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Is the United States an optimum currency area? An empirical analysis of regional business cycles

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Abstract
This paper develops a statistical model to study the business cycles of the eight U.S. BEA regions. By combining unobserved component and VAR techniques I identify not only common and idiosyncratic sources of innovation, but also common and idiosyncratic responses to common shocks. Using this model, I show, at the usual levels of statistical significance, that U.S. regions deviate significantly from Mundell's notion of an *optimum currency area*. I identify five *core* regions that have similar sources of disturbances and responses to disturbances (New England, Mideast, Great Lakes, Rocky Mountains and Far West) and three *non-core* regions that differ significantly from the core in their sources of disturbances and/or responses to disturbances (Southeast, Plains and Southwest), at business cycle frequencies.

JEL Classification: E32; E52; R11.

Key Words: VAR; Unobserved Components; Monetary Union;.

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1 Introduction

There was a great deal of doubt over the long-run viability of the U.S. Federal Reserve System in 1913, largely because it followed two previously unsuccessful attempts at establishing a U.S. central bank.[1] Similarly, there is widespread skepticism today surrounding the long-run viability of the EMU. Although, the debate over the viability of the EMU is more focused than the earlier FRS debate. This is due in large part to seminal work on currency areas by Mundell (1961). Mundell argued that the survival of a currency union depends on how close it comes to the notion of an optimum currency area (OCA). According to this theory, if a monetary union is not an OCA, then some of its members will incur macroeconomic costs (persistent high unemployment and low output) that will outweigh the microeconomic benefits of a single currency (lower transaction and hedging costs), forcing them to abandon the union. Many commentators argue that common monetary policy actions will be damaging to some member countries because the EMU is a long way from an OCA.[2]

Since Mundell's work, economists have basically agreed that four criteria must be met for a group of regions/countries to constitute an optimal currency area: (i) regions should be exposed to similar sources of economic disturbance (common shocks); (ii) the relative importance of these shocks across regions should be similar (symmetric shocks); (iii) regions should have similar responses to common shocks (common responses); and (iv) if regions are subject to region-specific economic disturbances (idiosyncratic shocks), they need to be capable of quick adjustment. The basic idea is that regions satisfying (i)-(iv) will have similar business cycles, so a common monetary policy response would be optimal.

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[1] The First Bank of the United States was disbanded in 1811, and the national charter of the Second Bank of the United States expired in 1836 after its renewal was vetoed four years earlier by President Andrew Jackson.

[2] See, for example, "Euro brief: The merits of one money" The Economist, October 28, 1998, pp. 85-86.

How far the EMU is from an OCA is an open question for research. At first glance, the data seem to support the skeptics' view that the EMU is not an OCA. First, EMU countries have experienced frequent and often large idiosyncratic shocks over recent years. A well-known example is German reunification. Second, persistent high unemployment rates throughout Europe suggest that EMU economies are slow to adjust to all economic disturbances.

These observations have spawned a small, but growing body of formal empirical research that assesses the long-run viability of potential European currency unions. These papers typically approach the issue of whether a region will be a viable monetary union by comparing the region with a well-functioning monetary union (the U.S.) along OCA criteria.[3] The basic idea is that if the monetary union is as close as the U.S. is to an OCA, then there can be no presumption that the monetary union will not be viable in the long run. Alternatively, if the monetary union is less like an OCA than the U.S., then there is some doubt about the long-run viability of the monetary union. Implicit in this hypothesis is the critical joint assumption that satisfying OCA criteria is sufficient for a monetary union to be viable and that the U.S. is an OCA. This paper examines the usefulness of this research to the EMU debate by formally investigating whether the U.S. is an OCA.

I do so, by estimating a quarterly structural vector autoregression (VAR) that allows me to examine whether the eight U.S. Bureau of Economic Analysis (BEA) regions satisfy (i)-(iv). The VAR includes the growth rates of real personal income in the BEA regions, the relative price of oil, and a monetary policy variable (federal funds rate). The estimation period is 1969:Q1 to 2002:Q1. Model based forecast error decompositions suggest that U.S. regions are largely subject to common sources of innovation. The relative importance of common shocks differs somewhat across regions. However, the main influence on regional activity appears to be a common shock

[3] See for example Eichengreen (1992), Eichengreen and Bayoumi (1993), and Kouparitsas (1999).

to income that is not explained by shocks to the relative price of oil or monetary policy. Impulse responses functions estimated from the VAR suggest that, with the exception of the Plain and Southwest regions, U.S. regions have similar responses to common shocks. Variance decompositions suggest that there is a great deal of variation in the share of income fluctuations explained by region specific shocks. While, the model's impulse response functions suggests that regions adjust quickly to region specific disturbances, with most of the adjustment to these shocks occurring in the first year after the shock.

The remainder of the paper is organized as follows. Section 2 introduces the data by way of the second-moment properties of the business cycle components of U.S. regional income. Section 3 describes in detail the structural VAR and estimation strategy. The empirical findings of the paper (details of forecast error decompositions, variance decompositions and impulse response functions) are reported in section 4. Section 5 concludes by summarizing the paper's main findings.

2 Business cycle properties of U.S. regional income

A simple and direct way of making a preliminary assessment of whether the U.S. is an OCA is to calculate the correlation between U.S. regional business cycles. A high correlation implies common sources of disturbances and similar responses to disturbances across U.S. regions, while a low correlation indicates differences in the sources of disturbances and/or different responses to disturbances across U.S. regions. Regional cyclical fluctuations are estimated by applying a Baxter and King (1999) business cycle band-pass filter to U.S. Department of Commerce, Bureau of Economic Analysis (BEA) quarterly state personal income from 1969:Q1 to 2001:Q1, deflated by the national consumer price index.[4,5]

Estimates reported in first column of the upper panel of Table 1 indicate a high level of comovement across U.S. regions, with the contemporaneous correlation between regional and aggregate U.S. income ranging from 0.77 for the Southwest to 0.99 for the Southeast. A similar picture emerges for the interregional correlation statistics. Regions that are geographically close tend to have correlation coefficients that are higher than regions that are not geographically close. For example, the correlation of New England and Mideast business cycle fluctuations is 0.94, while the correlation between New England and Southwest business cycle fluctuations is 0.52.

The lower panel of Table 1 reports the correlation coefficients for leads and lags of regional income. The main diagonal describes the persistence of regional fluctuations. Regional cycles are roughly as persistent as the aggregate cycle, with own-lag-correlation coefficients of between 0.92 and 0.95. The remaining cells of this panel do not indicate a strong lead/lag relationship for U.S. regional business cycles at one quarter: there are only a few cases where the lead/lag correlation exceeds the contemporaneous correlation and the differences are not statistically significant. The lead/lag relationship is considerably weaker at longer horizons of two to four quarters.

Overall, these results suggest that U.S. regions have common sources of innovation and common responses to these disturbances. On the basis of these findings the U.S. can not be ruled out as an OCA. An obvious weakness of this simple approach is that it does not allow for a comparison of the sources of disturbances or responses to disturbances across regions.

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[4] Gross state product (GSP) is an alternative measure of regional activity. The main drawback of GSP is that it is collected annually, which makes it less able to pick business cycle turning points with any precision.

[5] The Baxter-King business cycle filter isolates frequencies of the data that occur at 18 months to 8 years. I use this filter in large part because these frequencies are arguably of more interest to policymakers.

3 Empirical method

One way of overcoming the limitations of the simple correlation analysis is to use a structural vector auto regression (VAR). With appropriate parameter restrictions a VAR can identify common and idiosyncratic sources of innovation, and identify the shape of common and idiosyncratic responses to common shock.

3.1 The model

I approach the problem of identifying shocks and responses to shocks by classifying them as either being common or idiosyncratic. Common shocks affect all regions, while idiosyncratic shocks only affect one region. Similarly, a common response is a response to common shock that is the same across regions, while an idiosyncratic response is a response to a common shock that is region specific.

Working toward that end, I assume that the log-first-difference of real regional income in region *i* at time *t*, y_{it} , is the sum of two unobserved components, a common component of regional output x_t and an idiosyncratic (or region specific) component x_{it} . I permit regions to have different sensitivity to the common component governed by a parameter γ_i , so that,

$$y_{it} = \gamma_i x_t + x_{it} , \quad (1)$$

for all $i = 1,...,8$.

In this setting, if U.S. regions had no idiosyncratic component x_{it} , then regional income y_{it} would simply be proportional to the common component x_t , their business cycles would be perfectly correlated and they would easily satisfy the OCA criteria, (i)-(iv).

I follow the literature on regional business cycles by allowing for two other sources of economic disturbance to affect real regional income. In addition to shocks to the common and region-specific income components, regions are affected shocks to monetary policy and energy prices. Following many others, I use the first-difference of the level of the federal funds rate as my explicit indicator of monetary policy. While, energy prices are measured as the log-first difference of the price of oil relative to the CPI.

From here I divide the time series into common and idiosyncratic variables. The common variables include x_t, the monetary policy indicator m_t, and the relative price of energy p_t, while the idiosyncratic components are the x_{it}'s. I identify shocks to the common variables by following the approach of the VAR literature on identifying shocks to U.S macroeconomic variables. I do so by treating the common regional income component in the same way macroeconomic studies treat aggregate U.S. income. My approach is most closely related to Christiano, Eichenbaum and Evans (1994) in their work on identifying and measuring the aggregate effects of U.S. monetary policy shocks.

To be more specific the common components block of the model focuses on the dynamic behavior of a 3×1 vector,

$$Z_t = [p_t, x_t, m_t]'$$

The dynamics of Z_t are represented by a VAR,

$$AZ_t = B(L)Z_{t-1} + e_t \qquad (2)$$

where A is a 3×3 matrix of coefficients describing the contemporaneous correlation among the variables; $B(L)$ is a 3×3 matrix of polynomials in the lag operator L; and $e_t = [\varepsilon_{pt}, \varepsilon_{xt}, \varepsilon_{mt}]$ is a 3×1 vector of orthogonal structural disturbances.

Additional structure must be placed on A to identify the elements of e_t. Following Christiano, et al. I restrict A to be a unique lower triangular matrix with ones along the diagonal.

The implications of that assumption are that: innovations to p_t have a contemporaneous effect on x_t and m_t; innovations to x_t have a contemporaneous effect on m_t and a lagged effect on p_t; and innovations to m_t have a lagged effect on p_t and x_t. The underlying assumption is that in setting policy the U.S. Federal Reserve both reacts to and affects the economy. This is implemented by assuming that the monetary authorities feedback rule can be written as a linear function, Ψ, defined over a vector, Ω_t, of variables observed at or before date *t*, so that monetary policy is completely described by,

$$m_t = \Psi(\Omega_t) + A_{33}\varepsilon_{mt}, \tag{3}$$

where $\Psi(\Omega_t)$ is described by the third row of $B(L)$ and A_{33} is the (3,3) element of the matrix A. I model Ω_t as containing lagged values (date *t*-1 and earlier) of all variables in the common component block, as well as time *t* values of those variables that the monetary authority looks at contemporaneously in setting policy (energy prices and the common income component). In accordance the assumptions of the feedback rule, an exogenous shock to monetary policy ε_{mt} cannot contemporaneously affect time *t* values of the elements of Ω_t. However, lagged values of ε_{mt} can affect variables in Ω_t.

The idiosyncratic block of the model focuses on the dynamic behavior of a 8×1 vector of idiosyncratic components of regional income,

$$X_t = [x_{1t}, x_{2t}, \ldots, x_{8t}]'$$

I assume that the relative price of energy and monetary policy affect the idiosyncratic component of regional income in a similar way in which they affect the common component. In particular, I assume that innovations to p_t have a contemporaneous effect on x_{it}, while innovations to m_t have a lagged effect on x_{it}. In contrast to the common income component, innovations to the idiosyncratic component are assumed to have no effect on oil prices or monetary policy, either contemporaneously or lagged. Underlying this assumption is the idea that aggregate energy prices only respond to aggregate income shocks, while the Federal Reserve only reacts to common income fluctuations. I also assume for parsimony that innovations to x_{it} do not affect x_{jt} for $i \neq j$, either contemporaneously or with a lag.

Under these assumptions the dynamics of region *i*'s idiosyncratic component is explained by,

$$x_{it} = D_i(L)x_{it-1} + E_i(L)W_t + \varepsilon_{it}\,, \qquad (4)$$

for all *i*, where $D_i(L)$ is a scalar polynomial in the lag operator L; $E_i(L)$ is a 1×2 matrix of polynomials in the lag operator L; $W_t = [p_t, m_t]'$; and ε_{it} is an orthogonal structural disturbance (that is, $\varepsilon_{it} \perp \varepsilon_{jt}$ for all $i \neq j$).

Following from this, the dynamics of the idiosyncratic component vector X_t are represented by,

$$X_t = D(L)X_{t-1} + E(L)W_t + v_t \qquad (5)$$

where $D(L) = \begin{bmatrix} D_1(L) & 0 & 0 & 0 \\ 0 & D_2(L) & \cdots & 0 \\ \vdots & \vdots & \ddots & 0 \\ 0 & 0 & 0 & D_8(L) \end{bmatrix}$, $E(L) = \begin{bmatrix} E_1(L) \\ E_2(L) \\ \vdots \\ E_8(L) \end{bmatrix}$, $v_t = \begin{bmatrix} \varepsilon_{1t} \\ \varepsilon_{2t} \\ \vdots \\ \varepsilon_{8t} \end{bmatrix}$ and $e_t \perp v_t$.

With this model in hand, I assess the similarity of U.S. regional business cycles along two dimensions. First, by studying the sources of regional economic disturbances I can determine the extent to which fluctuations are caused by common and region-specific shocks. Common shocks include unanticipated changes to energy prices ε_{pt}, unanticipated shocks to monetary policy variable ε_{mt} and unanticipated shocks to the residual common income shock ε_{xt} that captures innovations to common output not captured by the other common shocks. Idiosyncratic shocks include unanticipated fluctuations in region i's income ε_{it} . The relative importance of the various sources of disturbance is revealed by ratios of the standard deviations of innovations and the model's one-step ahead forecast error decompositions.

Second, by studying the model's impulse response functions, I can assess whether regions have similar responses to common shocks and determine the time it takes a region to adjust to idiosyncratic shocks.

3.2 Previous approaches to modeling regional income fluctuations

The most closely related study is Carlino and Defina (1998), hereafter (CD).[6] They use a structural VAR to estimate the effects of U.S. monetary policy on the eight BEA regions. My approach to identifying shocks and responses to shocks differs from CD in three significant ways. First, they assume that there is no common income component across the eight BEA regions. In their model common shocks to the relative price of energy and monetary policy affect regional output with a one period lag, while the residual shocks to regional incomes are region specific. This is a major shortcoming of their study since my analysis suggests that a large share of the variation regional income across the eight BEA regions is explained by innovations in the common income component.

Second, following their earlier paper Carlino and Defina (1995) they allow region specific income shocks to spillover to other regions. However, the approaches of the two studies are quite different. The earlier paper controls for common shocks by removing a common component from regional income growth equal growth rate of aggregate income. This is similar to my approach, with the main difference being that I allow for the common component to be estimated in the model. The stated objective of allowing for spillovers in the later paper is so that there is an

[6] Carlino and DeFina (1998) provide an extensive literature review of empirical studies of regional business cycles.

aggregate income shock affecting regional income in the model. In other words, this is meant to capture common income fluctuations across regions. CD estimate their model using first differences of the log of regional output. While there is a very strong correlation between current and lagged regional incomes at business cycle frequencies (see Table 1) the correlation coefficients are significantly lower for first-difference data, which means that lagged aggregate regional output fails to capture the contemporaneous comovement of regional income across BEA regions. My model does not allow for spillovers of region specific shocks, since the impulse responses of region specific shocks from other regions were found to be not significantly different from zero.

Finally, CD allow region-specific shocks to affect the monetary policy variable contemporaneously, while my model only allows the common income shock to affect the monetary policy variable contemporaneously. My approach is arguably more appropriate, since it says that central banks do not respond to idiosyncratic shocks, which is the point of the debate surrounding the ECB monetary policy.

Using this approach CD find that unanticipated shocks to U.S. monetary policy have very different effects on the income of the eight BEA regions. They identify a core group of regions including New England, Mideast, Plains, Southeast and Far West and a non-core group including the Great Lakes, Southwest and Rocky Mountains. Regions in the core group have very similar responses to monetary policy shocks, while regions in the non-core have very different responses to monetary policy shocks. Their analysis implies that the U.S. is not an OCA, since it fails to meet the common response criteria due to the very different responses of the non-core regions. One of the drawbacks of their analysis is that they do not provide a formal statistical test of the hypothesis that the responses of regional income incomes to monetary policy vary significantly, so it remains an open question for research to test if regions respond differently to monetary policy shocks.

3.3 Data

I estimate the model using quarterly data from 1969:Q1 to 2001:Q1. Regional income is measured by real personal income across eight BEA regions. Real incomes are calculated by deflating each region's nominal income with the national consumer price index (CPI). The relative price of energy is the International Monetary Fund's U.S. dollar world crude oil price index deflated by the U.S. CPI. Following the wealth of empirical research on identifying monetary policy, I use the federal funds rate as my indicator of monetary policy.

I use maximum likelihood to estimate the model's parameters, so the variables used in the estimation must be stationary. Table 2 reports the results of Augmented Dickey-Fuller unit root tests applied to the log-levels and log-first-differences of real regional income and the relative oil price, and the levels and first-difference of the federal funds rate. The null of a unit root cannot be rejected for any of the log-level data series at the 5 percent level of significance. However, the null of a unit root is rejected for the log-first-difference data at the same level of significance. In light of this, I specify and estimate the model using the log-first-differences of real regional income and the relative oil price, and the first-difference of the federal funds rate. Finally, I multiply the log-first-difference data is by 100 so that standard deviations of disturbances and impulse response functions are expressed as percentages of regional income.

3.4 Estimation strategy

The model described by (1)-(5) is a variant of Watson and Engle's (1983) general dynamic multiple indicator-multiple cause (DYMIMIC) model. This framework allows unobserved variables to be dynamic in nature as well as be associated with observed variables. This latter feature is an important part of the present study, since one the goals is to see how much of the variation in the common income component is explained by shocks to observed variables (monetary policy and energy prices).

DYMIMIC models are estimated using maximum likelihood. Likelihood functions are evaluated by using the Kalman filter on the model's state space representation. In my case the state space representation of the model is described by the following: measurement equation,

$$\begin{bmatrix} I_{8\times 8} & 0 \\ 0_{2\times 8} & \widetilde{A} \end{bmatrix}\begin{bmatrix} Y_t \\ W_t \end{bmatrix} = \begin{bmatrix} 0_{8\times 10} & \\ 0_{2\times 8} & \widetilde{B}(L) \end{bmatrix}\begin{bmatrix} Y_{t-1} \\ W_{t-1} \end{bmatrix} + \begin{bmatrix} I_{8\times 8} & \Gamma \\ 0_{2\times 8} & \widetilde{C}(L) \end{bmatrix}\widetilde{X}_t + \begin{bmatrix} 0_{8\times 1} \\ \varepsilon_{pt} \\ \varepsilon_{mt} \end{bmatrix} \quad (6)$$

and transition equation,

$$\widetilde{X}_t = \begin{bmatrix} D(L) & 0 \\ 0 & D_x(L) \end{bmatrix}\widetilde{X}_{t-1} + \begin{bmatrix} E(L) \\ E_x(L) \end{bmatrix} W_t + \begin{bmatrix} v_t \\ \varepsilon_{xt} \end{bmatrix} \quad (7)$$

where $Y_t = [y_{1t}, y_{2t}, ..., y_{8t}]'$; $\widetilde{A}$ is an 2×2 lower triangular matrix; $\widetilde{B}(L)$ is an 2×2 matrix of polynomials in the lag operator *L*; $\Gamma = [\gamma_1, \gamma_2, ..., \gamma_8]'$; $\widetilde{C}(L)$ is an 2×1 matrix of polynomials in the lag operator L; $\widetilde{X}_t = [X_t', x_t]'$; $D_x(L)$ is a scalar polynomial in the lag operator *L*; $E_x(L)$ is an 1×2 matrix of polynomials in the lag operator *L*. These parameter matrices map into the model specified in (1)-(5) in the following way,

$$A = \begin{bmatrix} 1 & 0 & 0 \\ E_x(0)_{11} & 1 & 0 \\ \widetilde{A}_{21} & C(0)_{12} & 1 \end{bmatrix}, \text{ while } B(L) = \begin{bmatrix} \widetilde{B}(L)_{11} & \widetilde{C}(L)_{11} & \widetilde{B}(L)_{12} \\ E_x(L)_{11} & D_x(L) & E_x(L)_{12} \\ \widetilde{B}(L)_{21} & \widetilde{C}(L)_{21} & \widetilde{B}(L)_{22} \end{bmatrix} \text{ for all } L \geq 1$$

Identifying the parameters that govern the common income component, idiosyncratic responses and structural disturbances requires additional normalization restrictions. The variance of the common income component's structural disturbance is identified by normalizing γ_i to unity for one of the eight regions. The idiosyncratic responses of regional income to unanticipated shocks to the relative oil price and monetary policy are identified by normalizing one region's idiosyncratic responses to be the same as the common income component's responses. In other words, the idiosyncratic responses are identified by restricting $E_i(L) = 0$ for one of the eight regions. I use the Southeast as the normalizing region since it is has the highest correlation with aggregate U.S. income and it has virtually the same amplitude as aggregate U.S. income, at business cycle frequencies.

The lag length of the model is determined by changes in the value of the likelihood function. The number of lags of all variables was increased up to the point where the likelihood ratio statistic could not reject the null that the additional parameters were jointly equal to zero. Using this criterion the model was restricted to two lags in all variables.

I estimate the DYMIMIC model using the recursive EM algorithm described in Watson and Engle (1983). To avoid local optimization problems I examined a wide range of starting values and impose severe convergence criteria on the parameter space of 1×10^{-7}. Standard errors of the parameters are estimated using a standard gradient search algorithm to evaluate the matrix of second derivatives of the likelihood function at the EM parameter estimates.

3.5 Variance decompositions at business cycle frequencies

A goal of this paper is to decompose the variance of regional income at business cycle frequencies according to the various common and idiosyncratic sources of innovation. I do this by way of a linear filter $G(L)$ that allows me to map from the covariance of the first-difference of the regional income to the covariance of the business cycle components of regional income. The precise form of the filter is, $G(L) = \frac{BP_{6,32}(L)}{1-L}$, where $BP_{6,32}(L)$ is the Baxter-King approximate band-pass filter for quarterly data; and *L* is the lag operator. The mapping of covariance of the first-difference data to covariance of the business cycle frequency data is carried using standard spectral/Fourier analysis tools.

4 Empirical results

With estimates of the model in hand, I assess the similarity of U.S. regional business cycles along two dimensions. First, by studying the sources of regional economic disturbances I determine the extent to which fluctuations are caused by common and region-specific shocks. Second, by studying the model's impulse response functions, I assess whether regions have similar responses to common shocks and determine the time it takes a region to adjust to idiosyncratic shocks.

4.1 Sources of variation

The upper panel of Table 3 describes the level of the estimated standard deviation of the model's eleven structural disturbances, while the lower panel of Table 3 describes the relative volatility of region-specific shocks, using the Southeast as the normalizing region.

Focusing on the upper panel, we see that innovations to the common income component are estimated to have a standard deviation that is more than more than twice as large are the standard deviation of region specific shock to the Southeast. This implies that common shocks are an important source of variation in the Southeast. While, the lower panel reveals that there is a great deal of statistically significant variation in the relative size of the standard deviations of region-specific shocks. Estimates range from 1.29 for the Great Lakes up to 2.85 for the Plains, which, holding other things constant, suggests that region specific shocks are more important source of income variation in the Plains than in the Great Lakes.

Decompositions of the forecast errors of regional income reported in Table 4, provide a more complete picture of the relative importance of disturbances. These decompositions indicate the share of the forecast error attributable to a particular disturbance for a given horizon. The one-step-ahead errors are informative about the similarity of the sources of disturbances across regions, while step lengths of greater than one contain joint information about the similarity of disturbances and responses to disturbances.

Table 4 reveals that a large share of the disturbance to U.S. regions is due to common shocks (that is, unanticipated shocks to oil prices, monetary policy, and common income component). For example, common disturbances explain a large share of the Southeast's one-step-ahead forecast error, 87 percent. The Plains appear to have the largest region-specific influences, with only 47 percent of the variation in their one-step-ahead forecast error explained by common disturbances. The six other regions fall in between, with common disturbances explaining roughly 58 to 76 percent of the variation in their one-step-ahead forecast errors. The relative importance of different common disturbances is similar across regions. Shocks to the common income component are considerably more important than shocks to oil prices and monetary policy at all forecast horizons. With the exception of the Southeast and Plains, these results suggest that U.S. regions have similar sources of economic disturbances.

Table 4 also provides some indication of the similarity of responses to disturbances. Looking at horizons of greater than one quarter, the relative importance of common and idiosyncratic disturbances is similar across regions. This suggests that responses to common and idiosyncratic shocks are similar. A common finding is that unanticipated shocks to the common income component are less important at longer horizons.

4.2 Impulse response functions

Figures 1 to 6 describe in detail the cumulative responses of the log-first-difference of income of the eight BEA regions to common shocks. These impulse response functions describe the way that the level of regional income responds over time to a permanent one-standard deviation shock to the relative price of oil, the federal funds rate, and common component of income. The responses are presented in two ways. First, I plot the regional responses against each other to establish differences across the regions. Next, I plot the individual responses with their 95 percent confidence interval.[7]

Figure 1 shows that an unanticipated rise in the relative price of oil has a negative effect on income in all eight regions. Regions can be broken up into three groups. The Plains response is much larger than in the Southeast, while the responses in the Southwest, Rocky Mountains and Far West are much weaker than in the Southeast. Responses of the remaining regions are similar to those of the Southeast. Figure 2 reveals that with the exception of the weak response group, the response functions of the regions are all significantly different from zero.

Figure 3 reveals that an unanticipated shock to monetary policy (an unexpected rise in the federal funds rate) also has a negative effect on regional income in all eight regions. Regions fall into two groups. New England, Mideast, Southwest and Far West have weaker responses than the Southeast, while the Great Lakes, Plains and Rocky Mountains have responses that are stronger than the Southeast. The responses are shown in Figure 4 to be significantly different from zero across all regions two to three quarters after the shock, which reflects the well known lagged effect of monetary policy.

Responses to an unanticipated increase in the common income component are described in Figure 5. Regions fall into three groups. The Plains, Southwest, and Rocky Mountains have stronger responses than the Southeast, while the Mideast has a weaker response than the Southeast. New England, Great Lakes and Far West have responses that are similar to the Southeast. Figure 6 reveals that these responses are all significantly different from zero at all lags.

[7] Confidence intervals are calculated by Monte Carlo methods. Following Hamilton (1994) section 11.7, I randomly draw from the estimated distribution of the model's parameters. For each draw of parameters I generate an impulse response function. I repeat this process 10,000 times. At each lag I calculate the 2500th lowest and 9750th highest value across all 10,000 simulated response functions. The boundaries of the confidence intervals in the figures correspond to these values.

Overall, the response functions suggest that regions respond to common sources of disturbance in a similar way. However, there is some variation across regions in the sensitivity of the responses to these common disturbances. The objective of the next two sections is test if the differences in response functions are statistically significant. I do this by breaking down the responses into their common and idiosyncratic components

4.3 Common responses

Differences in common responses to common shocks across regions merely reflect differences in the sensitivity to the common component measured by γ_i. Regions with a $\gamma_i > 1$ have greater sensitivity to fluctuations of the common component, while regions with $\gamma_i < 1$ are less sensitive to fluctuations of the common component. Table 5 reports the maximum likelihood estimates of these parameters along with their standard errors and t-statistics for the null hypothesis that $\gamma_i = 1$. These statistics suggest that the null of a common response to the common component across all regions cannot be rejected at the 5 percent level of significance. At the 10 percent level, the null is rejected for the Plains and Far West.

4.4 Idiosyncratic responses

The model developed in the previous section is flexible enough to allow for different regional responses to common shocks. These so-called idiosyncratic responses capture the difference between the region's total and common response to a common shock.

Figure 7 shows that the idiosyncratic responses of regional income to an unanticipated rise in the relative price of oil is not significantly different from zero in New England, the Mideast and Great Lakes. The idiosyncratic response functions of the Southwest, Rocky Mountains and Far West are significantly greater than zero, while the response function of the Plains is significantly less than zero. This reflects the fact that the Southwest, Rocky Mountains and Far West are oil producing and distribution regions. The Plains, on the other hand, has a large agriculture sector, which is highly sensitive to oil price fluctuations.

Idiosyncratic responses to unanticipated shocks to monetary policy are plotted in Figure 8. They reveal that idiosyncratic responses to monetary policy shocks are not statistically different from zero in all eight BEA regions. This finding stands in contrast to the general conclusion of Carlino and Defina (1998) that monetary policy has a greater effect on the income of more manufacturing oriented regions, such as the Great Lakes. There is, however, some evidence in support of their conclusion that the Southwest is less sensitive to monetary policy. This is revealed by the fact that the idiosyncratic response of the Southwest is very close to being statistically different from zero at the 5 percent level.

Figure 9 reveals the effects of an unanticipated shock to the common income component on the idiosyncratic components of regional income. Shocks to the common component of income affect the idiosyncratic component through the lagged responses of oil prices and monetary policy. With the exception of the Southwest, the idiosyncratic responses to common income shock are not statistically different to zero. This reflects the fact that positive shocks to the common income component have a positive effect on oil prices and the federal funds rate, to which the South has a significant positive idiosyncratic response.

Responses to unanticipated region-specific shocks are reported in Figure 10. All eight regions have significant responses to their region-specific shocks. Regions generally complete their adjust to a region specific disturbance within a year of the shock. However, adjustment is slower in New England, Southwest and Far West, with adjustment lags of almost two years. In most cases the cumulative effect exceeds the impact effect. The main exceptions to this rule are Southeast and Plains. The main implication of this observation is that the relative importance of region-specific disturbances is relatively smaller at longer horizons in the Southeast and Plains, when compared to New England, Southwest and Far West (see Table 4).

4.5 Variance decomposition at business cycle frequencies

Panel A of Table 5 ties together the sources of disturbances and responses by decomposing the variance of regional output at business cycle frequencies. Each column breaks down the variance of regional income by source of shock. For example, the first element of the first column reveals that innovations to oil prices explain 16 percent of the business cycle fluctuations in Southeast income. The next entry reveals that a similar percentage is explained by monetary policy shocks, while common income shocks explain 64 percent of the variation in Southeast income. Moving on down the column, we see that common shocks explain 96 percent of the variation in Southeast income, with the remaining 4 percent of the variation in Southeast income explained by region specific shocks.

The remaining columns of the upper panel reveal that a large share of the business cycle fluctuations of U.S. regions is due to common shocks. Regions fall into three groups. At the upper end of the range common shocks explain more than 86 percent of the variation in regional income of the Southeast and Great Lakes, while at the lower end common shocks account for 56 and 63 percent of the income variation in New England and Southwest regions, respectively. The other regions fall in between with common shocks accounting for 68 to 74 percent of income fluctuations in the Mideast, Plains, Rocky Mountains and Far West.

Panel B highlights differences in the idiosyncratic responses of regions by breaking down the relative importance of the common sources of variation. The residual common-income-component shock is the most important source of disturbance explaining on average 70 percent of the variation explained by all three common shocks. While, monetary policy and relative oil price shocks account on average for 15 percent of the variation in regional income explained by common shocks. The variation across regions is greatest for oil price shocks, with oil price shocks explaining 4-5 percent of the variation in the Southwest, Rocky Mountains and Far West on up to 32 percent in the Plains. This reflects the relatively weaker responses in the former regions and the relatively strong response in the latter region. The relative importance of monetary policy shocks is more uniform across regions, with the main outlier being the Southwest, where shocks to monetary policy account for 8 percent of the variation explained by common shocks.

I assess the overall similarity of the regional business cycles by a simple distance measure that compares the variance decomposition of each region with the average across all regions. These statistics are reported at the bottom of Panel A (they are distributed as a χ^2 with 3 degrees of freedom). At the 5 percent level of significance I can reject the null of common sources of innovation and/or responses to innovations at business cycle frequencies in the Southeast, Plains and Southwest. This implies the U.S. regions can be divided into a core group of New England, Mideast, Great Lakes, Rocky Mountains and Far West, that meet Mundell's OCA criteria described by (i)-(iv), and a non-core group of the Southeast, Plains and Southwest that fail to meet this criteria.[8]

In the case of the Plains and Southeast these findings largely reflect differences in the relative volatility of region-specific disturbances when compared to the core group. In particular, region-specific disturbances account for a relatively small share of the business cycle volatility of Southeast income and a relatively large of the business cycle volatility of Plains income. On the other hand, these findings reflect the fact that the Southwest has very different responses to both common and idiosyncratic shocks, when compared to the core group.

[8] Relaxing the level of significance to the 1 percent level expands the optimum currency area to include the Southeast and Southwest.

5 Conclusion

This paper develops a statistical model to study the business cycles of the eight U.S. BEA regions. By combining unobserved component and VAR techniques I identify not only common and idiosyncratic sources of innovation, but also common and idiosyncratic responses to common shocks. I use formal statistical tests to show that the eight U.S. BEA regions deviate from Mundell's ideal of an optimum currency area, at typical levels of significance. Based on these results, I identify five core regions that have similar sources of economic disturbance and similar responses to these disturbances (New England, Mideast, Great Lakes, Rocky Mountains and Far West) and three non-core regions that differ significantly from the core in their sources of disturbance (Southeast and Plains) and responses to disturbances (Southwest), at business cycle frequencies.

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Table 1: Regional business cycle comovement and persistence

A. Contemporaneous correlation

	Income at time t								
Income at time t	**US**	**SE**	**NE**	**ME**	**GL**	**PL**	**SW**	**RM**	**FW**
United States	1.00	0.99	0.89	0.94	0.97	0.90	0.77	0.85	0.91
Southeast	0.99	1.00	0.89	0.92	0.96	0.89	0.76	0.88	0.86
New England	0.89	0.89	1.00	0.94	0.84	0.70	**0.52**	0.62	**0.81**
Mideast	0.94	0.92	0.94	1.00	0.88	**0.77**	**0.59**	**0.71**	**0.87**
Great Lakes	0.97	0.96	0.84	0.88	1.00	0.88	0.72	0.83	0.86
Plains	0.90	0.89	0.70	0.77	0.88	1.00	0.76	0.86	0.74
Southwest	0.77	0.76	0.52	0.59	0.72	0.76	1.00	0.87	0.65
Rocky Mountains	0.85	0.88	0.62	0.71	0.83	0.86	0.87	1.00	0.69
Far West	0.91	0.86	0.81	0.87	0.86	0.74	0.65	0.69	1.00

B. Lead/lag correlation

	Income at time t+1								
Income at time t	**US**	**SE**	**NE**	**ME**	**GL**	**PL**	**SW**	**RM**	**FW**
United States	0.94	0.94	0.82	0.84	0.92	0.86	0.75	0.83	0.89
Southeast	0.92	0.94	0.81	0.81	0.90	0.85	0.74	0.84	0.83
New England	0.87	0.87	0.95	0.88	0.82	0.70	**0.53**	0.62	**0.82**
Mideast	0.94	0.92	0.91	0.95	0.89	**0.81**	**0.62**	**0.73**	**0.89**
Great Lakes	0.92	0.91	0.78	0.79	0.95	0.84	0.70	0.80	0.84
Plains	0.81	0.83	0.63	0.65	0.80	0.91	0.72	0.81	0.69
Southwest	0.68	0.68	0.43	0.49	0.65	0.69	0.92	0.80	0.59
Rocky Mountains	0.78	0.81	0.55	0.60	0.76	0.80	0.82	0.94	0.65
Far West	0.84	0.79	0.72	0.75	0.79	0.70	0.63	0.65	0.94

Notes: US=United States, SE=Southeast, NE=New England, ME=Mideast, GL=Great Lakes, PL=Plains, SW=Southwest, RM=Rocky Mountains, and FW=FarWest. Regional and aggregate income data filtered using the quarterly business cycle band-pass filter described in Baxter and King (1999).

Sources: Author’s calcuations using data from the Bureau of Economic Analysis.

Table 2: Unit root tests

Variable	Log level	Log first difference
Southeast income	-3.27	-3.85
New England income	-2.67	-3.19
Mideast income	-2.31	-3.03
Great Lakes income	-1.90	-3.81
Plains income	-2.96	-3.52
Southwest Income	-2.26	-2.90
Rocky Mountains income	-2.07	-3.19
Far West income	-2.72	-3.23
Relative price of oil	-2.78	-4.04
Federal funds rate	-2.80	-4.21

Notes: With exception of funds rate all tests of unit roots in log-levels include include an intercept term and time trend, funds rate test only has an intercept. Unit root tests of log-first-differences include an intercept term.

Source: Author's calculations using regional income data from Bureau of Economic Analysis, oil price data from the International Monetary Fund and federal funds rate data from the Board of Governors of the Federal Reserve System.

Table 3: Estimated volatility of structural disturbances

Structural disturbance	Standard deviation	Standard error	t-statistic (σi=0)
Common			
Oil price	17.03	1.00	17.02
Common income	0.73	0.05	13.95
Monetary policy	0.99	0.06	16.20
Region specific			
Southeast	0.32	0.03	12.67
New England	0.49		
Mideast	0.55		
Great Lakes	0.42		
Plains	0.92		
Southwest	0.48		
Rocky Mountains	0.64		
Far West	0.42		

Structural disturbance	Relative standard deviation	Standard error	t-statistic (σi/σ1=1)
Region specific			
Southeast	1.00		
New England	1.53	0.14	3.86
Mideast	1.70	0.15	4.53
Great Lakes	1.29	0.12	2.32
Plains	2.85	0.23	8.19
Southwest	1.48	0.13	3.63
Rocky Mountains	1.99	0.18	5.49
Far West	1.31	0.12	2.59

Table 4: Sensitivity to common shock

Region	Coefficient (γi)	Standard error	t-statistic ($\gamma i=1$)
Southeast	1.00		
New England	0.89	0.07	-1.45
Mideast	0.87	0.08	-1.59
Great Lakes	1.04	0.06	0.69
Plains	1.20	0.10	1.92
Southwest	1.01	0.07	0.13
Rocky Mountains	1.10	0.09	1.03
Far West	0.88	0.06	-1.93

Table 5: Variance decomposition of U.S. regional income at business cycle frequencies

A. All sources of innovation	**Percentage of total variation due to innovation**								
Source of innovation:	**SE**	**NE**	**ME**	**GL**	**PL**	**SW**	**RM**	**FW**	**Average**
Relative oil prices	16	8	14	18	23	2	3	4	11
Monetary policy	16	7	12	14	9	5	14	10	11
Common income	64	41	46	54	42	56	53	54	51
Total common	96	56	72	86	74	63	69	68	73
Region-specific income	4	44	28	14	26	37	31	32	27
Total all shocks	100	100	100	100	100	100	100	100	100
Chi squared test (sources are common)	10.67	4.99	1.51	4.82	13.44	8.62	5.70	4.30	

B. Common sources of innovation	**Percentage of common variation due to innovation**								
Source of innovation:	**SE**	**NE**	**ME**	**GL**	**PL**	**SW**	**RM**	**FW**	**Average**
Relative oil prices	17	15	20	21	32	4	4	5	15
Monetary policy	17	12	16	16	12	8	20	14	14
Common income	66	73	64	63	57	88	77	80	71
Total common	100	100	100	100	100	100	100	100	100

Notes: SE=Southeast, NE=New England, ME=Mideast, GL=Great Lakes, PL=Plains, SW=Southwest, RM=Rocky Mountains, and FW=FarWest.

Figure 1: Cummulative impulse response of regional income to oil price shock

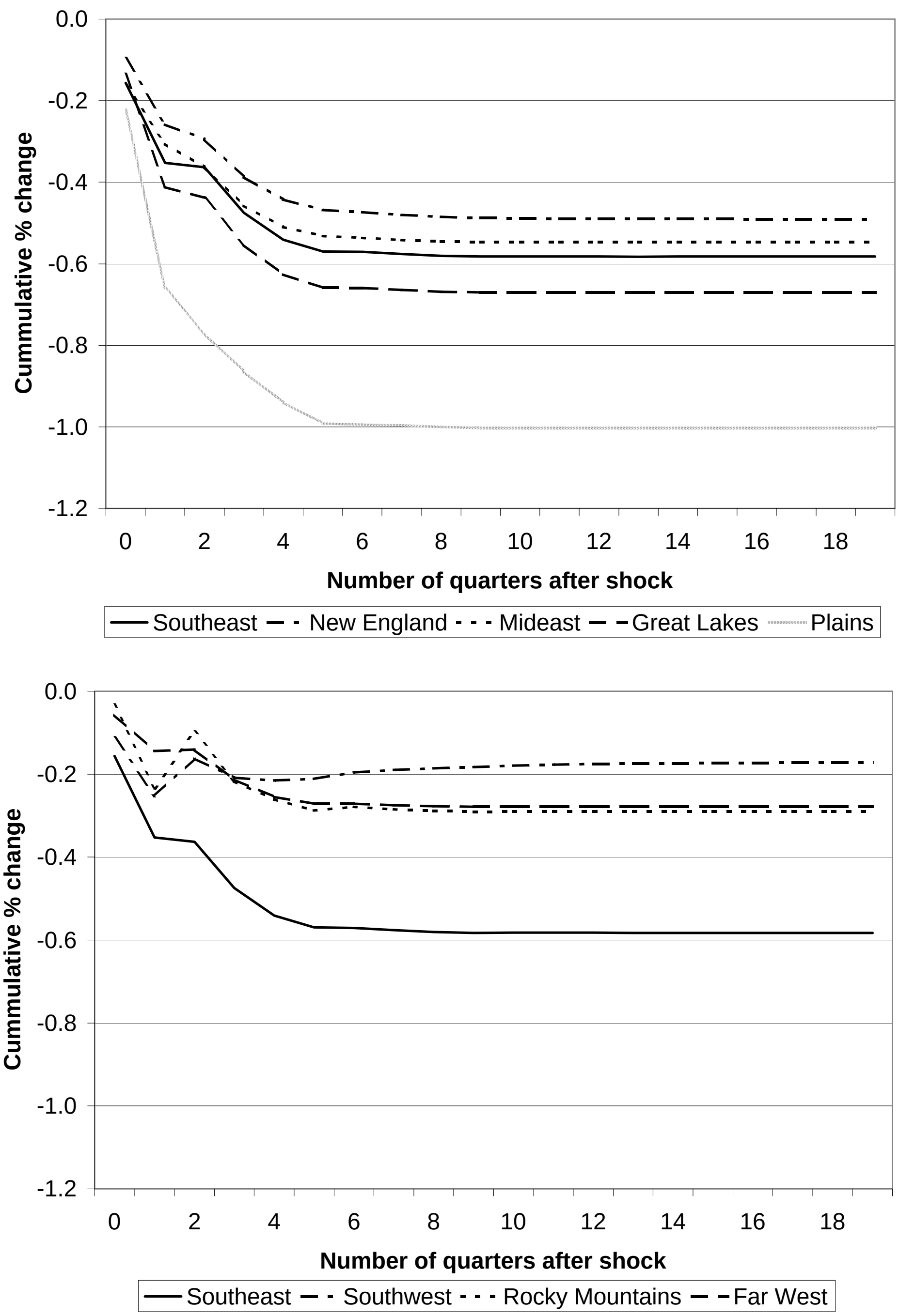


Figure 2: Cummulative impulse response of regional income to oil price shock (with 95 percent confidence interval)

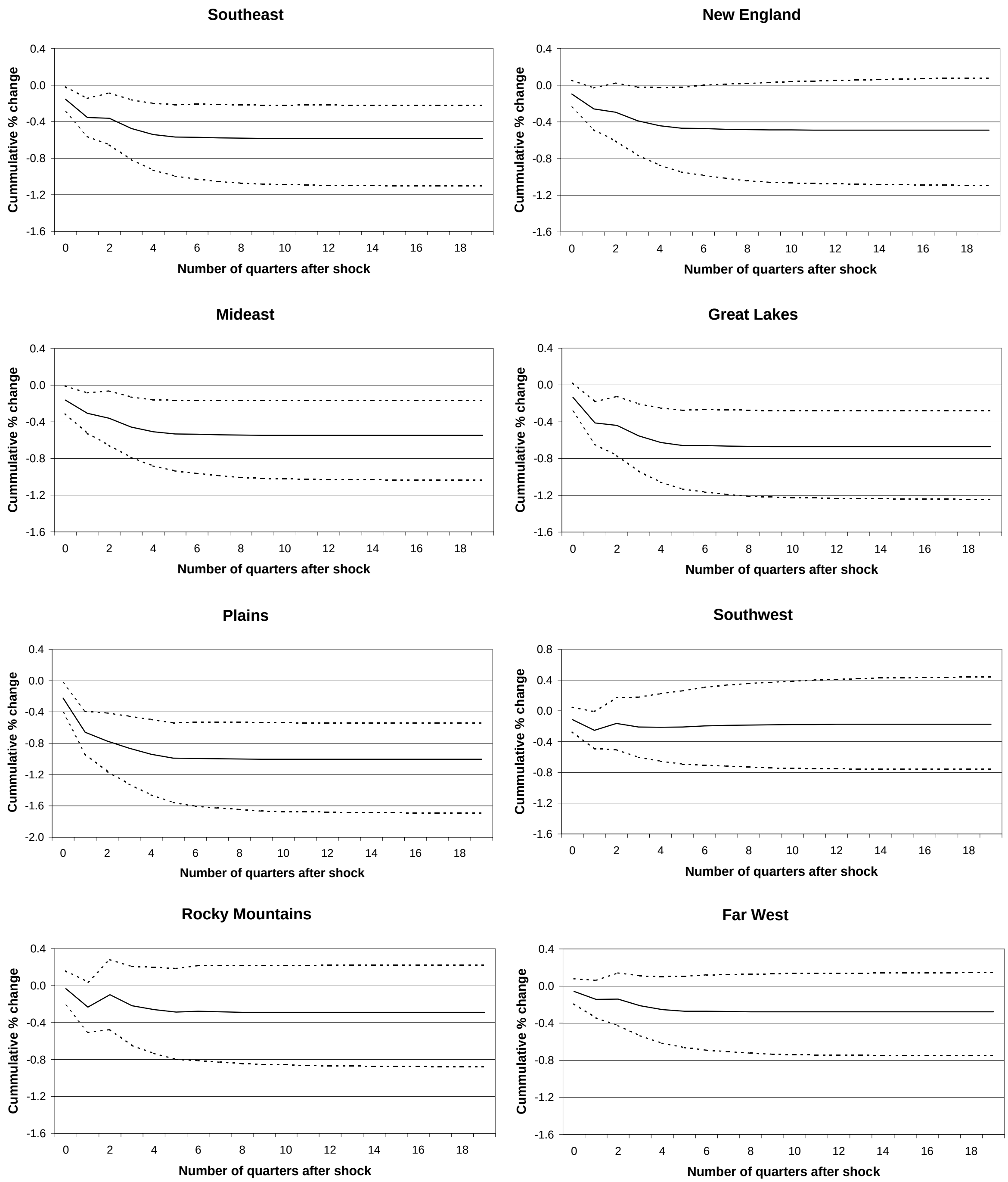
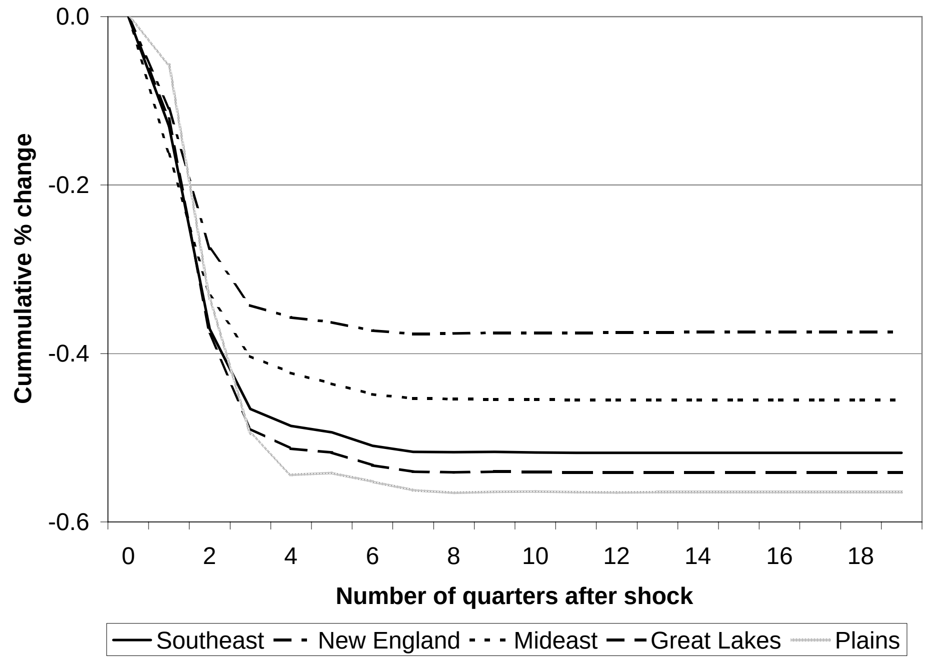


Figure 3: Cummulative impulse response of regional income to monetary policy shock



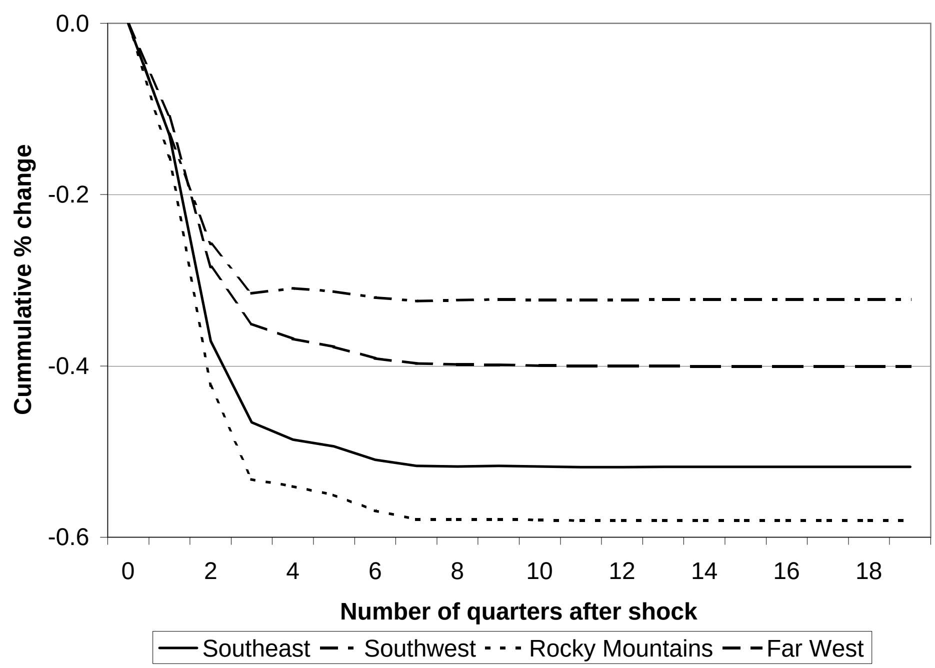


Figure 4: Cummulative impulse response of regional income to monetary policy shock (with 95 percent confidence interval)

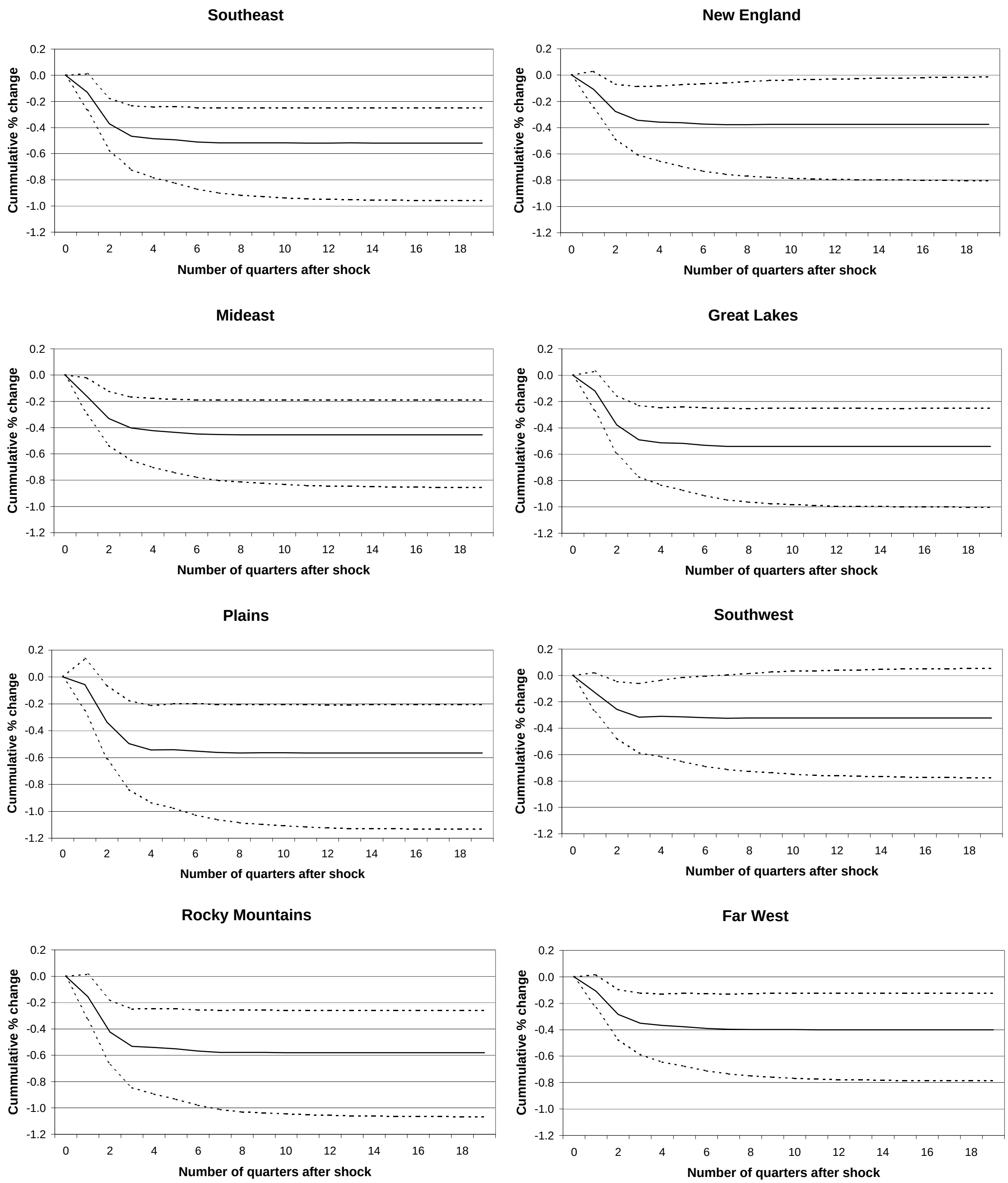


Figure 5: Cummulative impulse response of regional income to common income shock

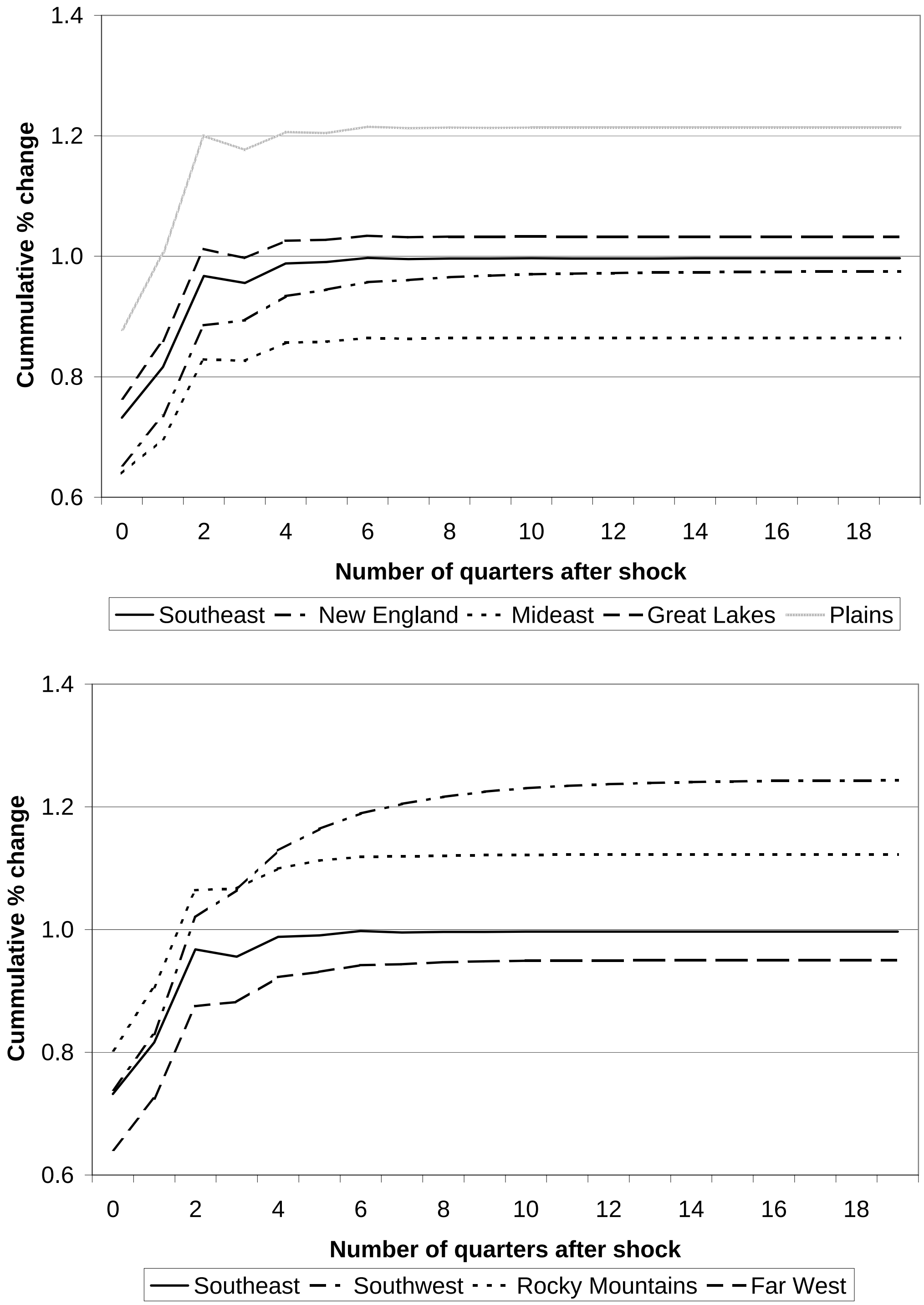


Figure 6: Cummulative impulse response of regional income to common income shock (with 95 percent confidence interval)

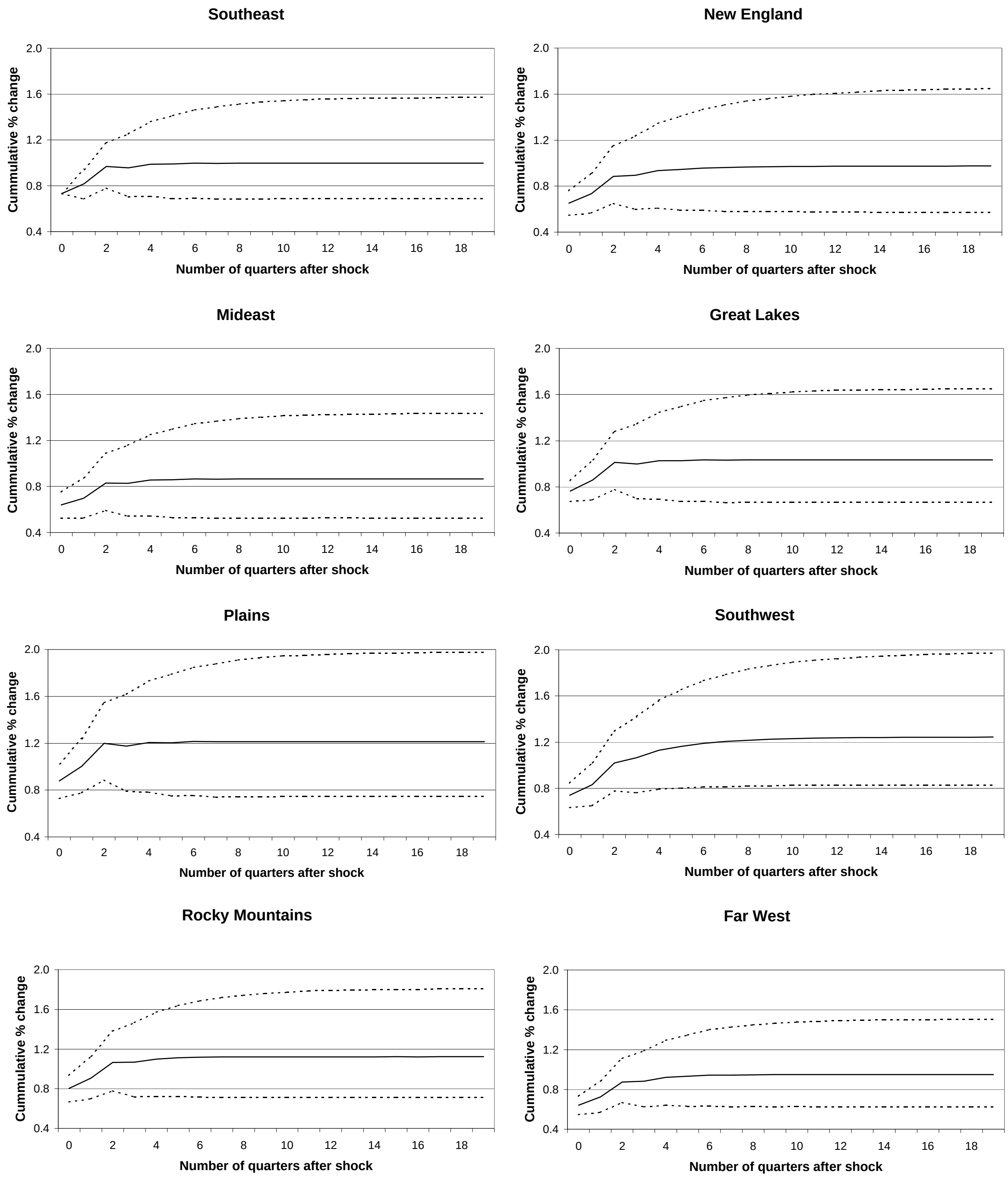


Figure 7: Cummulative impulse response of idiosyncratic regional income to oil price shock

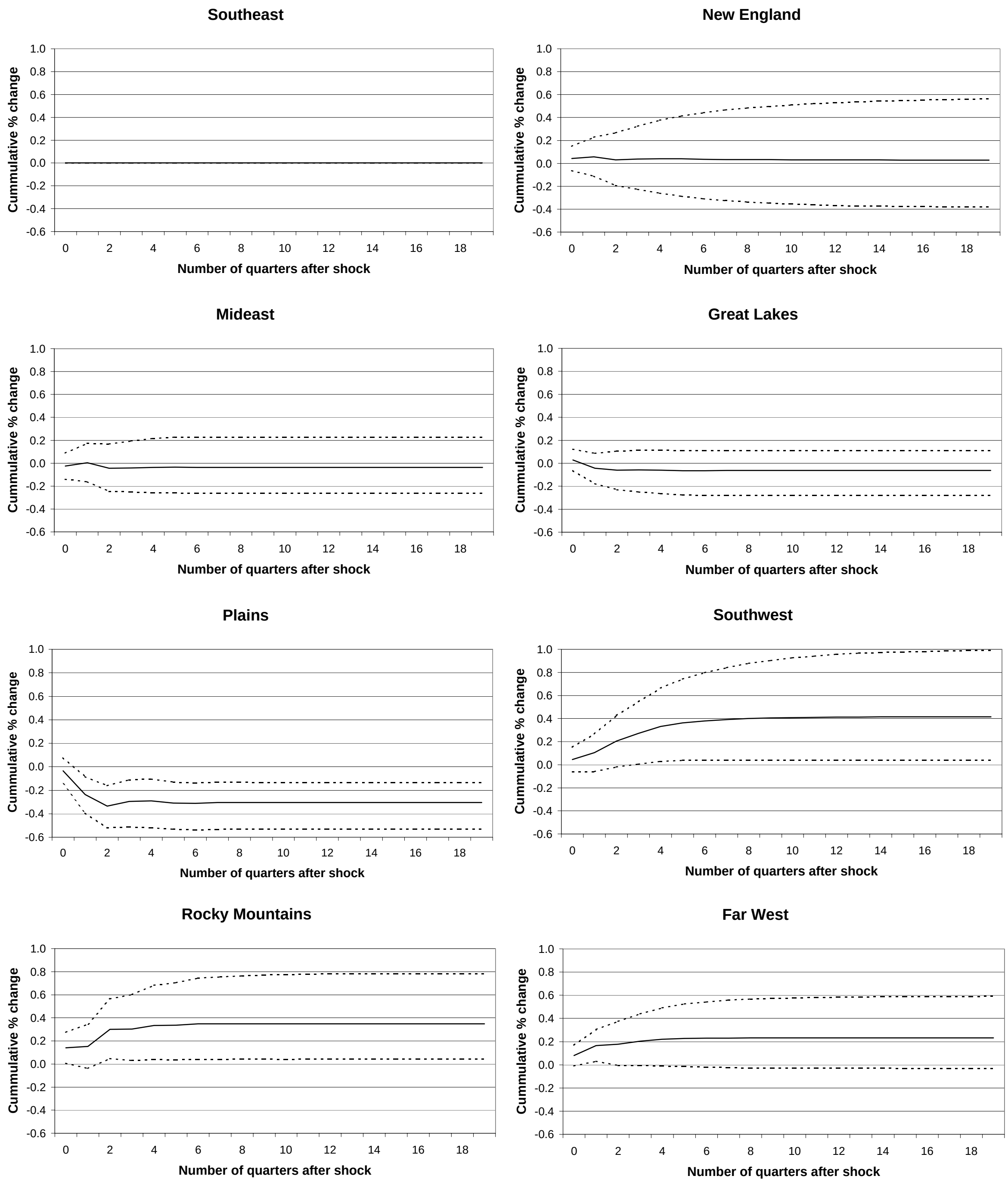


Figure 8: Cummulative impulse response of idiosyncratic regional income to monetary policy shock

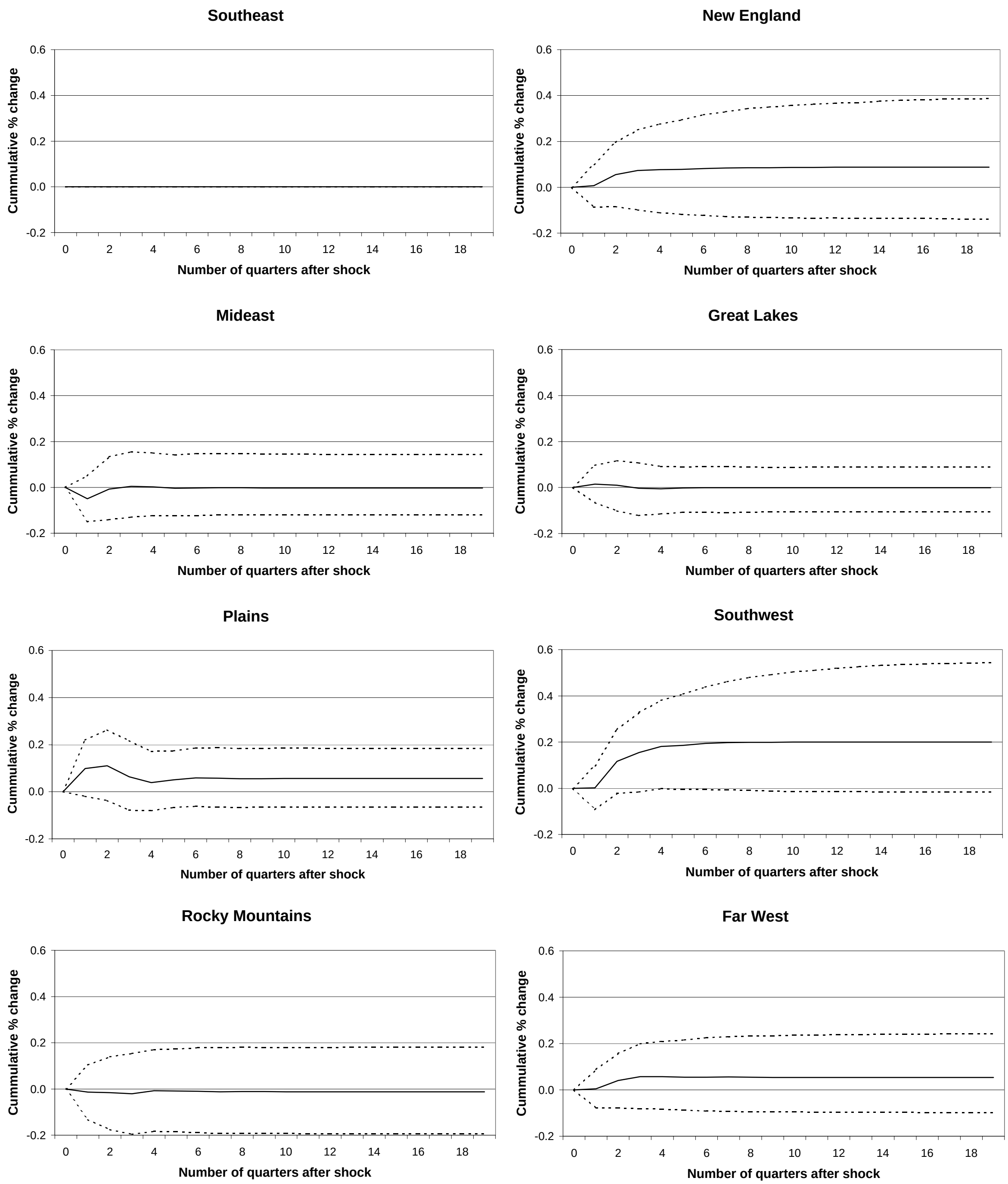


Figure 9: Cummulative impulse response of idiosyncratic regional income to aggregate output shock

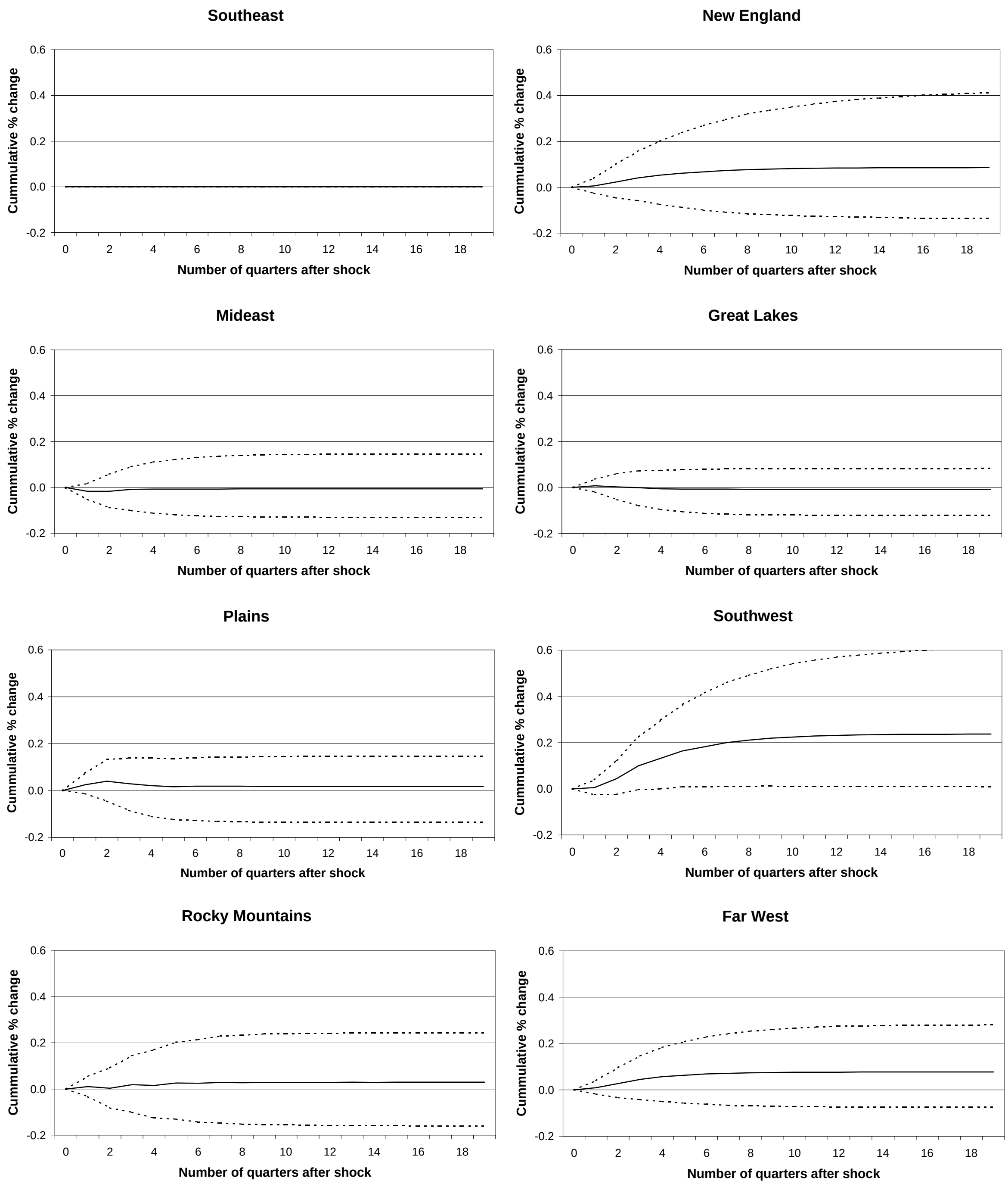


Figure 10: Cummulative impulse response of idiosyncratic regional income to region-specific output shock