$$\bar{P}_t = P_{t-1} + \in_{P,t} - \delta_P \in_{P,t-1} \qquad (11)$$

where the terms $\in_t, \in_{t-1}$ are independent random shocks with mean 0 and variance σ^2, i.e. "white noise" processes. Note that for forecasting P at time *t+1* given the information up to time *t* using the IMA(1,1) models above one shall have,

$$\bar{P}_{t+1} = P_t - \delta_P \in_{P,t} \qquad (12)$$

and since $\in_{P,t} = P_t - \bar{P}_t$, one can obtain,

$$\bar{P}_{t+1} = (1 - \delta_P)P_t - \delta_P \bar{P}_t \qquad (13)$$

Comparing the IMA(1,1) equation above with the EWMA filter, notice that the two representations are the same, with $\alpha_P = 1 - \delta_P$ and $\alpha_K = 1 - \delta_K$, implying that the decaying parameters α_P and α_K in the two EWMA filters above can be estimated using their respective IMA(1,1) representations. Based on that, the variables house price and cost of mortgage can be effectively detrended. To facilitate interpretation of the coefficients in the regression, I use the percentage deviations

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such as the ability to capture time-varying/adaptive trends, while handling structural breaks and preserving cyclical components. Other methods used in the literature, such as log-difference (see Campbell and Shiller 1987, 1988a, 1988b, and Shi et al. 2014, 2021), are more suitable for return calculation and stationarity purposes.

of the house price and cost of mortgage relative to their respective long-term trends. I then end up estimating the following linear regression using least-squares,

$$\frac{P_t-\bar{P}_t}{\bar{P}_t} = \varphi_0^h + \varphi_1^h \frac{K_{Mt-h}-\bar{K}_{Mt-h}}{\bar{K}_{Mt-}} + \vartheta_t \qquad (14)$$

where we should expect $\varphi_1^h < 0$. Notice that the term involving c vanishes as c is constant over time, implying that $c = \bar{c}$. Notice also that I allow for lagged effects to occur, by varying h. Therefore, the regression above can be viewed as a local projection (Jordà 2005), where φ_1^h measures the impulse response of $\frac{P_t-\bar{P}_t}{\bar{P}_t}$ given the shock $\frac{K_{Mt-h}-\bar{K}_{Mt-h}}{\bar{K}_{Mt-h}}$ for $h \geq 0$.

3.2. Estimation of interest rate sensitivities

To estimate the interest rate sensitivities of the cost of mortgage and house prices above, I first approximate the variables $\partial ln(K_M)$, $\partial ln(P)$ and ∂r using their discrete-time versions $\Delta K_M/K_M$, $\Delta P/P$ and Δr. I then use a nonparametric regression method where time-varying coefficients are estimated with a local linear estimator and kernel methods (Cleveland and Devlin 1988; Hastie and Loader 1993). More specifically, I estimate the following regressions,

$$\frac{\Delta K_{M_t}}{K_{M_{t-1}}} = \beta_t \Delta r_t + \epsilon_t \qquad (15)$$

$$\frac{\Delta P_t}{P_{t-1}} = \theta_t \Delta r_t + \varepsilon_t \qquad (16)$$

where the dependent variables are the percentage changes in the cost of mortgage and house price, and the independent variable is the change in the mortgage interest rate. The coefficients of interest, β_t and θ_t, work as time-varying measures of the interest rate sensitivities of cost of mortgage and house prices, and are both estimated using the following local linear least squares estimator,

$$\omega_t = \left[\sum_{j=1}^{T} w_{t,j}(g)\, \Delta r_{t,j+1}^2\right]^{-1} \left[\sum_{j=1}^{T} w_{t,j}(g) \Delta r_{t,j+1} Y_{t,j+1}\right] \qquad (17)$$

where $\omega_t \in \{\beta_t, \theta_t\}$, $Y_t \in \left\{\frac{\Delta K_{M_t}}{K_{M_{t-1}}}, \frac{\Delta P_t}{P_{t-1}}\right\}$, and $w_{t,j}(g)$ is a kernel function with bandwidth g that penalizes distant data. I use the Tri-weight kernel estimator,

$$w_{t,j}(g) = \frac{k_{t,j}(g)}{\sum_{j=1}^{T} k_{t,j}(g)}, \qquad k_{t,j}(g) = \frac{35}{32}\left[1 - \left(\frac{j-t}{g}\right)^2\right]^3 \tag{18}$$

while the bandwidth value is selected such that it minimizes the following leave-one-out cross-validation estimator,

$$CV(g) = \sum_{i=1}^{T}\left[Y_{t,q} - \hat{Y}_{t,-q}\left(\Delta r_{t,-q}; g\right)\right]^2 \tag{19}$$

where $\hat{Y}_{t,-q}\left(\Delta r_{t,-q}; g\right)$ is the fitted regression, but with the point $\left(Y_{t,q}, \Delta r_{t,q}\right)$ omitted. Econometrically, the main advantage of the local-linear least-squares estimator over the traditional least-squares is that it adds flexibility to a linear regression and allows capturing statistically significant effects that exist over time, but that would be hidden if the traditional least-squares was used instead. In a nutshell, the method estimates local unconditional means using data near the point of interest and uses these local estimates to construct the global function, allowing for time-variation over the sample to occur. The kernel estimator gives more weight to the observations that are closer to the point of interest, and the bandwidth value determines the number of observations used in the estimation of the local unconditional means.

4. Data

4.1. Data sources

I use quarterly data for six economies: US, UK, Sweden, Canada, Finland and France comprising the periods from 1971Q2 to 2023Q4 for the US, 1995Q1 to 2023Q4 for the UK, 1982Q1 to 2023Q4 for Sweden, 1975Q1 to 2023Q4 for Canada, 2000Q1 to 2023Q4 for Finland and France. I collect house price data from the BIS property prices database, which offers quarterly real (index) residential property prices for several economies.[6] Mortgage debt is collected from the BIS credit database and is approximated by the variable "Credit to households and Non-Profit Institutions Serving Households (NPISH)".[7] Mortgage interest rate data are collected from various sources. For the US, I use the 30-year fixed mortgage rate obtained from the FRED database. For the UK, I use the 5-year (75% LTV) fixed mortgage rate to households collected from the Bank of England. For Sweden, I use the mortgage rate to households for "total loans with rate fixation for new and renegotiated agreements" obtained from Statistics Sweden. As

[6] The BIS property price database can be accessed through the link https://data.bis.org/topics/RPP/data.
[7] The BIS credit database can be accessed through the link https://data.bis.org/topics/TOTAL_CREDIT/data.

this data is available from September 2005 only, I extend the series to start from 1982 using the average spread of this variable relative to the 3-month T-Bill interest rate collected from the Riksbank database. For Canada, I use the 5-year conventional mortgage rate obtained from the Bank of Canada. Finally, for Finland and France, I use the "banks' interest rates for loans to households for house purchase with a floating rate and an IRF period of up to one year" provided by the ECB.

4.2. Data setup and stylized facts

After collecting the data of interest, I conduct some preliminary data analysis. I start by computing the variables used in the estimation of the interest rate sensitivities, $\Delta P/P$, $\Delta K_M/K_M$ and Δr, as well as the ones used in the estimation of the effects of cost of mortgage on the house price, $(P_t - \bar{P}_t)/\bar{P}_t$ and $(K_{Mt} - \bar{K}_{Mt})/\bar{K}_{Mt}$. For obtaining $\bar{P}$ and $\bar{K}_M$, I first estimate the decaying parameters α_P and α_K using their respective IMA(1,1) representations. Table 1 shows the results. As can be seen, the degree of smoothness for interest rates are similar and comparable across economies. For house prices, however, the degree of smoothness is higher for the US than for Sweden.

Besides determining long-term trends, the estimated EWMA filters also help on the identification of short-term cycles in house prices and the cost of mortgage. These are shown in Figures 3 to 5 and Figures 6 to 11. As can be seen, house prices in the US, the UK, Finland and France exhibit a clear cyclical behavior, with well-defined peaks and throughs in every decade. For instance, the cyclical metric identifies the house price bubble of the mid-2000's and the subsequent crash in the four economies, the recent price appreciation following Covid-19 in the US, among other important periods. House prices in Sweden and Canada have shown a strong positive trend in the last decades, with a few price corrections. Regarding the cost of mortgage, also notice a cyclical pattern, following the interest cycles induced by the monetary contractions and expansions conducted by the central banks over time. For instance, following the interest rate hikes prior to subprime crisis of 2008, the cost of mortgage in both the US and the UK raised significantly. Similar behavior can be seen for Sweden, Finland and France, where one can notice strong increases in the cost of mortgage as interest rates rise. In Canada, despite declining interest rates, the cost of mortgage has shown a positive trend, following the increase in household indebtedness.

It is also important to describe the most recent movements in house prices, interest rates and the cost of mortgage, which have been similar across the six economies. One first important aspect is that the cost of mortgage rose significantly, with percentage deviations from their long-term trends reaching very high levels at the end of the sample, a result of the interest rate rises following the monetary contraction induced by central banks to fight inflation. This phenomenon is shown at the bottom charts of Figures 6 to 11. Concurrently, house prices started dropping from mid-2022, after reaching record high levels in all economies. The percentage deviations shown in Figures 3 to 5 are one indicator of this phenomenon and suggest that house prices have peaked in almost all economies in the first semester of 2022.

5. Estimation results

5.1. Effects of cost of mortgage on house prices

Results for the effects of cost of mortgage on house prices for each economy are shown in Figure 12, where I plot the impulse responses of percentage deviations in house prices to shocks in percentage deviations in the cost of mortgage. As can be seen, effects are mostly negative for all economies, as suggested by theory. In addition, notice that the effects are mostly lagged. The maximum negative effect of shocks to cost of mortgage on house prices happens for h = 12 quarters for the US, h = 20 quarters for the UK, h = 4 quarters for Sweden, h = 11 quarters for Canada, h = 3 quarters for Finland, and h = 6 quarters for France. The interpretation for the fast responses of house prices to shocks in the cost of mortgage in Finland and Sweden is that 96% and 70% of mortgage loans in the two economies are issued with variable interest rates. Because of that, a contractionary monetary policy that raises mortgage rates has relatively fast rising effects on the cost of existing mortgages and, as a result, households may wish to move to cheaper dwellings with lower mortgage costs, resulting in a relatively fast decline of house prices. A similar argument is valid for mortgage markets with a large share of fixed-rate loans with maturities ranging from one-year to over ten-years, such as the UK (around 90%), where the response of house prices to shocks in the cost of mortgage takes quite some time to materialize, around 20 quarters. The responses in France are also relatively fast, six quarters, as its mortgage market is characterized by a very large share of short-term fixed interest rate contracts (one- to five-years). Therefore, out of the six countries analyzed, Finland and Sweden are the ones with the fastest responses, followed by France, Canada, the US, and the UK.

In terms of values, Table 2 shows the maximum negative effects in the impulse responses shown in Figure 12, together with the associated lag (h). The estimates suggest that a 1% percentage increase in the deviation of cost of mortgage results in about 15 basis points drop in the deviation of house price in the US, 17 basis points drop in the UK, about 8 basis points drop in Sweden, around 13 basis points drop in Canada, and around 7 and 8 basis points drop in Finland and France, respectively. All results are highly statistically significant. Results also show a good degree of explanatory power in the regressions, with coefficients of determination (R2) of up to 35% (Finland).

As robustness, I also estimate a fixed-effect panel local projection, which considers data for all six countries together. This exercise provides a better identification of the effects of cost of mortgage on house price. To account for the relatively small number of cross-section observations (six), standard errors are estimated using White's estimator restricted and clustered by time to deal with heteroscedasticity. Results are shown by Figure 13 and confirm the previous ones. As can be seen, effects are negative and significant, with a maximum negative effect of -0.067 at h = 18 quarters.

5.2. Interest rate sensitivity of cost of mortgage

Results for the time-varying interest rate sensitivity of cost of mortgage are shown in Figure 14, which displays both the theoretical and the estimated sensitivity that is obtained from the time-varying coefficient regression model. As can be seen, the theoretical and estimated values line up quite well, with theoretical values remaining largely inside the estimated 95% confidence interval. This indicates a high level of accuracy in the estimation of β_t. Both sensitivities have also increased over time, as mortgage rates have shown a downtrend, reaching low levels in a recent past. However, more recently, as interest rates have increased, the two sensitivities have dropped considerably in all countries, except in Canada. Notice also that both measures of the interest sensitivity of cost of mortgage have raised in a cyclical fashion, following the monetary contractions and expansions induced by central banks over the period of analysis. As an example, the recent monetary expansion following Covid-19, when interest rates reached record lows, caused the interest rate sensitivity of cost of mortgage to spike in all economies. For instance, in the US, the measure reached 0.32, implying that a 10 basis points rise in the mortgage rate would increase the cost of mortgage by 3.5 percent. During the same period, the estimated sensitivity reached 0.64 in the UK, 0.79 in Sweden, 0.27 in Canada, 2.0 in Finland and 0.84 in France

5.3. Interest rate sensitivity of house prices

Results for the time-varying interest rate sensitivity of house prices are shown in Figure 15. Recall from the theoretical result that this sensitivity should decline with the cost of mortgage and rise with the loan-to-value ratio and with the share of variable mortgage rate contracts. Therefore, because the behavior of the interest rate sensitivity of house price is determined by these three terms, it becomes difficult to clearly identify what component is really driving its behavior over time.

As can be seen from Figure 15, results indicate the interest rate sensitivity of house prices have remained relatively constant and around zero in the US, with the average sensitivity over the whole period marking 0.0006. Results for the UK, Sweden, Canada, Finland and France differ. The sensitivity averages

-0.0051, -0.0138, -0.0028, -0.0188 and -0.0153 for each country, respectively. Importantly, the sensitivity also turns significantly negative recently in Sweden, Canada, Finland and France, when the loan-to-value ratio has increased substantially in these economies. In turn, similar movements happened in 2013 and 2016 in the UK, around 2003, 2015 and 2022 in Sweden, around 1985 and 2022 in Canada, 2008 and 2020 in Finland, and around 2003, 2008 and 2020 in France.

6. Implications

6.1. *General implications for house prices*

The results above have key implications for house prices. As interest rates have shown a declining trend over the past decades, the interest rate sensitivity of the cost of mortgage has increased, causing the cost of mortgage to be more subject to sudden rises when mortgage rates increase. When that happens, house prices shall react negatively. As a result, the recent monetary contraction induced by several central banks to fight inflation has caused the cost of mortgage to rise sharply and house prices to react negatively in several economies. Moreover, results suggest that the speed of the reaction is correspondent to the share of variable interest rate mortgage contracts in the economy, and the strength, in turn, depends on the level of the loan-to-value ratio and on the effects of the cost of mortgage on the house price itself. Following this argument, the data analyzed in this study indicate stronger house price declines in Finland, Sweden and Canada recently. These results have also key implications for real estate investments. As house prices commonly react with lags, sharp rises in the cost of mortgage may suggest future house price declines. Under this scenario it might be wise that real estate investors pull out their funds from highly risky markets and redirect them to more favorable ones.

6.2. *Policy implication: the attenuation effect*

Results described above also have policy implications. More specifically, as the mortgage rate r declines, results regarding the interest rate sensitivity of the cost of mortgage can be attenuated when the constraints that the zero-lower bound imposes on the mortgage rate are softened. This happens either when (i) the central bank shifts its focus towards lowering longer-term interest rates through unconventional monetary policy, or (ii) when the central bank and market participants perceive the effective lower bound as being lower or negative. The theoretical result of it is a parallel shift in the expression of the interest rate sensitivity of cost of mortgage defined in section 2.1. More specifically, one may have,

$$\frac{\partial ln(K_M)}{\partial r^*} = \frac{\eta}{r^*} = \frac{\eta}{r+\mu}, \quad r^* = r + \mu, \quad \mu > 0 \qquad (20)$$

where one can think of r^* as the new mortgage rate in cases (i) and (ii) above. Notice that when longer-term interest rates are more in focus, a premium μ is added to r, as long-term rates are on average traded at higher levels than short-term rates. Similarly, when the effective lower bound becomes lower or negative, r is allowed to assume negative values, towards $-\mu$. The key implication of it is the *attenuation effect,* that is, the cost of mortgage becomes less sensitive to interest rate changes. Notice also that, according to the expression above, the interest rate sensitivity of cost of mortgage approaches infinite when r^* approaches zero or when r approaches $-\mu$. Graphically, this is illustrated by Figure 1(b).

7. Concluding remarks

This paper examines the implications of the maturity structure of mortgage contracts for the effects of the cost of mortgage on house prices. The argument is that economies which experience a large share of mortgage contracts with variable interest rates present faster responses of house prices to changes in mortgage rates and the cost of mortgage. To study that, I present theoretical results which show that the cost of mortgage becomes more sensitive to changes in mortgage rates the larger the share of variable mortgage rate contracts and the lower the mortgage interest rate. Regarding house prices, my theoretical results imply that house prices become more sensitive to changes in mortgage rates the larger the effects of the cost of mortgage on house prices, the higher the loan-to-value ratio, and the larger the share of variable mortgage interest rate contracts in the economy. I also present empirical results that support my arguments. Local projections (Jordà 2005) estimated using data for the US, UK, Sweden, Canada, Finland and France show negative and significant impulse responses of house prices to shocks on the cost of mortgage for all economies. Effects are also lagged, with the maximum responses happening after thirteen quarters for the US, twenty quarters for the UK, four quarters for Sweden, eleven quarters for Canada, three quarters for Finland and six quarters for France. The speed of adjustment of the impulse responses are closely connected to the share of mortgage contracts with variable (or short-term fixed) interest rates in the economies. Results also indicate that the estimated interest rate sensitivity of the cost of mortgage increases as the mortgage interest rate declines, which is line with theory. Moreover, the estimated values track closely the theoretical result based on the data only, confirming the ability of the time-varying coefficient model proposed in this paper to replicate the data.

The theoretical and empirical results in this paper have important implications for how monetary policy affects house prices. As interest rates have shown a declining trend over the past decades, the interest rate sensitivity of the cost of mortgage has increased, making the cost of mortgage more subject to sudden rises when monetary policy is contracted. As a result, house prices shall react negatively, with the speed of reaction being correspondent to the share of variable interest rate mortgage contracts in the economy, and with the magnitude of the reaction depending on the loan-to-value ratio, keeping constant any other factors that may affect house prices. As the data analyzed shows, these results are more strongly seen in Finland, Sweden and Canada, the three countries with the fastest speeds of adjustment. Another implication is that the increase seen in the interest rate sensitivity of cost of mortgage can be attenuated when the constraints imposed by the zero-lower bound on the mortgage rate are softened. This happens when the central bank shifts its focus towards changing longer-term interest rates through unconventional monetary policy, or when the central bank and market participants perceive the effective lower bound as being lower or negative. Finally, there are also implications for real estate investments, as sharp rises in the cost of mortgage may suggest future house price declines. Under this scenario, real estate investors may choose to reallocate their funds from highly risky markets to more favorable ones

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Table 1: Estimation results for decaying parameters α_P and α_K

	House price (α_P)	Cost of mortgage (α_K)
US	0.1338	0.1867
UK	0.1318	0.0950
Sweden	0.2323	0.0517
Canada	0.2245	0.1626
Finland	0.2855	0.2464
France	0.2963	0.2000

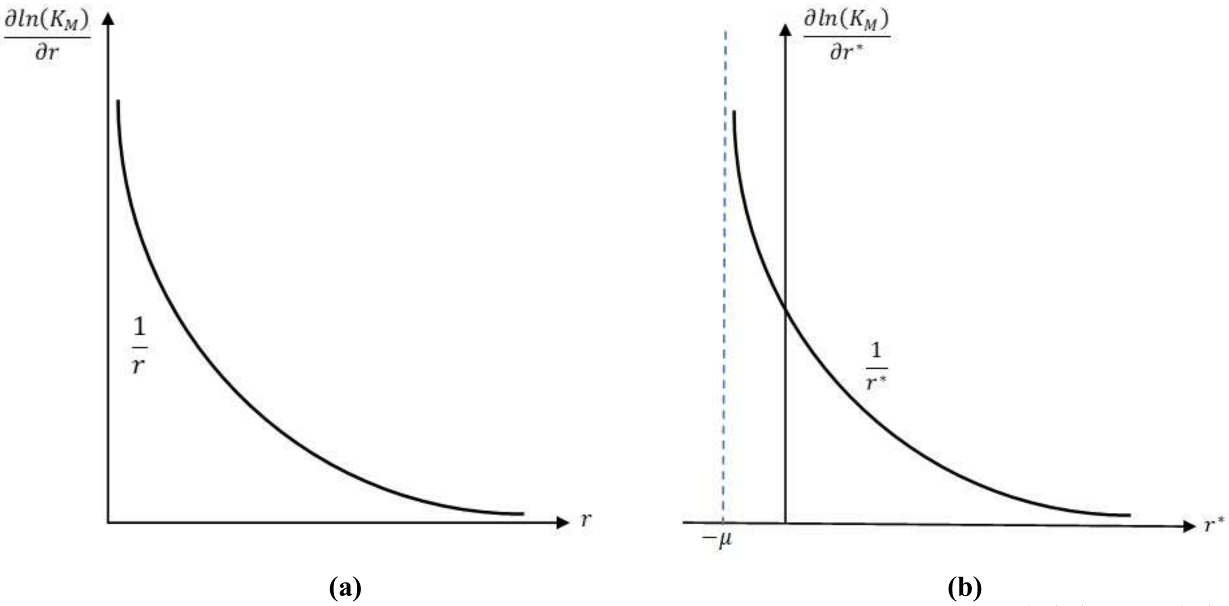
Notes: This table shows the estimation results for the decaying parameters α_P and α_K in the EWMA filters for housing prices and cost of mortgage for the US, UK, Sweden, and Canada.

Table 2: Maximum negative effect of cost of mortgage on house prices

	Lag (h) in quarters	Effect (φ_1^h)	$\bar{R}^2$
US	*h = 13*	-0.1474*** (0.0499)	0.042
UK	*h = 20*	-0.1677*** (0.0493)	0.108
Sweden	*h = 4*	-0.0748*** (0.0133)	0.162
Canada	*h = 11*	-0.1338*** (0.0277)	0.113
Finland	*h = 3*	-0.0711*** (0.0101)	0.349
France	*h = 6*	-0.0777*** (0.0260)	0.091

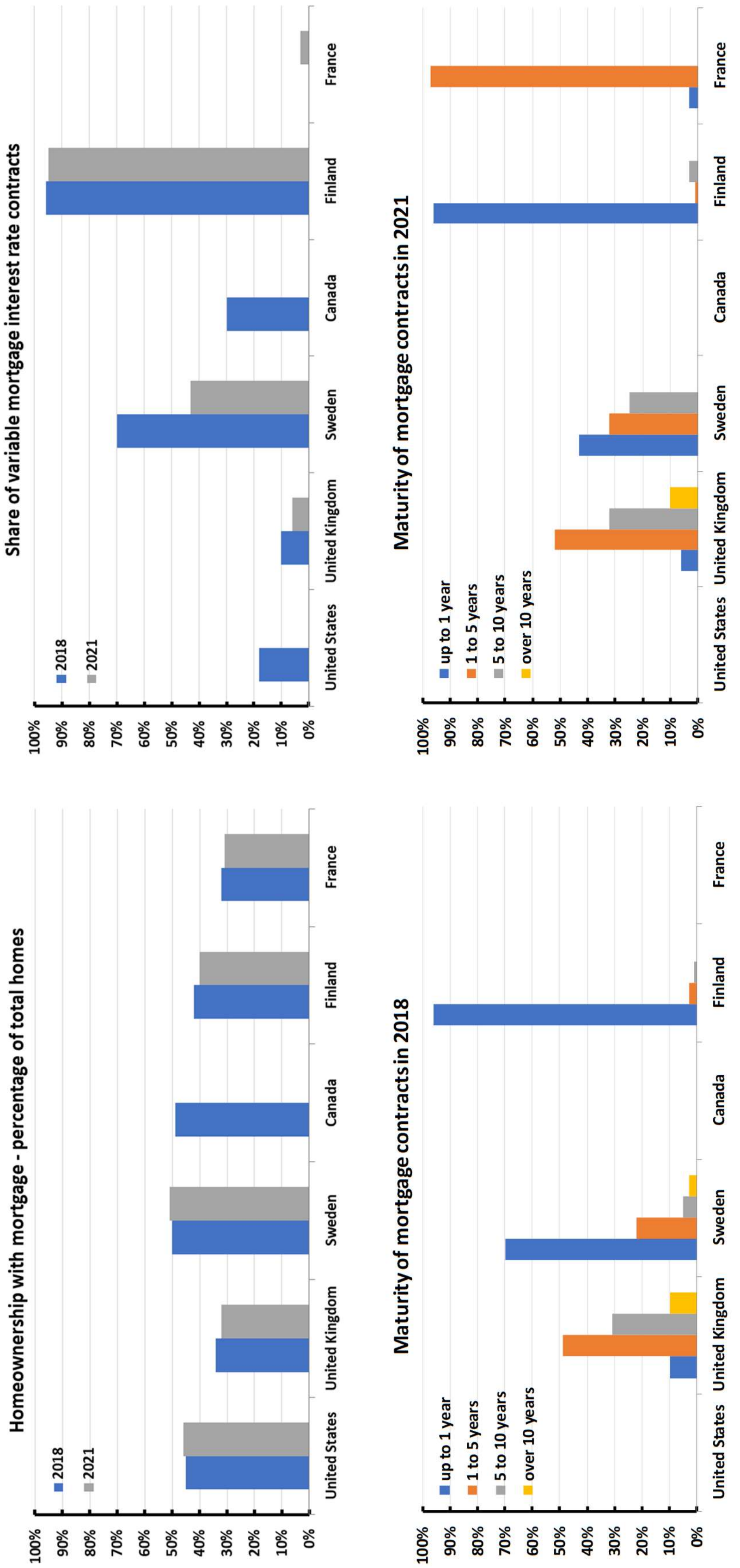
Notes: This figure shows the maximum negative effect of (deviations in) cost of mortgage on (deviations in) house prices, estimated using the local projection $\frac{P_t - \bar{P}_t}{\bar{P}_t} = \varphi_0^h + \varphi_1^h \frac{K_{Mt-h} - \bar{K}_{Mt-h}}{\bar{K}_{Mt-h}} + \vartheta_t$, where the minimum effect is captured through the minimum value of the coefficient φ_1^h considering different lags h. (***) indicates significance at 1% level. Standard errors are shown in parenthesis.

Figure 1: Interest rate sensitivity of the cost of mortgage (in percentage terms)



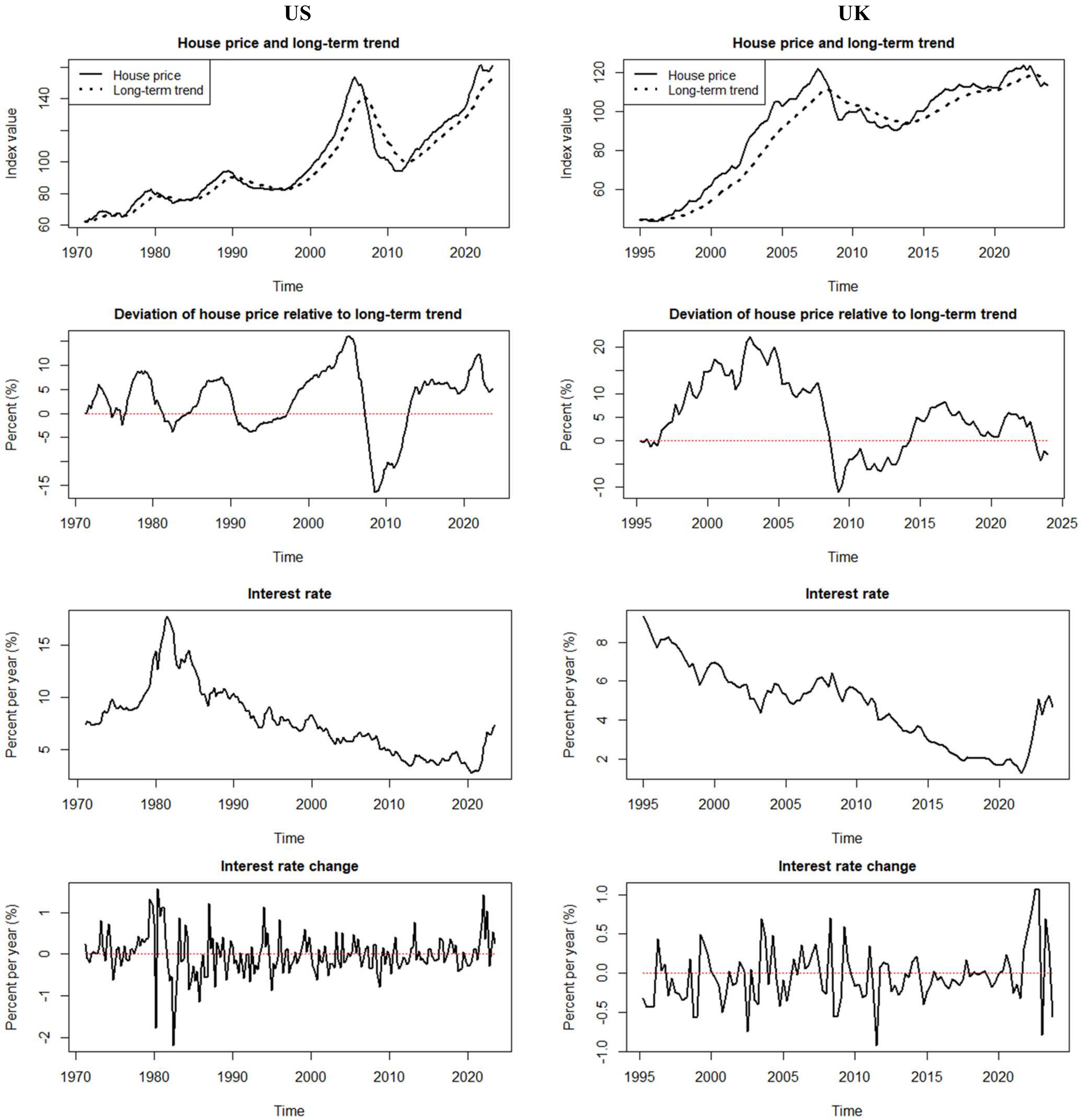
Notes: This figure shows the interest rate sensitivities of the cost of mortgage (in percentage terms) defined as $\frac{\partial ln(K_M)}{\partial r} = \frac{1}{r}$ and $\frac{\partial ln(K_M)}{\partial r^*} = \frac{1}{r+\mu}$, respectively.

Figure 2: Characterization of mortgage markets



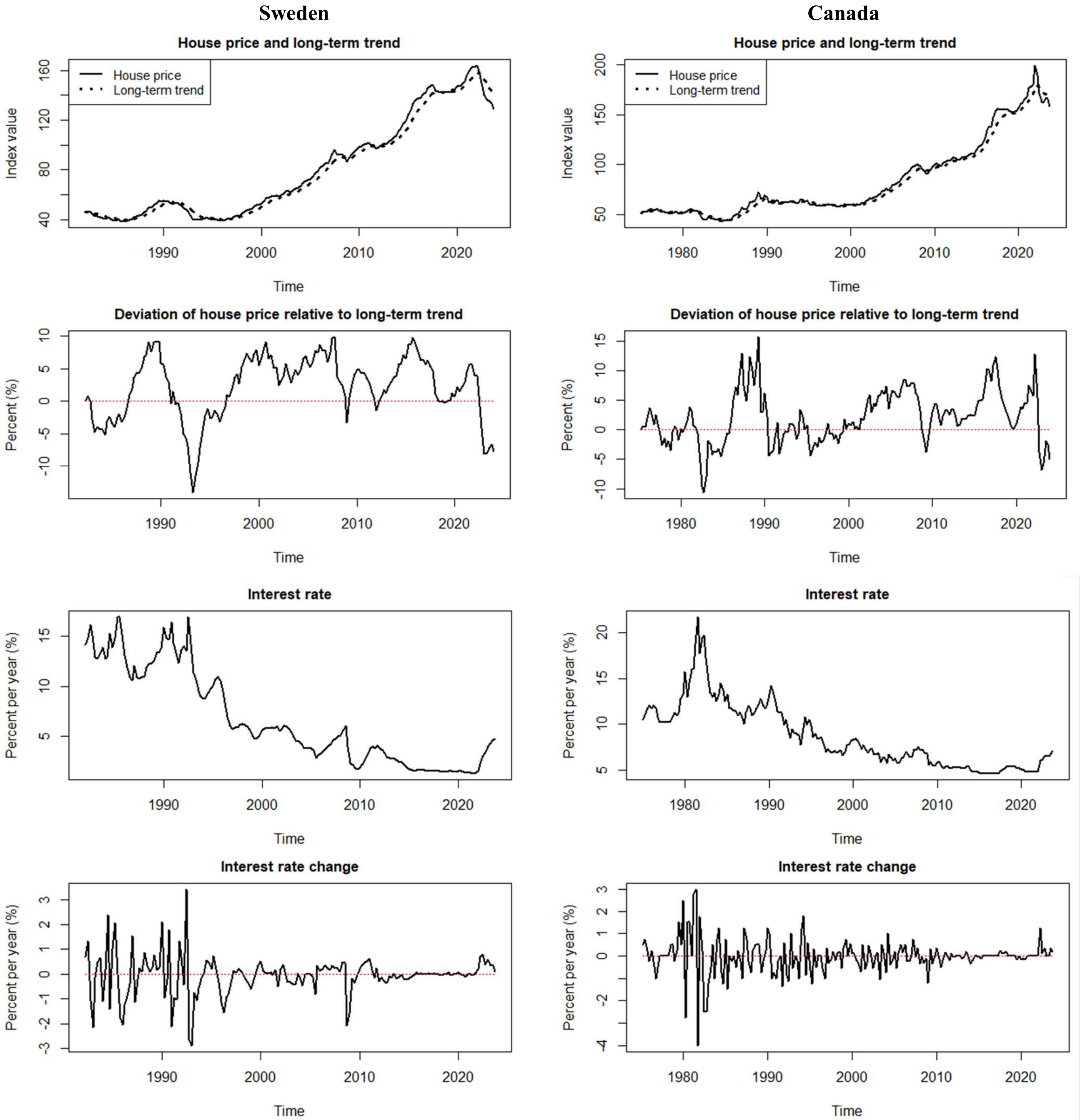
Notes: This figure shows the statistics characterizing the mortgage markets of US, UK, Sweden, Canada, Finland and France. It is shown (i) the percentage of homeownership with mortgage (top-left), (ii) the share of variable interest rate mortgage contracts (top-right), and (iii) the maturity of mortgage contracts in 2018 and 2021 (bottom).

Figure 3: House prices and interest rates for the US and UK



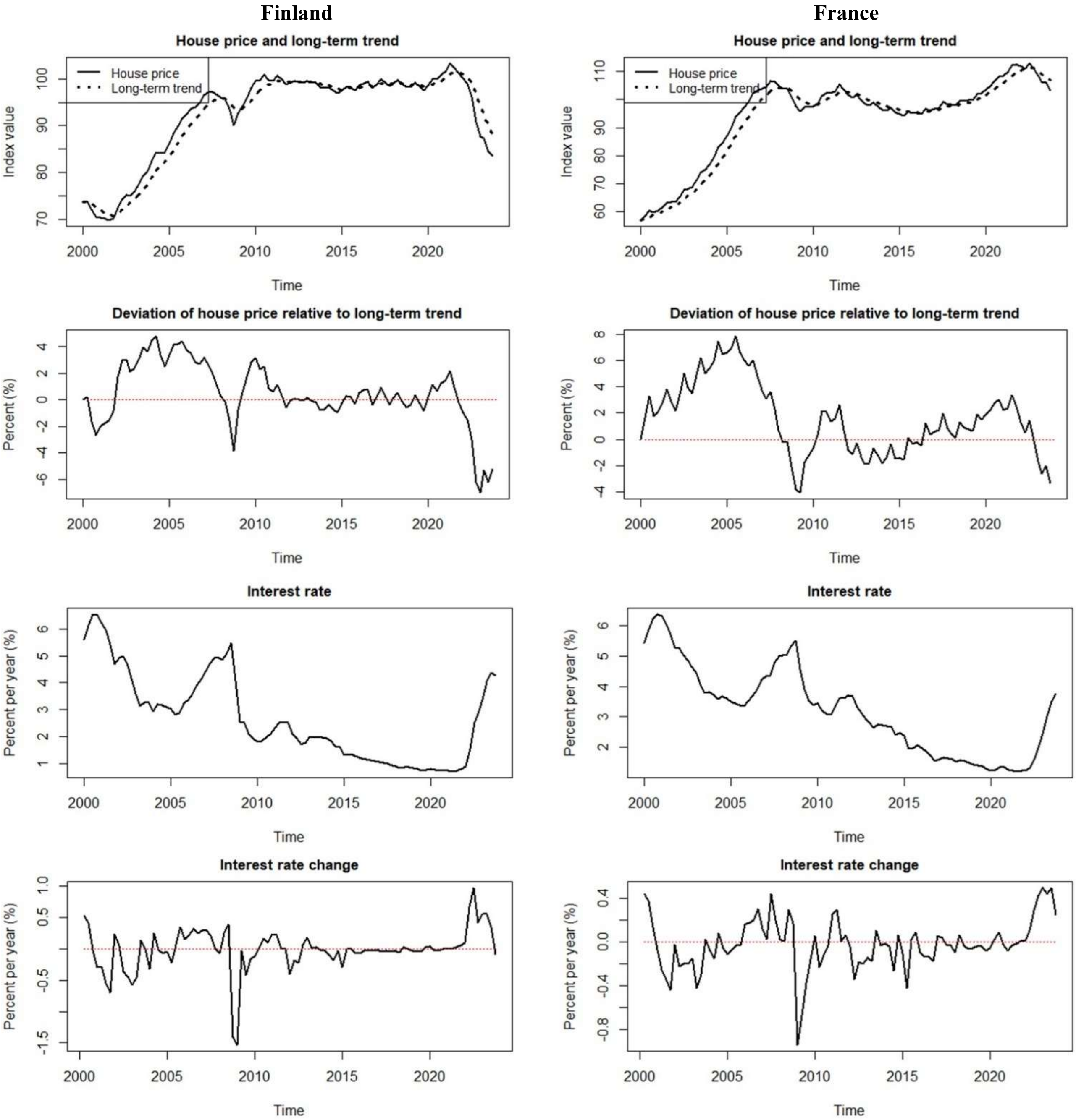
Notes: The four charts in the top show the time-series of house prices, its estimated long-term trend, as well as the percentage deviation of the house price relative to its long-term trend for the US and the UK. The four charts in the bottom show the time-series of the mortgage interest rates as well as their changes.

Figure 4: House prices and interest rates for Sweden and Canada



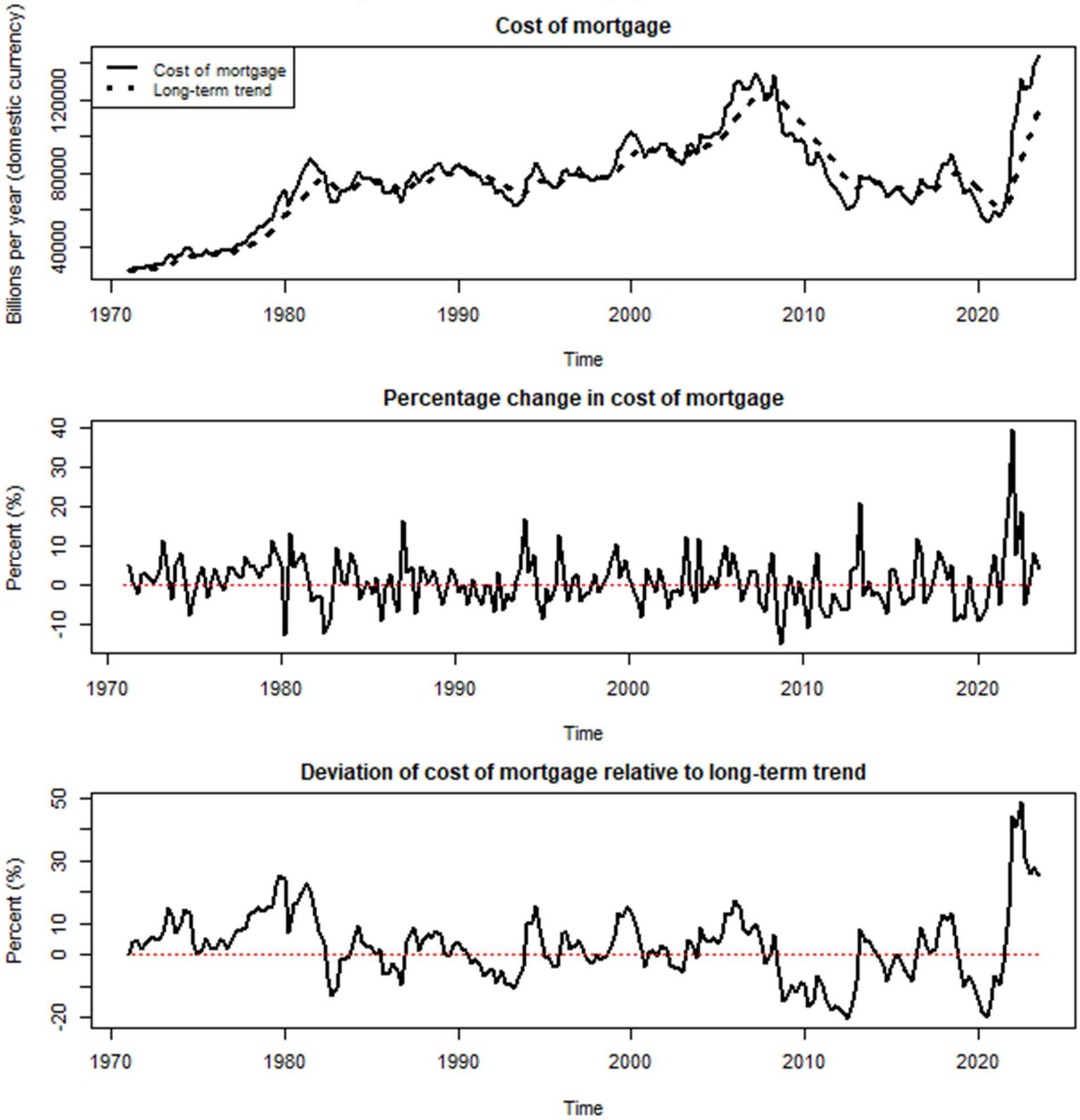
Notes: The four charts in the top show the time-series of house prices, its estimated long-term trend, as well as the percentage deviation of the house price relative to its long-term trend for Sweden and Canada. The four charts in the bottom show the time-series of the mortgage interest rates as well as their changes.

Figure 5: House prices and interest rates for Finland and France



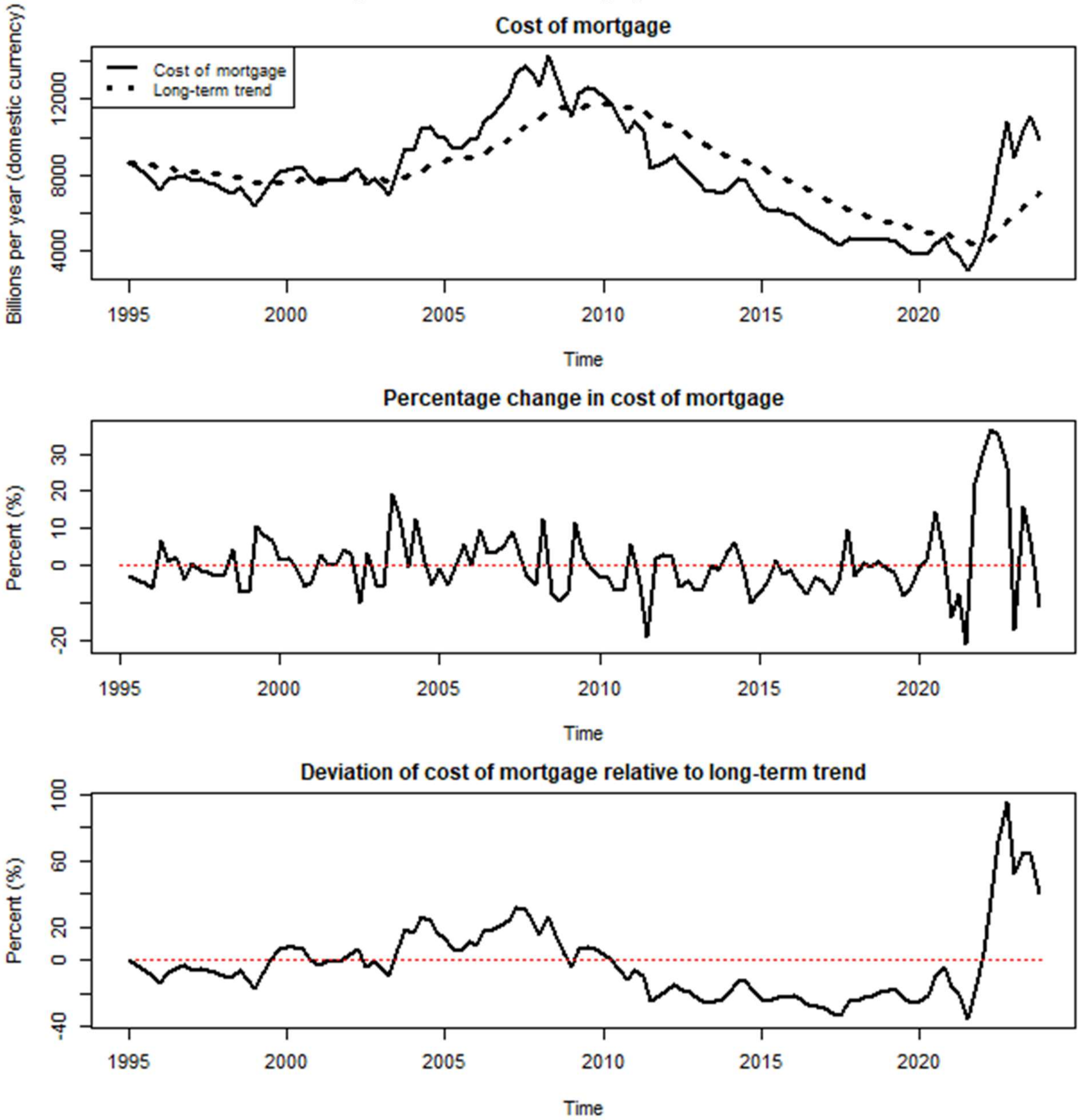
Notes: The four charts in the top show the time-series of house prices, its estimated long-term trend, as well as the percentage deviation of the house price relative to its long-term trend for Finland and France. The four charts in the bottom show the time-series of the mortgage interest rates as well as their changes.

Figure 6: Cost of mortgage for the US



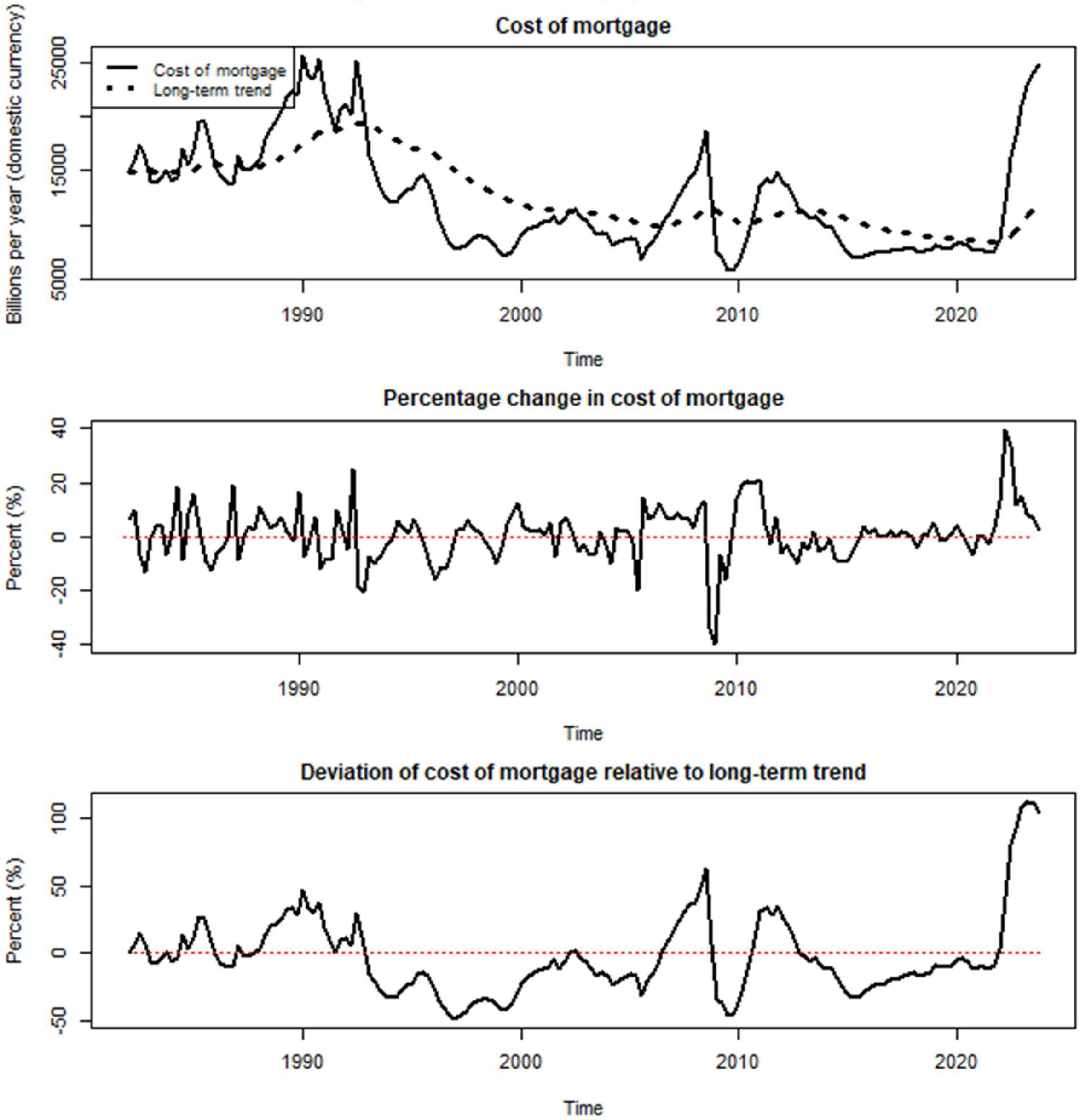
Notes: This figure shows the time-series of the cost of mortgage (K_M), percentage change in cost of mortgage and deviation of cost of mortgage relative to its long-term trend (in percentage terms) for the US. The long-term trend is estimated using an EWMA.

Figure 7: Cost of mortgage for the UK



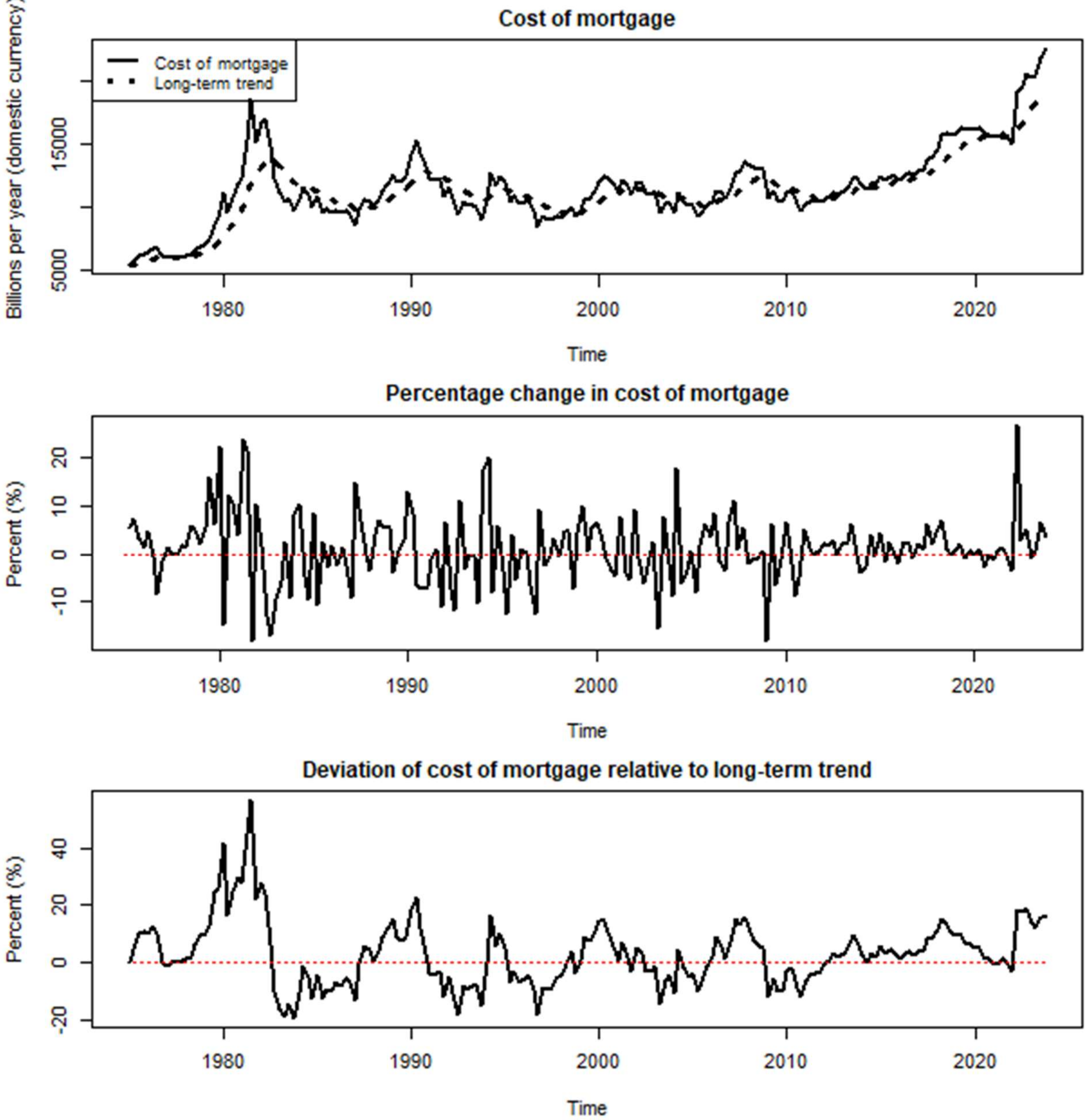
Notes: This figure shows the time-series of the cost of mortgage (K_M), percentage change in cost of mortgage and deviation of cost of mortgage relative to its long-term trend (in percentage terms) for the UK. The long-term trend is estimated using an EWMA.

Figure 8: Cost of mortgage for Sweden



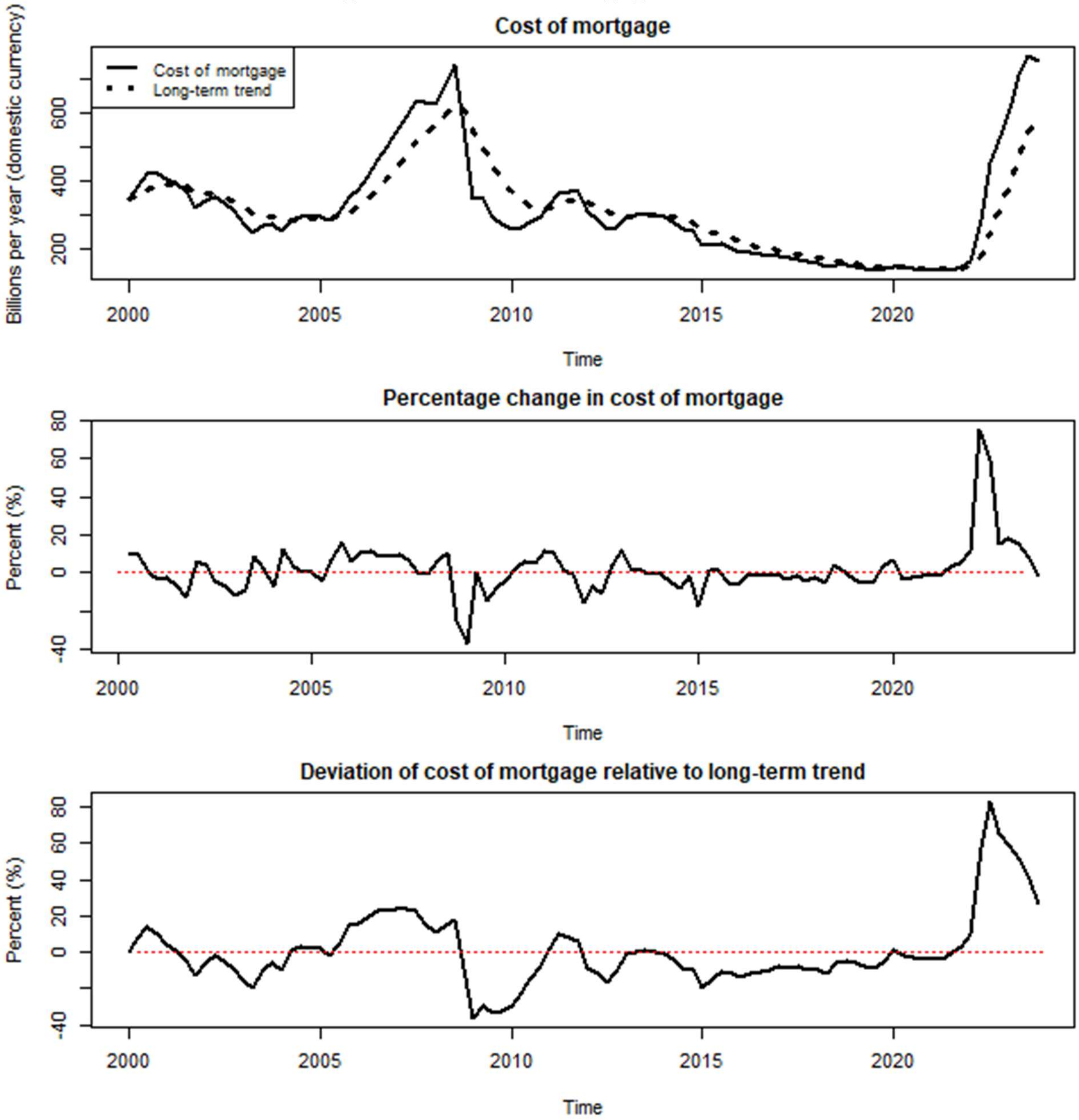
Notes: This figure shows the time-series of the cost of mortgage (K_M), percentage change in cost of mortgage and deviation of cost of mortgage relative to its long-term trend (in percentage terms) for Sweden. The long-term trend is estimated using an EWMA.

Figure 9: Cost of mortgage for Canada



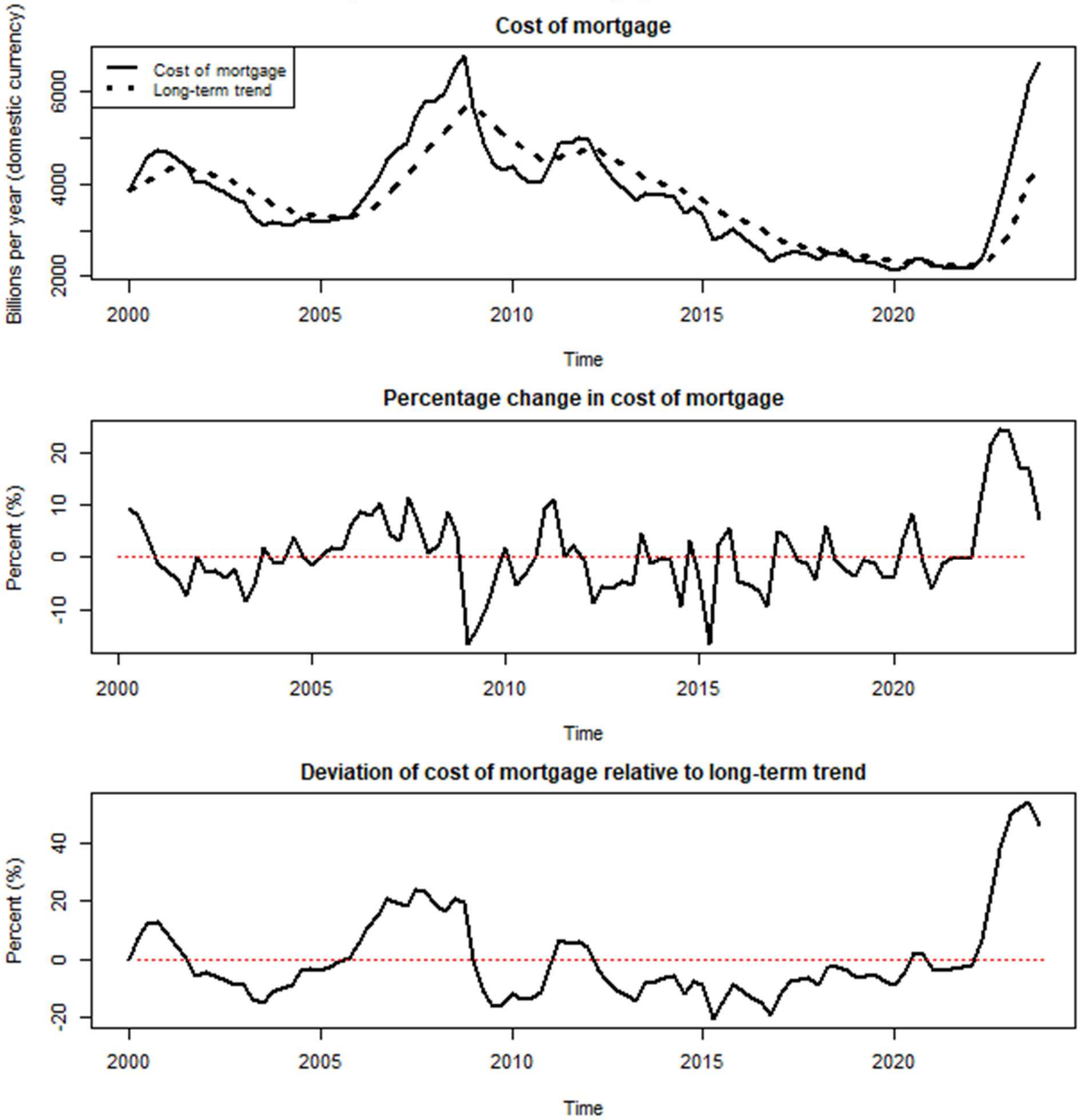
Notes: This figure shows the time-series of the cost of mortgage (K_M), percentage change in cost of mortgage and deviation of cost of mortgage relative to its long-term trend (in percentage terms) for Canada. The long-term trend is estimated using an EWMA.

Figure 10: Cost of mortgage for Finland



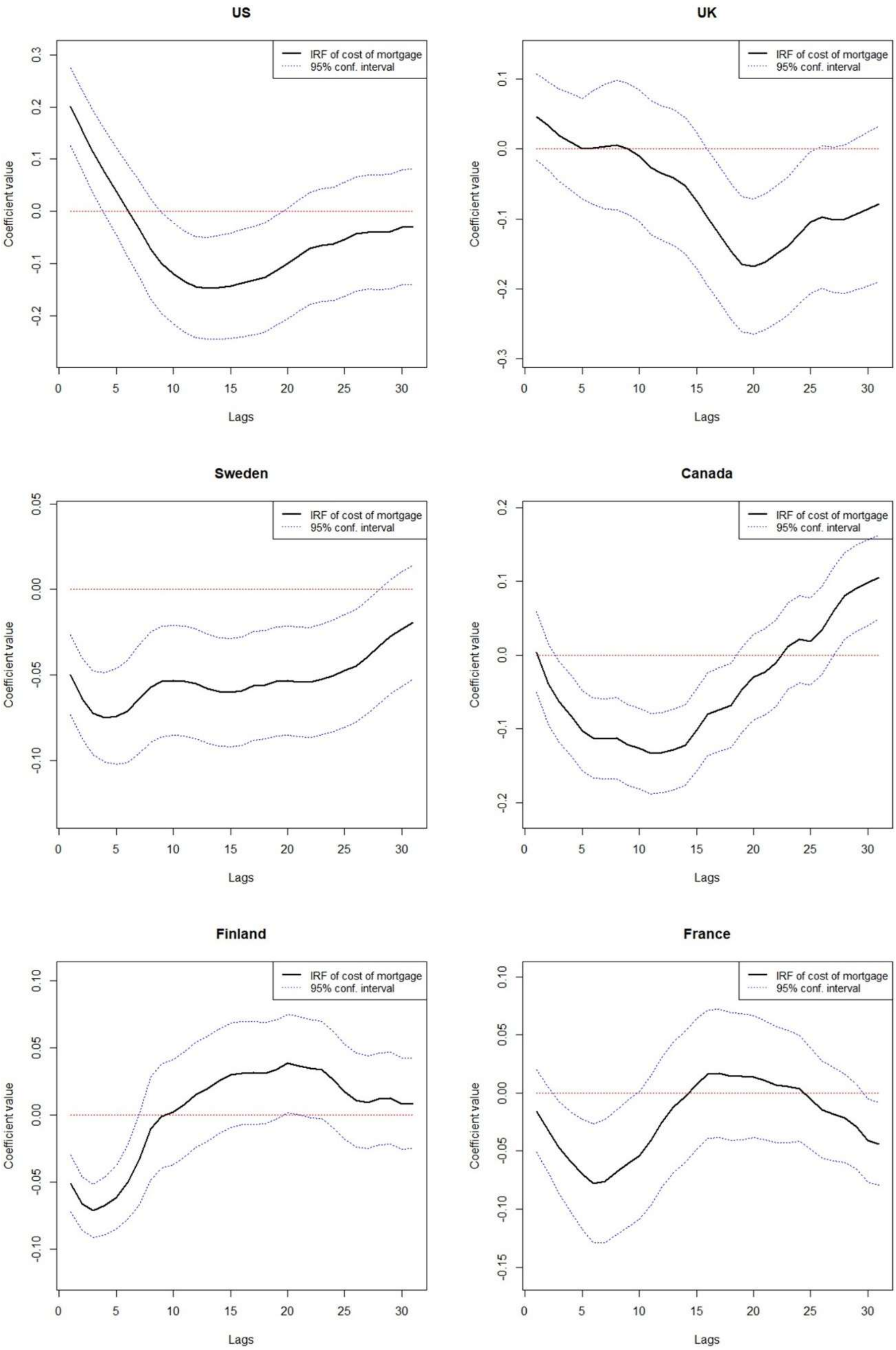
Notes: This figure shows the time-series of the cost of mortgage (K_M), percentage change in cost of mortgage and deviation of cost of mortgage relative to its long-term trend (in percentage terms) for Finland. The long-term trend is estimated using an EWMA.

Figure 11: Cost of mortgage for France



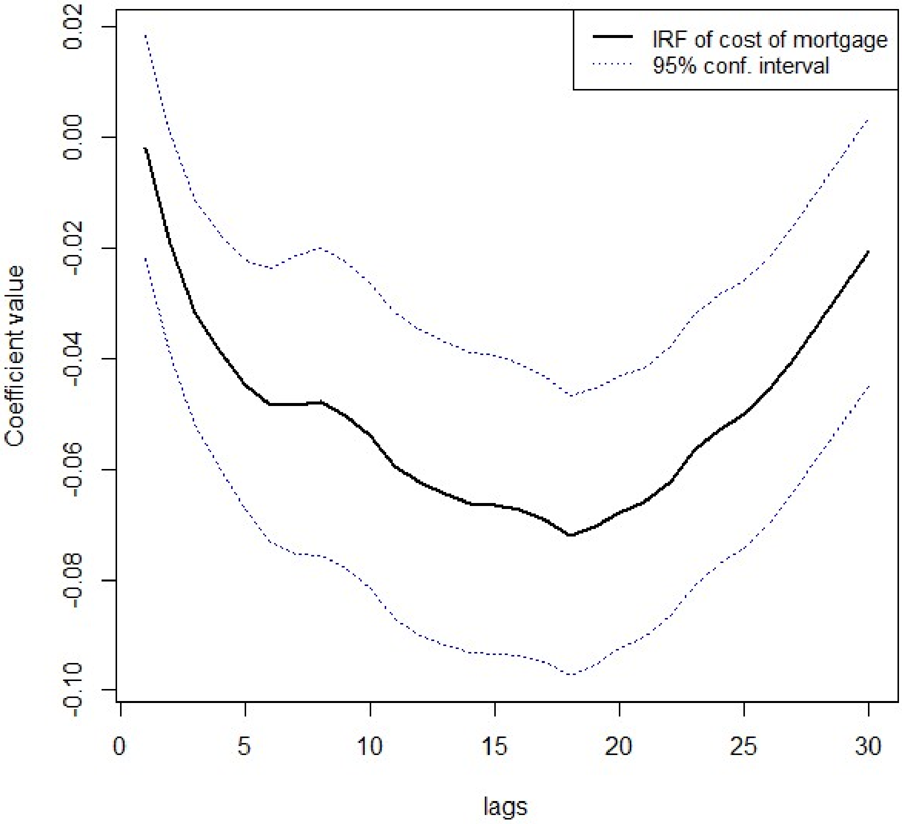
Notes: This figure shows the time-series of the cost of mortgage (K_M), percentage change in cost of mortgage and deviation of cost of mortgage relative to its long-term trend (in percentage terms) for France. The long-term trend is estimated using an EWMA.

Figure 12: Effects of cost of mortgage on house prices



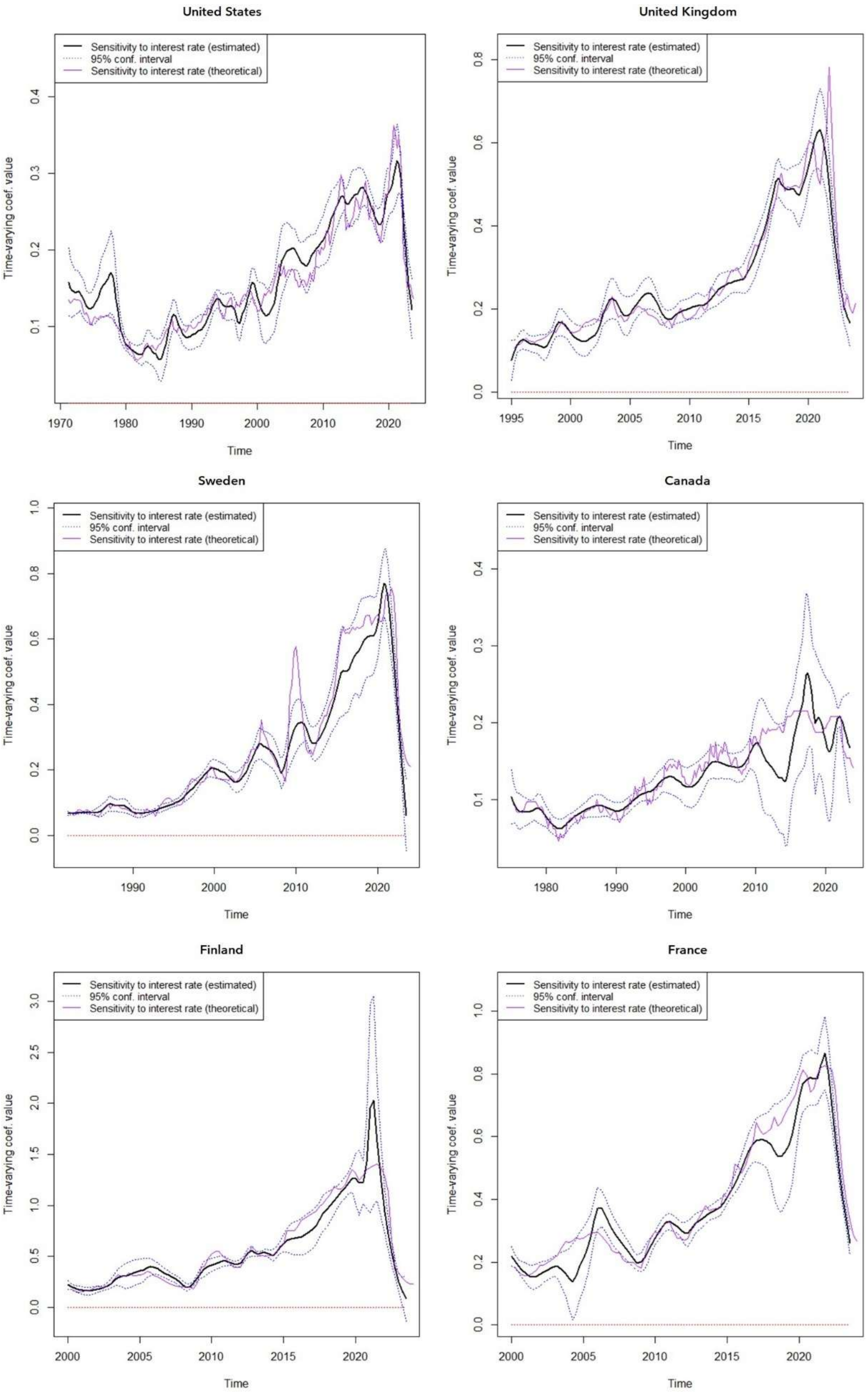
Notes: This figure shows the effects of (deviations in) cost of mortgage on (deviations in) house prices. These are estimated using the local projection $\frac{P_t-\bar{P}_t}{\bar{P}_t} = \varphi_0^h + \varphi_1^h \frac{K_{Mt-h}-\bar{K}_{Mt-h}}{\bar{K}_{Mt-h}} + \vartheta_t$, where effects are captured through the coefficient φ_1^h for different lags h. 95% confidence intervals are shown as blue-dashed lines.

Figure 13: Effects of cost of mortgage on house prices - panel



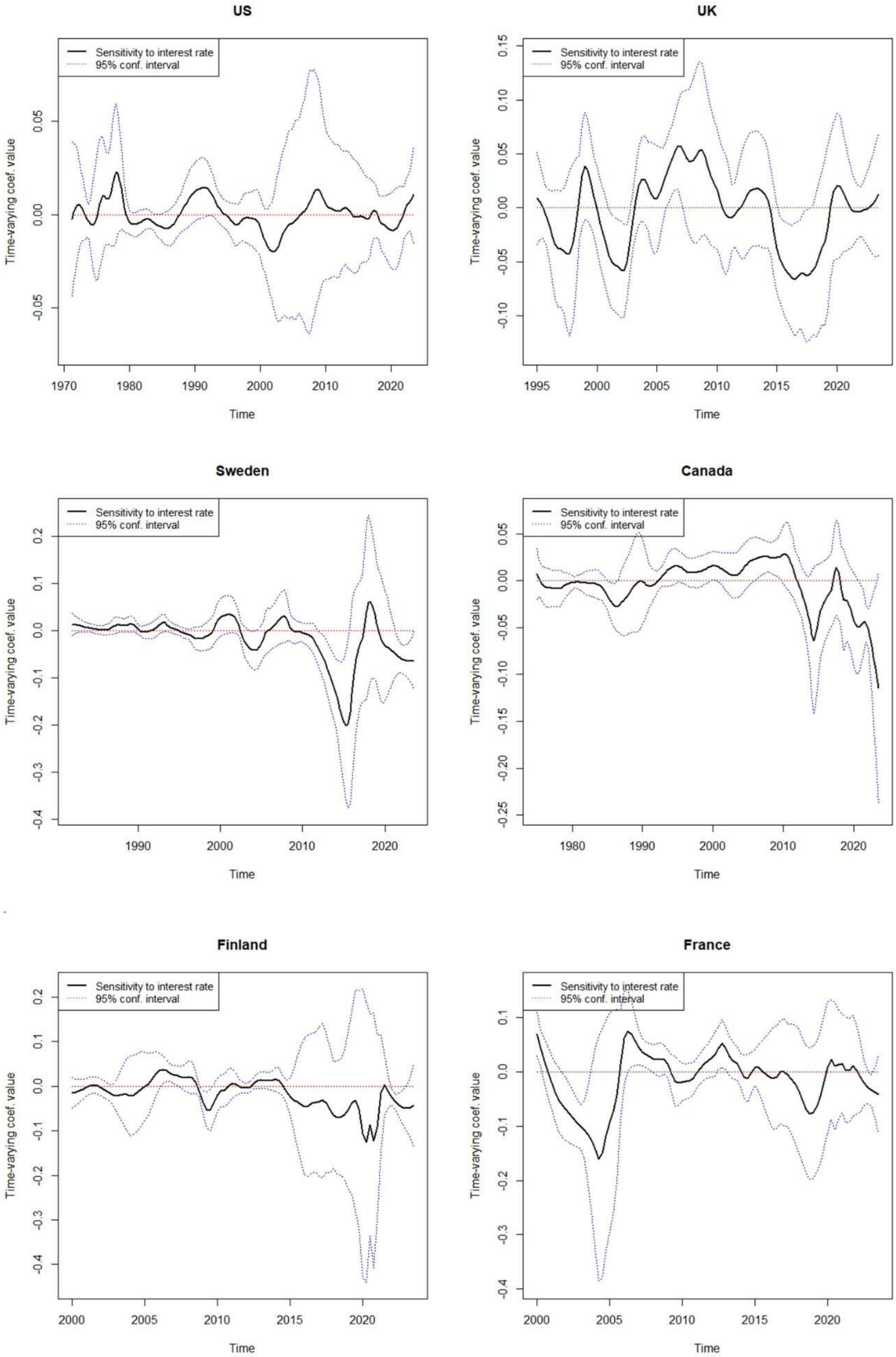
Notes: This figure shows the effects of (deviations in) cost of mortgage on (deviations in) house prices. These are estimated using a panel (fixed-effects) linear local projection model. 95% confidence intervals are shown as blue-dashed lines.

Figure 14: Interest rate sensitivity of cost of mortgage



Notes: This figure shows the theoretical (purple line) and estimated (black line) sensitivity of cost of mortgage to the interest rate (in percentage terms). The theoretical sensitivity is obtained from $\frac{\partial ln(K_M)}{\partial r} = \frac{1}{r}$, and the estimated sensitivity is obtained from the coefficient β_t in the regression $\frac{\Delta K_{M_t}}{K_{M_{t-1}}} = \beta_t \Delta r_t + \epsilon_t$. 95% confidence interval for the estimated sensitivity β_t is shown as blue-dashed lines.

Figure 15: Interest rate sensitivity of house price



Notes: This figure shows the estimated sensitivity of house price to the interest rate (in percentage terms). The estimated sensitivity is obtained from the coefficient θ_t in the regression $\frac{\Delta P_t}{P_{t-1}} = \theta_t \Delta r_t + \varepsilon_t$. 95% confidence interval for the estimated sensitivity θ_t is shown as blue-dashed lines.