Monetary Policy, Housing Rents, and Inflation Dynamics*

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Abstract

In this paper we study the effect of monetary policy shocks on housing rents. Our main finding is that, in contrast to house prices, housing rents increase in response to contractionary monetary policy shocks. We also find that, after a contractionary monetary policy shock, rental vacancies and the homeownership rate decline, while the homeowner vacancy rate increases. This combination of results suggests that monetary policy may affect housing tenure decisions (own versus rent). In addition, we show that, with the exception of the shelter component, all other main components of the consumer price index (CPI) either decline in reponsive to a contractionary monetary policy shock or are not responsive. These findings motivated us to study the statistical properties of alternative measures of inflation that exclude the shelter component. We find that measures of inflation that exclude shelter have most of the statistical properties of the widely used measures of inflation, such as the CPI and the price index for personal consumption expenditures (PCE), but have higher standard deviations and react more to monetary policy shocks. Finally, we show that the response of housing rents accounts for a large proportion of the "price puzzle" found in the literature.

JEL classification codes: E31, E43, R21.

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1 Introduction

It is now a well established result that the housing sector plays an important role in the transmission mechanism of monetary policy - Iacoviello (2005), Del Negro and Otrok (2007), Calza et al. (2013) and Luciani (2015) are examples of studies showing the effects of monetary policy on housing. Most of the literature on housing and monetary policy has primarily focused on house prices and residential investment, and, to the best of our knowledge, there are no studies on the effect of monetary policy on housing rents. In this paper we fill this gap in the literature and use a small-scale structural vector autoregressive (SVAR) model and a factor-augmented VAR (FAVAR) model to study the effect of monetary policy shocks on housing rents.

Our main finding is that, in contrast to house prices, housing rents increase after a contractionary monetary policy shock. We also find that, after a contractionary monetary policy shock, rental vacancies and the homeownership rate decline, while the homeowner vacancy rate increases. This combination of results suggests that monetary policy may affect housing tenure decisions (own versu. rent). In addition, we show that, with the exception of shelter, all other main components of the consumer price index (CPI) or the price index of personal consumption expenditure (PCE) either decline in response to contractionary monetary policy shocks or are not responsive. These findings motivated us to study the statistical properties of alternative measures of inflation that exclude the shelter component. Relative to the widely used measures of inflation, such as the CPI or PCE, these alternative measures of inflation have a slightly lower mean, a slightly higher variance, but similar autocorrelation patterns to those of existing measures of inflation. Importantly, we find that these alternative measures of inflation react more to monetary policy shocks. We also show that the response of housing rents accounts for a large proportion of the "price puzzle" found in the literature. Our findings contribute to the literature on housing and macroeconomics and to the literature on inflation dynamics.

Although housing was not completely absent from the macroeconomics literature before the global financial crisis, it was seen as a minor component of the economy which did not deserve special attention (Piazzesi and Schneider (2016)). However, since the great financial crisis, housing has gained much more attention in the macroeconomics literature, as it became clear that housing was much more important than previously recognized. A distinctive characteristic of housing is that it is not only an asset (the land and the dwelling) but also a consumption good (in the form of housing services). As a consumption good, housing services have the largest weight in the consumption bundle of the typical household, and, for most households, their house is their most important asset. As such, shocks that affect the cost of housing consumption or the price of houses are likely to have first-order effects in the welfare of most households. We contribute to this literature by showing that monetary policy affects the housing market by simultaneously affecting house prices and house rents, but with opposite effects on such prices and rents.

Our finding about the effect of monetary policy on housing rents has important implications for inflation dynamics because, directly and indirectly, rents have a weight of about 30% in the CPI and about 15% in the PCE. Therefore, the response of consumer prices to monetary policy shocks combines the responses of housing and non-housing prices. We show that, relative to the CPI and PCE, a measure of prices that excludes shelter prices has a larger response to monetary policy shocks than do the measures of prices that include all goods. In other words, we find that low responses of overall consumer prices to monetary policy shocks are the result of strong opposing movements in nominal housing rents and the nominal prices of all other goods in the economy. This result suggests that consumer prices in the United States may be more responsive to monetary policy shocks than currently thought (Gertler and Karadi (2015), Pivetta and Reis (2007)). A higher level of consumer prices responsiveness will have implications for the trade-off between price stability and economic growth. On the one hand, the monetary policy authority can control prices with smaller monetary shocks; on the other hand, if prices are more responsive to monetary policy shocks, the monetary authority will possibly have to accept higher inflation when it tries to close negative output gaps. (For a discussion about the tradeoff between price stability and economic growth, see Woodford (2000), Erceg et al. (2000), or Debortoli et al. (2017).

Finally, we find that, for the approaches for identifying monetary policy shocks that still produce a "price puzzle" (Romer and Romer (2004), and Bernanke et al. (2005)), the measures of inflation that exclude shelter costs show a much reduced "price puzzle". Therefore, the response of housing rents to monetary policy shocks goes a long way in explaining this puzzle.

The rest of the paper is organized as follows: in section 2, we present the empirical methodology and describe the data used; in section 3, we present the results relating to the effects of monetary policy on housing rents; in section 4, we discuss the implications of housing prices for inflation dynamics; and in section 5, we conclude.

2 Methodology

In this section, we describe the methodologies we followed and the data we used.

2.1 Empirical Models and Identification of Monetary Policy Shocks

To study the effect of monetary policy on housing rents, we use two different approaches that are standard in the literature: we estimate (1) a small-scale SVAR model as in Gertler and Karadi (2015) at a monthly frequency from July 1979 to June 2012, and (2) a FAVAR model as in Bernanke et al. (2005) at a quarterly frequency from 1959:Q1 to 2009:Q1. We used these two empirical methods for several reasons. First, by using two approaches, we show that our results do not depend on the estimation method or on the method employed to identify the monetary policy shocks. Second, although we are primarily interested in studying the effect of monetary policy shocks on housing rents, something for which the SVAR model would have sufficed, we also want to see how other variables of interest respond to these shocks (e.g.,the stock of houses available for rent, the homeownership rate, etc.). Unlike the SVAR model, the FAVAR model allows us to increase the number of variables analyzed without having to increase the number of parameters as drastically as in the SVAR model. Third, and finally, some of the variables we are interested in are available only at a quarterly frequency, but we would like to use monthly data whenever possible. As all of the variables we use in the SVAR model are available at a monthly frequency, we used monthly data to estimate that model, but because some variables used in the FAVAR model are available only at a quarterly frequency, we used quarterly data to estimate the FAVAR model.

2.1.1 SVAR

Let Y_t be an $n \times 1$ vector of observable time series variables. An SVAR with p lags is given by:

$$Y_t = A_0 + A_1 Y_{t-1} + A_2 Y_{t-2} + ... + A_p Y_{t-p} + H\varepsilon_t, \tag{1}$$

which can be rewritten with lag-operator notation as

$$A(L)Y_t = H\varepsilon_t, \tag{2}$$

where $A(L)$ is a $p \times n$ matrix of lag polynomials, H is an $n \times n$ matrix, and ε_t a vector of n structural shocks. This equation characterizes all dynamics of the observable time-series variables in the model. The structural shocks are assumed to be uncorrelated at all leads and lags.

In this paper, we are interested in disentangling the policy/feedback rule and monetary policy shocks. In other words, we want to study the effect of monetary policy surprises on the dynamics of the observable series Y_t. The column j of matrix H provides the contemporaneous effect of a change in structural shock j on each variable in Y_t. Following Stock and Watson (2012) notation, we assume that the monetary policy shock corresponds to the first column of H and we denote it as H_1.

The impulse response function (IRF) of Y_t with respect to a monetary policy shock is then given by

$$Y_t = A(L)^{-1}H_1 \tag{3}$$

The parameters $A(L)^{-1}$ can be identified directly from equation 1 with $H\varepsilon_t = \eta_t$ innovations, which we can estimate via ordinary least squares. However, H_1 remains to be identified. To identify the monetary policy shocks, H_1, we use the external instrument based on high-frequency identification of shocks approach as in Gertler and Karadi (2015), which combines the external instrument approach to identification of structural shocks as in Stock and Watson (2012) and Mertens and Ravn (2013) with high frequency event studies around monetary policy announcements as in Kuttner (2001), Gurkaynak et al. (2005), Hamilton (2008), and Campbell et al. (2012).

We need an external instrument, Z_t, that fulfills the following assumptions:

1. Relevance: $E(\varepsilon_{1t}Z_t) = \alpha \neq 0$
2. Exogeneity: $E(\varepsilon_{jt}Z_t) = 0$, $j = 2, ..., n$

These two assumptions show that a valid set of instruments must be correlated with the structural monetary policy shock, but not with other structural shocks. As in Gertler and Karadi (2015), we use changes in the three-month-ahead monthly fed funds futures around a monetary policy announcement as a valid instrument. The difference before and after a policy announcement represents the change in the expectations of financial market participants due to an unanticipated monetary policy action. The main concept behind using an external instrument is that, when regressing the VAR innovations η_t on the instrument Z_t, the fitted value of the regression identifies the structural shock up to its sign and scale. Further details on the derivation of structural shocks using external instruments are presented in Stock and Watson (2012), Mertens and Ravn (2013), and Gertler and Karadi (2015).[1]

2.1.2 FAVAR

The distinguishing feature of the FAVAR relative to the SVAR is the information structure assumed by the econometrician.[2] In the FAVAR, we drop the assumption that both the central bank and the econometrician observe perfectly all of the variables that enter the dynamic system 1. Instead, we assume that we observe perfectly only a subset of Y_t. All other variables, denoted by F_t with dimensions $r < n \times 1$, are assumed to not be observed perfectly by the econometrician but are, nevertheless, strongly correlated with a large number, $N >> n$, of observable economic and financial time series, X_t. Letting Y_t be the set of observable factors and F_t the set of unobservable factors, we have that a FAVAR system with p lags is given by

$$\begin{bmatrix} Y_t \\ F_t \end{bmatrix} = A(L) \begin{bmatrix} Y_{t-1} \\ F_{t-1} \end{bmatrix} + H\varepsilon_t \tag{4}$$

$$X_t = \Lambda_F F_t + \Lambda_Y Y_t + \nu_t \tag{5}$$

where Λ_F is an $N \times r$ matrix of factor loadings related to the unobserved factors, Λ_Y is an $N \times (n-r)$ matrix of factor loadings related to the observable factors, $A(L)$ is a matrix lag polynomial, and H is an $r \times r$ matrix. The common shocks and the idiosyncratic components are assumed to be uncorrelated at all leads and lags. We estimate 4 and 5 using a two-step principal components procedure and identify the structural shocks through a recursive assumption – we assume factors respond with a lag to changes in the monetary policy indicator as in Bernanke et al. (2005).[3]

2.2 Data and Model Set-Up

In the SVAR model, we use five variables at a monthly frequency from July 1979 to June 2012: industrial production, CPI, one-year Treasury rate, excess bond premium, and nominal rent of pri-

[1] The Gertler and Karadi (2015) shock is not criticism free. Ramey (2016) argues that the shock may be unanticipated but not exogenous to the economy. As such, if the econometrician does not account for the Fed's private information about the state of the economy, the validity of the inference based on this shock may be limited. In addition, this shock also includes the so-called information shock, and therefore it is not a pure monetary policy shock; Jarocinski and Karadi (2018) tackle this issue.

[2] For seminal contributions other than Bernanke et al. (2005), see Giannone et al. (2004), Stock and Watson (2005), and Forni et al. (2009). For a formal treatment of the model, see Forni et al. (2009) and Stock and Watson (2016).

[3] We also tried an external instrument approach using high-frequency data around policy announcements as in the SVAR. However, the first-stage regression had an F-test value below 10, and therefore the instrument was weak in the context of the FAVAR model.

mary residence from the CPI. With the exception of the nominal housing rents variable, which was taken from the Bureau of Labor Statisticis (BLS), the other four variables were obtained from Gertler and Karadi (2015). As for the data used in the FAVAR model, we used a quarterly database similar to that in Bernanke et al. (2005), to which we added a few variables relating to the housing market and other CPI components.[4] The data set has a total of 122 variables and it covers the period from 1959:Q1 to 2009:Q1. The complete list of variables, sources, and the transformations used to make the variables stationary is available in Appendix A.

We follow Gertler and Karadi (2015) and select the number of lags, p, in the SVAR model to be 12.[5] In the FAVAR model, we assume that the federal funds rate is the only factor that is perfectly observable. To determine the number of unobservable factors in the FAVAR model, we used the eigenvalue difference method proposed by Onatski (2010). This method led us to select 3 unobservable factors. Finally, we used the Akaike information criterion approach and selected 4 lags for the FAVAR model.[6]

3 The Effect of Monetary Policy Shocks on Housing Rents

In this section we present the main result of the paper — the effect of monetary policy on housing rents —, provide an explanation for the result based on the effect on monetary policy shocks on housing tenure decisions, and show that this result is not observed for the prices of goods or other services.

Figure 1 shows the IRFs of a 25 basis point (bps) monetary policy shock on the five variables included in the SVAR model. The IRFs of industrial production, CPI, one-year Treasury rate, and excess bond premium are standard and well known.[7] The novel result pertains to the response of nominal housing rents to a monetary policy shock. In contrast to the prices of goods or other services, nominal housing rents increase in response to a contractionary monetary policy shock. Note that this result implies that real housing rents - defined as the ratio of nominal housing rents to consumer prices - also increase in response to a contractionary monetary policy shock, but by

[4]We thank Dalibor Stevanovic for providing us the data, which was used in Stevanovic et al. (2015).

[5]Both the Akaike and Schwarz information criteria approaches select 3 lags instead. We conducted a robustness analysis with 3 lags, and the results remained unchanged.

[6]We estimated the model with different combinations of the numbers of factors and lags, and the results remained unchanged.

[7]In the case of the CPI, the result is standard for this identification of monetary policy shocks; however, with other identifications of monetary policy shocks, it is still common to observe a slight increase of prices before they start to decline, a result known in the literature as the "price puzzle" (Sims (1992)).

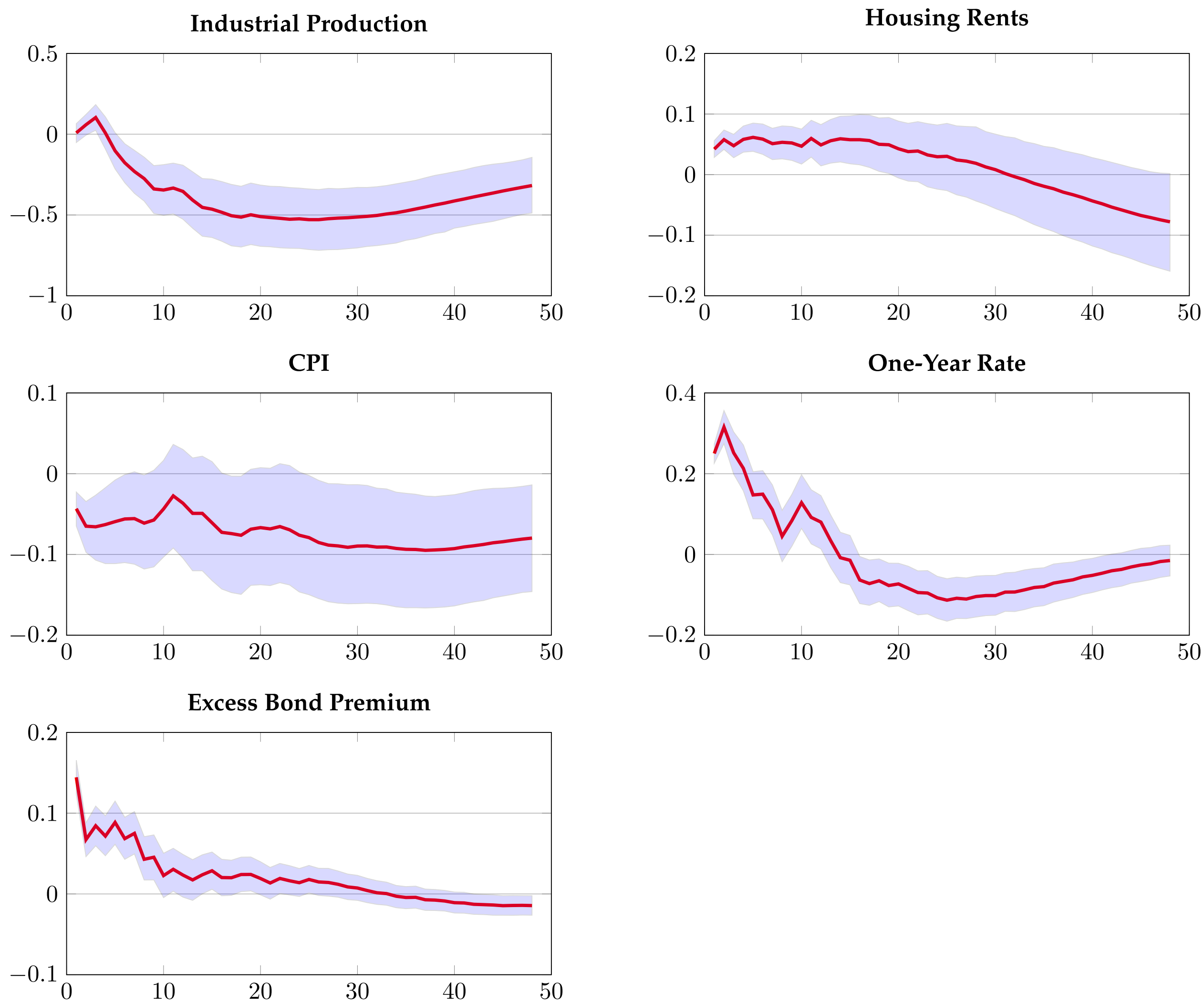

Figure 1: Baseline results: percentage responses of the baseline model variables to a 25 bps monetary policy shock identified with high-frequency surprises on federal funds 3-month futures around policy meetings. The shaded area corresponds the 68% confidence bands, which were computed using a wild bootstrap method. The first-stage regression F-test has a value of 23.9, and its robust R^2 is 8.7%.

more than nominal housing rents.[8] This finding is surprising because nominal housing rents are the price of a service — shelter — and, from standard monetary theory, it would be expected that all nominal prices should decline (or at least not increase) after a contractionary monetary policy shock. For instance, if rents were very sticky, it would follow that nominal rents would not change (or would change at a lower rate than other goods) and that, as other nominal consumer prices fall, real housing rents would increase. Our results show, however, that this mechanism cannot be at

[8]In Figure 8 in Appendix B, we show the IRF of real housing rents. The main differences between the response of nominal and real housing rents are that (1) the initial response of nominal housing rents is about half of the response of real housing rents, and (2) nominal housing rents start declining after about 1.5 years while real housing rents only start declining after around 2 years.

play because nominal rents react quickly, which in turn implies that there must be a strong reaction in real terms of the housing rental market.

One possible explanation for this result is that the monetary shocks are not well identified, and therefore the response of housing rents to monetary policy shocks shown in Figure 1 is spurious. This explanation seems implausible because the IRFs of the other four variables included in the SVAR model behave as expected.[9] Moreover, the identification we follow is the same as that used in Gertler and Karadi (2015), which is a well-established method in this literature. An alternative explanation is that monetary policy affects housing tenure decisions — own versus rent. If the supply of housing for rental or for ownership is inelastic in the short run and there is limited convertibility between homes for sale and homes for rent, when interest rates go up, mortgage rates rise and the cost of homeownership increases. As homeownership costs rise, the demand for rental housing also rises, and, as a result, housing rents also rise. We used the FAVAR model to check the plausibility of this hypothesis. In Figure 2, we show the IRFs of seven variables — fed funds rate, real gross domestic product (GDP), real housing prices, real housing rents, housing stock for ownership vacancy rate, housing stock for renting vacancy rate, and homeownership rate — to a contractionary monetary policy shock based on the estimates of the FAVAR model discussed earlier. As in the case of the SVAR model, real housing rents increase after a contractionary monetary policy shock. At the same time, house prices decline in response to the same monetary policy shock. Because house prices decrease while housing rents increase, it must be the case that fewer people want to buy houses and more people want to rent. Consistent with this interpretation, we find that, in response to the same monetary policy shock, the housing stock available for rent declines, the housing stock available for ownership increases, and the homeownership rate decreases.

So far, we have showed only that housing rents increase in response to a contractionary monetary policy shock; however, housing rents are only a small portion of the total consumer consumption bundle and the overall CPI. A natural question is whether other components of the CPI behave similarly to housing rents. In Figure 3, we show the IRFs of the main CPI components. The first three variables — rent of primary residence (same as housing rent), owners' equivalent rent (OER), and shelter (the combination of rents and the OER) — are all part of the housing component of CPI, while the other six variables — food and beverages, transportation, apparel, medical care, education and communication, and recreation — are the remaining major components of the CPI.[10]

[9] We note that our results are robust to using different approaches to identify monetary policy shocks and to different sample periods.

[10] In the next section we discuss in some detail the concept of owner's equivalent rent and how it is constructed by the

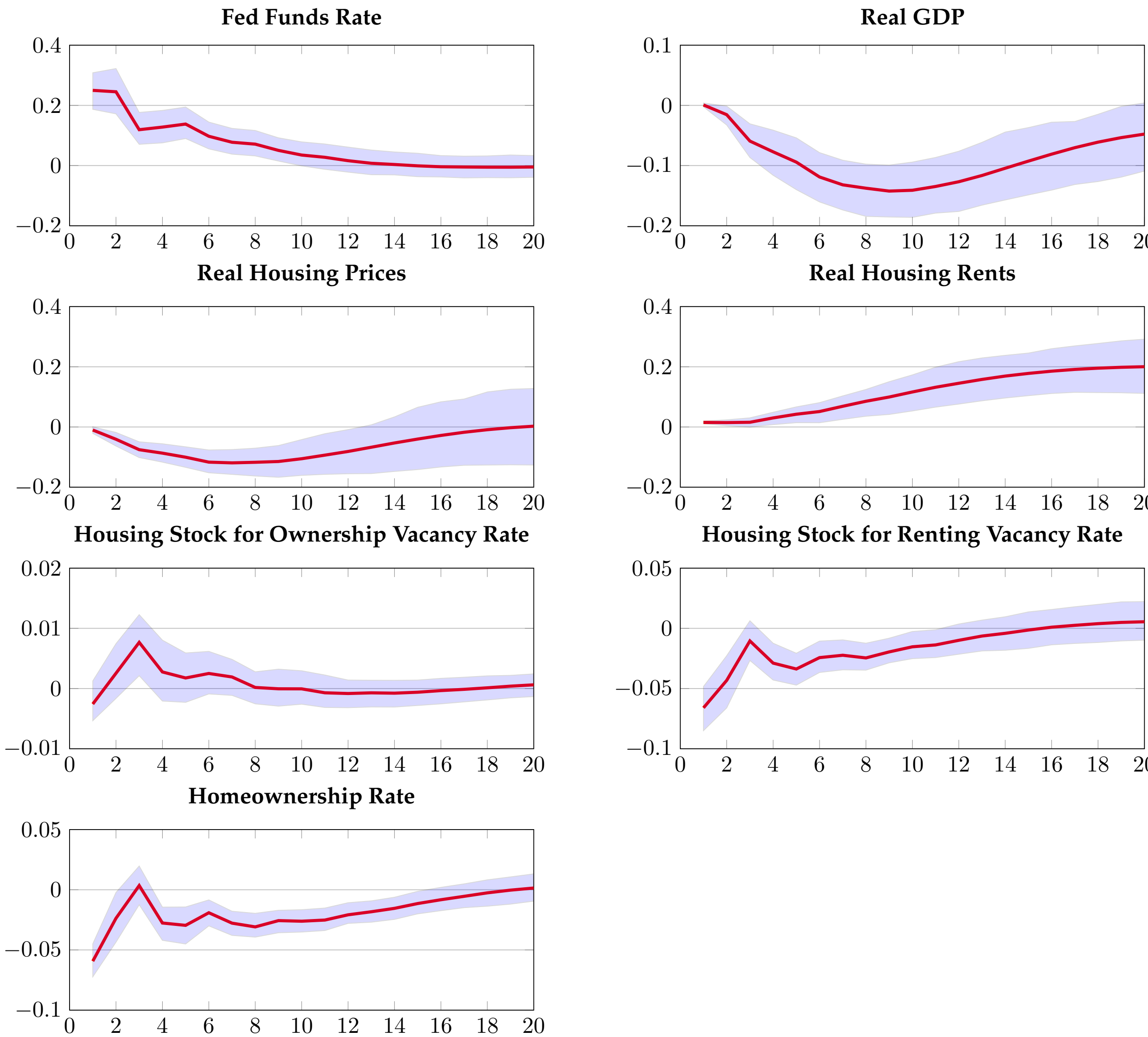

Figure 2: Testing the housing tenure choice channel: percentage responses of selected variables of the FAVAR model to a 25 bps shock in the federal funds rate. The shaded area corresponds to 68% confidence bands, which were computed using a wild bootstrap method.

The first row of Figure 3 shows that not only housing rents rise after a contractionary monetary policy shock, but also the OER, and, consequently, shelter, which we defined as the combination of housing rents and OER.[11] As for the other major components, with the exception of medical care, the results show that prices either decrease (food and beverages, transportation, and apparel) or have no reaction to a monetary policy shock (education and communication and recreation). The

BLS.

[11]Our definition of shelter costs is slightly different from that of the BLS, as we consider only the rent of primary residence and the OER components, while the BLS also includes costs for lodging away from home. Because the weigh of such costs is only about 1%, for practical purposes, there is no relevant difference between our measure of shelter costs and that of the BLS.

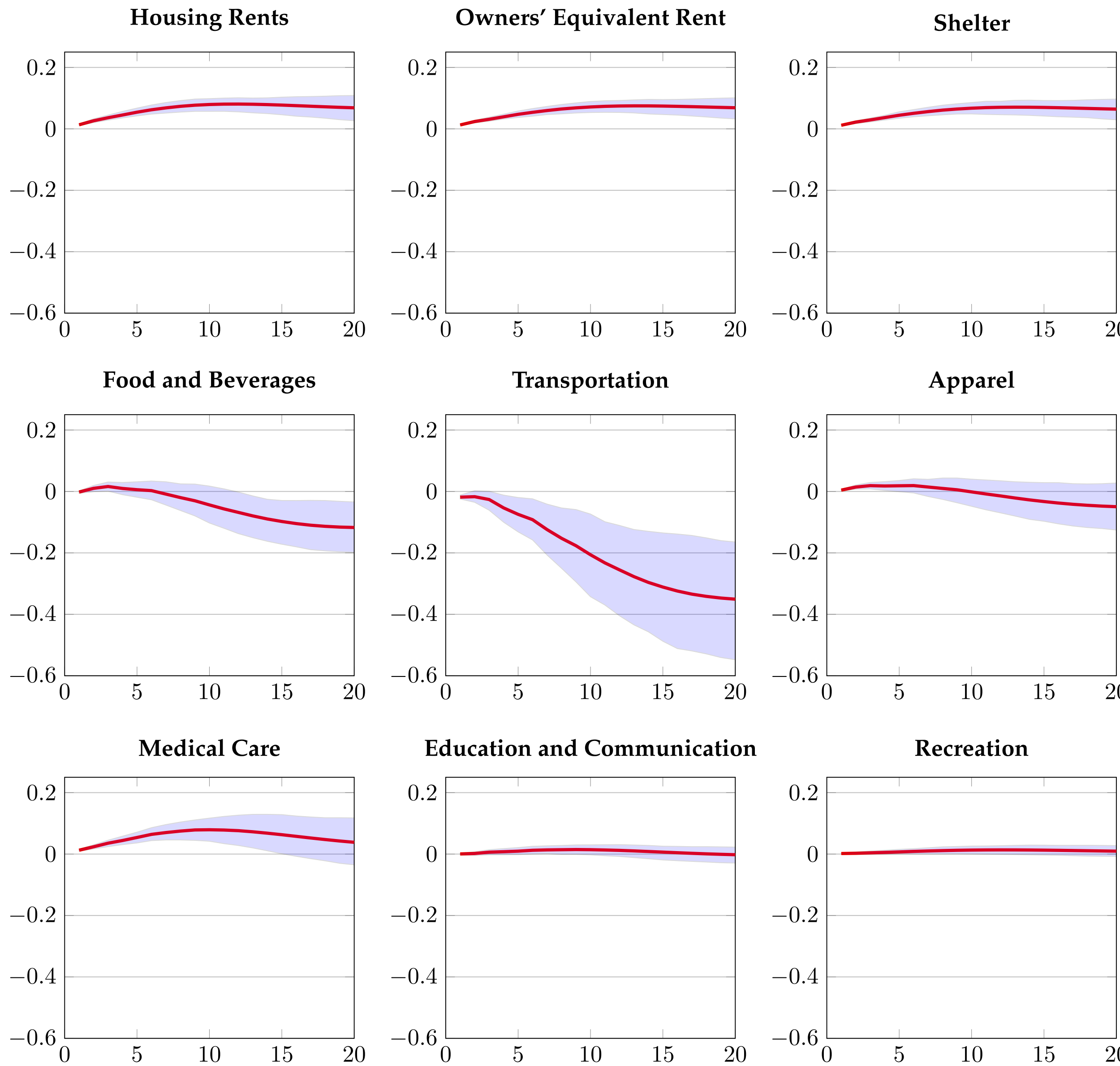

Figure 3: Response of the main components of the CPI to a monetary policy shock: percentage responses of selected variables of the FAVAR model to a 25 bps shock in the federal funds rate. The shaded area corresponds to 68% confidence bands, which were computed using a wild bootstrap method.

statistical significance of the response of medical care to a monetary policy shock is likely to be spurious, because when we use an SVAR model and the high-frequency instrument approach to identify the monetary policy shocks, the response of medical care to monetary policy shocks is no longer statistically significant (see Figure 9 in Appendix B).

The fact that the OER behaves similarly to housing rents should not be surprising, as the OER an estimate of homeowners' rents that uses housing rents as an input. However, the fact that two sub-components of the CPI that account for about one-third of the total CPI increase after a contractionary monetary policy shock raises the question of the importance of housing for inflation dynamics. We tackle this question in the next section.

4 Shelter Costs and Inflation Dynamics

In this section, we study the implications of the dynamics of shelter costs (rents and the OER) for inflation dynamics. We start by describing how the shelter costs component of the CPI or PCE is constructed, compare some of the statistical properties of the widely used measures of inflation (the CPI and PCE) with those of alternative measures of inflation that exclude shelter costs, and end by comparing the responses to monetary policy shocks of inflation measures including and excluding shelter costs.

4.1 Shelter Costs in Measures of Inflation

Housing expenses are the largest component of the CPI, with a total weight of 42% in the index. This component has two sub-components: shelter and other housing-related expenses, with the former currently weighing around 33% in the total CPI and the latter about 9%. The fact that shelter costs have such a large weight in the overall CPI suggests that the index will be very sensitive to what happens in this component. As for the PCE, housing expenses are also its largest component; however, the weight is smaller than in the CPI, as such expenses account for only close to 24% of the index, and shelter is only 16% of the overall index — about half of the weight of shelter in the CPI. Given the lower weight of shelter costs, we expect that the PCE will be less sensitive to changes in shelter costs than the CPI.

Although the prices of most of the sub-components of housing (e.g., rent of primary residence, utilities, or insurance) are relatively easy to measure, the price of shelter for homeowners is not, because it is not a market price. Before 1983, the BLS used house prices, mortgage interest rates, property taxes, insurance, and maintenance costs to estimate shelter costs for homeowners. Because not all of these items represent costs for a homeowner, in 1983, the BLS changed its approach and began using the concept of OER to estimate the rental cost for homeowners. The OER is an estimate of the rent that a homeowner would have to pay if he or she was renting that same home. To compute the OER, the BLS uses observed rents and the characteristics of the homes being rented.[12]

[12] For more details on how the BLS constructs the rent of primary residence and the OER, see Bureau of Labor Statistics (2009)

As a result, the correlation between the year-on-year growth rate of the two series is very high — close to 85%. For this reason, we consider rent of primary residence and the OER to be basically the same, and, from here on, we analyze only shelter costs.

4.2 Inflation Measures Net of Shelter Costs

One way to understand the importance of shelter costs for inflation dynamics is by considering alternative measures of inflation that exclude shelter costs. In Figures 4 and 5, we show the level and the month-to-month growth rates of (1) the CPI and the CPI net of shelter and (2) of the PCE and the PCE net of shelter, while in Table 1, we provide some descriptive statistics.

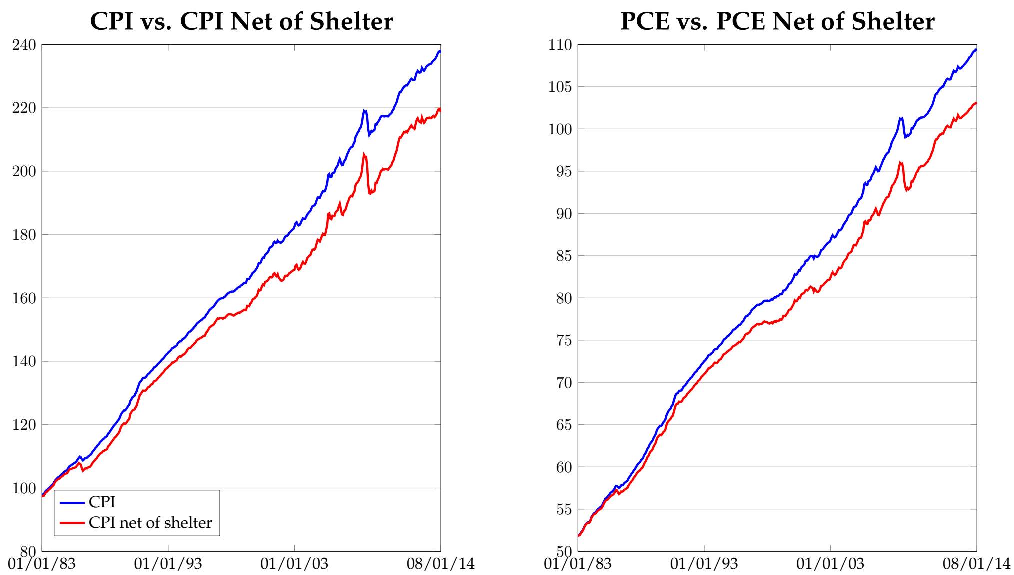

Figure 4: Monthly index time series of CPI vs. CPI net of shelter, and PCE vs. PCE net of shelter from 1983 to 2014.

Table 1: Inflation indexes descriptive statistics.

	mean	s.d.	ρ_1: x_t, x_{t-1}	ρ_2: x_t, x_{t-2}	ADF[a]
CPI	0.23	0.26	0.43	0.04	-6.92
CPI net of shelter	0.21	0.38	0.43	0.05	-7.13
PCE	0.19	0.19	0.43	0.12	-6.29
PCE net of shelter	0.18	0.23	0.43	0.13	-6.56

[a] ADF is Augmented Dicky-Fuller

The visual inspection of Figures 4 and 5 suggests that the price indexes with and without shelter

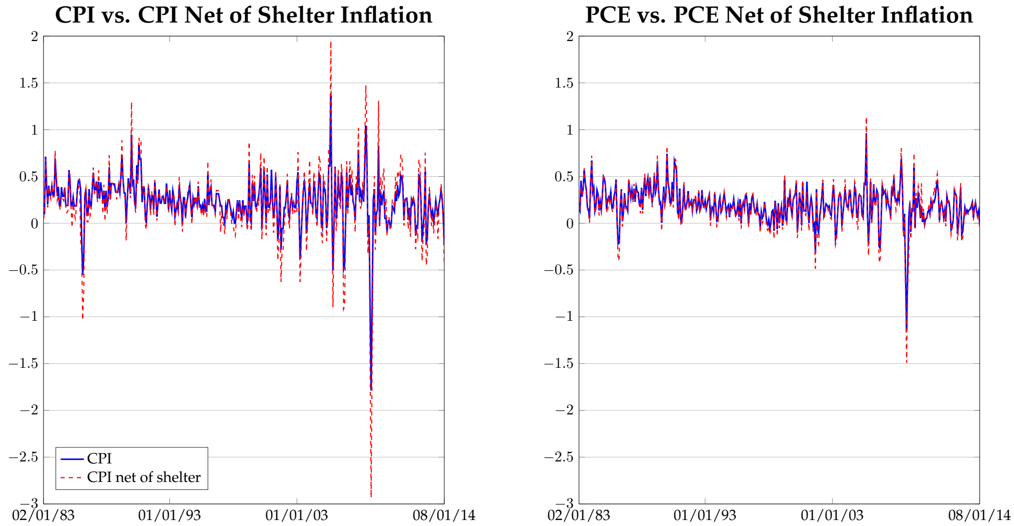

Figure 5: Monthly inflation time series of CPI vs. CPI net of shelter, and PCE vs. PCE net of shelter from 1983 to 2014.

costs are not too different from each other. The most noticeable difference is that the price measures including shelter costs increased at a slightly faster pace than those excluding such costs, as the blue lines in Figure 4, corresponding to the overall price indexes, are always above the red lines, corresponding to the price indexes excluding shelter costs. In addition, Figure 5 suggests that the overall price indexes are less volatile than the price indexes excluding shelter costs — the entries in Table 1 confirm this result. Despite some small differences in the mean and the standard deviation, the two pairs of inflation measures show remarkably similar autocorrelation structures — the first- and second-order autocorrelation terms are almost identical, and all series are stationary.

Although the two pairs of variables are very similar in several dimensions (as shown in Figures 4 and 5 and Table 1), we are interested in knowing whether these variables respond differently to monetary shocks. The left-hand panels of Figure 6 show the IRFs of (1) the CPI and the CPI net of shelter and (2) the PCE and the PCE net of shelter, based on a six-variable SVAR model similar to the SVAR model described in section 2; while the right-hand panels of the same figure show the difference between the impulse responses of (1) the CPI and CPI net of shelter and (2) the PCE and the PCE net of shelter.[13] The results in Figure 6 show that the measures of inflation that exclude shelter react more to a monetary policy shock than the measures of inflation that include all

[13]Relative to the SVAR model described in section 2, we added the CPI and the PCE net of shelter to the model, as a way of testing whether the impulse responses of the two inflation measures — the CPI (PCE) and the CPI (PCE) net of shelter — are statistically different. To compute the Wald-statistic of the hypothesis that the impulse responses of the CPI (PCE) and the CPI (PCE) net of shelter are statistically different, we estimated the SVAR model with both inflation measures and then bootstrapped the difference between the impulse responses to the same monetary policy shock.

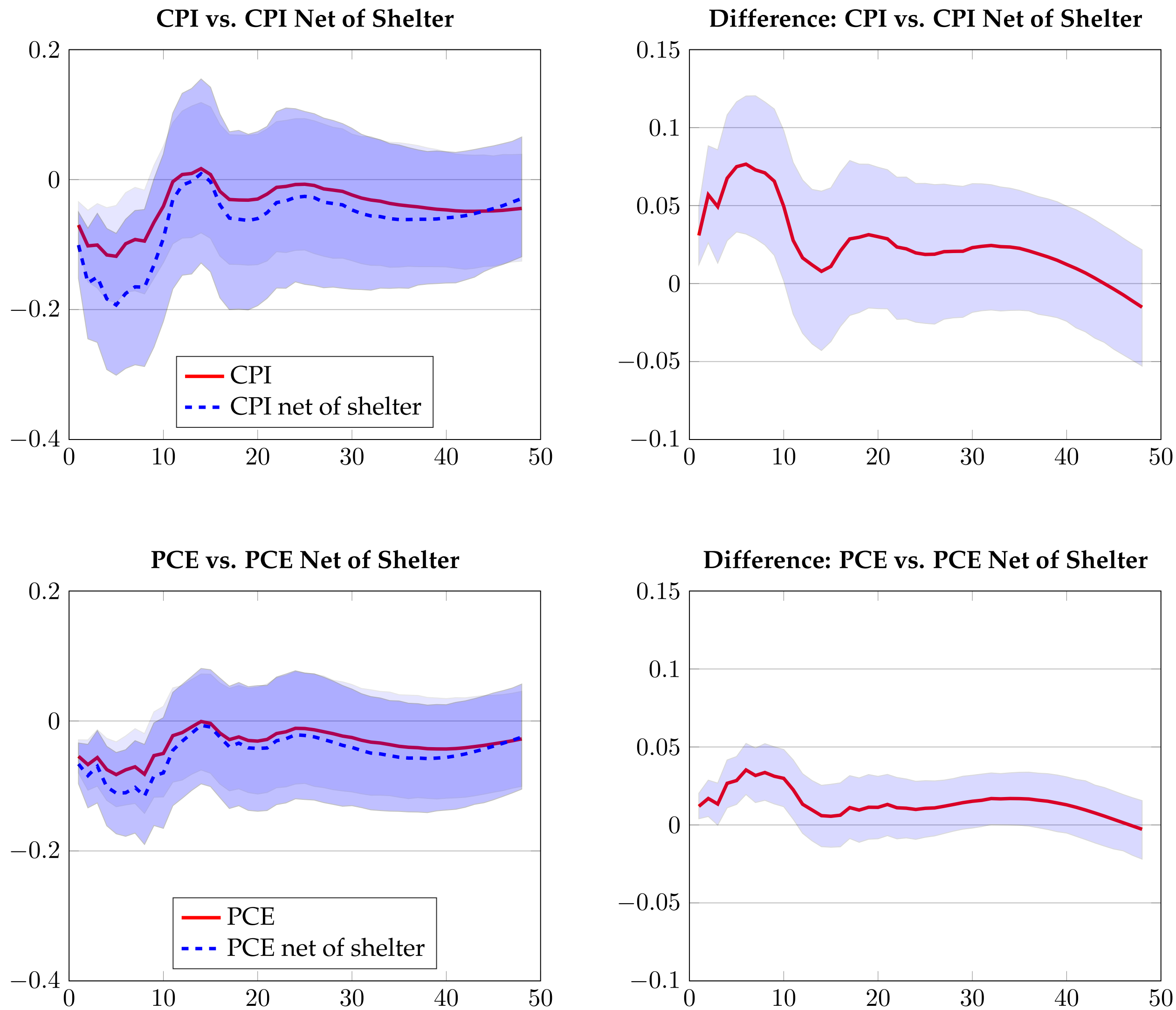

Figure 6: All-items inflation measures vs. net-of-shelter measures: percentage responses of the baseline model variables to a 25 bps monetary policy shock identified with high-frequency surprises on federal funds 3-month futures around policy meetings. The shaded area corresponds to 68% confidence bands, which were computed using a wild bootstrap method. The first-stage regression *F-test* has a value of 23.9, and its robust R^2 is 8.7%.

items. Moreover, as shown in the right-side panels of Figure 6, the difference between the impulse responses of the two inflation measures is statistically significant. As expected, given the larger weight of shelter in the CPI, the difference is larger for the CPI than for the PCE; however, the difference is statistically significant in both cases.

A natural question is, why do these findings matter? First, by not taking into account the response of rents (vis-à-vis shelter) to monetary policy, monetary models will be missing an important element of the effect of monetary policy on prices, and therefore theory and data will not be well mapped. Second and more important, when monetary policy authorities target a measure of inflation like the CPI or the PCE, for the same response of inflation, monetary authorities will need larger monetary policy shocks, with resulting larger real effects and nominal price volatility. Given the results of this paper, looking at the total CPI or PCE reactions to monetary policy masks important heterogeneity in consumer price variation. We find that low responses of overall consumer prices to monetary policy shocks are the result of strong opposing movements in nominal housing rents and the nominal prices of all other goods and services in the economy.

In addition, based on our results, the response of rents to monetary policy shocks is likely to be the result of a shift in demand — between rental and owner-occupied homes. Therefore, the change in rents as a result of monetary policy shocks is a relative price movement and not a change in trend (or the underlying inflation rate). Monetary policy should react to changes in the trend of prices (inflation) but not to relative price changes. A measure of inflation that includes rents/shelter will likely lead monetary authorities that follow a monetary policy rule, such as the Taylor rule, to respond both to changes in inflation and to relative price movements.

4.3 Housing Rents and the "Price Puzzle"

One argument in favor of using the high-frequency instrument approach, as in Gertler and Karadi (2015), to identify monetary policy shocks is that, when this approach is used, there is no "price puzzle" — prices rising after a contractionary monetary policy shock. Our empirical results based on the high-frequency instrument approach confirm this finding. However, as we mentioned previously, the Gertler and Karadi (2015) shock is not criticism free, and some authors prefer using the Romer and Romer (2004) shock. One critique of Romer and Romer (2004) is that the response of prices to a contractionary monetary policy shock still exhibits a "price puzzle". In Figure 7, we compare the responses of prices including and excluding shelter for different methods of identifying monetary policy shocks. What we find is that, for all cases, the response of prices excluding shelter costs to a contractionary monetary policy shock turns negative much faster than that of price measures including shelter costs.

Although we cannot claim that excluding shelter costs from price measures solves the "price puzzle", it greatly ameliorates the puzzle. In other words, the response of housing rents to monetary policy shocks does not fully account for the "price puzzle", but it goes a long way in explaining the puzzle.

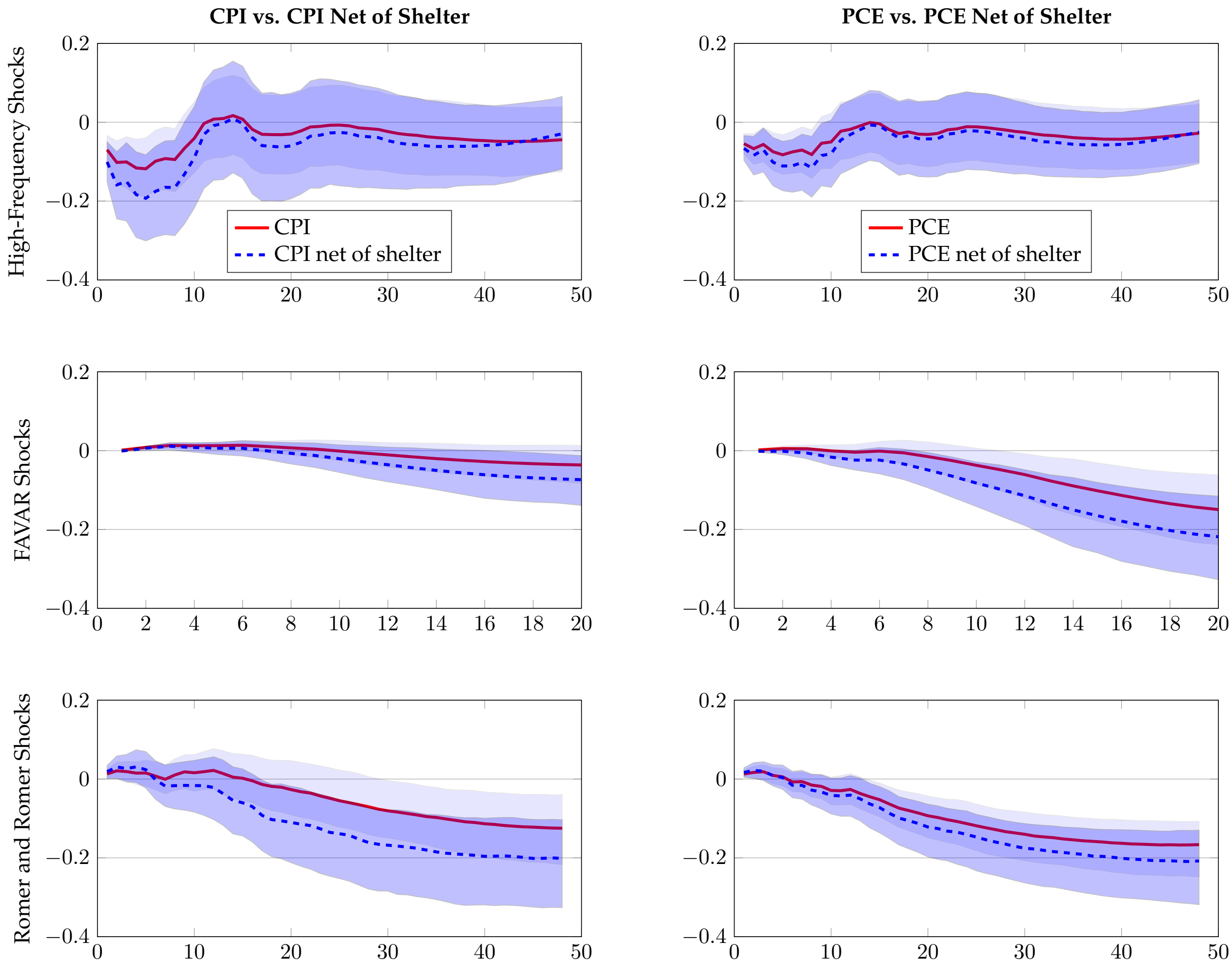

Figure 7: All-items inflation measures vs net-of-shelter measures: percentage responses of the consumer price indexes to a 25 bps monetary policy shock identified with high-frequency, FAVAR, and Romer and Romer (2004) shocks. The shaded area corresponds to 68% confidence bands, which were computed using a wild bootstrap method.

5 Concluding Remarks

In this paper, we show that housing rents, in contrast to the prices of other services and goods, increase in response to a contractionary monetary policy shock. In addition, we show that this result extends to the shelter component of the CPI and the PCE, and that the responses of these price indexes to monetary shocks are attenuated by the response of shelter costs. We argue that it is important to take into account the response of shelter costs for three reasons: first, for the purpose of linking the measures in theoretical monetary models to the same measures in the data; second, to enable monetary authorities to avoid excess consumer price variation when conducting monetary policy; and third, to explain to a large extent, using the response of shelter costs to monetary policy shocks, the “price puzzle” found in the literature.

In future research, we plan to analyze the welfare effects of monetary policy in the context of housing tenure choice. In particular, we are interested in understanding whether monetary policy has different welfare effects on homeowners and renters and whether the monetary authority should consider these effects when setting monetary policy.

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A Data used in the FAVAR model[14]

The transformation codes are as follows: 1, no transformation; 2, first difference; 4, logarithm; 5, first difference of logarithm; and 0, variable not used in the estimation (used only for transforming other variables). An asterisk (*) indicates a series that is considered a slow-moving variable.

Table 2: Data from 1959:Q1 to 2009:Q1 used for FAVAR factor estimation.

No.	Series Code	T-Code	Series Description
1	DRIINTL:GDPRC@US.Q	5*	NIA REAL GROSS DOMESTIC PRODUCT (CHAINED-2000), SA - U.S.
2	USCEN:GDPGDR.Q	5*	REAL GDP-GDS,BILLIONS OF CH (2000) $,SAAR-US
3	USCEN:GDPSVR.Q	5*	REAL GDP-SVC,BILLIONS OF CH (2000) $,SAAR-US
4	USCEN:GDPSR.Q	5*	REAL GDP-STRUC,BILLIONS OF CH (2000) $,SAAR-US
5	BASIC:IPN11.M	5*	INDUSTRIAL PRODUCTION INDEX - PRODUCTS, TOTAL
6	BASIC:IPN300.M	5*	INDUSTRIAL PRODUCTION INDEX - FINAL PRODUCTS
7	BASIC:IPN12.M	5*	INDUSTRIAL PRODUCTION INDEX - CONSUMER GOODS
8	BASIC:IPN13.M	5*	INDUSTRIAL PRODUCTION INDEX - DURABLE CONSUMER GOODS
9	BASIC:IPN18.M	5*	INDUSTRIAL PRODUCTION INDEX - NONDURABLE CONSUMER GOODS
10	BASIC:IPN25.M	5*	INDUSTRIAL PRODUCTION INDEX - BUSINESS EQUIPMENT
11	BASIC:IPN32.M	5*	INDUSTRIAL PRODUCTION INDEX - MATERIALS
12	BASIC:IPN34.M	5*	INDUSTRIAL PRODUCTION INDEX - DURABLE GOODS MATERIALS
13	BASIC:IPN38.M	5*	INDUSTRIAL PRODUCTION INDEX - NONDURABLE GOODS MATERIALS
14	BASIC:IPN10.M	5*	INDUSTRIAL PRODUCTION INDEX - TOTAL INDEX
15	USCEN:UTLB00004.M	1*	CAPACITY UTILIZ-MFG,SA-US
16	BASIC:PMI.M	1*	PURCHASING MANAGERS INDEX (SA)
17	BASIC:PMP.M	1*	NAPM PRODUCTION INDEX (PERCENT)
18	DRIINTL:WS@US.Q	5*	NIA NOMINAL TOTAL COMPENSATION OF EMPLOYEES, SA - U.S.
19	USCEN:YPR.M	5*	PERS INCOME CH 2000 $,SA-US
20	USCEN:YP@V00C.M	5*	PERS INCOME LESS TRSF PMT CH 2000 $,SA-US
21	USCEN:AHPMF.M	5*	AHE,PROD WORKERS: MFG,SA-US
22	USCEN:AHPCON.M	5*	AHE,PROD WORKERS: CONSTR,SA-US
23	USCEN:HPMF.M	5*	AWH,PROD WORKERS: MFG,SA-US
24	USCEN:HOPMD.M	5*	AVG WEEKLY OT,PROD WORKERS: DUR,SA-US
25	BASIC:LHEL.M	5*	INDEX OF HELP-WANTED ADVERTISING IN NEWSPAPERS (1967=100;SA)
26	BASIC:LHELX.M	1*	EMPLOYMENT: RATIO; HELP-WANTED ADS:NO. UNEMPLOYED CLF
27	BASIC:LHEM.M	5*	CIVILIAN LABOR FORCE: EMPLOYED, TOTAL (THOUS.,SA)
28	BASIC:LHNAG.M	5*	CIVILIAN LABOR FORCE: EMPLOYED, NONAGRIC.INDUSTRIES (THOUS.,SA)
29	BASIC:LHUR.M	1*	UNEMPLOYMENT RATE: ALL WORKERS, 16 YEARS & OVER (%,SA)
30	BASIC:LHU680.M	1*	UNEMPLOY.BY DURATION: AVERAGE(MEAN)DURATION IN WEEKS (SA)
31	BASIC:LHU5.M	5*	UNEMPLOY.BY DURATION: PERSONS UNEMPL.LESS THAN 5 WKS (THOUS.,SA)
32	BASIC:LHU14.M	5*	UNEMPLOY.BY DURATION: PERSONS UNEMPL.5 TO 14 WKS (THOUS.,SA)
33	BASIC:LHU15.M	5*	UNEMPLOY.BY DURATION: PERSONS UNEMPL.15 WKS + (THOUS.,SA)
34	BASIC:LHU26.M	5*	UNEMPLOY.BY DURATION: PERSONS UNEMPL.15 TO 26 WKS (THOUS.,SA)
35	BASIC:CES001.M	5*	EMPLOYEES, NONFARM - TOTAL NONFARM
36	BASIC:CES002.M	5*	EMPLOYEES, NONFARM - TOTAL PRIVATE
37	BASIC:CES003.M	5*	EMPLOYEES, NONFARM - GOODS-PRODUCING
38	USCEN:CR.Q	5*	REAL PCE,BILLIONS OF CH (2000) $,SAAR-US
39	USCEN:JQCDR.Q	5*	REAL PCE-DUR,QTY INDEX (2000=100),SA,SA-US
40	USCEN:JQCNR.Q	5*	REAL PCE-NDUR,QTY INDEX (2000=100),SA,SA-US
41	USCEN:JQCSVR.Q	5*	REAL PCE-SVC,QTY INDEX (2000=100),SA,SA-US
42	USCEN:JQCXFAER.Q	5*	REAL PCE EX FOOD&ENERGY,QTY INDEX (2000=100),SAAR-US
43	DRIINTL:CGRCUS.Q	5*	REAL GOVERNMENT CONS. EXPEND.& GROSS INVESTMENT (CHAINED-2000), SA - U.S.
44	USCEN:I.Q	5*	GROSS PRIV DOM INVEST,BILLIONS OF $,SAAR-US
45	USCEN:IF.Q	5*	GROSS PRIV DOM INVEST-FIXED,BILLIONS OF $,SAAR-US
46	USCEN:IFNRE.Q	5*	GROSS PRIV DOM INVEST-FIXED NONRES,BILLIONS OF $,SAAR-US
47	USCEN:IFRES.Q	5*	PRIV FIXED INVEST-RES-STRUC,BILLIONS OF $,SAAR-US
48	USCEN:IFRE.Q	5*	GROSS PRIV DOM INVEST-FIXED RES,BILLIONS OF $,SAAR-US
49	USCEN:II.Q	1*	GROSS PRIV DOM INVEST-CH IN PRIV INVENT,BILLIONS OF $,SAAR-US
50	USCEN:IIF.Q	1*	GROSS PRIV DOM INVEST-CH IN PRIV INVENT-FARM,BILLIONS OF $,SAAR-US

[14]We thank Dalibor Stevanovic for providing us with the data.

51	BASIC:HSFR.M	4	HOUSING STARTS:NONFARM(1947-58);TOTAL FARM&NONFARM(1959-)(THOUS.,SA
52	BASIC:HMOB.M	4	MOBILE HOMES: MANUFACTURERS SHIPMENTS (THOUS.OF UNITS,SAAR)
53	BASIC:PMNV.M	1	NAPM INVENTORIES INDEX (PERCENT)
54	BASIC:PMNO.M	1	NAPM NEW ORDERS INDEX (PERCENT)
55	BASIC:PMDEL.M	1	NAPM VENDOR DELIVERIES INDEX (PERCENT)
56	BASIC:MOCMQ.M	5	NEW ORDERS (NET) - CONSUMER GOODS & MATERIALS, 1996 DOLLARS (BCI)
57	BASIC:MSONDQ.M	5	NEW ORDERS, NONDEFENSE CAPITAL GOODS, IN 1996 DOLLARS (BCI)
58	USCEN:M.Q	5	IMPORTS OF GDS&SVC,BILLIONS OF $,SAAR-US
59	USCEN:X.Q	5	EXPORTS OF GDS&SVC,BILLIONS OF $,SAAR-US
60	BASIC:FSPCOM.M	5	S&PS COMMON STOCK PRICE INDEX: COMPOSITE (1941-43=10)
61	BASIC:FSPIN.M	5	S&PS COMMON STOCK PRICE INDEX: INDUSTRIALS (1941-43=10)
62	BASIC:FSDXP.M	1	S&PS COMPOSITE COMMON STOCK: DIVIDEND YIELD (% PER ANNUM)
63	BASIC:FSPXE.M	1	S&PS COMPOSITE COMMON STOCK: PRICE-EARNINGS RATIO (%,NSA)
64	BASIC:EXRUK.M	5	FOREIGN EXCHANGE RATE: UNITED KINGDOM (CENTS PER POUND)
65	BASIC:EXRCAN.M	5	FOREIGN EXCHANGE RATE: CANADA (CANADIAN $ PER U.S.$)
66	BASIC:FYGM3.M	1	INTEREST RATE: U.S.TREASURY BILLS,SEC MKT,3-MO.(% PER ANN,NSA)
67	BASIC:FYGM6.M	1	INTEREST RATE: U.S.TREASURY BILLS,SEC MKT,6-MO.(% PER ANN,NSA)
68	BASIC:FYGT1.M	1	INTEREST RATE: U.S.TREASURY CONST MATURITIES,1-YR.(% PER ANN,NSA)
69	BASIC:FYGT5.M	1	INTEREST RATE: U.S.TREASURY CONST MATURITIES,5-YR.(% PER ANN,NSA)
70	BASIC:FYGT10.M	1	INTEREST RATE: U.S.TREASURY CONST MATURITIES,10-YR.(% PER ANN,NSA)
71	BASIC:FYAAAC.M	1	BOND YIELD: MOODYS AAA CORPORATE (% PER ANNUM)
72	BASIC:FYBAAC.M	1	BOND YIELD: MOODYS BAA CORPORATE (% PER ANNUM)
73	FYGM6-FYFF	1	SPREAD
74	FYGM3-FYFF	1	SPREAD
75	FYGT1-FYFF	1	SPREAD
76	FYGT5-FYFF	1	SPREAD
77	FYGT10-FYFF	1	SPREAD
78	FYAAAC-FYFF	1	SPREAD
79	FYBAAC-FYFF	1	SPREAD
80	BASIC:FM1.M	5	MONEY STOCK: M1(CURR,TRAV.CKS,DEM DEP,OTHER CKABLE DEP)(BIL$,SA)
81	BASIC:FM2.M	5	MONEY STOCK:M2(M1+ONITE RPS,EURO$,G/P&B/D MMMFS&SAV&SM TIME DEP(BIL$)
82	USCEN:MNY2@00.M	5	MONEY SUPPL-M2 IN 2000 $,SA-US
83	BASIC:FMFBA.M	5	MONETARY BASE, ADJ FOR RESERVE REQUIREMENT CHANGES(MIL$,SA)
84	BASIC:FMRRA.M	5	DEPOSITORY INST RESERVES:TOTAL,ADJ FOR RESERVE REQ CHGS(MIL$,SA)
85	BASIC:FMRNBA.M	2	DEPOSITORY INST RESERVES:NONBORROWED,ADJ RES REQ CHGS(MIL$,SA)
86	USCEN:ALCIBL00Z.M	5	COML&IND LOANS OUTST,SA-US
87	BASIC:FCLBMC.M	1	WKLY RP LG COML BANKS:NET CHANGE COML & INDUS LOANS(BIL$,SAAR)
88	BASIC:CCINRV.M	5	CONSUMER CREDIT OUTSTANDING - NONREVOLVING(G19)
89	DRIINTL:PGDP@US.Q	5*	NIA PRICE DEFLATOR - GROSS DOMESTIC PRODUCT, SA - U.S.
90	DRIINTL:PCP@US.Q	5*	NIA PRICE DEFLATOR - PRIVATE CONSUMPTION EXPENDITURE, SA - U.S.
91	USCEN:PDII.Q	5*	GROSS PRIV DOM INVEST,PRICE DEFLATORS (2000=100),SA,SA-US
92	USCEN:JPCD.Q	5*	PCE-DUR,PRICE INDEX (2000=100),SA,SA-US
93	USCEN:JPCN.Q	5*	PCE-NDUR,PRICE INDEX (2000=100),SA,SA-US
94	USCEN:JPCSV.Q	5*	PCE-SVC,PRICE INDEX (2000=100),SA,SA-US
95	BASIC:PUXM.M	5*	CPI-U: ALL ITEMS LESS MEDICAL CARE (82-84=100,SA)
96	BASIC:PUXHS.M	5*	CPI-U: ALL ITEMS LESS SHELTER (82-84=100,SA)
97	BASIC:PUXF.M	5*	CPI-U: ALL ITEMS LESS FOOD (82-84=100,SA)
98	BASIC:PUS.M	5*	CPI-U: SERVICES (82-84=100,SA)
99	BASIC:PUCD.M	5*	CPI-U: DURABLES (82-84=100,SA)
100	BASIC:PUC.M	5*	CPI-U: COMMODITIES (82-84=100,SA)
101	BASIC:PUNEW.M	5*	CPI-U: ALL ITEMS (82-84=100,SA)
102	BASIC:PWFSA.M	5*	PRODUCER PRICE INDEX: FINISHED GOODS (82=100,SA)
103	BASIC:PMCP.M	1*	NAPM COMMODITY PRICES INDEX (PERCENT)
104	UOMO83	1	COMPONENT INDEX OF CONSUMER EXPECTATIONS, NSA, CONFBOARD AND U.MICH.
105	DRIINTL:JLEAD@US.Q	5	COMPOSITE CYCLICAL INDICATOR (1996) - LEADING, SA - U.S.
106	DRIINTL:JLAG@US.Q	5	COMPOSITE CYCLICAL INDICATOR (1996) - LAGGING, SA - U.S.
107	DRIINTL:JCOIN@US.Q	5	COMPOSITE CYCLICAL INDICATOR (1996) - COINCIDENT, SA - U.S.
108	BASIC:FYFF.M	1	INTEREST RATE: FEDERAL FUNDS (EFFECTIVE) (% PER ANNUM,NSA)

Table 3: Other data of interest not used in factor estimation.

No.	Series Code	T-Code	Series Description
109	BASIC:USSTHPI.Q	5	ALL-TRANSACTIONS HOUSE PRICE INDEX (1980:1=100, NSA)-US (1975:1-2009:1)
110	BASIC:RSAHORUSQ156S.Q	1	HOMEOWNERSHIP RATE, SA-US (1980:1-2009:1)
111	BASIC:RHVRUSQ156N.Q	1	HOMEOWNER VACANCY RATE, NSA-US (1975:1-2009:1)
112	BASIC:RRVRUSQ156N.Q	1	RENTAL VACANCY RATE, NSA-US (1975:1-2009:1)
113	BASIC:CUSR0000SEHA.M	5	CPI-U: RENT OF PRIMARY RESIDENCE (1982-84=100, SA)-US (1981:1-2009:1)
114	BASIC:CUSR0000SEHC.M	5	CPI-U: OWNERS' EQUIVALENT RENT (1982=100, SA)-US (1983:1-2009:1)
115	SHELTER.M	5	CPI-U: RENT+OWNER'S EQ. RENT (1982-84=100, SA)-US (1983:1-2009:1)
116	BASIC:CPIFABSL.M	5	CPI-U: FOOD AND BEVERAGES (1982-84=100, SA)-US (1967:1-2009:1)
117	BASIC:CPIAPPSL.M	5	CPI-U: APPAREL (1982-84=100, SA)-US (1959:1-2009:1)
118	BASIC:CPITRNSL.M	5	CPI-U: TRANSPORTATION (1982-84=100, SA)-US (1959:1-2009:1)
119	BASIC:CPIMEDSL.M	5	CPI-U: MEDICAL CARE (1982-84=100, SA)-US (1959:1-2009:1)
120	BASIC:CPIRECSL.M	5	CPI-U: RECREATION (1997=100, SA)-US (1993:1-2009:1)
121	BASIC:CPIEDUSL.M	5	CPI-U: EDUCATION AND COMMUNICATION (1997=100, SA)-US (1993:1-2009:1)
122	CPINET.M	5	CPI-U: CPI-U NET OF SHELTER, SA-US (1983:1-2009:1)

B Additional Figures

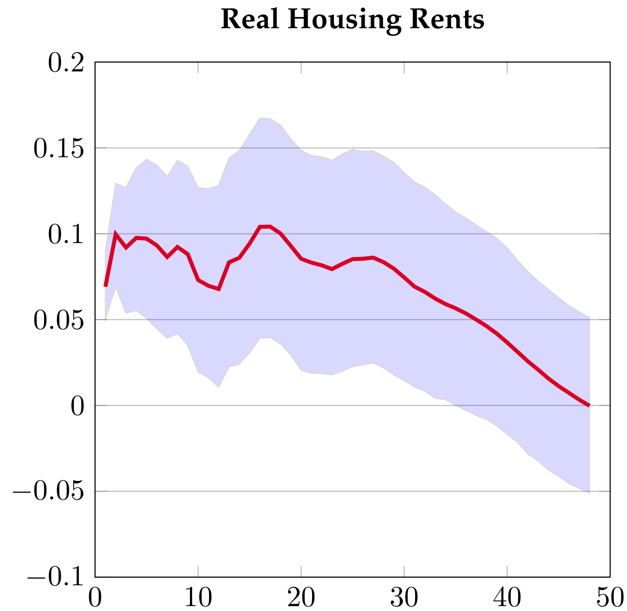

Figure 8: Percentage response of real housing rents to a 25 bps monetary policy shock identified with high-frequency surprises on federal funds 3-month futures around policy meetings. The shaded area corresponds to 68% confidence bands, which were computed using a wild bootstrap method. Real rents are computed using all-items CPI.

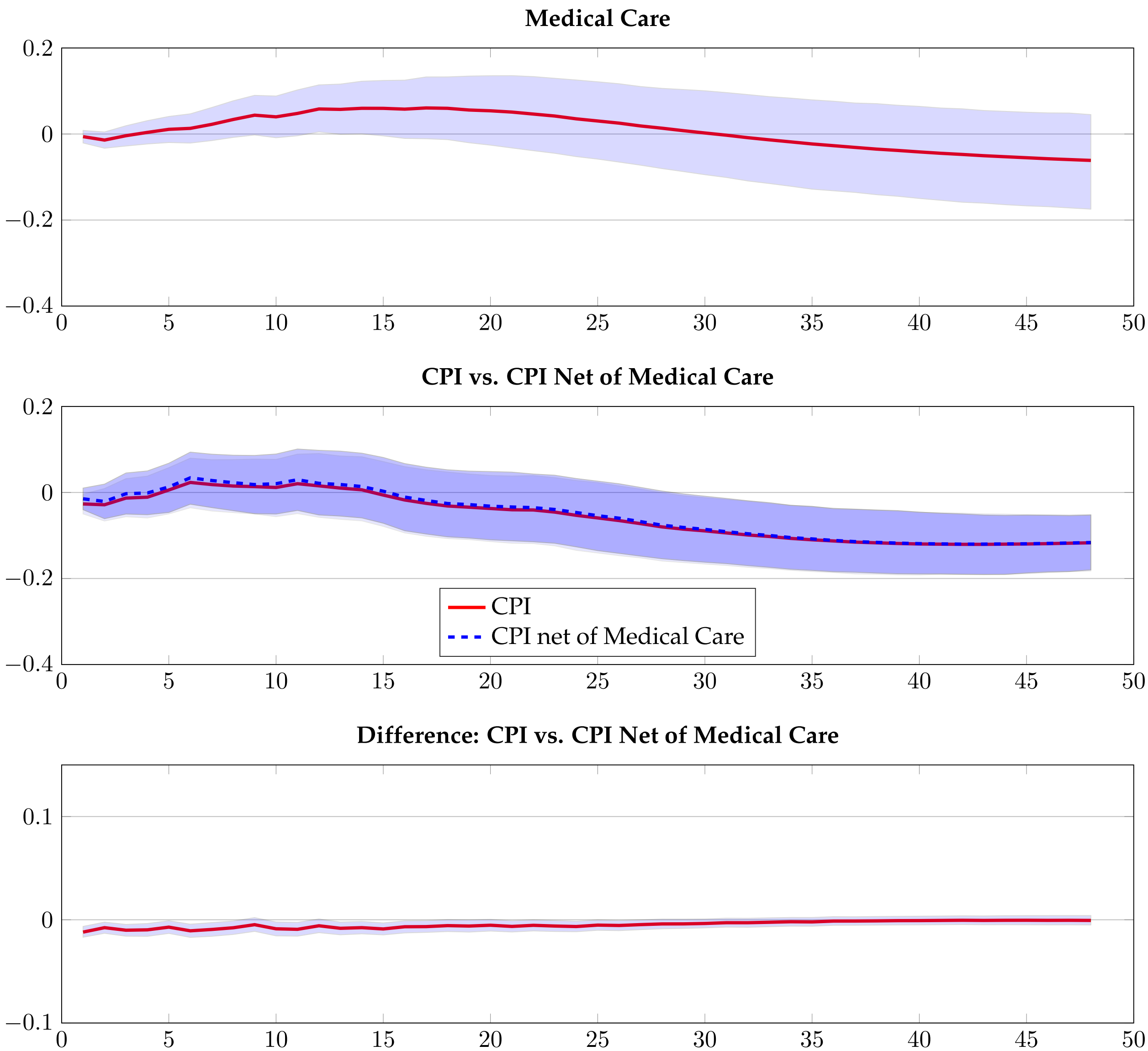

Figure 9: Percentage response of Medical Care to a 25 bps monetary policy shock identified with high-frequency surprises on federal funds 3-month futures around policy meetings. The shaded area corresponds to 68% confidence bands, which were computed using a wild bootstrap method.

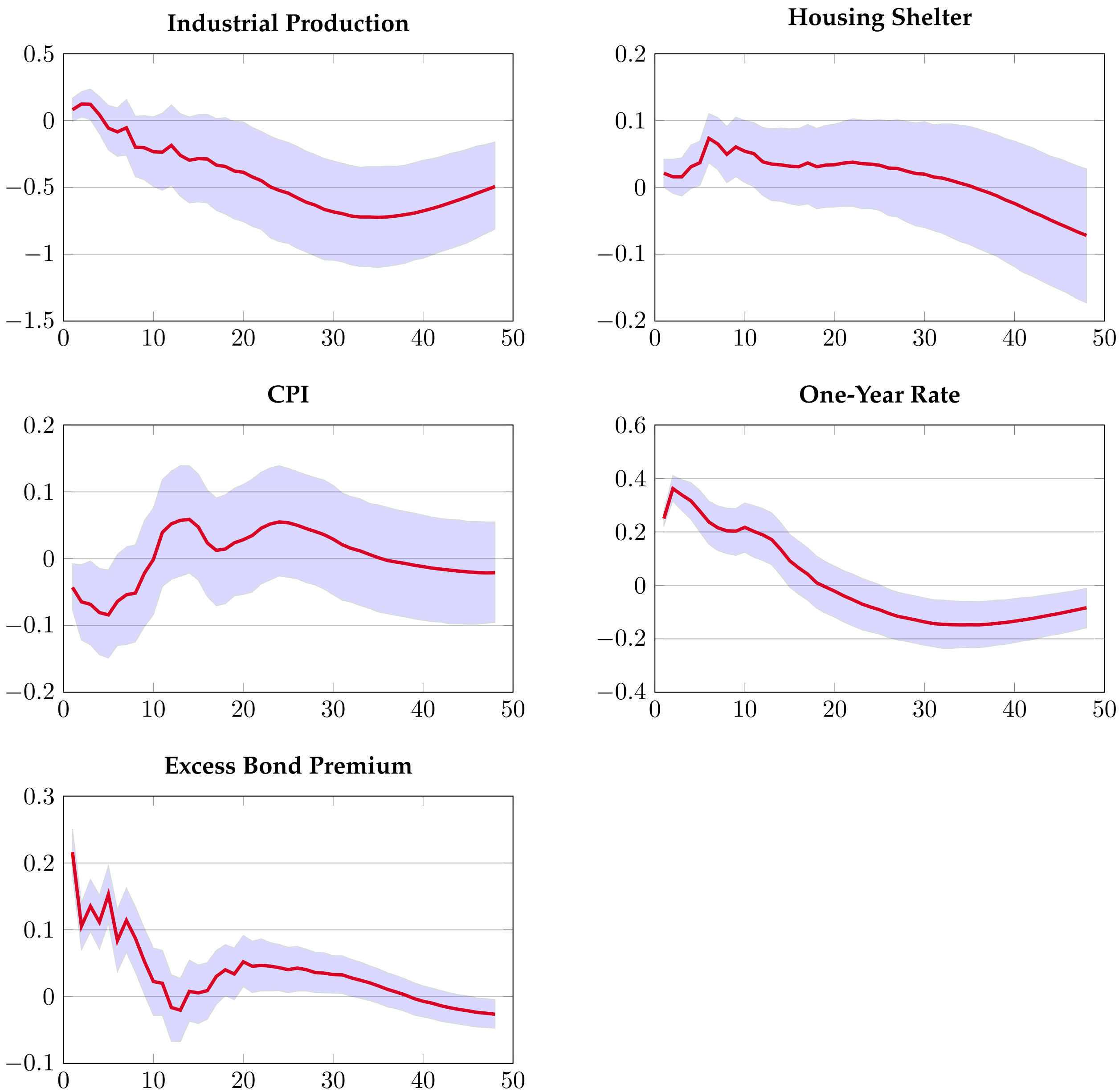

Figure 10: Housing shelter: percentage responses of variables to a 25 bps monetary policy shock identified with high-frequency surprises on federal funds 3-month futures around policy meetings. The shaded area corresponds to 68% confidence bands, which were computed using a wild bootstrap method. The first-stage regression *F-test* has a value of 23.9, and its robust R^2 is 8.7%