Asymmetric effects of monetary policy shocks across U.S. states

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Abstract

This paper provides new empirical evidence of the asymmetric effects of monetary policy shocks across regions. Using a measure of unanticipated changes in the Fed's policy rates over the period 1969Q3-2008Q4 and a local projection method extended to account for spatial effects, we find that monetary policy tightening leads to a long-lasting decrease in states' real personal income, with asymmetric effects across states that are amplified by spatial spillovers. The paper then investigates the role played by several transmission channels finding larger contractionary effects of monetary policy tightening in states with higher manufacturing share, smaller firms, smaller banks and higher house prices.

Keywords: Monetary policy shocks, Transmission channels, Regional asymmetries.

JEL Classification: E52, R11, R12.

1. Introduction

In the last decades, the discussion on the asymmetric effects of monetary policy has gained prominence in the context of the Optimum Currency Area framework and the creation of the European Monetary Union (i.e. Angeloni et al. 2003; Giannone and Reichlin 2006; Barigozzi et al. 2014; De Grauwe and Ji 2015). Recently, this discussion has reemerged, focusing on regional (Beraja et al., 2017) and household heterogeneity (Coibion et al. 2017; Furceri et al. 2018).

Previous studies have documented that monetary policy shocks may have differential effects at a lower level of spatial aggregation (regions or states) since interest rate changes may have asymmetric effects depending on the different sensitivity of regional (state) economic activity to policy shocks (e.g., Bias, 1992; Carlino and DeFina, 1998, 1999; Horvath, 2000; Fratantoni and Schuh, 2003). Empirically, existing studies have relied on changes in federal funds rate (FFR) or vector autoregressive models (VARs) innovations to identify monetary policy shocks, implicitly assuming that economic conditions do not have contemporaneous effects on monetary policy decisions. However, as discussed by Romer and Romer (2004), since changes in policy rates react positively to news in economic activity, this assumption is likely to understate the effect of monetary policy shocks on the economy.

Another pitfall in most previous studies on the regional effects of monetary policy shocks is that they have neglected the role of spatial spillovers. To the extent that changes in state economic activity caused by monetary policy shocks may spill over to neighborhood areas, for example, through financial and trade linkages, the exclusion of these spatial interactions may lead to biased estimations (Elhorst, 2003; Anselin 2013; Brady, 2011 and 2014).[1]

[1] An exception is Carlino and DeFina (1999) who tried to capture interrelationship among subnational economies by incorporating state correlations with a shock to state personal income within a region, affecting with a delay the surrounding regions. Di Giacinto (2003) also included geographical information in a SVAR model.

This paper revisits the regional effect of US monetary policy by overcoming these two limitations. In particular, the contribution of this paper to the literature on the regional effects of monetary policy is threefold. First and, to the best of our knowledge, for the first time, we use a measure of unanticipated exogenous changes in policy rates—that is, the monetary policy shocks identified by Romer and Romer (2004). Second, we include a spatial component in the model in order to capture spillovers effects across U.S. states. Third, building on the literature related to the transmission channels of monetary policy, we investigate how the differential response of output across states depends on states' characteristics such as: (i) industry-mix; (ii) housing conditions; (iii) share of small firms; (iv) share of small banks.

Although some of these channels may be more connected with lower levels of spatial aggregation (i.e. metropolitan areas for housing markets) we focused on states since understanding the effects of monetary policy across all the states can help U.S. policymakers to analyze how the aggregate economy responds to monetary shocks. In fact, metropolitan areas (MSAs) capture only a small part of the overall states income (about 37 percent, see Fratantoni and Schuh 2003).

The analysis focuses on conventional monetary policy shocks, as exogenous unconventional monetary policy measures are harder to identify. This would require identifying measures — such as unexpected changes in central banks' balance sheets — that are orthogonal to changes in economic activity. As discussed by Furceri et al. (2018) such identification is harder and existing papers on the distributional effects of unconventional monetary policy measures assume that changes in central banks' balance sheets are uncorrelated to contemporaneous changes in economic activity. This assumption is likely to be violated.

For the period 1969Q3-2008Q4, we find that exogenous monetary policy tightening leads to a long-lasting decrease in states' real personal income.[2] In addition, the spatial proximity amplifies the effects because of linkages among states' economies. An unanticipated policy rate increase of 100

[2] As we discuss in more detail in section 3, the sample is dictated by the availability of monetary policy shocks.

basis points decreases, on average, the states' real personal income by about 0.8 percent after 4 quarters (short term) and by about 1.3 percent after 8 quarters. In addition, the peak effect (after 8 quarters) is about 20 percent greater than the one obtained using endogenous changes in the monetary policy rate and about 35 percent higher than the one resulting from changes in the policy rate and no spatial proximity. This suggests that the results presented in many of the previous studies (e.g. Carlino and DeFina 1999) may have underestimated the regional effects of monetary policy.

The effects vary significantly across states. For example, the largest response among states (Wyoming) exceeds the smallest (Alaska) by more than 5 percentage points. In addition, we find that several theoretically motivated state-specific attributes contribute to explain the states' different response to monetary shocks. In particular, we find that the effect is larger in states with a larger manufacturing share and higher house prices, providing evidence of the interest rate channel of monetary policy, and in those characterized by smaller firms and banks, which proxy the credit channel of monetary policy. These findings differ from previous results on the regional effects of U.S. monetary policy (Carlino and DeFina 1998 and 1999), which have offered supportive evidence of the interest rate channel only.

The remainder of the paper is organized as follows. The next section provides a review of the existing literature on the sub-national effect of monetary policy shocks. Section 3 describes the data and the empirical strategy. Section 4 presents the baseline results, whereas Section 5 examines empirically the transmission channels of monetary policy. Section 6 concludes and provides some policy implications.

2. Literature review

The mechanisms through which monetary policy impacts real economic activity is one of the most studied areas of monetary economics. Monetary transmission belongs to two main categories (Boivin et al. 2010): (i) the neoclassical channel, which assumes that financial markets are perfect and monetary transmission concerns the impact of interest rates on the cost of capital and hence on business and household (residential) investment spending;[3] and (ii) the non-neoclassical channel that involves financial market imperfections, and is usefully referred as the credit channel.[4]

The literature on the monetary transmission mechanism also provides several reasons why the effect of monetary policy can vary across regions. These include regional differences in the mix of interest-sensitive industries and house prices (interest rate channels), and differences in the mix of small versus large firms and banks (credit rate channels).

A first commonly considered channel pertains to firms' sensitivity to interest rate shocks that depends on their type of production. When regions (states) differ in industrial composition, and industries differ in their sensitivity to changes in the interest rate, the *industry-mix* matters, and the impact of monetary policy actions may vary across industries because of different sensitivities in the demand for products. Similarly, monetary policy can be transmitted to the real economy also through the *housing market* since regional house prices may have different sensitivity to interest rate changes. The main direct effect is a cash flow effect. Higher interest rates increase the interest burden of any outstanding debt and after-housing-costs disposable income falls (Elbourne 2008). Collateralized borrowing plays a key role since interest rate cuts encourage households to refinance their mortgages and this affect home equity (Beraja et al. 2017). In particular, since property values affect the sensitivity to interest rate changes, refinancing is much more limited in states with lower property values because of the relative difficulty to take advantage of a fall in interest rates (Caplin et al. 1997). Therefore, aggregate demand in states with higher property values should exhibit more sensitivity to monetary policy shocks.

Credit market conditions also affect the transmission of monetary policy at the regional level. The rationale is that monetary policy affects the borrowers' financial positions and the banks' loan supply. In this context, firm size may be relevant because of different costs in access to finance (Bernanke

[3] Reifschneider et al. (1999), Edge et al. (2007) and Endut et al. (2018) are examples of studies that have analyzed these effects for the U.S. economy at the aggregate level.
[4] Recent studies testing these channels for the for U.S. are Bayoumi and Melander (2008), Aron et al. (2012), Jiménez et al. (2012), Ciccarelli et al. (2015), Gertler and Karadi (2015) and Bordo et al. (2016).

and Blinder 1988, Bernanke and Gertler 1995). Usually, small firms need to deal with intermediaries to meet their credit needs and they usually face higher information and transaction costs than large firms (*broad credit channel*). In addition, bank size plays an important role because of the different ability of banks to make loans (Kashyap and Stein 1994). During periods of contractionary monetary policy, small banks tend to be more limited than large banks in their ability to find alternative sources of funding (and therefore to make loans), due to restrictions in bank reserves (*bank lending channel*, or *narrow credit channel*).

Previous empirical research on the asymmetric regional effect of monetary policy has mainly focused on the U.S., by analyzing the asymmetric effects on, among others, banking flows (Miller, 1978; Bias, 1992), manufacturing earnings (Garrison and Chang, 1979) and state aggregate economic activity. All these studies have relied on VAR approaches, assuming that changes in the FFR do not respond to changes in economic activity within the same quarter and that they are orthogonal to expectations about future economic cycles. As discussed by Ramey (2016), these approaches are not able to properly identify the causal effect of monetary policy—an issue we address in this paper.

Carlino and DeFina (1998, 1999) investigated the regional and state effects of monetary policy by estimating a VAR model for the period 1958-1992. They found an asymmetric effect of monetary policy across U.S. states and regions, with differences across states explained by differences in production (industry-mix), but not by differences in market imperfections. Fratantoni and Schuh (2003) estimated the regional effect of monetary policy through a heterogeneous-agent vector autoregressive model (HAVAR) for the period 1986-1996. They found that housing market conditions are an important transmission channel. Owyang and Wall (2009) analyzed the regional effects of monetary policy using a VAR for the period 1960-2002, and they found that the magnitude and persistence of the effect of FFR changes have varied over time due to changes in the industry-mix. Di Giacinto (2003) improved upon these previous studies by introducing geographical information in the VAR approach.

The literature on the asymmetric effect of monetary policy shocks in other countries has been more limited. De Lucio and Izquierdo (1999) conducted a similar exercise to Carlino and DeFina (1999) for Spanish regions. Dow and Montagnoli (2007) focused on the regional structure of the financial sector to investigate the regional transmission of UK monetary policy. Rodríguez-Fuentes and Dow (2003) investigated the regional impact of monetary policy with particular focus on Spanish regions, finding in the credit market heterogeneity a source of asymmetric policy transmission.

3. Data and empirical strategy

3.1. Monetary policy shocks

Previous studies on regional effects of monetary policy have relied on VAR approaches, assuming that changes in the FFR do not respond to changes in economic activity within the same quarter and that they are orthogonal to future expectations about the economy. This approach has some limitations because the funds rate often moves endogenously with changes in economic conditions and their target series are often responses to information about future economic developments. To overcome these problems, in this paper we use the measure of unanticipated exogenous monetary policy shocks proposed by Romer and Romer (2004). They estimate a Taylor rule whose residuals are considered a proxy of policy shocks. They first derive a series of intended changes in the FFR. Then, they use the Fed's internal Greenbook forecasts of inflation and real growth to control the intended FFR series for monetary policy actions taken in response to information about future economic developments, specifically real GDP growth, inflation, and unemployment. Finally, they estimate the following equation:

$$\Delta ff_m = \alpha + \beta ffb_m + \sum_{i=-1}^{2} \gamma_i \, \Delta\tilde{y}_{m,i} + \sum_{i=-1}^{2} \lambda_i \, (\Delta\tilde{y}_{m,i} - \Delta\tilde{y}_{m-1,i}) + \sum_{i=-1}^{2} \phi_i \, \tilde{\pi}_{m,i} + \sum_{i=-1}^{2} \theta_i \, (\Delta\tilde{\pi}_{m,i} - \Delta\tilde{\pi}_{m-1,i}) + \rho\tilde{u}_{m0} + \epsilon_m \quad (1)$$

where:

- Δff_m is the change in the intended FFR around meeting m;
- ffb_m is the level of the target FFR before the change in the meeting m (included to capture any mean reversion tendency);
- $\tilde{\pi}$, $\Delta\tilde{y}$ and $\tilde{u}$ are the Greenbook forecasts of inflation, real output growth, and unemployment rate; note that both the current forecast and the change since the last meeting are used;
- The i subscript refers to the horizon of the forecast: -1 is the previous quarter, 0 the current quarter, 1 the next quarter, 2 the next quarter;

The residuals from this regression capture changes in the funds rate that are orthogonal to information about past and future economic developments, and therefore can be deemed as *exogenous* policy shocks. The shocks are computed for the period up to 2008Q4, since the FFR reached the zero-lower bound afterward. Figure 1 presents the evolution of monetary policy shocks and compares it with the pattern of change in the FFR.

[insert Figure 1 near here]

The shocks are particularly large and volatile in the early 1980s during the Volcker disinflation plan. In the periods 1994-1995 and 2005-2006, it is visible a pattern of consistently positive monetary policy shocks meaning that policy was more contractionary than usual conditional on real-time forecasts. Conversely, monetary policy shocks were negative in the 2000-2004 period. Figure 1 also shows that changes in the FFR are typically larger than the exogenous shocks, because a significant part of the variation in monetary policy action is due to the response of the Fed to the current and expected future states of the economy (Ramey 2016).

3.2. Outcome variable

To measure the state-level economic activity we use the real personal income of 51 U.S. states for the period 1969Q3-2008Q4.[5] As earlier mentioned, we focused on states rather than metropolitan areas also because, when dealing with MSAs data, some problems may arise. In fact, income data for MSAs is available only annually from 2001 to 2017. In some studies, quarterly income is determined at MSA level by imputing the state personal income value to the MSAs located in the same state according to the share of MSA population over total state population (see Fratantoni and Schuh 2003, data appendix). In this way, since the proportion of MSA population does not change too much over time, variations in MSA personal income within the same state would mainly depend on the income state variation and therefore, the variability of the dependent variable across units will be strongly reduced, therefore introducing data distortions which may affect the estimates.

In addition, we use personal income for two reasons. First, it is consistent with previous studies (e.g., Carlino and DeFina 1999; Owyang and Wall 2009), therefore, allowing an easier comparison of the results. Second, although an alternative variable for measuring regional economic activity is GSP, historical data on this variable at the state level are published annually (quarterly data are available only starting from 2005), and as such, are not well suited for our analysis of the effects of monetary policy shocks which covers a longer period.

3.3. Empirical strategy

Two reduced-form empirical specifications are used to examine the state effects of monetary policy shocks on demand. The first consists of tracing-out the average response of states' real personal income to unanticipated changes in policy rates. The second allows for the interaction between policy changes and states' characteristics in order to identify the transmission channels of the monetary policy.

[5] Data are taken from the Bureau of Economic Analysis (BEA). Consistently with other studies (e.g., Carlino and DeFina 1999) we deflate nominal personal income quarterly data with the National Consumer Price Index (CPI-U) due to the unavailability of state price indices.

The first specification follows the approach initially proposed by Jordà (2005) and then extended by Brady (2011, 2014) to take into account the spatial correlation.[6] This method allows the direct estimation of Impulse Response Functions (IRFs) based on local projections of the effect of monetary policy shocks on state output and is particularly suited to assess non-linearities in the dynamic response of the variable of interest in the aftermath of a shock. The local projection method is an alternative way to estimate IRFs without specifying a vector autoregressive model (Autoregressive-Distributed Lag or ARDL). In fact, the latter approach tends to be sensitive to a variety of misspecifications, such as the choice of the number of lags (Teulings and Zubanov 2014). On the contrary, the local projection method does not impose the dynamic restrictions embedded in ARDL models and is particularly suited to estimating nonlinearities in the dynamic response.

The inclusion of the spatial component allows taking into account the spillover effects of policy changes.[7] There are several possible transmission mechanisms through which economic activity can spill over across borders. Di Giacinto (2003) suggests trade and financial linkages, as well as workers commuting as three important (spatial) transmission channels. In the case of trade, positive (or negative) income shocks in a given state may affect production and income in trading partners by increasing (or decreasing) the imports from those economies. Trade linkages are usually stronger between neighbor areas. On the other hand, an increase in demand in a given state may lead to an inflow of capital from other states, therefore generating negative spillovers. Workers that commute between two regions (states) may act as a transmission channel in the case of an increase in unemployment generated by a tightening in monetary policy in the state where commuters work. In this case, there may be a contraction in the state where workers live, that may reinforce the direct impact of monetary policy shocks. Other channels of transmission include tax competition (Besley

[6] This approach is advocated, among others, by Stock and Watson (2007), Teulings and Zubanov (2014).
[7] For example, in Carlino and DeFina (1999) no contemporaneous feedback is allowed, therefore simultaneous propagation of economic disturbances among regions is excluded. In Di Giacinto (2003), though the spatial effects were considered, the specification adopted does not permit an accurate identification of exogenous monetary policy shocks.

and Case 1995), direct transfer across states, and factors affecting housing markets spatial correlation (equity transfers, spatial arbitrage; see for details Pollakowski and Ray 1997)

To evaluate the impact of monetary policy shocks on regional output, we estimate the following equation for each future period *k*:

$$y_{t+k} - y_{t-1} = \alpha^k + \rho^k W \Delta y_t + \beta^k MP_t + \delta^k X_t + \varepsilon_t^k \quad (2)$$

for k=0,1, 2, … , 12 (quarters)

where:

- y_t is the log of state real personal income;
- W is the spatial weight matrix (according to the contiguity-queen approach);
- $W\Delta y_t$ is the spatial lag of the dependent variable;
- MP_t are monetary policy shocks;
- X_t are control variables such as: (i) past changes in real personal income to implicitly take into account short-term factors affecting change in personal income that are potentially correlated with monetary policy shocks; (ii) past changes in monetary policy shocks to consider serial correlations in our measure of shock.

The spatial matrix W is defined by contiguity, where the border relationships between i and its neighbors are weighted equally, with the weights across each state summing to one. This weighting of the contiguity matrix, which is common in the spatial literature, is done for simplicity but it also proves convenient in the estimation of spatial models because it does not require to model the potentially large set of spatial factors (see Anselin and Bera, 1998, for a complete discussion).[8] In the

[8] More specifically, with the contiguity-queen spatial matrix, states with common sides and common vertices are considered neighbors.

section of robustness check, we show that the results are robust to alternative methodologies to compute the spatial matrix.

Impulse response functions (IRFs) of the effects of monetary policy shocks on state personal income are obtained using the estimated coefficient β^k ,while spatial impulse responses are obtained using the estimated coefficient ρ^k. The confidence intervals are computed using the estimated standard errors of the same coefficients. Equation (1) is estimated for each state separately. As in Brady (2011, 2014), spatial IRFs are generated from a single-equation spatial model, where the response of a state's average personal income to an income shock in adjacent states is estimated using direct forecasting techniques. Unlike VAR models in which a number of restrictions are required (i.e. Holly et al. 2010, 2011; Kuethe and Pede, 2011), the single-equation spatial approach provides the flexibility to control for state specific factors and allows to specify the spatial factor.

The second specification is designed to explain asymmetries in the effects of monetary policy shocks. Previous studies have investigated the issue mainly using the observations referred to the regional output loss at trough or the total regional output loss as dependent variables and the transmission channels as explanatory variables, neglecting the role of spatial spillovers. In contrast, we investigate the role of each transmission channel allowing the interaction between policy changes and economic conditions:

$$y_{i,t+k} - y_{i,t-1} = \alpha_i^k + \varphi_t^k + \rho^k W \Delta y_{i,t} + \beta^k Z_i MP_t + \delta^k X_t + \varepsilon_{i,t}^k \qquad (3)$$

for k=0,1, 2, … , 12 (quarters)

i=1,2,…,51 (states)

where:

- α_i represents country fixed effects, to control for unobservable state specific factors which may affect changes in real personal income;

- φ_t are time fixed effects, included to take account of global shocks, such as changes in oil prices or in the global business cycle;
- Z_i is the variable indicating the transmission channel;
- X_t are past changes in real personal income to implicitly control for short-term factors affecting change in personal income that are potentially correlated with monetary policy shocks.

Compared to a two-step approach (that is, first estimate the effects of monetary policy shocks and then regress them on variables capturing the transmission channels), the one-step approach (the interaction of policy shocks and transmission channels) used in the paper improves the efficiency and the precision of the estimates.[9]

4.Results

4.1. Baseline

Table 1 and Figure 2 show the output response to monetary policy shocks for the 51 U.S. states. Looking at the figure, it appears immediately that monetary policy shocks have a negative, statistically significant and long-lasting effect on states' real personal income.

[insert Figure 2 near here]

[insert Table 1 near here]

Specifically, an unanticipated policy rate increase of 100 basis points decreases the states' real personal income by about 0.81 percent (on average) in the short term (after 4 quarters) and by about

[9] When the dependent variable in a regression is based on estimates, the second stage estimates are less efficient. The reason is that the regression residual can be thought of as having two components. The first component is sampling error (the difference between the true value of the dependent variable and its estimated value). The second component is the random shock that would have obtained even if the dependent variable were directly observed as opposed to be estimated (Lewis and Linzer 2005).

0.83 percent in the medium term (after 12 quarters). The maximum effect is usually reached 8 quarters after the shock, at -1.26 percent (Table 2, column I).

The effect is not only statistically significant but also economically large. To illustrate this, we re-estimate equation (2) including exogenous measures of tax and expenditure shocks.[10] The results reported in Figure 3 and Table 2 show that the peak effect of an exogenous 1 percent increase in the policy rate is considerably larger (more than twice) in absolute value than a 1 percent of GDP exogenous change in tax and spending.

[insert Figure 3 near here]

[insert Table 2 near here]

As discussed earlier, the inclusion of the spatial effects in the model allows to analyze the importance of spatial relationships. To this regard, we carry out two exercises. First, we compute the spatial IRFs for each state by obtaining results that are shown in Figure 4 (ρ^k coefficient in equation 2). Our findings suggest that, for all the states considered, the response of real personal income to positive changes in income of neighbor states is positive, long-lasting and statistically significant. This suggests that the effects of monetary policy are transmitted in part through spatial relationships among states.

[insert Figure 4 near here]

[10] Data on spending changes are computed by Ramey and Zubairy (2018) and are exogenous to business cycles and unpredictable with ex-ante information held by agents. These shocks are based on a narrative approach, which exploits information from the press (*Business Week*, *New York Times*, and *Washington Post*), and they cover the period 1889-2015. Tax shocks are taken from Romer and Romer (2010). They, make use of narrative records, such as budget documents and speeches, to identify the size, timing, the principal motivation for fiscal actions, and to separate out tax changes that were made based on attempts to respond to current economic situations from those that are exogenous to current economic conditions. Exogenous tax changes are those that are not motivated by the objective to influence short-run conditions—such as counteracting influences on the economy or paying for increases in government spending—but those motivated by long-run goals—such as a desire to restore long-run budgetary balance or to spur long-run growth through lower marginal rates—or by a shift in government ideology. Romer and Romer shocks cover both expansion and consolidation episodes at a quarterly frequency from 1945 to 2007.

Second, we estimate again the model without considering the spatial effects (so we exclude the spatial lag of the dependent variable from equation (2)). Table 1 shows the estimated eight-quarter cumulative response of personal income for the two cases. From a quick look we can see that the magnitude of the contractionary effects obtained with the inclusion of the spatial effects is usually much larger than the one obtained with their exclusion, suggesting that the spatial spillover effects reinforce the effectiveness of policy actions. Particularly, the difference in the point estimates is very large in the case of North Dakota and Rhode Island reaching 0.9 and 0.8 percentage points, respectively. [11]

The maximum total contractionary effect is reached in Wyoming, followed by Arizona, North Dakota, Michigan and Florida. In these cases, the cumulative loss in real personal income is above 2 percentage points two years after the occurrence of the shock.

4.2. Effective federal funds rate

To compare our results with those produced in the previous literature, we repeat the analysis using changes in the effective federal funds rate as measures of monetary policy shocks (both including and excluding, alternatively, the spatial effects). The results obtained are presented in Figure 5 and Table 3 (column 3 and 4). They confirm that changes in the FFR have statistically significant and long-lasting effect on states' real personal income, with the effects varying across states markedly. At the same time, as expected, the effects are considerably smaller than those obtained by using Romer and Romer shocks: the average cumulative effect is halved (or one quarter of the effect, in the version without spatial effects) through period 4.

[insert Figure 5 near here]

[11] Differences between the point estimations obtained with the two versions of the model range from 0 (Alaska and Hawaii) to 0.92 (North Dakota).

[insert Table 3 near here]

The fact that the magnitude of the effects is smaller when using changes in effective policy rates is because an increase in the policy rate may be due to better realized or expected economic conditions, which tend to offset the contractionary effect of monetary policy shocks (Furceri et al. 2018).

4.3. Different spatial matrices

Since our results may be affected by the type of the spatial weight matrix adopted in the analysis (Le Gallo and Ertur 2003; Anselin 2013) we check their robustness by using alternative spatial matrices. First, we estimate the model with a restricted version of the baseline spatial weight matrix, in which only states with common sides are considered neighbors (*the contiguity-rook* approach). Second, we use the *k-nearest neighbors (knn)* approach that is a more sophisticated generalized distance-based method in which spatial weight matrices are based on a critical cut-off. The critical cut-off is the same for all regions and is determined by the number of neighbors. To this regard we use values of *k* from 1 to 10.

Table 4 shows the results of these exercises for the average response across U.S. states and for each quarter after the monetary policy shocks.[12] The results are similar to those obtained in the baseline case (*contiguity-queen*) suggesting that the type of spatial weight matrix adopted does not influence the results remarkably.

[insert Table 4 near here]

[12] Estimation results and IRF graphs for each state are not included but are available upon request from the authors.

5. Transmission channels

As discussed in section 2, there are several mechanisms that can explain why monetary policy actions have heterogeneous effects across states. In this section, we empirically investigate some of them. To the extent that states have heterogeneous industrial and banking structure, as well as different sensitivity of house prices to changes in interest rates, we might expect a different reaction of state outputs to the same shock. The rationale is that the magnitude and the duration of income responses to policy shocks may vary over time depending on regional conditions.

Although previous studies have empirically investigated numerous transmission channels (see section 2 for more details) they have not always found the expected results, probably because they confined the analysis to the regional (state) output loss at trough or to the total regional output loss as dependent variables, understating the role played by spatial spillovers and using endogenous and not exogenous measures of monetary policy shocks.

To evaluate the role of the industry-mix in each state, we use the percentage of the Gross State Product (GSP) accounted for manufacturing durable goods. To investigate the credit channel, we use two different measures to consider both the *broad* (firm size) and the *narrow* (bank size) *credit channels*. In the first case, we use the state employment accounted for by small firms (<250 employees). In the second case, we use the percentage of loans made by state's small banks. Consistently with Carlino and DeFina (1999), we identify small banks as those at or below the 90^{th} percentile in assets at the national level. To investigate the role of housing markets we use a house price index (all-transactions index) deflated by the National Consumer Price Index (CPI-U) due to the unavailability of states' price indices.[13] Table 5 shows descriptive statistics for these variables for the U.S. states, suggesting significant heterogeneity which may result in a regional diversified impact over the transmission channels.[14]

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[13] In all-transactions house price index, appraisal values from refinance mortgages are added to the purchase-only data.
[14] Data sources and time coverage of each variable are indicated in table A1 in the appendix.

[insert Table 5 near here]

We estimate equation (3) for each variable in turn and present the results in Tables 6-9.[15] Unlike previous studies, the results displayed in the tables show that all the identified channels work as expected. Contractionary effects of monetary policy tightening are larger in states with higher manufacturing share (Table 6) and higher house prices (Table 7), confirming the importance of the interest rate as key transmission channel. In addition, our findings demonstrate the relevance of the credit channel (broad and narrow). The contractionary effect of monetary policy shocks is also larger in states with higher share of small firms (Table 8) and small banks (Table 9).

In the case of manufacturing share, the negative effects are typically transmitted the first quarter after the occurrence of the shock and tend to vanish after 6 quarters. In the other cases, the effects are typically transmitted 2-3 quarters ahead and the peak effect is usually reached 11-12 quarters after the shock. Therefore, all the identified channels (with a partial exception for the manufacturing share) tend to have long lasting effects. Also in this case, our results show that spatial effects are statistically significant and that the spatial spillover effects reinforce the effectiveness of monetary policy actions.

[insert Tables from 6 to 9 near here]

In order to better illustrate the heterogeneity in responses, Figure 6 presents the differential effects on personal income obtained by estimating equation (3) for each channel. In the short term (i.e. up to 4 quarters after the shock), the differences in output effects generated by monetary policy tightening appear to be conveyed mainly through the industrial-mix. In particular, the results suggest that the differential short-term personal income loss for a state with relatively high manufacturing durable goods share (at the 75th percentile of the distribution) compared to the one for a state with

[15] To check the robustness of the results, we have estimated equation (3) excluding the spatial effects. These results are qualitatively very similar and broadly unchanged with respect to those presented in the paper. We must note that, also in these cases, the inclusion of the spatial effects reinforces the effectiveness of each transmission channel.

relatively low manufacturing durable goods share (at the 25th percentile of the distribution) is about 0.5 percentage point. In the medium-term the transmission of the monetary policy, instead takes place mainly through the credit channels and the housing markets. For example, the differential medium-term output loss for a state with relatively high house prices (at the 75th percentile of the distribution) compared to a relatively low house price state (at the 25th percentile) is about 2.3 percentage points.

[insert Figure 6 near here]

Finally, these results on the transmission mechanisms are robust to the exclusion of islands and economically small states such as Alaska, DC and Hawaii (Table A2 in the Appendix) as well as of statistical outliers (Table A3 in the Appendix).

6. Conclusions and policy implications

In this paper we show how unanticipated exogenous monetary policy shocks have strong heterogeneous effects across states. After a slight initial rise, monetary policy tightening generally leads to a long-lasting decrease in states' real personal income but with different magnitude and duration. The inclusion of the spatial interactions matters. The effects tend to be magnified by the spatial correlations of personal income across U.S. states reaching the peak 8 quarters after the shock (-1.26 percent, on average). We also show how asymmetries in the effects of monetary policy shocks are explained by several transmission channels (i.e. industrial mix, credit channel, housing market channel).

The evidence of the asymmetric effects of monetary policy suggested by our findings highlights the difficulty of conducting a national monetary policy and raises issues of cross-state equity. A possible solution may be a more effective collection of information at the sub-central level to improve the accuracy of decisions and prevent or smooth differences in reactions. In fact, though the Central Banks (the Fed in our case) collects information at the sub-central level, the conventional view is that monetary policy should focus only on aggregate economic conditions with little regard for its regional distribution.

The identification of several economic and financial conditions that work as transmission channels provides a better understanding of the different effectiveness of monetary policy across states. However, to the extent that these conditions are likely to change over time only slowly, the asymmetric response of states' economic activity will tend to remain in the long run and self-perpetuate. For example, the asymmetric effects of monetary policy caused by differences in states' industry-mix are difficult to eradicate through direct government intervention. If industrial specialization increases (the Krugman hypothesis), disparities in monetary policy transmission will probably rise. Governments can try to compensate states through fiscal policy or design incentives to firms' relocation which may, however, create other distortions. Also, it is interesting to note that not only the size of the firms but also the size of the banks produces asymmetric effects. Therefore, only a deeper understanding of the processes underlying each transmission channel could lead to substantial improvements in the evaluation of the efficiency and the effectiveness of monetary policy.

Our results stimulate further research on several points. For example, it would be interesting to analyze whether the effects depend on the state of the business cycle, or whether they change according to the fiscal policy adopted. Our analysis encourages also an extension to the Euro-Area context. In fact, it would be interesting to shed more lights on the sub-national effects of monetary policy changes in Europe since the relative role of the various transmission channels may be different in this context.

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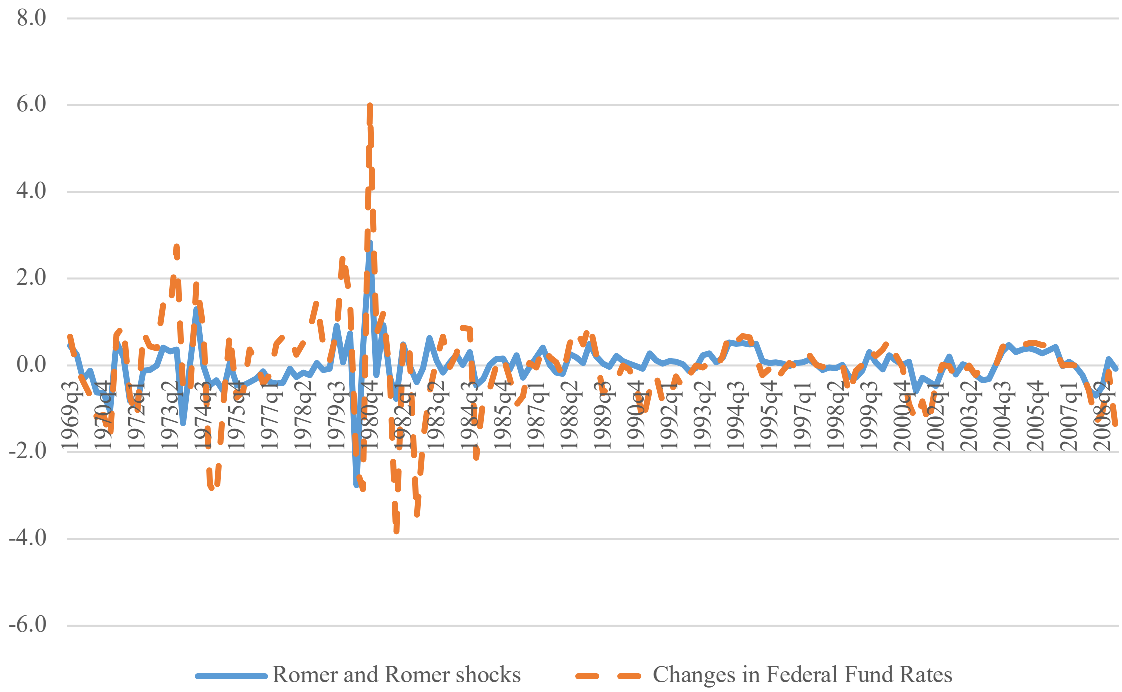
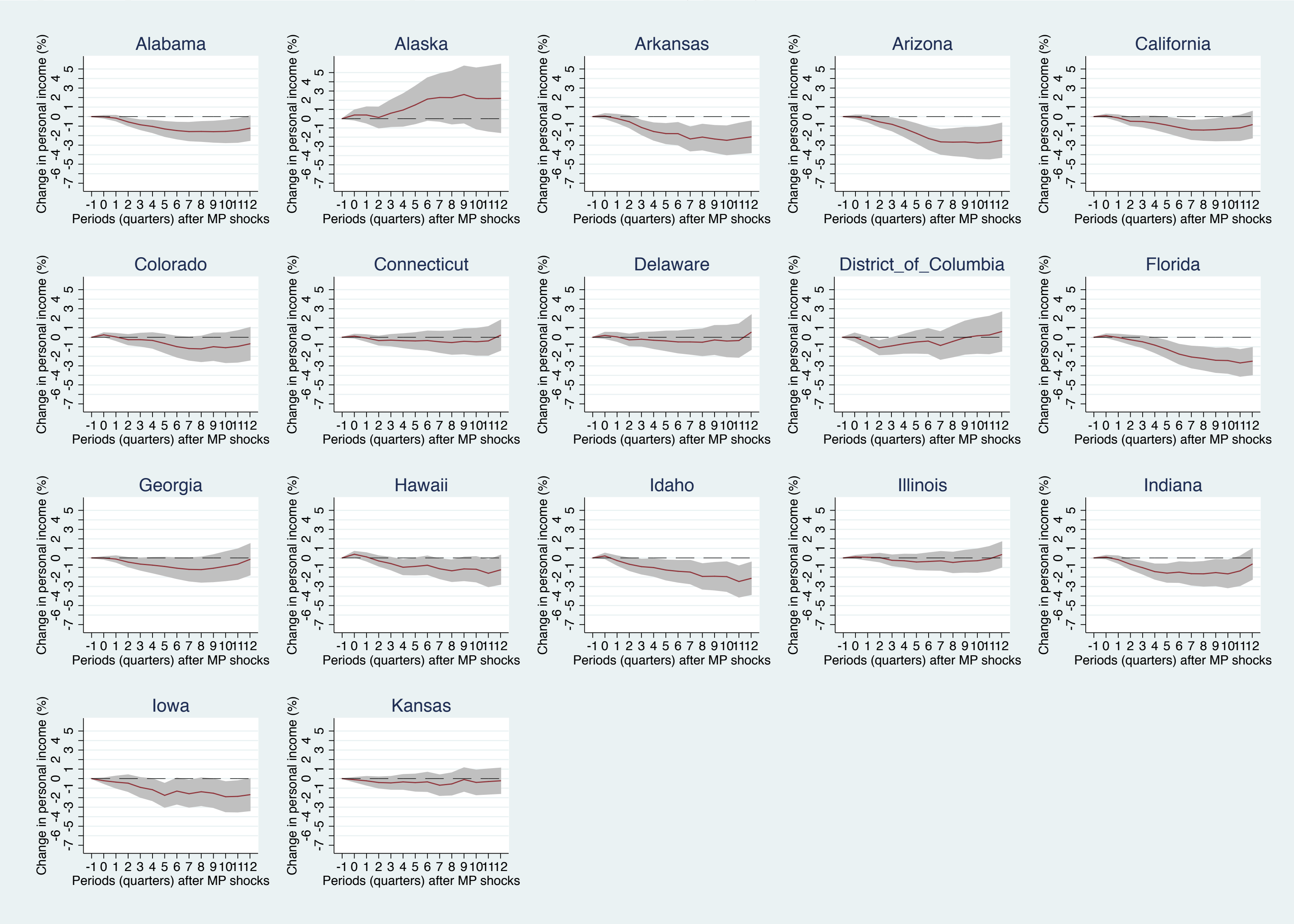
FIGURES

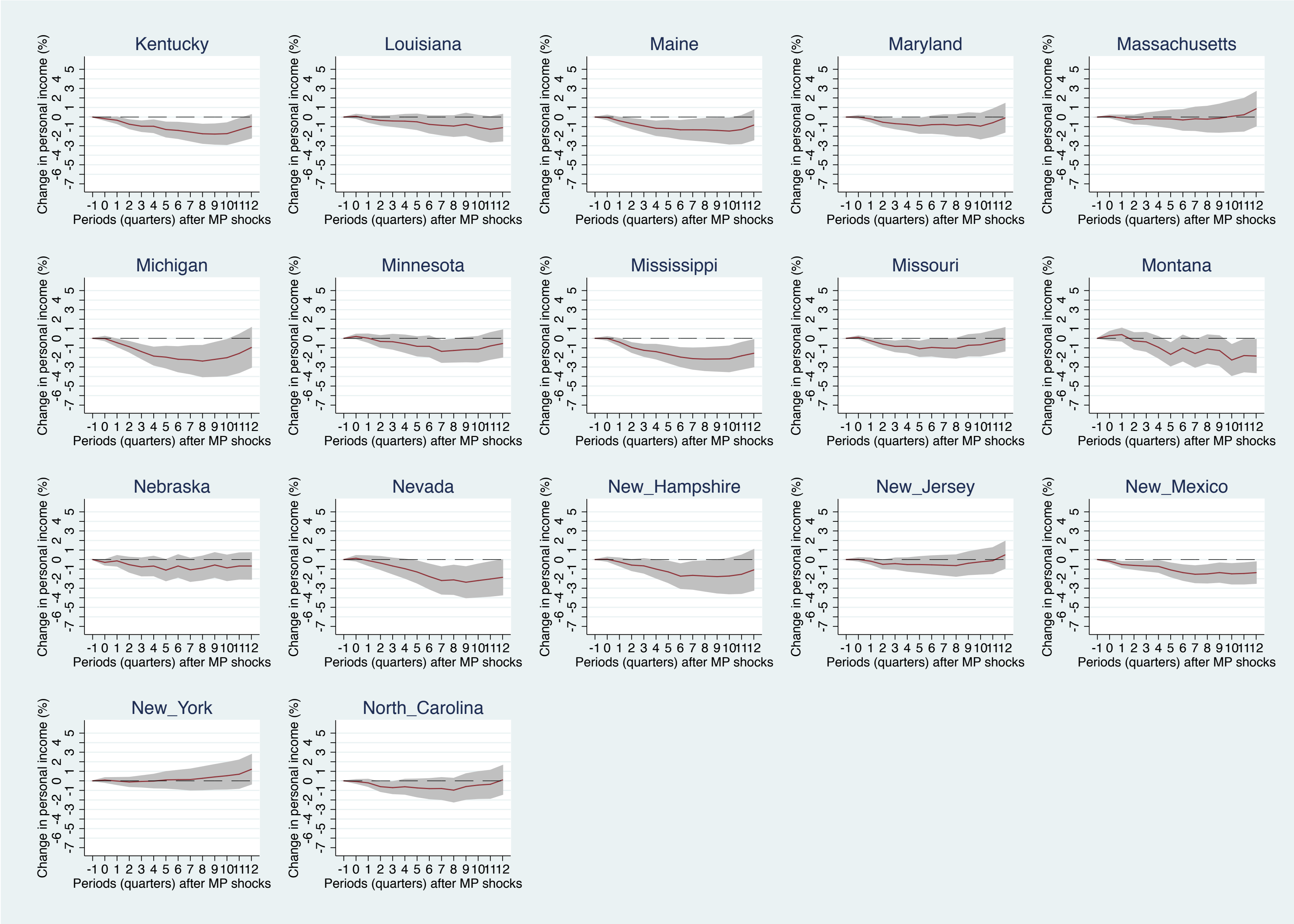
Figure 1. Measures of monetary policy shocks



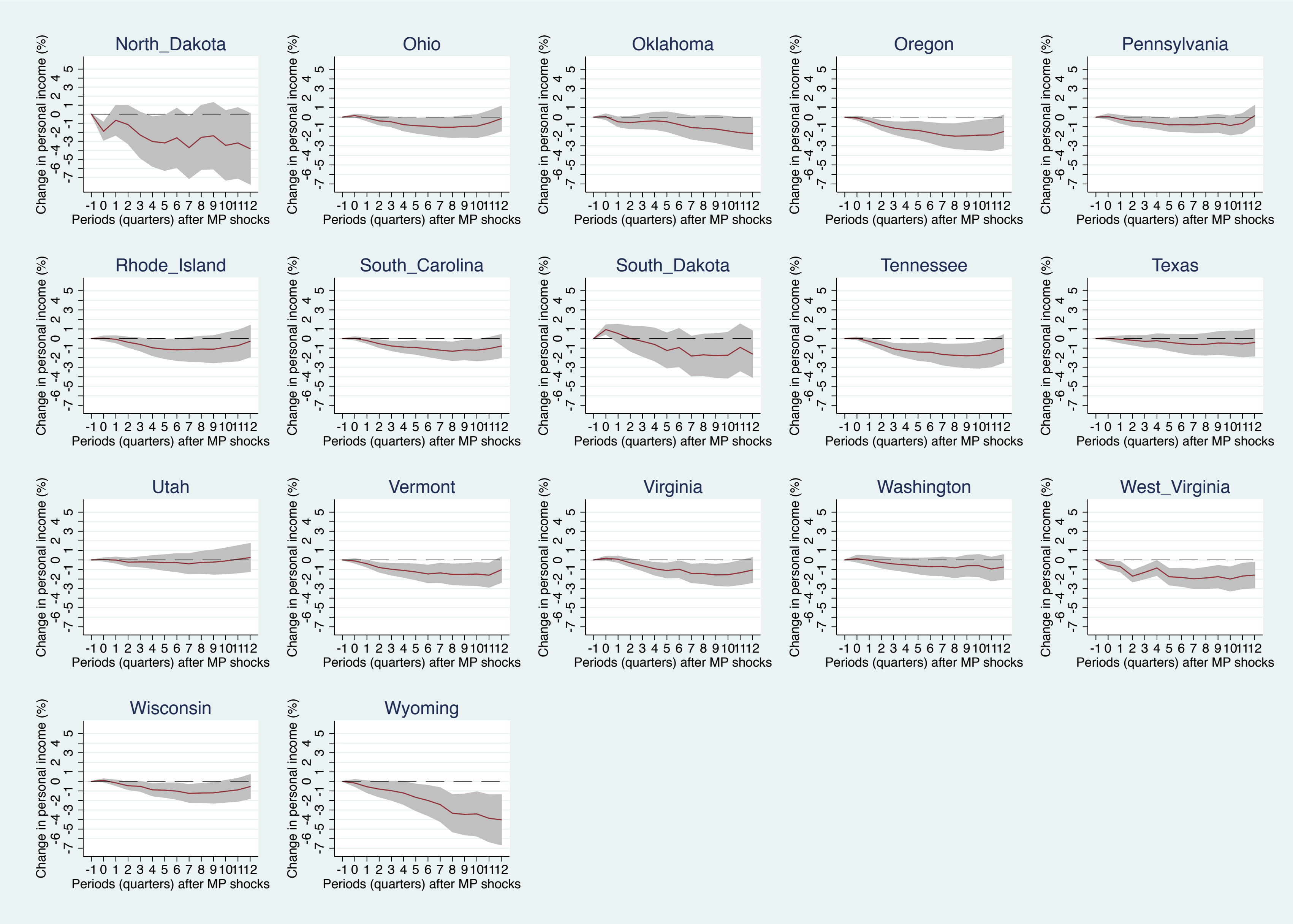
Note: The x-axis denotes time (quarters). The y-axis denotes percentage points.

Figure 2. Impulse response functions of state real personal income to monetary policy shocks – R&R shocks



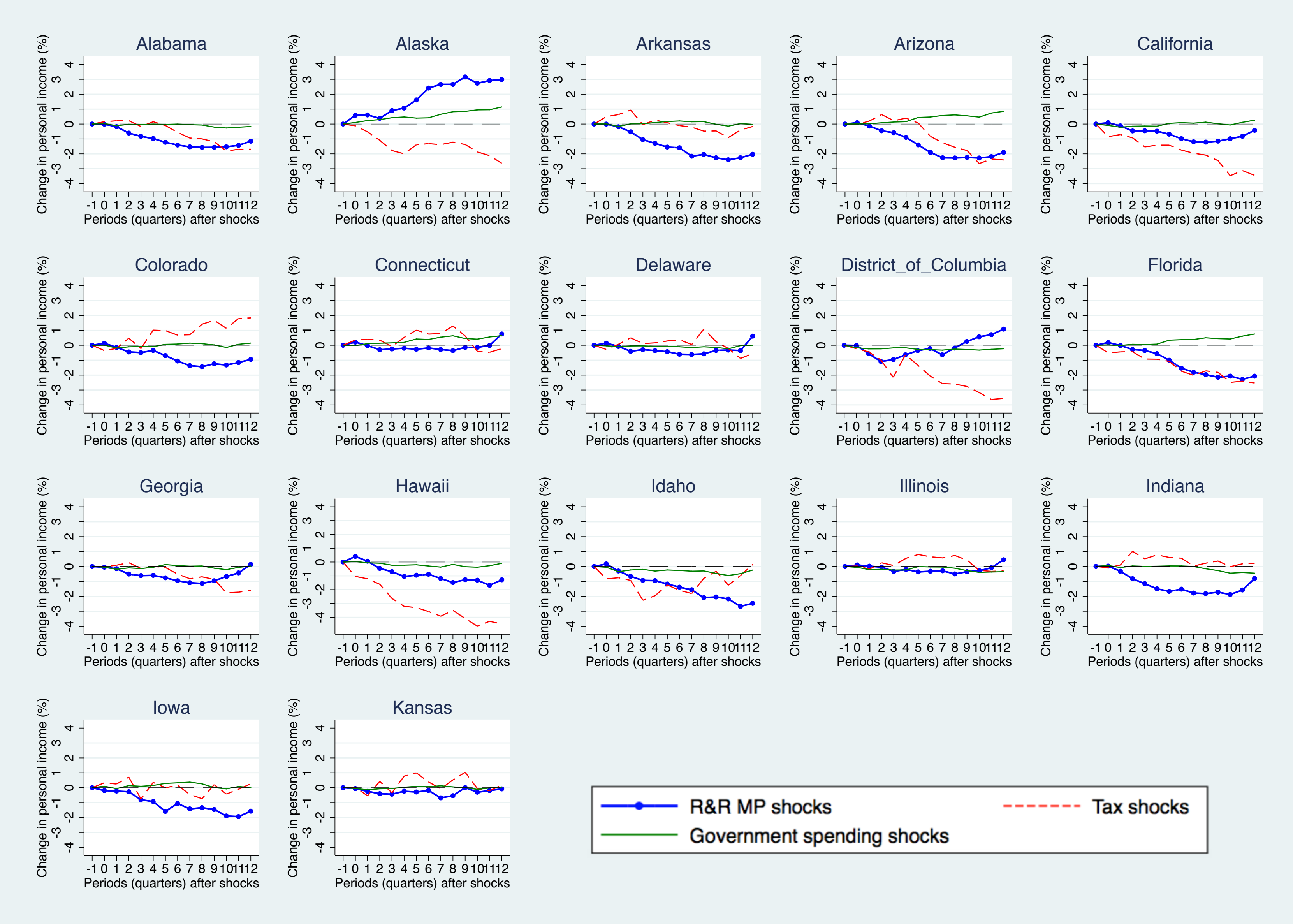


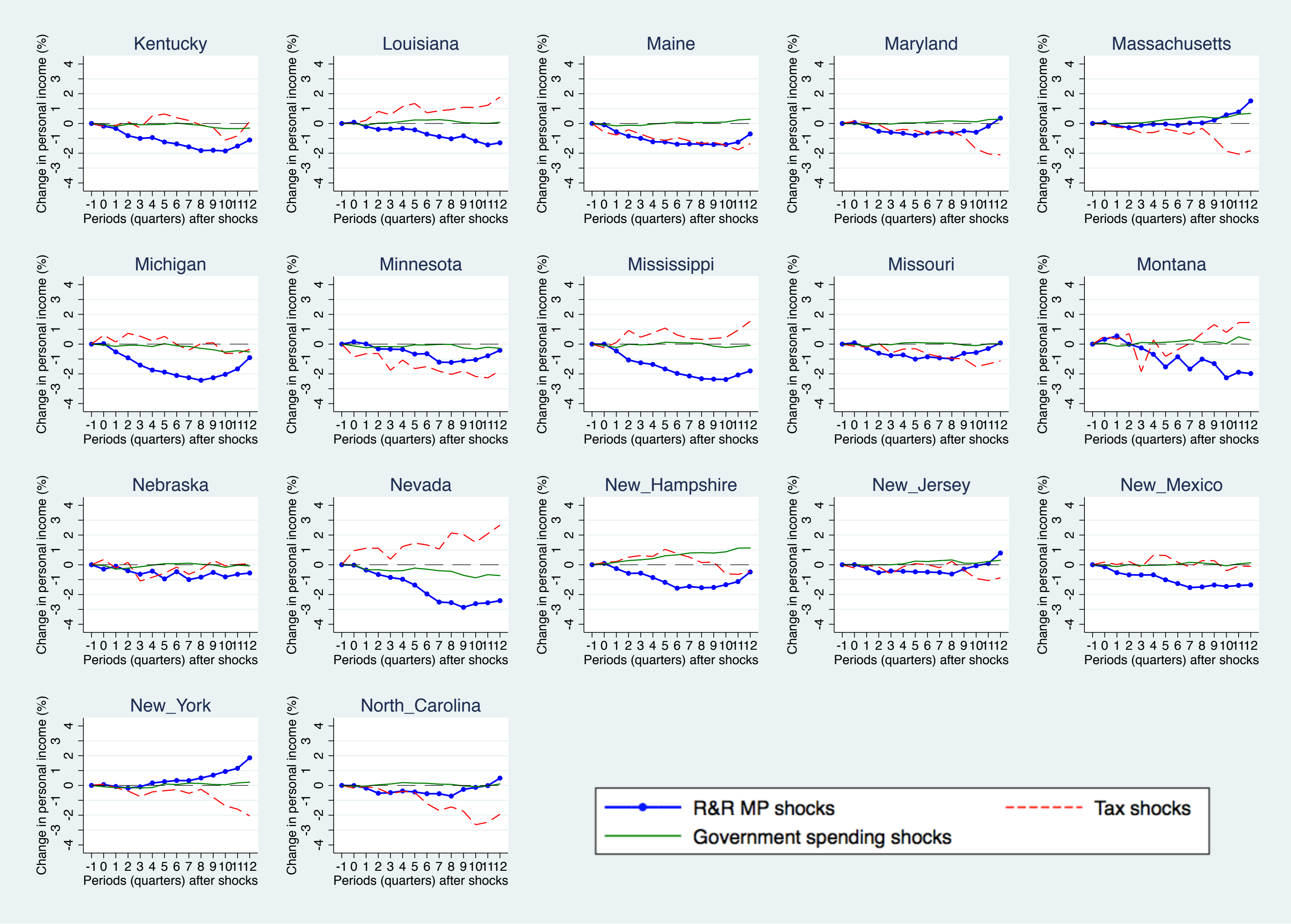
Kentucky
Louisiana
Maine
Maryland
Massachusetts
Michigan
Minnesota
Mississippi
Missouri
Montana
Nebraska
Nevada
New_Hampshire
New_Jersey
New_Mexico
New_York
North_Carolina
Change in personal income (%)
-7 -6 -5 -4 -3 -2 -1 0 1 2 3 4 5
-1 0 1 2 3 4 5 6 7 8 9 10 11 12
Periods (quarters) after MP shocks



Note: estimates based on equation (2). In y-axis, the impulse response (β^k coefficient) and 90 percent confidence bands. In the x -axis, quarters after the shock.

Figure 3. Monetary vs. fiscal policy shocks




Kentucky
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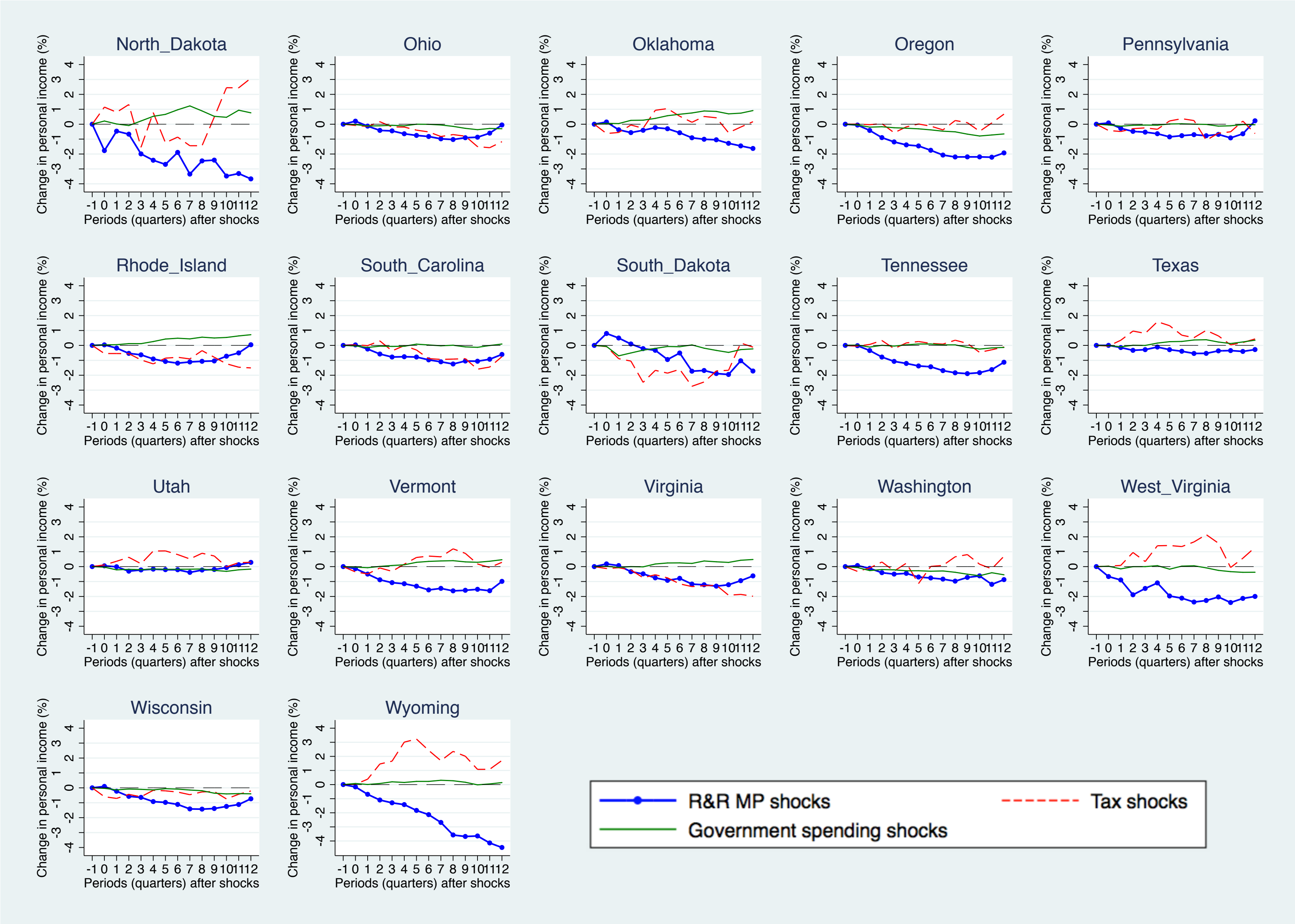
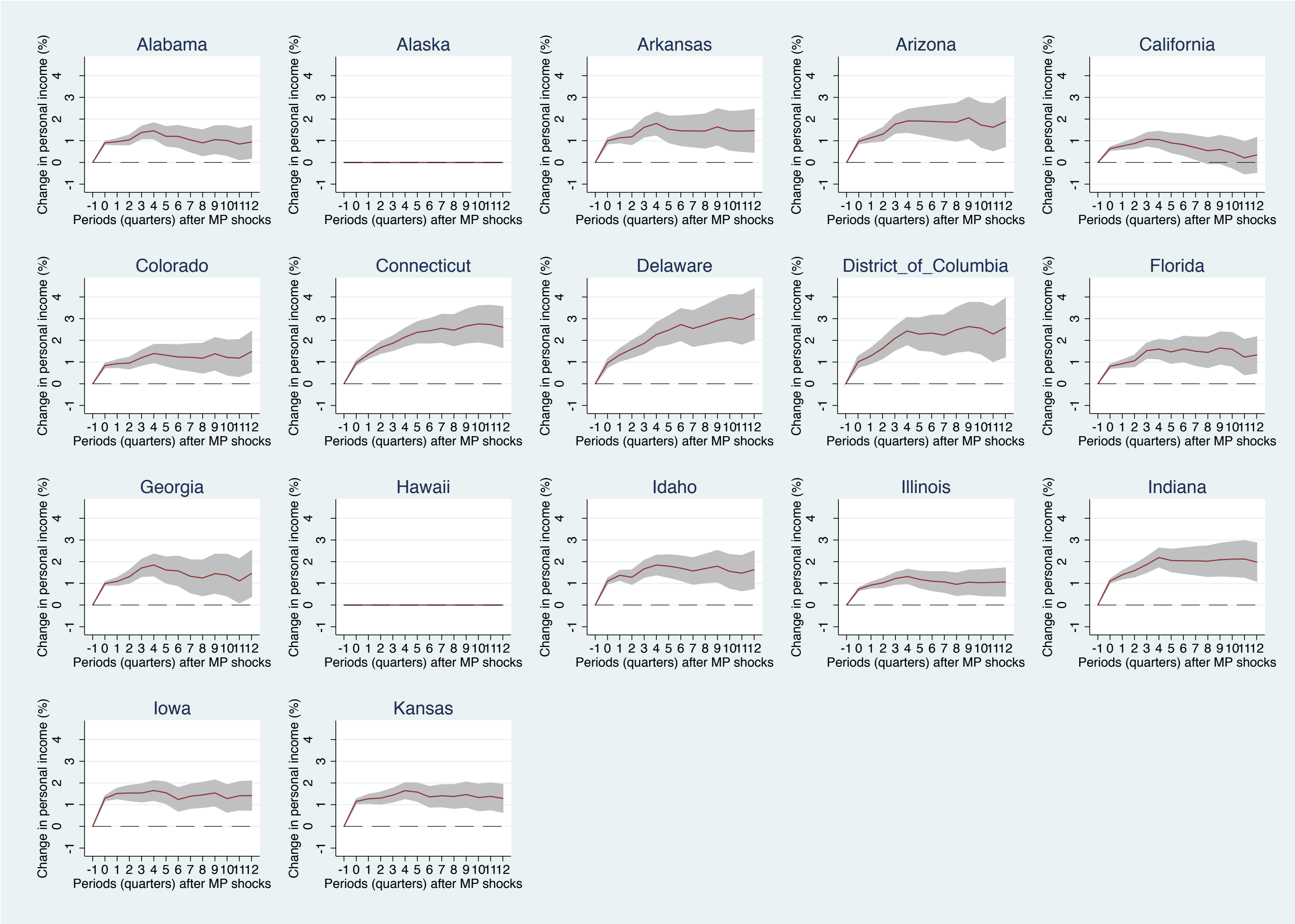
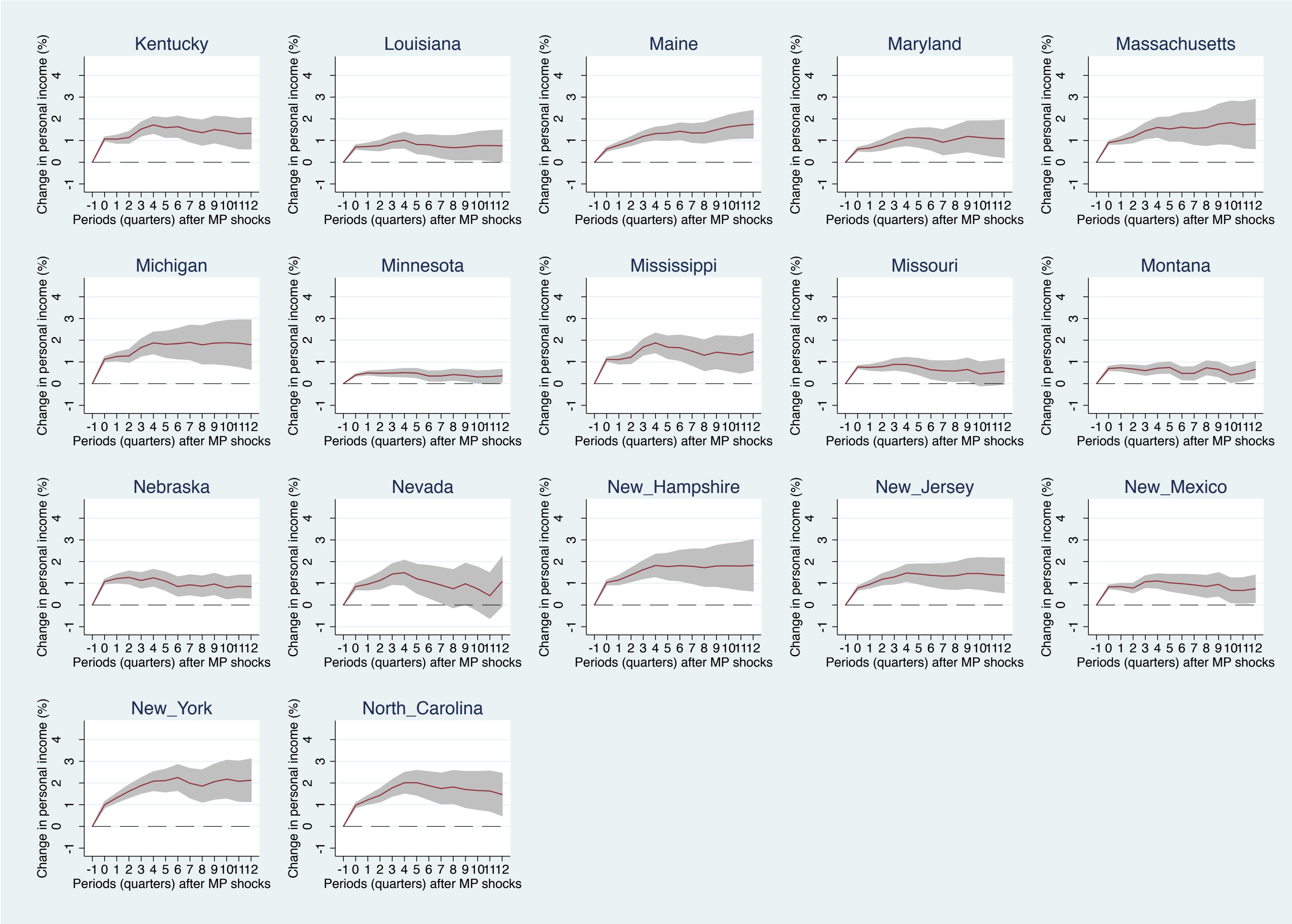
Massachusetts
Michigan
Minnesota
Mississippi
Missouri
Montana
Nebraska
Nevada
New_Hampshire
New_Jersey
New_Mexico
New_York
North_Carolina
Change in personal income (%)
Periods (quarters) after shocks
R&R MP shocks
Tax shocks
Government spending shocks



Note: estimates based on equation (2). In y-axis, the impulse response (β^k coefficient). In the x -axis, quarters after the shock.

Figure 4. Spatial Impulse response functions – R&R shocks




Kentucky
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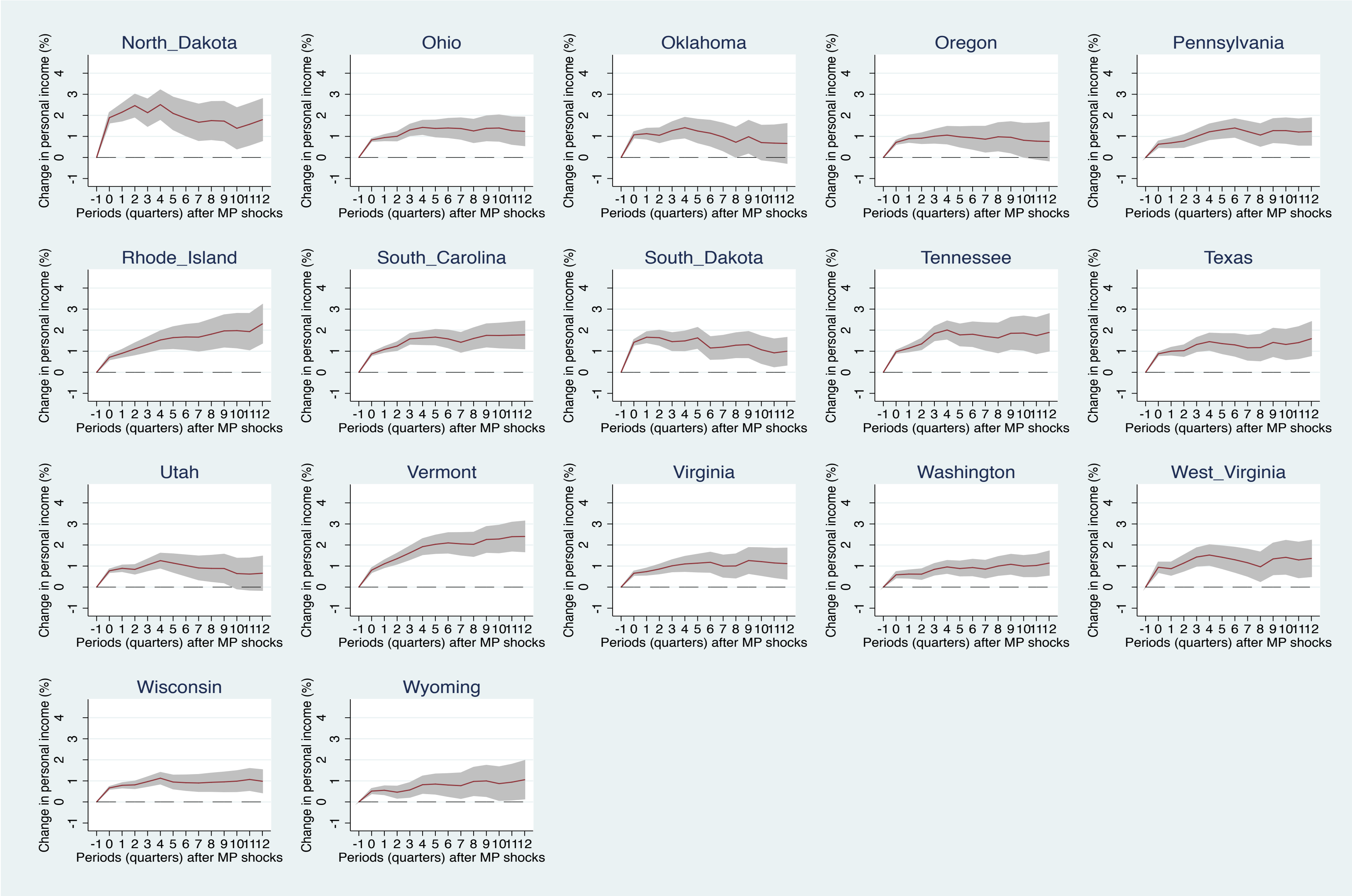
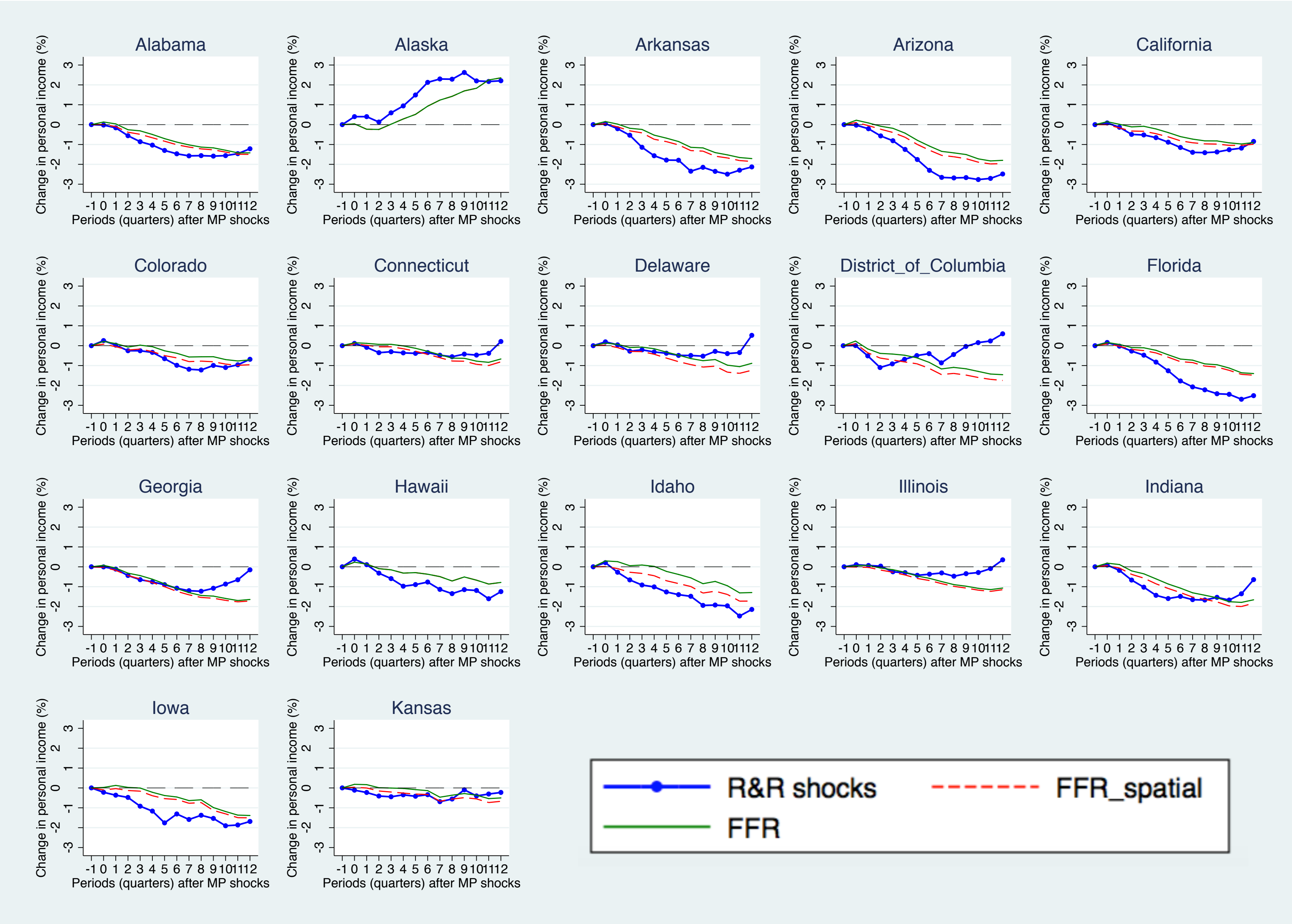
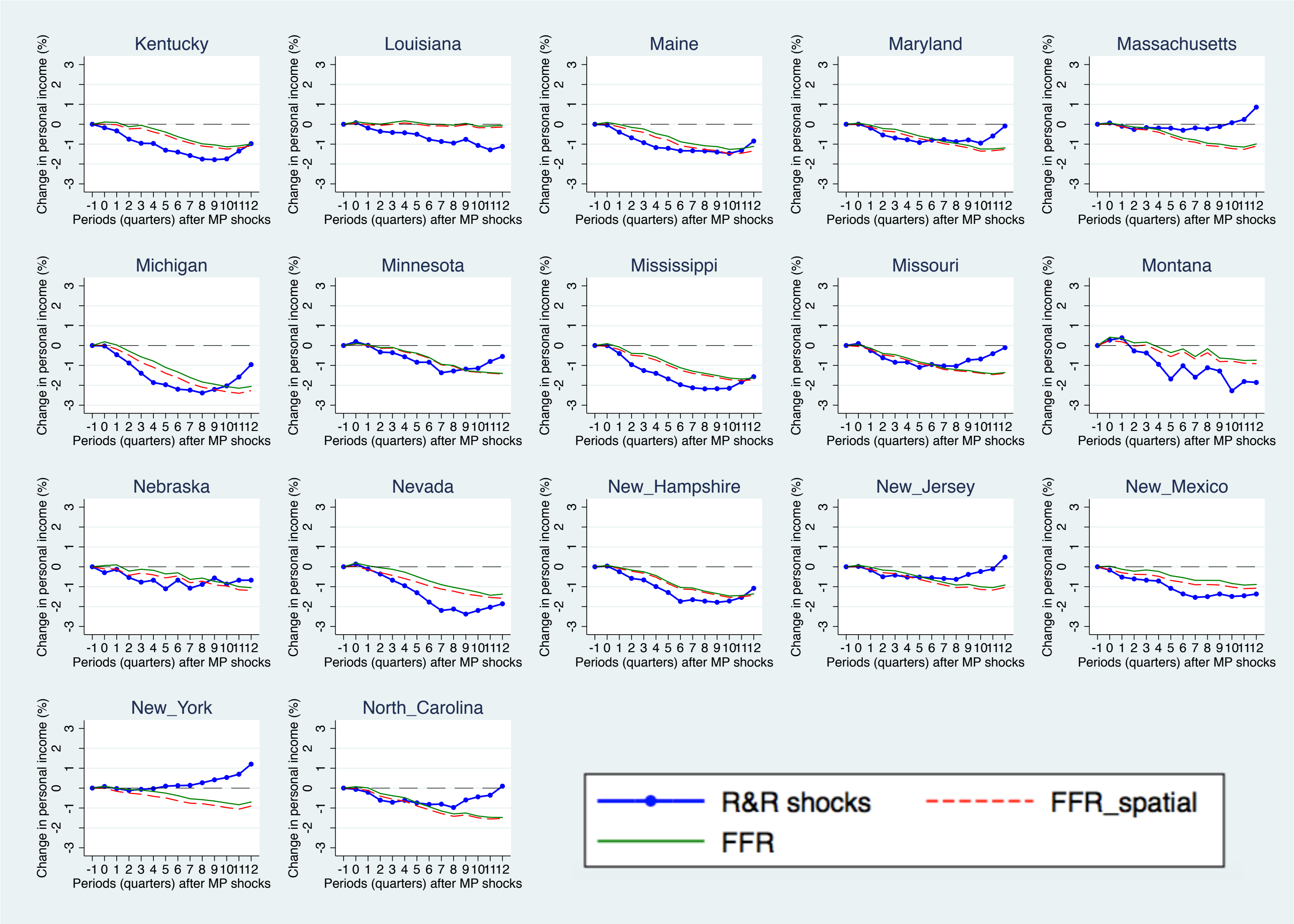
Maryland
Massachusetts
Michigan
Minnesota
Mississippi
Missouri
Montana
Nebraska
Nevada
New_Hampshire
New_Jersey
New_Mexico
New_York
North_Carolina
Change in personal income (%)
-1 0 1 2 3 4
-1 0 1 2 3 4 5 6 7 8 9 10 11 12
Periods (quarters) after MP shocks



Note: estimates based on equation (2). In y-axis, the spatial impulse response (ρ^kcoefficient) and 90 percent confidence bands. In the x -axis, quarters after the shock. Since Hawaii and Alaska are islands we have no spatial IRFs and identical monetary policy shock IRFs.

Figure 5. Impulse response functions of state real personal income to monetary policy shocks – R&R shocks vs. changes in the FFR




Kentucky
Louisiana
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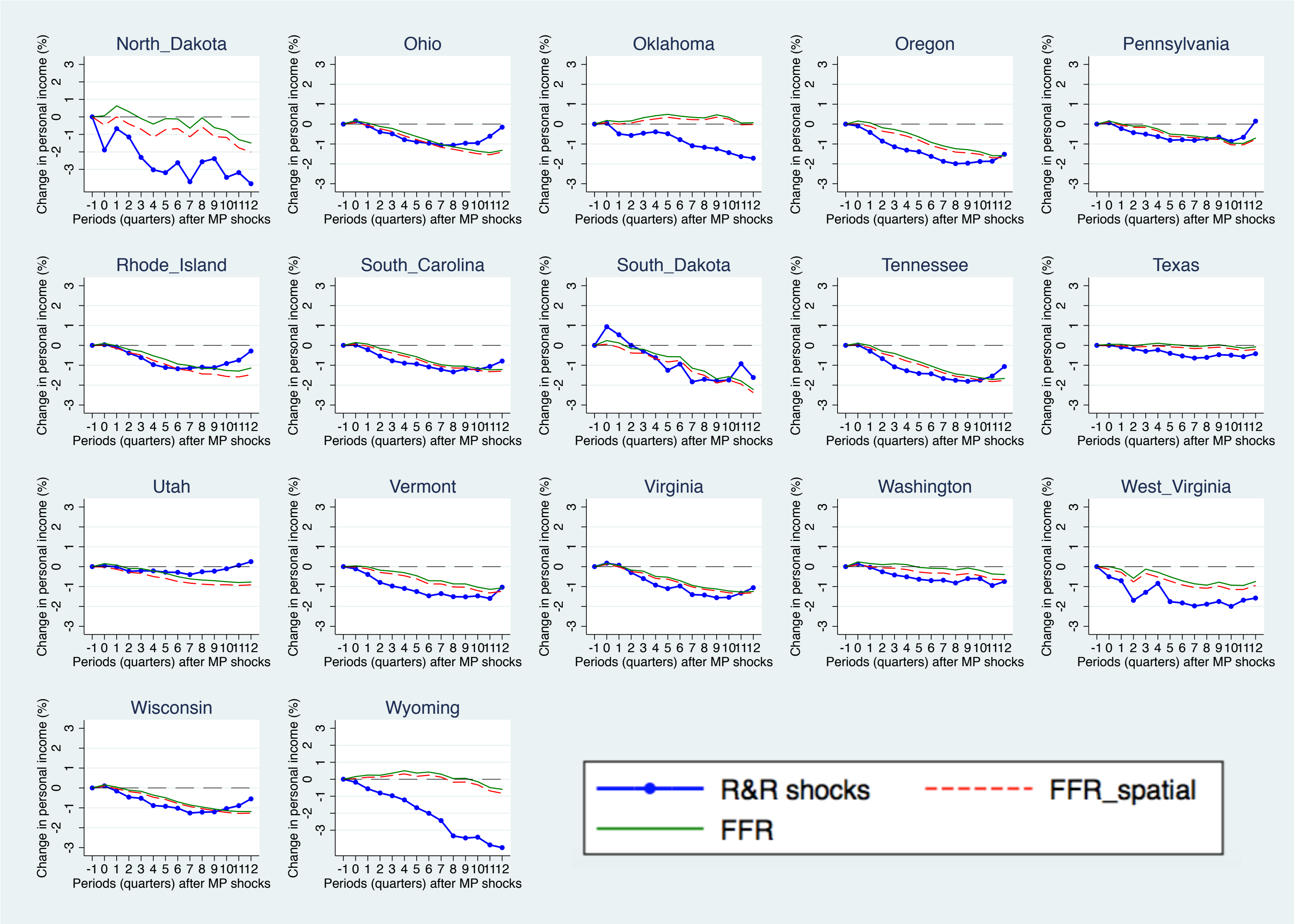
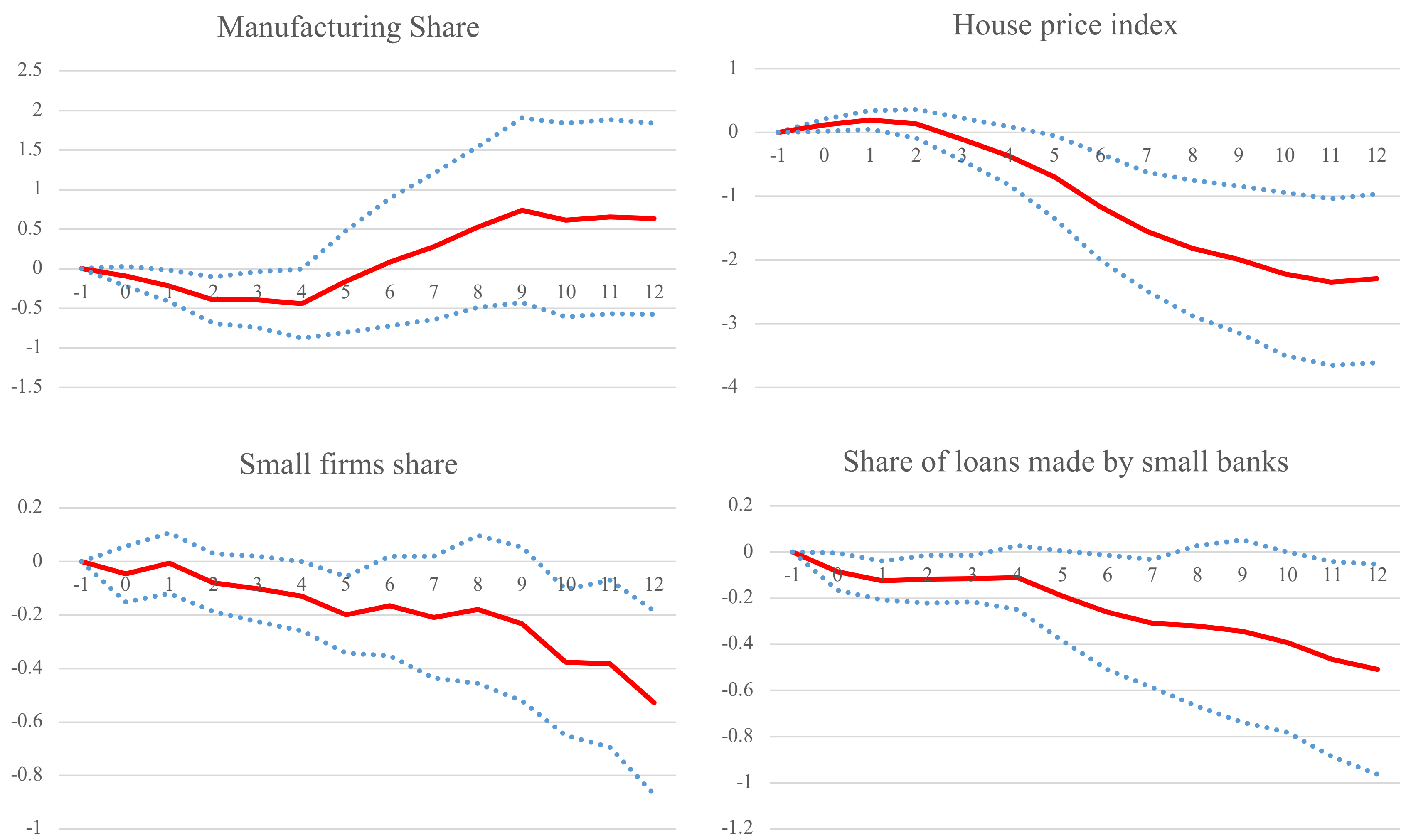
Massachusetts
Michigan
Minnesota
Mississippi
Missouri
Montana
Nebraska
Nevada
New_Hampshire
New_Jersey
New_Mexico
New_York
North_Carolina
Change in personal income (%)
Periods (quarters) after MP shocks
R&R shocks
FFR_spatial
FFR



Note: Line represents point estimates based on equation (2). In y-axis, the impulse response (β^k coefficient). In the x -axis, quarters after the shock.

Figure 6. The differential effect of monetary policy shocks



Note: estimates based on equation (3). Solid line denotes the differential effect (in %) of monetary policy shocks on personal income between states with high levels of the variable of interest (at the 75th percentile of the distribution) and states with low levels of the variable of interest (at the 25th percentile of the distribution). Dotted lines indicate 90 percent confidence interval based on standard errors clustered at state level. The x-axis denotes time (quarters).

TABLES

Table 1. Eight-quarter cumulative response of personal income to monetary policy shocks.

States	With spatial effects (%)	Without spatial effects (%)	States	With spatial effects (%)	Without spatial effects (%)
Wyoming	-3.34	-2.89	Georgia	-1.23	-1.12
Arizona	-2.68	-2.28	Colorado	-1.22	-1.02
North Dakota	-2.57	-1.65	Wisconsin	-1.22	-0.92
Michigan	-2.39	-1.82	Oklahoma	-1.17	-1.04
Florida	-2.22	-2.05	Montana	-1.12	-0.90
Mississippi	-2.18	-2.00	Rhode Island	-1.10	-0.32
Arkansas	-2.15	-1.81	Ohio	-1.06	-0.91
Nevada	-2.12	-1.90	Missouri	-1.03	-0.93
Oregon	-1.99	-1.68	North Carolina	-0.98	-0.83
Idaho	-1.94	-1.48	Louisiana	-0.95	-0.82
West Virginia	-1.89	-1.77	Nebraska	-0.89	-0.57
Kentucky	-1.75	-1.53	Maryland	-0.88	-0.73
Tennessee	-1.75	-1.53	Washington	-0.82	-0.47
New Hampshire	-1.73	-1.44	Pennsylvania	-0.74	-0.59
South Dakota	-1.71	-1.62	New Jersey	-0.63	-0.30
Indiana	-1.67	-1.29	Texas	-0.61	-0.43
Alabama	-1.56	-1.38	Connecticut	-0.56	0.00
Vermont	-1.51	-0.97	Kansas	-0.56	-0.26
New Mexico	-1.50	-1.26	Delaware	-0.53	-0.02
Virginia	-1.43	-1.36	Illinois	-0.47	-0.26
California	-1.41	-1.29	District of Columbia	-0.44	-0.01
Iowa	-1.38	-0.85	Utah	-0.26	-0.03
Hawaii	-1.35	-1.35	Massachusetts	-0.22	0.11
Maine	-1.35	-1.03	New York	0.27	0.62
South Carolina	-1.33	-1.27	Alaska	2.29	2.29
Minnesota	-1.28	-1.19			

Note: Estimates based on equation (2).

Table 2. Response of personal income to monetary and fiscal policy shocks (%)

Periods after the shock	MP shocks	Tax shocks	Government spending shocks
0	0.02	-0.08	-0.01
1	-0.18	-0.10	-0.12
2	-0.51	0.13	-0.04
3	-0.67	-0.49	-0.03
4	-0.81	0.00	0.01
5	-1.01	-0.04	0.10
6	-1.06	-0.24	0.11
7	-1.26	-0.48	0.13
8	-1.26	-0.25	0.12
9	-1.18	-0.29	0.00
10	-1.24	-0.86	-0.07
11	-1.12	-0.70	0.06
12	-0.83	-0.49	0.10

Note: Estimates based on equation (2). Results display the average cumulative response of personal income to monetary and fiscal policy shocks and are expressed in percent.

Table 3. Response of personal income to alternative monetary policy shocks (%) – The role of spatial effects

Periods after the shock	Average cumulative response (%)			
	MP shocks – Baseline (with spatial effects)	MP shocks – (without spatial effects)	Changes in FRR (without spatial effects)	Changes in FRR (with spatial effects)
0	0.02	0.19	0.13	0.02
1	-0.18	0.03	0.05	-0.09
2	-0.51	-0.27	-0.13	-0.27
3	-0.67	-0.37	-0.15	-0.32
4	-0.81	-0.48	-0.28	-0.47
5	-1.01	-0.70	-0.43	-0.62
6	-1.06	-0.77	-0.57	-0.75
7	-1.26	-0.98	-0.75	-0.91
8	-1.26	-0.98	-0.82	-0.98
9	-1.18	-0.88	-0.87	-1.04
10	-1.24	-0.95	-1.00	-1.15
11	-1.12	-0.83	-1.09	-1.24
12	-0.83	-0.54	-1.05	-1.20

Note: Estimates based on equation (2). Results display the average cumulative response of personal income to changes in FRR or to monetary policy shocks and are expressed in percent.

Table 4. Cumulative response of personal income to monetary policy shocks - Different spatial weight matrices.

Periods after the MP shock	Baseline (Contiguity - queen)	Contiguity-rook	knn=1	knn=2	knn=3	knn=4	knn=5	knn=6	knn=7	knn=8	knn=9	knn=10
0	0.02	0.02	0.06	0.04	0.02	0.02	0.03	0.03	0.02	0.02	0.01	0.02
1	-0.18	-0.18	-0.13	-0.15	-0.17	-0.17	-0.17	-0.17	-0.17	-0.17	-0.18	-0.18
2	-0.51	-0.51	-0.45	-0.48	-0.50	-0.50	-0.50	-0.49	-0.50	-0.50	-0.51	-0.51
3	-0.67	-0.67	-0.59	-0.63	-0.66	-0.66	-0.66	-0.65	-0.65	-0.66	-0.67	-0.67
4	-0.81	-0.81	-0.73	-0.77	-0.80	-0.81	-0.81	-0.80	-0.80	-0.81	-0.83	-0.82
5	-1.01	-1.01	-0.93	-0.97	-1.00	-1.01	-1.00	-1.00	-1.00	-1.01	-1.02	-1.02
6	-1.06	-1.06	-0.99	-1.02	-1.05	-1.06	-1.05	-1.04	-1.04	-1.05	-1.06	-1.06
7	-1.26	-1.26	-1.20	-1.23	-1.25	-1.26	-1.25	-1.24	-1.24	-1.25	-1.26	-1.25
8	-1.26	-1.26	-1.20	-1.23	-1.25	-1.27	-1.26	-1.25	-1.24	-1.25	-1.26	-1.26
9	-1.18	-1.18	-1.11	-1.14	-1.17	-1.18	-1.17	-1.17	-1.16	-1.17	-1.18	-1.18
10	-1.24	-1.24	-1.17	-1.21	-1.23	-1.24	-1.23	-1.23	-1.22	-1.23	-1.24	-1.23
11	-1.12	-1.12	-1.06	-1.09	-1.11	-1.12	-1.11	-1.11	-1.10	-1.11	-1.12	-1.11
12	-0.83	-0.83	-0.76	-0.79	-0.82	-0.83	-0.82	-0.82	-0.81	-0.81	-0.82	-0.82

Note: Estimates based on equation (2). Results display the average cumulative response of personal income to monetary policy shocks and are expressed in percent.

Table 5. Descriptive statistics

state	Manufacturing durable goods share (%)	House Price Index	Small firms share (%)	Loans made by state's small banks (%)
Alabama	8.3	169.1	70.9	73.3
Alaska	0.4	151.0	75.6	2.9
Arizona	7.0	172.8	70.3	61.6
Arkansas	9.6	150.3	68.6	51.4
California	5.5	234.9	71.1	23.8
Colorado	4.0	186.1	74.5	46.0
Connecticut	7.9	232.4	69.9	29.4
Delaware	2.2	228.7	66.9	17.0
District of Columbia	0.1	221.3	63.7	100.0
Florida	3.1	188.5	66.9	59.2
Georgia	4.9	180.2	70.0	58.1
Hawaii	0.5	220.0	73.5	10.7
Idaho	5.6	160.3	73.9	48.8
Illinois	7.3	190.1	68.9	46.3
Indiana	15.3	156.9	69.7	44.0
Iowa	10.4	144.3	71.0	75.8
Kansas	9.9	142.6	74.1	65.2
Kentucky	10.5	166.9	72.0	60.9
Louisiana	3.5	133.5	73.6	64.5
Maine	4.8	241.4	77.6	35.6
Maryland	2.4	217.4	74.4	43.7
Massachusetts	6.3	321.9	67.8	39.5
Michigan	14.9	175.4	70.9	22.8
Minnesota	7.5	178.6	69.4	65.7
Mississippi	8.7	147.7	70.3	35.2
Missouri	7.0	166.6	70.1	43.0
Montana	2.4	169.3	86.6	51.5
Nebraska	5.4	152.2	70.1	60.8
Nevada	2.4	173.2	62.0	17.5
New Hampshire	8.4	219.1	75.6	85.0
New Jersey	3.0	247.0	69.3	25.1
New Mexico	4.7	165.8	79.1	48.8
New York	2.9	289.5	66.0	18.9
North Carolina	7.0	180.8	71.3	28.8
North Dakota	5.4	136.2	80.4	43.0
Ohio	12.3	162.7	70.9	47.3
Oklahoma	7.0	124.4	74.7	63.0
Oregon	10.9	186.6	76.7	14.2
Pennsylvania	7.1	198.3	69.7	28.8
Rhode Island	6.7	256.0	73.7	0.3
South Carolina	9.3	181.4	71.7	47.1
South Dakota	7.1	156.2	78.8	9.7
Tennessee	9.3	167.2	69.0	60.0
Texas	5.8	136.9	69.5	48.5
Utah	6.7	174.6	69.1	8.2
Vermont	7.6	216.4	76.4	75.7
Virginia	4.0	203.9	71.7	41.0
Washington	9.8	205.8	75.3	26.4
West Virginia	5.3	128.6	77.5	37.7
Wisconsin	12.0	171.3	71.2	58.9
Wyoming	1.2	129.7	85.4	84.3

Note: For small firms share and loans made by state's small banks values refer to 2005 and 2008, respectively. For manufacturing durable goods share and house price index, values refer to the average of the periods 1997-2008 and 1975-2008, respectively.

Table 6. Industry-mix – R&R shocks

	K=0	K=1	K=2	K=3	K=4	K=5	K=6	K=7	K=8	K=9	K=10	K=11	K=12
MP_RR*man_share	-2.053	-4.743*	-8.648**	-8.552*	-9.600	-3.525	1.825	6.130	11.50	16.11	13.41	14.31	13.80
	(1.669)	(2.625)	(3.906)	(4.688)	(5.777)	(8.524)	(10.71)	(12.23)	(13.41)	(15.45)	(16.20)	(16.25)	(15.99)
$\mathbf{D}y_{t,t-1}$	-0.041	0.064	0.126*	0.204**	0.201*	0.195*	0.190	0.207*	0.181	0.168	0.118	0.066	0.045
	(0.048)	(0.057)	(0.074)	(0.098)	(0.104)	(0.112)	(0.117)	(0.119)	(0.133)	(0.142)	(0.134)	(0.140)	(0.163)
$\mathbf{D}y_{t,t-2}$	0.085***	0.148***	0.236***	0.253***	0.243***	0.252***	0.278***	0.264**	0.267**	0.219*	0.172	0.162	0.0496
	(0.022)	(0.036)	(0.061)	(0.074)	(0.090)	(0.092)	(0.092)	(0.104)	(0.111)	(0.111)	(0.115)	(0.130)	(0.156)
$W\Delta$y	0.534***	0.540***	0.671***	0.783***	0.950***	0.873***	0.812***	0.754***	0.687***	0.798***	0.724***	0.688***	0.730***
	(0.077)	(0.081)	(0.102)	(0.128)	(0.135)	(0.130)	(0.125)	(0.136)	(0.158)	(0.171)	(0.187)	(0.213)	(0.227)
Observations	2,448	2,397	2,346	2,295	2,244	2,193	2,142	2,091	2,040	1,989	1,938	1,887	1,836
R-squared	0.541	0.529	0.500	0.506	0.521	0.517	0.514	0.503	0.509	0.532	0.541	0.556	0.572
Differential effect (%)	-0.09	-0.22	-0.40	-0.39	-0.44	-0.16	0.08	0.28	0.53	0.74	0.62	0.66	0.63

Note: Estimates based on equation (3). Robust-clustered standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. Differential effects are computed as following: (beta coefficient)*($Z^{75th\ percentile}$ - $Z^{25th\ percentile}$).

Table 7. Housing market channel – R&R shocks

	K=0	K=1	K=2	K=3	K=4	K=5	K=6	K=7	K=8	K=9	K=10	K=11	K=12
MP_RR*HPI_AT	0.213*	0.359**	0.250	-0.196	-0.667	-1.282*	-2.143**	-2.851***	-3.328***	-3.658***	-4.075***	-4.305***	-4.201***
	(0.107)	(0.164)	(0.250)	(0.375)	(0.509)	(0.727)	(0.929)	(1.036)	(1.183)	(1.284)	(1.424)	(1.457)	(1.476)
$\mathbf{D}y_{t,t-1}$	-0.0298	0.0265	0.0456	0.121	0.101	0.108	0.141	0.198	0.176	0.155	0.139	0.209	0.224
	(0.0371)	(0.0652)	(0.107)	(0.122)	(0.157)	(0.174)	(0.189)	(0.194)	(0.212)	(0.220)	(0.244)	(0.211)	(0.201)
$\mathbf{D}y_{t,t-2}$	0.0461	0.0617	0.139	0.137	0.155	0.194	0.260*	0.243	0.231	0.212	0.277	0.276	0.263*
	(0.0325)	(0.0712)	(0.0905)	(0.119)	(0.135)	(0.150)	(0.151)	(0.166)	(0.169)	(0.195)	(0.166)	(0.169)	(0.157)
$W\Delta$y	0.683***	0.763***	0.849***	0.905***	1.022***	1.065***	0.998***	1.062***	1.175***	1.183***	1.130***	1.231***	1.407***
	(0.115)	(0.125)	(0.134)	(0.141)	(0.160)	(0.142)	(0.137)	(0.141)	(0.147)	(0.170)	(0.181)	(0.191)	(0.203)
Observations	6,934	6,883	6,832	6,781	6,730	6,679	6,628	6,577	6,526	6,475	6,424	6,373	6,322
R-squared	0.459	0.465	0.460	0.471	0.485	0.495	0.497	0.499	0.503	0.510	0.512	0.517	0.520
Differential effect (%)	0.12	0.20	0.14	-0.11	-0.36	-0.70	-1.17	-1.55	-1.81	-1.99	-2.22	-2.35	-2.29

Note: Estimates based on equation (3). Robust-clustered standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. Differential effects are computed as following: (beta coefficient)*($Z^{75th\ percentile}$ - $Z^{25th\ percentile}$).

Table 8. Broad credit channel – R&R shocks

	K=0	K=1	K=2	K=3	K=4	K=5	K=6	K=7	K=8	K=9	K=10	K=11	K=12
MP_RR*small_firms	-0.942	-0.141	-1.582	-2.051	-2.605	-3.993**	-3.331	-4.170	-3.581	-4.685	-7.547**	-7.661**	-10.57**
	(1.265)	(1.383)	(1.313)	(1.488)	(1.569)	(1.736)	(2.256)	(2.784)	(3.362)	(3.494)	(3.334)	(3.801)	(4.180)
D$y_{t,t-1}$	-0.0182	0.0397	0.0343	0.0800	0.0763	0.0850	0.122	0.197	0.208	0.180	0.158	0.203	0.162
	(0.0319)	(0.0562)	(0.101)	(0.118)	(0.144)	(0.164)	(0.184)	(0.180)	(0.184)	(0.187)	(0.205)	(0.182)	(0.200)
D$y_{t,t-2}$	0.0431*	0.0396	0.0835	0.0848	0.0939	0.129	0.208	0.222	0.195	0.170	0.212	0.181	0.126
	(0.0250)	(0.0670)	(0.0865)	(0.111)	(0.133)	(0.153)	(0.149)	(0.152)	(0.153)	(0.174)	(0.154)	(0.168)	(0.179)
$W\Delta$y	0.717***	0.818***	0.917***	0.931***	1.026***	1.043***	0.992***	1.050***	1.161***	1.207***	1.147***	1.175***	1.277***
	(0.141)	(0.162)	(0.180)	(0.164)	(0.193)	(0.166)	(0.168)	(0.164)	(0.165)	(0.186)	(0.187)	(0.201)	(0.217)
Observations	8,007	7,956	7,905	7,854	7,803	7,752	7,701	7,650	7,599	7,548	7,497	7,446	7,395
R-squared	0.473	0.477	0.477	0.490	0.508	0.516	0.516	0.516	0.514	0.512	0.506	0.503	0.500
Differential effect (%)	-0.05	-0.01	-0.08	-0.10	-0.13	-0.20	-0.17	-0.21	-0.18	-0.23	-0.38	-0.38	-0.53

Note: Estimates based on equation (3). Robust-clustered standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. Differential effects are computed as following: (beta coefficient)*($Z^{75th\ percentile}$ - $Z^{25th\ percentile}$).

Table 9. Bank lending channel – R&R shocks

	K=0	K=1	K=2	K=3	K=4	K=5	K=6	K=7	K=8	K=9	K=10	K=11	K=12
MP_RR*loan_sm_banks	-0.260*	-0.377**	-0.362*	-0.352*	-0.339	-0.580	-0.795*	-0.943*	-0.979	-1.045	-1.191	-1.416*	-1.549*
	(0.150)	(0.156)	(0.192)	(0.189)	(0.255)	(0.362)	(0.459)	(0.514)	(0.644)	(0.732)	(0.724)	(0.783)	(0.843)
D$y_{t,t-1}$	-0.0177	0.0401	0.0350	0.0806	0.0770	0.0860	0.123	0.199	0.209	0.182	0.160	0.206	0.165
	(0.0322)	(0.0567)	(0.101)	(0.119)	(0.145)	(0.165)	(0.185)	(0.182)	(0.186)	(0.189)	(0.207)	(0.185)	(0.203)
D$y_{t,t-2}$	0.0435*	0.0394	0.0844	0.0860	0.0955	0.131	0.210	0.224	0.197	0.173	0.217	0.186	0.132
	(0.0250)	(0.0672)	(0.0866)	(0.110)	(0.133)	(0.152)	(0.148)	(0.151)	(0.153)	(0.174)	(0.153)	(0.168)	(0.178)
$W\Delta$y	0.717***	0.818***	0.917***	0.930***	1.025***	1.040***	0.990***	1.048***	1.160***	1.204***	1.143***	1.171***	1.271***
	(0.140)	(0.162)	(0.180)	(0.163)	(0.192)	(0.165)	(0.167)	(0.163)	(0.164)	(0.185)	(0.185)	(0.199)	(0.214)
Observations	8,007	7,956	7,905	7,854	7,803	7,752	7,701	7,650	7,599	7,548	7,497	7,446	7,395
R-squared	0.473	0.478	0.477	0.490	0.508	0.515	0.516	0.516	0.515	0.512	0.506	0.503	0.499
Differential effect (%)	-0.09	-0.12	-0.12	-0.12	-0.11	-0.19	-0.26	-0.31	-0.32	-0.34	-0.39	-0.46	-0.51

Note: Estimates based on equation (3). Robust-clustered standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. Differential effects are computed as following: (beta coefficient)*($Z^{75th\ percentile}$ - $Z^{25th\ percentile}$.

APPENDIX

Table A1. Data sources and time coverage of transmission channels

Transmission channel	Variable	Source	Time coverage
Industry mix	% of GSP accounted for by manufacturing durable goods	Bureau of Economic Analysis (BEA)	1997-2008
Broad credit channel	Employment accounted for by a state's small firms (<250 employees)	Bureau of Labor Statistics (BLS)	2005
Narrow credit channel	% of loans made by state's small banks	Federal Financial Institutions Examination Council (FFIEC)	2008
Housing market channel	HPI -All-Transactions Index	Federal Housing Finance Agency (FHFA)	1975-2008

Table A2. Robustness check excluding Islands and D.C. (For each channel Alaska, D.C., and Hawaii are excluded from the estimation)

	K=0	K=1	K=2	K=3	K=4	K=5	K=6	K=7	K=8	K=9	K=10	K=11	K=12
MP_RR*man_share	-3.554**	-8.033***	-13.92***	-15.25***	-15.91***	-9.409	-1.105	5.828	11.85	19.03	15.54	14.66	13.78
	(1.491)	(2.364)	(3.391)	(3.992)	(5.845)	(9.809)	(13.07)	(15.18)	(16.72)	(19.12)	(19.94)	(19.92)	(19.69)
MP_RR*HPI_AT	0.291**	0.452**	0.339	-0.0792	-0.527	-1.148	-2.050**	-2.793**	-3.322**	-3.646**	-3.935**	-4.084***	-3.848**
	(0.112)	(0.184)	(0.267)	(0.387)	(0.519)	(0.752)	(0.972)	(1.092)	(1.256)	(1.363)	(1.483)	(1.491)	(1.468)
MP_RR*small_firms	-1.098	-0.656	-2.381*	-2.682*	-3.034*	-4.423**	-3.896*	-5.061*	-4.035	-5.032	-7.845**	-7.990**	-11.02**
	(1.350)	(1.439)	(1.250)	(1.503)	(1.585)	(1.724)	(2.264)	(2.824)	(3.463)	(3.547)	(3.382)	(3.931)	(4.387)
MP_RR*loan_sm_banks	-0.277	-0.318	-0.295	-0.331	-0.393	-0.624*	-0.740*	-0.829*	-1.005*	-1.109*	-1.440**	-1.771**	-2.001**
	(0.179)	(0.197)	(0.219)	(0.235)	(0.284)	(0.328)	(0.387)	(0.445)	(0.564)	(0.624)	(0.600)	(0.669)	(0.764)

Note: Estimates based on equation (3). Only coefficients for impulse response functions are showed. Robust-clustered standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

Table A3. Robustness check to outliers.

	K=0	K=1	K=2	K=3	K=4	K=5	K=6	K=7	K=8	K=9	K=10	K=11	K=12
MP_RR*man_share	-2.053	-4.743*	-8.648**	-8.552*	-9.600	-3.525	1.825	6.130	11.50	16.11	13.41	14.31	13.80
	(1.669)	(2.625)	(3.906)	(4.688)	(5.777)	(8.524)	(10.71)	(12.23)	(13.41)	(15.45)	(16.20)	(16.25)	(15.99)
MP_RR*HPI_AT	0.236*	0.394*	0.250	-0.277	-0.868	-1.671*	-2.682**	-3.451***	-4.012***	-4.368***	-4.886***	-5.163***	-5.071***
	(0.128)	(0.199)	(0.307)	(0.457)	(0.607)	(0.838)	(1.048)	(1.168)	(1.327)	(1.455)	(1.608)	(1.626)	(1.650)
MP_RR*small_firms	-1.468	-0.238	-1.636	-2.557	-2.553	-3.511	-2.954	-3.411	-2.449	-2.735	-5.176	-4.802	-8.077*
	(1.690)	(1.287)	(1.503)	(1.573)	(2.029)	(2.338)	(2.871)	(3.672)	(3.054)	(3.634)	(4.053)	(4.093)	(4.627)
MP_RR*loan_sm_banks	-0.260*	-0.377**	-0.362*	-0.352*	-0.339	-0.580	-0.795*	-0.943*	-0.979	-1.045	-1.191	-1.416*	-1.549*
	(0.150)	(0.156)	(0.192)	(0.189)	(0.255)	(0.362)	(0.459)	(0.514)	(0.644)	(0.732)	(0.724)	(0.783)	(0.843)

Note: Estimates based on equation (3). Only coefficients for impulse response functions are showed. Robust-clustered standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1.