Assessing the Regional Business Cycle Asymmetry in a Multi-level Structure Framework: A Study of the Top 20 U.S. MSAs

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Abstract: Evaluating the impact of a national shock, such as a monetary/fiscal policy, on a regional economy requires an understanding of the dependency of the regional business cycle on the national business cycle. Dating the regional business cycle phases using a Markov-switching model revealed that the regional cycle phase transition depends on the national cycle phase, but the propagation speed of the national phase into a regional cycle varies across the regions. The estimation of the national factor loadings on regional economies showed that the response of a regional economy to a national impact is mostly greater during a national contraction phase.

Key Words: Regional Business Cycle, Markov-switching Model, Multi-level Structure, Impulse Response

JEL Classifications: C11, C13, O18, R11

1. Introduction

This paper attempts to answer two questions regarding regional business cycles. The first one is how different are the regional business cycles from the national business cycles. As Hayashida

& Hewings (2009) revealed, there exists a significant level of heterogeneity between regional business cycles in terms of timing and duration of the cycle phase. However, in terms of the cycle phase transitions, there are more similarities between regional economies than differences. Since the overall evolution of the regional business cycle phases are mostly similar to the national ones, this similarity might imply that the regional business cycle phase is predominantly dependent on the national cycle phase. If the similarity is due to the dependency on the national cycle phase, then the current national cycle phase can be a good predictor for the future regional cycle phase. In this paper, using a Markov switching model to date the national and the regional business cycle phases, it is shown that the local level business cycle phase transition is dependent on the national level business cycle phase, and especially during the national contraction phase, regional business cycle tends to transit to contraction phases promptly.

The second question is whether an impact, such as a monetary/fiscal policy shock, on the regional economy is different depending on the cycle phase of a regional economy. In evaluating a policy impact, the consideration of the regional business cycle phase can be critical since the same size of shock can have a different impact on the regional economy depending on the cycle phase of the regional economy. Many empirical studies,[1] for example, have revealed that a contractionary monetary policy shock during an expansion period has a negative, but relatively smaller impact on the output of the national economy, while an expansionary monetary policy shock during a contraction period has a positive and relatively bigger impact on the output. This asymmetry results from the asymmetric response mechanism of the national economy from a national shock. However, the study of the asymmetric response mechanism at the regional level is very rarely compared to its national counterpart. In similar fashion to the national level

[1] Examples include Garcia (2002), Karras (1996) and Ravn (2004). Especially, Garcia (2002) used a Markov-switching model in dating the business cycle phase of the U.S.

response mechanism, it can be conjectured that a regional economy will respond differently to an impact depending on the regional or the national cycle phases. Using an ARIMAX model augmented with cycle phase distinction, this paper revealed that the magnitude of a response to a national shock is mostly greater during a national contraction phase, but the shapes of the impulse response functions are similar across regional units.

In analyzing the regional business cycle, this paper used a multi-level framework of regional economies. In contrast to national level business cycle analysis, the analysis of regional business cycles should include considerations of the multi-level structure of regional economies since they are exposed to national shocks that are common to all regions within the nation. The examples of those shocks common to all regions are an international commodity price shock or a monetary/fiscal policy shock; these are assumed to be represented by a single index (Chicago Fed National Activity Index, CFNAI). Thus, a regional economic activity is composed of the national factor (CFNAI) and a region specific factor. This paper contributes to the literature on regional business cycle analysis by adding this multi-level structure of regional economies (for more details, see Chung, 2013).

One main findings of this paper is that regional economies are heavily dependent on the national economy both in terms of the cycle phase transition and the impulse response mechanism. As Chung (2013) noted, the U.S. state level economic activity is mostly driven by national level shocks; the analysis of the top 20 U.S. Metropolitan Statistical Areas (MSAs) in this paper also revealed that the role of the national economy is important in predicting regional economic evolution. Conclusively, more emphasis should be drawn on the similarities between regional economies than the attention directed to regional heterogeneity in the regional business cycle literature.

The organization of paper is as follows. Section 2 reviews some previous studies on the identification of regional business cycle phases. Section 3 briefly describes the concept of the multi-level structure of a regional economy, while section 4 dates the cycle phases using a Markov-switching model using the multi-level idea described in section 3. The impulse response functions of regional economies against the national shock subject to different cycle phases are described in section 5. Section 6 offers some conclusions and provides a practical application example of this phase analysis.

2. Previous Literatures on Regional Business Cycle Phase Analysis

The literature focusing on the regional business cycle analysis often uses a factor analysis or a Markov-switching model, in similar fashion to models of national economic activity. However, the adoption of a multi-level approach for modeling regional economies exposed to a common (national) shock is somewhat unusual in the regional economic analysis literature, and the study of the business cycle phases with such a framework is even less commonly employed.

Regarding regional business cycle phase analysis, many studies have revealed that there are significant differences between regions in terms of timing and the duration of the business cycle phase transitions. For example, Hayashida and Hewings (2009) applied a Markov-switching model on the first principal component of four different regional business indicators, and revealed that different regions have different turning points of business cycles. Wall (2006) revealed very similar results in his study on regional business cycle phases in Japan.

Owyang *et al.* (2005, 2008) further investigated the determinants of the average growth rate for each regime by cross sectional analyses on U.S. states and cities, respectively. In their study, regional business cycle measures were decomposed into high-growth (expansion) and low-growth (contraction) phases, and the average of the high growth phase and that of the low-growth phase was regressed on exogenous variables such as human capital, industry mix and average firm size to identify the determinants of the economic performance of each city in different cycle phases. They found that the high-growth phase is related to human capital, industry mix, and average firm size, while the low-growth phase is related to the level of non-education human capital.

The study of the regional response to a national impact has a much longer history compared to the study of the cycle phase study, starting from Scott Jr (1955)'s analysis of monetary policy's impact on a regional economy, but many studies have used regional input-output models to capture the impacts of national programs; the latter type of analyses are outside the scope of this paper's focus. Similar to this paper's methodology is the one adopted by Carlino & DeFina (2004). In their study of U.S. states, they used a structural VAR model, and revealed that individual regions respond differently against a national policy, and the magnitude of response is significantly related to industry-mix variables.

The attempt to combine the regional and the national business cycle can be found in Rissman (1999) and Artis *et al.* (2004). Rissman (1999) noted that "regional employment growth is driven in large part by a common business cycle (p.28)," a finding that is similar to the one found in this paper. One notable thing is that her Kalman filtering method of estimating unobserved common business cycle across nine U.S. regions have a form of multi-level structure in the specification, although she did not mentioned the multi-level terminology explicitly. Using her original notation, the observed economy is assumed to be of the form shown in equation (1):

$$y_{it} = \alpha_i + \beta_0^i C_t + \beta_1^i C_{t-1} + \beta_2^i C_{t-2} + \gamma_i y_{it-1} + \varepsilon_{it} \quad (1)$$

where $\varepsilon_{it} \sim N(0, \sigma_i^2)$ (regional disturbance),

$C_t = \phi_1 C_{t-1} + \phi_2 C_{t-2} + u_t$ (unobserved state of common business cycle),

$u_t \sim N(0, \sigma_u^2)$ (common disturbance),

and y_{it} is region i's employment growth in year t.

The "common business cycle" term is equivalent to a region common factor, or a national shock in this paper's terminology. The concepts in Rissman (1999) are almost the same as in this paper except for that this paper used CFNAI to represent the common business cycle measure. Further, the present paper tries to incorporate a non-linear structure into this model using the identified cycle phase, thus the coefficients β_n^i, γ_i, σ_i^2, ϕ_n and σ_u^2 are dependent on the state of the regional economy.

In her paper, Rissman (1999) found out that the "aggregate disturbance" (national shock in this paper's terminology) and "local disturbance" (region specific shock in this paper's terminology) both contribute significantly to regional employment growth, but the role of a local shock was not the same across the regions. For example, the variance of cyclical shock, or the contribution of the national shock, accounted for about 60% for West South Central region, while it was only about 10% for East South Central region. These results are consistent with the findings in this paper that many regional economies exhibit different compositions of national shock and regional shock. In this paper, however, by incorporating the cycle phase dependent structure, it will be shown that the contribution of the national factor (or the aggregate disturbance) is more significant during the regional contraction phase.

Artis *et al.* (2004) investigated the contribution of the common European business cycle to the individual European country cycles. In his study of nine European countries, he found that in Europe, the variance of the country specific component is much higher than that of the European-wide component, which is the opposite of the U.S. case in this paper's analysis. In his paper, he first extracted the European business cycle measure (European cycle phase) from individual countries' index of industrial production (IIP) using a Markov-switching VAR model. In this stage, he further decomposed individual countries' growth rate into European business cycle component and individual component, as shown in equation (2):

$$A(L)\Delta y_t = \mathrm{v}(s_t) + \Sigma^{\frac{1}{2}}(s_t)\varepsilon_t \qquad (2)$$

where s_t is the state of economy represented by either a recession, a growth, or a high growth regime,

$\mathrm{v}(s_t)$ represents European business cycle contribution to individual countries,

ε_t is a Gaussian component representing the country specific component,

and Δy_t is a vector of individual countries' IIP growth rate.

In this model structure, it is assumed that individual countries' average growth rate is determined by the European common cycle phase, and the rest of the irregular parts are determined locally. This model structure also has a type of multi-level structure since the local innovation, Δy_t, is decomposed into common cycle factor, $\mathrm{v}(s_t)$, and regional innovation component, ε_t. Unlike the structure in Artis *et al.* (2004), this paper assumed that the average growth rate of a region is represented by the region specific cycle phase rather than the common cycle phase (national cycle phase). Additionally, the regional innovation is also further decomposed into a national component and a regional component. Basically, the estimation strategy in this paper can be regarded as an extension of Artis *et al.* (2004).

3. A Conceptual Description of the Multi-level Structure of a Regional Business Cycle

Since many components of regional economic activity have common characteristics, there is an extensive literature investigating the similarities of the business cycles between regions. For example, Chudik *et al.* (2011) referred to the prime source of this co-movement as “strong dependency.” On the other hand, Chung (2013) argued that this co-movement is largely driven by the common shock originating from a higher level (in this case, the national level) in the hierarchical structure of a regional economy. It was also argued that the dependency between regional economies net of the national level shock was much weaker than estimated in a non-hierarchical formulation; this would provide an example of “weak dependency” in the terminology of Chudik *et al.* (2011). In a multi-level perspective, the regional economic activities are assumed to be structured as in figure 1.

<< Insert figure 1 here >>

In this figure, it is assumed that the spillovers between regional economies and that from the regional economy to the national economy are ignored based on Chung (2013)’s findings. Although, the national business cycle measures are constructed based on the aggregated regional series in many parts, the aggregation procedure does not necessarily imply that the regional shock would have significant impact on the national economy. For example, as described in figure 2, since goods and labors can be freely move between regions, a regional shock that have a significant impact on regional economy can have no impact on the national economy, especially when there are many regional units. On the contrary, as history has shown, commodity price shock or technology innovations that are non-regional in nature have bigger impact on both regional and national economy. Chung (2013)’s finding also supports this reasoning in that the regional economy is largely affected by the national factor (60~90%) while the national factor is not much affected by the regional factor (less than 2% total).

<< Insert figure 2 here >>

After the elimination of the seasonal component, economic activity can be decomposed into a business cycle phase represented by the average growth rate at each phase and the irregular movements. In reality, the cycle phase can be regarded as a market environment. For example, if the market participants' expectation for the economy is optimistic, firms' investment and households' consumption will be increasing. On the contrary, if the market participants' expectation is pessimistic, investment or consumption will decrease even when the firms or households have the same economic resources as they have during more optimistic times. This behavioral change at each phase can be expressed as an "average trend" of the growth rate of the economic activity measure, and can be captured with a Markov-switching model.

On the other hand, the irregular component of an economic activity can be regarded as the response of the economy to shocks such as national level monetary/fiscal policy shocks or commodity price shock or even regional-level events. Also, if this irregular component affects the regional economy dynamically, it can have an autoregressive structure. The cycle component and the irregular component of the regional economic activities should both be dependent on the higher-level economic activities. In this sense, the regional economic activity's dependency on the national economic activity can be characterized by (1) the regional phase dependency on the national cycle phase, and (2) the national factor loadings on the regional factor evolvements.

Previous empirical analyses of regional business cycle adopted various methodologies, and most of them used either a factor model or a Markov-switching model, or a combination of both. is the reasoning lies in that fact that these two models reflect the two key elements of business cycle, 1) the co-movements of various macroeconomic indicators and 2) persisting separate phases (regimes).

The concept of the co-movements of indicators can be developed in a factor model. Since Burns and Mitchell (1946)'s pioneering work,[2] many features of business cycles have been uncovered both theoretically and empirically, and most of the literature agrees that macroeconomic indicators such as output movements and employment "exhibit high coherence" (Lucas, 1977, p.3). This "coherence" can be expressed by a factor model that assumes there exists a single (or sometimes a few) unobserved states of the economy that govern the movements of observed macroeconomic variables. A principal component analysis and a dynamic factor model (Stock and Watson, 1989) are the most widely used tools.

On the other hand, "persisting separate regimes" can be modeled with Hamilton (1989)'s Markov-switching model. One of the problems in phase analysis of regional business cycles is that, unlike the national economy, there is no official organization such as National Bureau of Economic Research (NBER) that announces the business cycle turning points, necessitating the identification of the phases using a statistical tool such as a Markov-switching model.[3] The model captures the transition between each phase and the asymmetric behavior of economic activities subject to different phases. Unlike other statistical techniques based on regular frequencies, the Markov-switching model can identify the cycle with different phase durations.

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[2] Burns and Mitchell (1946) defined business cycle as the following: Business Cycles are a type of fluctuation found in the aggregate economic activity of nations that organize their work mainly in business enterprises: a cycle consists of expansions occurring at about the same time in many economic activities, followed by similarly general recessions, contractions, and revivals which merge into the expansion phase of the next cycle. (p.3)

[3] NBER does not define the national business cycle turning points using Markov-switching model. In NBER website of "U.S. Business Cycle Expansions and Contractions" section, it says:

"The NBER does not define a recession in terms of two consecutive quarters of decline in real GDP. Rather, a recession is a significant decline in economic activity spread across the economy, lasting more than a few months, normally visible in real GDP, real income, employment, industrial production, and wholesale-retail sales."

This paper used Markov-switching model in identifying the business cycle phases to let the statistical model work as the regional version of the business cycle dating committee.

In this paper, using the monthly employment data of 20 Metropolitan Statistical Areas (MSA), the analysis of the regional business cycle asymmetry is conducted by a two-step procedure. In the first step, a Markov-switching model is employed to date a regional business activity index into expansion and contraction phases.[4] In the next step, the national factor loading of a regional economic activity is identified to derive the response of the regional economy from a national impulse.

In identifying the regional cycle phase, however, unlike other standard Markov-switching models, the transition of the regional cycle phase is assumed to be dependent on the national cycle phase to reflect the hierarchical structure of the regional economic activity. Since a regional economy is exposed to the national level economic activities, the transition of the regional cycle phase should also be dependent on the national cycle phase. As noted earlier, the market environment represented by the average growth trend at the regional level should be affected by the national cycle phase. The estimated regional business cycle transition dynamics also demonstrate the dependency on the national level cycle phase.

4. Dating the Business Cycle Phases of the MSAs with a Multi-level Idea

For the regional cycle phase identification, many studies, including this research, adopted a Markov-switching model, while filtering methods can also provide the information on the cyclical part of the economic activities. For example, Kouparitsas (1999) and Carlino and DeFina (2004) used band-pass filters to extract the cycle component. Also, Carlino and Sill (2001) and Partridge and Rickman (2005) used trend-cycle decompositions. However, for two

[4] Some of the literature uses more than two regimes. For example, Potter (1995) and Sichel (1994) refers to a third regime of very fast growth at the beginning of an expansion phase (recovery phase). However, this phase was not clearly appeared in our regional data set except for a few cities.

reasons, Hamilton (1989)'s Markov-switching model was used to identify the regional business cycle phases in this paper. First of all, as Owyang (2005) noted, Markov-switching models "produce[s] a reasonably accurate replication of the NBER chronology… (p.2)." While most of the filtering methods extract cycles with regular frequencies, Markov-switching models can be applied to cases with irregular appearance of business cycle phases, thus providing a more realistic approach. Also, Hamilton (2005) argued that the discrete phases of expansion and contraction can be better understood with a Markov-switching model than its alternatives. By comparing and testing the linear autoregressive structure of the U.S. unemployment rate and the Markov-switching structure of the series, he showed that the Markov-switching model performs better in analyzing the cycle phases. For these reasons, much of the literature on regional business cycle phase analysis has adopted a Markov-switching model in identifying the cycle phase.

Also, the present paper adopted the first principal component of regional employment series of various sectors to represent the regional business cycle measure. The reason that the first principal components were used to represent the regional economic activity instead of a Stock and Watson (1989) type of dynamic factors is that the dynamic structure of a factor model does not fit well with a Markov-switching formulation. In other studies, of course, there have been many successful attempts to combine both features of dynamic factor model and Markov-switching model (see for example, Diebold and Rudebusch (1994), Shepard (1994) and De Jong and Shepard (1995) using an EM algorithm, and Watanabe (2003), Kaufmann (2000), Kim (1998) and Chauvet (1998) and using Gibbs Sampler approach). However, in this paper where there are only two phases (expansion and contraction) of the cycle to mimic the NBER chronology, the phase-dependent autoregressive coefficient (the dynamic term) can hinder the proper identification of phases. For example, since a typical contraction phase exhibits lower growth rates with a larger autoregressive coefficient, sometimes higher growth rates with larger autoregressive coefficients (i.e., recovery phase in Potter, 1994 and Sichel, 1994) could be statistically identified as a contraction phase. Harding and Pagan (2002) also noted that a Markov-switching Autoregressive (MSAR) model does not perform well compared to its alternatives. [5] For this reason, this paper used a Markov-switching model as a phase identification tool rather than a factor structure identification tool. Similar approaches can be found in Leiva'Leon (2012) and Owyang (2005) using a regional index, from Crone (2005), Hamilton & Owyang (2012) and Owyang *et al.* (2008) using quarterly employment series, and Wall (2006) using an Index of Industrial Production (IIP).

4.1 Identification Strategy

In dating the regional cycle phase, unlike other conventional Markov-switching models, the transition between phases of each region is assumed to be dependent on the national cycle phase. Thus, the formulation of the phase identification has two parts, the national level phase identification and the regional level phase identification. The cycles are assumed to have two phases, an expansion phase and a contraction phase. An expansion phase is the period that exhibits persistent above-trend average growth rates, and a contraction phase is the period that exhibits persistent below-trend average growth rate. The phase at time t, S_t and S_{rt}, can have value of either 0 or 1 depending on whether the economy is in a contraction or an expansion phase, respectively. Equations (3) and (4) describe this dating scheme:

(National Phase Identification using National Level Business Activity Index, g_t)

$$g_t = \mu_{St} + \varepsilon_{St} \qquad (3)$$

[5] Thus, a dynamic factor model with a regime switching and an AR(1) structure will require at least 4 distinct phases defined in order to effectively identify the business cycle phase.

where $\varepsilon_{St} \sim N(0, \sigma_{St}^2)$, $\mu_{St} = \mu_0 + \mu_1 S_t$, $0 < \mu_1$, and $S_t = \{0,1\}$

(Regional Phase Identification using Regional r Business Activity Index, f_t^r)

$$f_t^r = \mu_{Srt}^r + \varepsilon_{Srt}^r \tag{4}$$

where $\varepsilon_{Srt}^r \sim N(0, \sigma_{Srt}^{r\ 2})$, $\mu_{Srt}^r = \mu_0^r + \mu_1^r S_{rt}$, $0 < \mu_1^r$, and $S_{rt} = \{0,1\}$

Equations (3) and (4) are basically the same except for the regional notation *r* in equation (4). However, the probability process that drives the regional phase switching is assumed to be dependent on the national level phase. Thus, the structure of the transition matrices associated with the regimes are different for the national and for the regional economies, as shown in equations (5) and (6).

(National Phase Transition Matrix)

$$\begin{pmatrix} p_{00} & p_{01} \\ p_{10} & p_{11} \end{pmatrix}, \text{ where } p_{ij} = \Pr[\, S_t = j \mid S_{t-1} = i \,] \tag{5}$$

(Regional Phase Transition Matrix)

$$\begin{pmatrix} p_{r\,00}^s & p_{r\,01}^s \\ p_{r\,10}^s & p_{r\,11}^s \end{pmatrix}, \text{ where } p_{r\,ij}^s = \Pr[\, S_{rt} = j \mid S_{r\,t-1} = i,\ \ S_t = s \,],\ s = \{0,1\} \tag{6}$$

In other words, depending on the national cycle phase,[6] [7] the transition probability of a regional cycle phase also changes. If the transition matrix does not change depending on the national

[6] The regional phase transition is assumed to be dependent on the current state of the national phase (S_t) instead of the past state of the national phase (S_{t-1}). This is because 1) for most of the cities, their business cycle tends to lag the national business cycle, and consequently 2) the VAR granger causality test largely rejects the null hypothesis that the regional business cycle Granger-causes the national business cycle. In this sense, the current national phase state is assumed to be exogenous to the current transition probability of regional business activities.

[7] Since many of the national economic indicators that are used in constructing the national business cycle index are aggregated series of regional economic indicators, the assumption that the national business cycle phase transition dynamics are independent of the regional business cycle phases is somewhat unrealistic. However, in this paper, the national phase transition is nevertheless assumed to be look like equation (5) based on the argument in previous chapter that the unobserved state of the national economy is mostly determined by non-regional factors such as monetary/fiscal policy, international commodity markets and conglomerates business decisions and innovations.

cycle phase, then the regime switching probability will be the same ($H_0 : p_{ij}^0 = p_{ij}^1$), but for all of the MSAs, the testing results reject this null hypothesis.[8]

An additional feature of the above model is that it accounts for the heteroskedasticity of the uncertainty in each phase. Since the volatility of the contraction phase is typically larger than that of the expansion phase, having the same volatility measure in each phase can exaggerate the duration of the expansion phase. A Heteroskedasticity augmented Markov-switching Model can remedy this problem by allowing each phase to have different range of fluctuations.

4.2 Data Description

To represent the national economic activity, the Chicago Fed. National Activity Index (CFNAI) was used. For the regional counterparts, the first principal components of five monthly regional time series from Bureau of Labor Statistics (BLS) were used. For the cross sectional comparison purposes, the series are normalized to have zero means and unit variances. For the regional units, the top 20 MSAs in terms of 2011 Gross Metropolitan Product (GMP) were selected for the analysis. The list of the cities is provided in table 1.

<< Insert table 1 here >>

Each of the MSA business cycle measures (economic activity index) was constructed from the five monthly series – unemployment rate and employment in manufacturing, retail, professional & business, and leisure & hospitality – using a principal component analysis. Since some of the observations exhibit abnormal deviations from the trend, those observations that exhibit more than five standard deviations away from the trend were selectively deleted. For example, in 1996 July and August, the Olympic games in Atlanta caused some disturbances in the city's

[8] The resulting phase probability, S_{rt}, is not very much different even when we use a conventional single-level structure phase transition matrix. The only difference between the multi-level structure Markov-switching model and the single-level structure Markov-switching model is the transition matrix itself.

employment series. Usually, 2~5 observations for Miami, Seattle, San Francisco, Atlanta, San Jose, Detroit, San Diego and Baltimore are way off from the trend. Although, there are many pre-estimation smoothing techniques, for example, Crone (2005) used the Census Bureau's ARIMA X11 to smooth some data series, this kind of smoothing technique can eliminate some important information about regional economic behavior reflected in the irregular part of the economic activities described in figure 1. Instead, for those cities noted, some suspected observations (one or more shifts in the level of the business activity index series in a single month that may be the result of a change in the current population sample) were deleted. Those deleted observations are listed in table 2.

<< Insert table 2 here >>

After the deletion, the series were seasonally adjusted using U.S. Census ARIMA X12. Then, the first principal component for each city is derived from the five series using the IPCA imputation algorithm[9] to represent the business cycle measure. Applying the dating scheme described in the previous section on this business cycle measure, the probability of the phase being in an expansion is derived.

4.3 Phase Identification Results

Equations (3) ~ (6) are estimated using a Gibbs sampling procedure[10] in WINBUGS.[11] The Gibbs sampler draws iteratively from the conditional posterior distribution of each parameter

[9] For the detailed description of IPCA algorithm, refer to Imtias *et al.* (2008).

[10] The priors for the parameters are specified as below:

μ^r_{Srt} and μ_{St} are given an improper normal prior with mean 0 and precision 0.0001,

σ_{St} and σ^r_{Srt} are given an improper inverse gamma prior with parameter (0.0001,0.0001), and

$p_{i0} = 1 - p_{i1}$ and $p^s_{r\,i0} = 1 - p^s_{r\,i1}$ are given an improper uniform prior *Unif*(0,1).

The state parameters, *S* and *Sr* are drawn from Bernoulli distribution.

given the data and the rest of the parameters drawn from the previous iteration. To ensure convergence, the first 10,000 draws were discarded. Also, every 10th draw of the samples is used for the estimation of the posterior distributions to eliminate the autocorrelation between iterations. The final sample size is 10,000. The estimated phase probabilities are provided in figure 3.

<< Insert figure 3 here >>

To depict some features about the regional cycle phase, it can be seen that the shapes of the regional cycle phases are almost the same with few exceptions. For example, during the sample period, there are three distinct national contraction periods, in 1990~1991 (oil price shock, 1st recession), in 2001 (dot-com bubble burst, 2nd recession) and in 2008~2009 (sub-prime mortgage crisis, 3rd recession). Although, many cities entered into a regional contraction later than the national contraction, largely, the timing of the regional contraction phase approximately coincides with the national contraction. This indicates that the cyclical phases of regional economies are closely related to the national cycle phase. Some exceptions are Houston in early 1999 and Atlanta, Miami and Denver in early 2003.

The contraction period of Houston in early 1999 was due to the oil price cut after OPEC decided to raise its quota by 10% following the Asian financial crisis. Since the Houston economy is heavily dependent on the energy industry, the drop in the oil price could have hurt the performance of the Houston economy. This result concords with the previous study on the regional business cycle heterogeneity by Park and Hewings (2012), that asserted that the sectorial composition of the regional economies were the main source of regional heterogeneity.

[11] Bayesian Inference Using Gibbs Sampling for Windows

On the other hand, the contraction period of Atlanta, Miami and Denver in early 2003 came shortly after the economic recovery after the 2nd national recession. For the same period, New York, Los Angeles, Minneapolis, Phoenix, San Diego, Portland and Baltimore were experiencing expansion, but the estimated probability of being in an expansion phase for those cities was less than 90%. Also, for the same period, Chicago, Houston, Dallas, San Francisco, Boston and San Jose were experiencing a recession that was prolonged after the 2nd national recession. This seems to imply that the national economic recovery in year 2002 that was propagated among cities generated a temporary or weak effect in some metropolitan areas.

In sum, almost every city has experienced the same cycles, and regional economies are heterogeneous only in terms of the (1) timing and the duration depicted by the phase transition dynamics, and (2) the average growth rate in each phase. These findings concord with Hamilton and Owyang (2012)'s study of state-level business cycles wherein they noted that "[t]he primary differences we find across states come down to timing – when did the recession begin and end for that state – and not whether the state was able to avoid national downturn altogether. This suggests to us that although recessions are different in terms of their causes, there is something similar about the event itself. We would propose that a salient characteristic of a recession is the co-movement across states and the eventual tendency for the entire nation or at least a very large region to experience contraction at the same time."

To check whether the phases are distinctively identified, the growth rate and the volatility differences were tested. As can be seen in table 3, the average growth rate of the expansion phase and that of the contraction phase is positive and negative respectively, and the differences are significantly different from the null at the 95% confidence level.

<< Insert table 3 here >>

Also, the volatility measures are significantly different for most of the cities except for a few (Washington, Philadelphia, Atlanta, Miami and Phoenix). The results are presented in table 4.

<< Insert table 4 here >>

4.4 Phase Transition Dynamics

Depending on the national cycle phase, the estimated Markov transition matrices of MSAs are different, implying that the regional phase transition is dependent on the national phase. The Markov phase transition matrices estimated from the equations (3) ~ (6) are presented in table 5.

<< Insert table 5 here >>

Propagation of National Cycle Phase into Regional Economies

One of the findings is that when the national economy and the regional economy are in the same phase, the regional phase tends to remain in this phase. For example, when the national economy and the regional economy are both in expansion phases, the regional phase tends to stay in the expansion phase with probability of 98% ~ 99%. It is also similar for the regional contraction period; the regime persists with probability of 93%~96%.

However, when the national and regional phases do not coincide, the probability of the phase switching is mostly lower when the national phase is in expansion, although the probability varies significantly depending on the city. In other words, the propagation of the national recession is more rapid and stronger than that of the national expansion. For example, when the Chicago economy is in contraction, and the national economy is in expansion, the transition probability that Chicago economy will switch to an expansion phase is 20%. On the contrary, when Chicago economy is in expansion, and the national economy is in contraction, the transition probability that Chicago economy will enter into a recession is 71%. For all of the cities except for Seattle, Detroit and Portland, the speed of propagation of the national phase is faster for the contraction phase.

Regional Phase Susceptibility against the National Phase Transition

To test whether the Markov transition matrices of MSAs are different depending on the national cycle phases, two hypotheses were tested: $H_0\text{: A} - B = 0$ (the probability of staying in an expansion phase is the same regardless of the national cycle phase) and $H_0: C - D = 0$ (the probability of staying in a contraction phase is the same regardless of the national cycle phase). The test results are provided in table 5. For all cases, when the regional economy is initially in expansion, the transition probability differs significantly depending on the national phase (reject $H_0\text{: A} - B = 0$). On the contrary, when the regional economy is initially in contraction, the transition probability does not differ much (cannot reject $H_0: C - D = 0$) except for Washington, Philadelphia, Atlanta, Miami and Phoenix.

These results might be due to the asymmetric phase transmission channel from the national economy to the regional economy depending on the cycle phase of the regional economy. For example, when a regional economy is in an expansion phase, the reaction to the national contraction should be prompt since if a business reacts against the national recession in a causal way, the business could be fatally harmed. On the contrary, when a regional economy is in a contraction phase, the business should react carefully to the national expansion to avoid the risk associated with the false judgment on the national cycle phase. In other words, the regional economies are more responsive to the aggregate market atmosphere during their expansion phase.

City-level Differences

Although, most of the cities exhibit similar phase transition dynamics, the speed of the national phase propagation implied in the transition matrix is different across cities. While all of the cities coincide or lag the national cycle, some catch up the national cycle almost promptly, while others are lagging significantly behind the national cycle when the national cycle and the regional cycle do not coincide. As presented in table 6, some metropolitan economies, such as New York, Los Angeles, Houston, Dallas, San Francisco, Boston and San Jose, take more than half a year on average to recover from contraction even when the national economy is in an expansion phase. In contrast, most of the economies take just 1~2 months to enter into contraction when the national economy is in contraction phase. An exception is Houston where the speed of national phase propagation is the slowest, probably because Houston is an energy-industry city.

<< Insert table 6 here >>

This difference between transition probabilities might be due to the industry composition of the cities, as Park and Hewings (2012) noted. Since the different industry sectors occupy different positions in the value chain of the production cycle, it might be the case that the cities with larger manufacturing sectors might more promptly react to the national business cycle phase transition. In addition, the position in the value chain of establishments within a metropolitan area (early transformation as opposed to production of the final product) may also help explain the different temporal responses to national business cycle movements. Some other explanations can be demographic composition or the city size, but a clear answer was not provided in this paper; this unsolved question is left for future research.

5. Impulse Response Analysis of Regional Business Cycle

In the previous section, it was revealed that the national phase affects the transition dynamics of the regional cycle phase. As shown in figure 1, the irregular part of the business cycle measure (the original measure net of the cycle trend component) also contains important information about national-regional interactions. Since, at a glance, figure 3 also shows that most of the regional economies exhibit asymmetric performances depending on their phases, one might conjecture that the national factor loadings or the impact transmission structure will also be asymmetric depending on the regional cycle phases.

The usefulness of accounting for this asymmetry in business cycles is that by separately identifying the factor loadings for each business cycle phase, the asymmetric effect of a policy impact can be understood more specifically. For example, if the national factor loadings are more dominant in a contraction period, the national policy impact should be greater for that period, and vice versa.

This asymmetric national policy impact is in accordance with historical experiences as well. Since most of the expansionary monetary/fiscal policy effects in a national recession aim to "alter" the pessimistic economic expectations of the market participants, while contractionary monetary/fiscal policy in national expansion phase aim to "mollify" too much optimism, the magnitude of impact should be asymmetric depending on the cycle phase. For example, the same market interest rates might be regarded as "high" in a contraction period, and "low" in an expansion period, having different effect on lending and depositor behaviors. Thus, it can be expected that the shock transmission mechanism in an expansion phase and that in a contraction phase will be different because of the differences in market participants' behavior.

In order to decompose the idiosyncratic behavior of the regional economy into a national component and a regional component, a multi-level structure model was adopted for the identification of the factor loadings.

5.1 Identification of the National Factor Loadings for MSAs

After the identification of the business cycle phases, the regional economic activities (f_t^r) are analyzed in a multi-level structure model, as shown in equation (7):

$$f_t^r = \mu_{Srt}^r + \alpha_{Sr}^r(f_{t-1}^r - \mu_{Srt-1}^r) + \beta_{Sr}^r(g_t - \mu_{St}) + \varepsilon_{Srt}^r,\ \varepsilon_{Srt}^r \sim \mathrm{N}(0, {\sigma_{Sr}^r}^2) \quad (7)$$

where S and Sr: cycle phase notation of national economy and region *r* economy respectively,

μ_{Srt}^r: average growth rate of regional *r* economic activity at *t* given state Sr,

μ_{St} : average growth rate of national economic activity at *t* given state S,

α_{Sr}^r: lagged regional factor loading of regional *r* given state Sr,

β_{Sr}^r: national factor loading of regional *r* given state Sr,

μ_{Srt}^r, μ_{St}, S_{rt} and S_t are assumed to be predetermined before the factor loadings identification, thus given at the phase identification stage.

In equation (7), the national component, g_t, is assumed to be an exogenous shock to the regional performances based on Chung (2013)'s findings. The national counterpart of equation (7) is obtained using equation (8):

$$g_t = \mu_{St} + \alpha_S(g_{t-1} - \mu_{St-1}) + \varepsilon_{St},\ \ \varepsilon_{St} \sim N(0, {\sigma_S}^2) \quad (8)$$

where α_S is the coefficient for the lagged national business cycle measure given state S.

Tests were also made to see whether the parameters are different depending on the cycle phase.[12] The results are presented in table 7.

<< Insert table 7 here >>

As expected, the national business activity measure (CFNAI) exhibits a significant level of asymmetry. The volatility of the expansion phase is significantly smaller than that of the

[12] Although, the original identification of the business cycle phase has already incorporated in different variances for each phase, at this stage of analysis, the sources of shock on each regional economy are decomposed into national component + its own regional lag + idiosyncratic component. Thus, the variance measured in equation (7) represents the variance of idiosyncratic part of the regional series, while the variance measured in phase identification stage represents the total variance of the regional series.

contraction phase. Also, the autoregressive parameter is smaller in the expansion phase indicating that the response from a unit shock in the contraction phase will be significantly greater than that during the expansion phase. Thus, if the cost of the unit shock is approximately the same for an expansion phase and a contraction phase, an expansionary monetary/fiscal policy at the time of recession will have a greater effect in magnitude than a contractionary monetary/fiscal policy at the time of expansion.

On the contrary, regional business activity measures exhibit different results with respect to factor loadings. National factor loadings are mostly significant during a contraction phase, but they are insignificant for an expansion phase for many cities. The differences of the national factor loadings between an expansion phase and a contraction phase are not very significant except for Chicago and Washington mainly because of the low significance level of the national factor loadings during the expansion phase. Also, the volatility measures are not significantly different between expansion and contraction except for New York, Houston, Boston, San Jose and Baltimore. This implies that the asymmetry of volatility between phases mostly comes from the national factor loadings, i.e., uncertainties are mostly symmetric at the regional level. The coefficient for the lagged regional series, and the differences of this coefficient between phases are insignificant for some cities, but for those cities with significant values, the magnitudes are larger in a contraction phase than in an expansion phase, reflecting similar variations with the national measure. Also, the magnitude of the national factor loadings are much greater than the coefficient for the lagged regional factor, suggesting that the national factor loadings play a more important role in regional business cycle evolution than the autoregressive force of the regional factor itself.

5.2 Impulse Response Analysis

Impulse response functions against the unit shock at the national level were drawn from the estimated factor loadings. The responses are calculated in such a way that the response of the regional economy against the national shock should vary depending on the cycle phase of the national economy, and on the cycle phase of the regional economy. The estimated responses are presented in figure 5.

<< Insert figure 5 here >>

Figure 5 exhibits the regional channel of the propagation of the national shock. The positive national shock propagates into the regional economy more rapidly at the national contraction phase. One notable feature of this figure is that the magnitude of the response at the regional level is larger when the national economy is in contraction. This is because (1) the regional economic activity is mostly determined by the national economic activity, and (2) the national economy itself responds against the national shock to a greater extent during the contraction phase than during the expansion phase. One possible explanation is that the positive national shock at the national contraction phase alters the expectations of the market participants at the national level, and this positive effect propagates into the regional economy more rapidly at the contraction phase. On the contrary, the negative but same order of magnitude national shock during the national expansion phase does not have much of an effect on the market participants and thus the effect should be limited. Some exceptions are Houston and San Jose. Both of these regional economies' responses against the national shock when the national phase is in contraction and the regional phase is in expansion exhibit high levels of uncertainty. Since the Houston economy relies heavily on the energy industry, and considering that a high energy price is beneficial for the Houston economy, (but might increase the cost of the operations of other industries) it is natural that the response of Houston economy should be sometimes the opposite of other economies against the national economic impact. San Jose also exhibits a similar response against the positive national shock. Supposedly, the industry mix or the relative position in the production chain might affect the regional response against the national shock.

6. Conclusion

One of the main difference of this papers conclusion compared to the previous literature is that the national business cycle phase can be a more important factor in predicting the evolvution of a regional economy. In most of the cities, the number of contraction and expansion phases in regional business cycles is the same as that of the national business cycle, suggesting that the regional business cycle phase only differs from the national business cycle in terms of the duration and the timing, implying that it is difficult to find a regional cycle that is independent of the national cycle. In section 4, the results revealed that the regional business cycle phases are so heavily dependent on the national business cycle phase that when a regional cycle phase does not correspond to the national cycle phase, they have tendencies to follow the national cycle phase within a short period of time. Although, Harding and Pagan (2002) proposed the concordance measure to represent the degree to which two business cycles are in sync by calculating the proportion of time that the national economy and the regional economy are in the same phase,[13] this measure can be misunderstood if we take it to represent the degree of dependency of the regional economy on the national economy since greater differences in timing and duration do not imply more independence from the national cycle.

[13] The concordance of the region i cycle and the U.S. national cycle can be expressed as below:

$$C_{i,US} = \frac{1}{T}\sum_{t=1}^{T}[S_{i\,t}\,S_{US\,t} + (1 - S_{i\,t})(1 - S_{US\,t})]$$

where $S_{i\,t}$ is the probability of region i being in an expansion phase at time t.

Another finding is that the national phase transmission or the propagation of the market effects into the regional economies are asymmetric. Although, the transition probabilities are different for each city, the national pessimism alters the phase transition dynamics of the regional economies more dramatically than the national optimism, and the regional economies catch up the national contraction phase more rapidly than during the national expansion phase.

Finally, the results revealed that the regional economies respond differently to a national impact in expansion as opposed to a contraction phase. Although there was regional heterogeneity in terms of national/regional factor loadings, in most of the cases, the cumulative impulse response is greater in a national contraction phase than in a national expansion phase. This result implies that an expansionary monetary/fiscal policy is more effective in a contraction period than in an expansion period, and likewise, a contractionary monetary/fiscal policy does not harm the regional economy in a national expansion period as much as it does in a national contraction period.

In this perspective, the phase-augmented regional business cycle analysis can provide useful information regarding the regional cycle phase identification and the impact analysis. For example, a temporary drop of the business activity index can confuse the users of the index, but the Markov-switching model can provide a statistical guide to determine which phase the economy is in. Also, a policy impact at the local level or one at the national level can be differently analyzed again depending on which the cycle phase the regional economy is in.[14]

However, questions regarding the causes of the differences of the regional business cycle phase transitions and the asymmetric responses against the national shock still remain to be explored. As shown earlier, some cities react more promptly against the national phase transition than

[14] Appendix 1 provides an example of usage of this analysis on Chicago Metropolitan Area.

others, and some cities are responding more sensitively against the national shock than others. These differences could be attributed to the different industry composition as Park and Hewings (2012) noted, but more elaborated study on this matter remains as a future research. Finally, the results suggest that the national factor loadings play a more important role in regional business cycle evolution than the autoregressive force of the regional factor itself creating a need to consider explicitly the multi-level dimensions in regional business cycle analysis.

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Table 1.

Top 20 MSAs in terms of 2011 GMP (Gross Metropolitan Product)

Cities	GMP rank in year										
	‘01	‘02	‘03	‘04	‘05	‘06	‘07	‘08	‘09	‘10	‘11
New York-Northern New Jersey-Long Island, NY-NJ-PA	1	1	1	1	1	1	1	1	1	1	1
Los Angeles-Long Beach-Santa Ana, CA	2	2	2	2	2	2	2	2	2	2	2
Chicago-Joliet-Naperville, IL-IN-WI	3	3	3	3	3	3	3	3	3	3	3
Washington-Arlington-Alexandria, DC-VA-MD-WV	4	4	4	4	4	4	4	4	4	4	4
Houston-Sugar Land-Baytown, TX	5	5	5	5	6	6	5	6	5	5	5
Dallas-Fort Worth-Arlington, TX	6	6	6	6	5	5	6	5	6	6	6
Philadelphia-Camden-Wilmington, PA-NJ-DE-MD	7	7	7	7	7	7	7	7	7	7	7
San Francisco-Oakland-Fremont, CA	8	8	8	8	8	8	8	8	8	8	8
Boston-Cambridge-Quincy, MA-NH	9	9	9	9	9	9	9	9	9	9	9
Atlanta-Sandy Springs-Marietta, GA	10	10	10	10	10	10	10	10	10	10	10
Miami-Fort Lauderdale-Pompano Beach, FL	11	11	11	11	11	11	11	11	11	11	11
Seattle-Tacoma-Bellevue, WA	13	13	13	13	13	12	12	12	12	12	12
Minneapolis-St. Paul-Bloomington, MN-WI	14	14	14	14	14	15	15	15	13	13	13
San Jose-Sunnyvale-Santa Clara, CA	18	20	20	18	18	17	17	17	17	16	14
Detroit-Warren-Livonia, MI	12	12	12	12	12	13	13	14	15	15	15
Phoenix-Mesa-Glendale, AZ	15	15	15	15	15	14	14	13	14	14	16
San Diego-Carlsbad-San Marcos, CA	16	16	16	16	16	16	16	16	16	17	17
Denver-Aurora-Broomfield, CO	17	17	17	17	17	18	18	18	18	18	18
Portland-Vancouver-Hillsboro, OR-WA	28	28	28	25	26	21	21	20	20	19	19
Baltimore-Towson, MD	20	19	19	19	19	19	19	19	19	20	20

* Those 20 cities occupy about 47% of total U.S. GDP.

Table 2.

Deleted Observations

San Francisco	Jan.94, Retail and Professional & Business
Atlanta	Jul.96 and Aug.96, Retail, Leisure & Hospitality and Professional & Business
Miami	Sep.04 and Oct.04, Retail, Manufacturing, Leisure & Hospitality and Professional & Business / Nov.05 and Dec.05, Retail and Leisure & Hospitality
Seattle	Jan.91, Retail and Professional & Business / Jan.93, Leisure & Hospitality / Jul.95, Leisure & Hospitality / Jul.07, Retail and Leisure & Hospitality
San Jose	Jan.94, Retail, Manufacturing and Unemployment Rate / Dec.94, Jan.95, Feb.95, Manufacturing
Detroit	Jan.01, Professional & Business / Jan.09, Manufacturing and Professional & Business
San Diego	Jan.93, Jan.98, Retail, Manufacturing and Professional & Business

Table 3.

Growth Rate Asymmetry between Cycle Phases

	Average Growth Rate above/beyond the Historical Trend		A – B*		
	Expansion Phase (A)	Contraction Phase (B)	mean	2.5%	97.5%
National	0.2849	-1.7380	2.0230	1.5610	2.4700
New York	0.5871	-2.0420	2.6290	2.1310	3.1180
Los Angeles	0.6046	-1.6810	2.2860	1.8870	2.7010
Chicago	0.4959	-1.6630	2.1580	1.7650	2.6100
Washington	0.4406	-1.5530	1.9940	1.5300	2.4960
Houston	0.5799	-1.5040	2.0840	1.7190	2.4540
Dallas	0.6496	-1.8530	2.5030	2.1700	2.8240
Philadelphia	0.4630	-1.7110	2.1740	1.7170	2.6700
San Francisco	0.6132	-1.5920	2.2060	1.7730	2.7860
Boston	0.5494	-1.9080	2.4570	2.0490	2.8590
Atlanta	0.3755	-1.7890	2.1650	1.7100	2.5840
Miami	0.4102	-2.0840	2.4940	2.0040	2.9630
Seattle	0.3567	-2.0650	2.4220	1.8250	3.0740
Minneapolis	0.3626	-2.0040	2.3660	1.8340	2.9120
San Jose	0.6338	-1.9080	2.5420	2.1120	2.9810
Detroit	0.2791	-1.9440	2.2230	1.7550	2.6930
Phoenix	0.4800	-2.3510	2.8320	2.3150	3.3170
San Diego	0.3759	-1.2850	1.6610	1.2610	2.1440
Denver	0.4843	-2.0430	2.5270	1.9130	3.3780
Portland	0.4344	-2.6120	3.0460	2.1910	3.8340
Baltimore	0.3275	-1.2870	1.6140	1.1170	2.1130

* The test statistics for all of the cities are significant at 5% confidence interval.

Table 4.

Uncertainty Asymmetry between Phases

	Standard Deviations		A – B		
	Expansion Phase (A)	Contraction Phase (B)	mean	2.5%	97.5%
National	0.5879	1.1924	-0.6279	-0.9521	-0.3699
New York	1.0611	1.6884	-0.6468	-1.0210	-0.3275
Los Angeles	1.0132	1.4347	-0.4340	-0.7244	-0.1655
Chicago	0.9600	1.3042	-0.3571	-0.6356	-0.1177
Washington	1.1046	1.3141	-0.2277	-0.5977	0.0553
Houston	0.8704	1.3119	-0.4520	-0.7037	-0.2216
Dallas	0.9345	1.2000	-0.2769	-0.5428	-0.0508
Philadelphia	1.1161	1.3699	-0.2703	-0.5955	0.0086
San Francisco	0.8959	1.4426	-0.5619	-0.8864	-0.2481
Boston	1.0179	1.2955	-0.2913	-0.5745	-0.0466
Atlanta	0.9152	1.0703	-0.1734	-0.4589	0.0765
Miami	1.0881	1.1919	-0.1273	-0.5012	0.1586
Seattle	1.0048	1.3706	-0.3964	-0.8165	-0.0647
Minneapolis	1.0687	1.3959	-0.3526	-0.7336	-0.0362
San Jose	0.8658	1.5314	-0.6802	-0.9906	-0.4172
Detroit	0.9436	1.2617	-0.3431	-0.7093	-0.0636
Phoenix	1.0270	1.2736	-0.2725	-0.6214	0.0474
San Diego	0.9676	1.2449	-0.2932	-0.6134	-0.0275
Denver	1.0055	1.5497	-0.5709	-0.9939	-0.1878
Portland	1.1132	1.5996	-0.5522	-1.2300	-0.0439
Baltimore	1.0119	1.2913	-0.3028	-0.6867	-0.0007

* Shaded cities exhibit no significant difference of regional uncertainty between cycle phases

Table 5.

Markov Transition Matrix of MSAs

* $A = \Pr[S_{r\,t} = expansion \mid S_{r\,t-1} = expansion,\ S_t = expansion]$
$B = \Pr[S_{r\,t} = expansion \mid S_{r\,t-1} = expansion,\ S_t = contraction]$
$C = \Pr[S_{r\,t} = expansion \mid S_{r\,t-1} = contraction, S_t = expansion]$
$D = \Pr[S_{r\,t} = expansion \mid S_{r\,t-1} = contraction,\ S_t = contraction]$

National Phase		Expansion		Contraction	
		expansion	contraction	expansion	contraction
New York	expansion	0.99	0.01	0.41	0.59
	contraction	0.16	0.84	0.04	0.96
			mean	2.5%	97.5%
		A - B	0.59	(0.16	0.97)
		C - D	0.12	(-0.03	0.31)
		expansion	contraction	expansion	contraction
Los Angeles	expansion	0.99	0.01	0.41	0.59
	contraction	0.11	0.89	0.04	0.96
			mean	2.5%	97.5%
		A - B	0.58	(0.16	0.96)
		C - D	0.08	(-0.05	0.23)
		expansion	contraction	expansion	contraction
Chicago	expansion	0.99	0.01	0.29	0.71
	contraction	0.20	0.80	0.04	0.96
			mean	2.5%	97.5%
		A - B	0.70	(0.26	0.98)
		C - D	0.16	(-0.02	0.47)
		expansion	contraction	expansion	contraction
Wash-shington	expansion	0.99	0.01	0.34	0.66
	contraction	0.20	0.80	0.05	0.95
			mean	2.5%	97.5%
		A - B	0.65	(0.19	0.98)
		C - D	0.15	(-0.06	0.57)
		expansion	contraction	expansion	contraction
Houston	expansion	0.99	0.01	0.71	0.29
	contraction	0.10	0.90	0.06	0.94
			mean	2.5%	97.5%
		A - B	0.27	(0.05	0.66)
		C - D	0.04	(-0.15	0.16)

National Phase		Expansion			Contraction		
		expansion	contraction		expansion	contraction	
Dallas	expansion	0.99	0.01		0.45	0.55	
	contraction	0.12	0.88		0.04	0.96	
			mean		2.5%	97.5%	
		A - B	0.55	(	0.17	0.94	)
		C - D	0.08	(	-0.05	0.21	)
		expansion	contraction		expansion	contraction	
Phila-	expansion	0.99	0.01		0.39	0.61	
delphia	contraction	0.21	0.79		0.04	0.96	
			mean		2.5%	97.5%	
		A - B	0.61	(	0.18	0.97	)
		C - D	0.16	(	-0.03	0.50	)
		expansion	contraction		expansion	contraction	
San	expansion	0.99	0.01		0.48	0.52	
Francisco	contraction	0.11	0.89		0.04	0.96	
			mean		2.5%	97.5%	
		A - B	0.51	(	0.13	0.95	)
		C - D	0.07	(	-0.07	0.27	)
		expansion	contraction		expansion	contraction	
Boston	expansion	0.99	0.01		0.62	0.38	
	contraction	0.13	0.87		0.04	0.96	
			mean		2.5%	97.5%	
		A - B	0.37	(	0.07	0.87	)
		C - D	0.09	(	-0.04	0.25	)
		expansion	contraction		expansion	contraction	
Atlanta	expansion	0.98	0.02		0.32	0.68	
	contraction	0.54	0.46		0.04	0.96	
			mean		2.5%	97.5%	
		A - B	0.66	(	0.23	0.97	)
		C - D	0.51	(	0.08	0.94	)
		expansion	contraction		expansion	contraction	
Miami	expansion	0.98	0.02		0.33	0.67	
	contraction	0.64	0.36		0.04	0.96	
			mean		2.5%	97.5%	
		A - B	0.65	(	0.22	0.97	)
		C - D	0.60	(	0.19	0.95	)

National Phase		Expansion			Contraction		
		expansion	contraction		expansion	contraction	
Seattle	expansion	0.99	0.01		0.58	0.42	
	contraction	0.54	0.46		0.06	0.94	
			mean		2.5%	97.5%	
		A - B	0.41	(	0.07	0.92	)
		C - D	0.48	(	0.05	0.93	)
		expansion	contraction		expansion	contraction	
Minnea-	expansion	0.99	0.01		0.44	0.56	
polis	contraction	0.46	0.54		0.05	0.95	
			mean		2.5%	97.5%	
		A - B	0.55	(	0.15	0.96	)
		C - D	0.41	(	0.06	0.87	)
		expansion	contraction		expansion	contraction	
San	expansion	0.99	0.01		0.46	0.54	
Jose	contraction	0.14	0.86		0.05	0.95	
			mean		2.5%	97.5%	
		A - B	0.54	(	0.16	0.95	)
		C - D	0.09	(	-0.06	0.25	)
		expansion	contraction		expansion	contraction	
Detroit	expansion	0.99	0.01		0.38	0.62	
	contraction	0.77	0.23		0.05	0.95	
			mean		2.5%	97.5%	
		A - B	0.60	(	0.18	0.96	)
		C - D	0.72	(	0.29	0.97	)
		expansion	contraction		expansion	contraction	
Phoenix	expansion	0.99	0.01		0.45	0.55	
	contraction	0.30	0.70		0.05	0.95	
			mean		2.5%	97.5%	
		A - B	0.55	(	0.15	0.96	)
		C - D	0.25	(	0.01	0.55	)
		expansion	contraction		expansion	contraction	
San	expansion	0.99	0.01		0.42	0.58	
Diego	contraction	0.19	0.81		0.06	0.94	
			mean		2.5%	97.5%	
		A - B	0.57	(	0.16	0.96	)
		C - D	0.14	(	-0.09	0.68	)

National Phase		Expansion			Contraction		
		expansion	contraction		expansion	contraction	
Denver	expansion	0.99	0.01		0.50	0.50	
	contraction	0.26	0.74		0.04	0.96	
			mean		2.5%	97.5%	
		A - B	0.49	(	0.10	0.95	)
		C - D	0.21	(	-0.02	0.71	)
		expansion	contraction		expansion	contraction	
Portland	expansion	0.99	0.01		0.50	0.50	
	contraction	0.60	0.40		0.07	0.93	
			mean		2.5%	97.5%	
		A - B	0.49	(	0.15	0.92	)
		C - D	0.53	(	0.06	0.93	)
		expansion	contraction		expansion	contraction	
Baltimore	expansion	0.98	0.02		0.28	0.72	
	contraction	0.30	0.70		0.07	0.93	
			mean		2.5%	97.5%	
		A - B	0.70	(	0.26	0.98	)
		C - D	0.23	(	-0.08	0.77	)
		expansion	contraction				
National	expansion	0.98	0.02				
	contraction	0.10	0.90				

Table 6.

Average Months of the Regional Phase to catch up the National Phase

Cities	Contraction → Expansion (National Phase=Expansion)	Expansion → Contraction (National Phase=Contraction)
New York	6.4	1.7
Los Angeles	8.8	1.7
Chicago	4.9	1.4
Washington	4.9	1.5
Houston	10.0	3.5
Dallas	8.7	1.8
Philadelphia	4.8	1.6
San Francisco	8.8	1.9
Boston	7.7	2.6
Atlanta	1.8	1.5
Miami	1.6	1.5
Seattle	1.9	2.4
Minneapolis	2.2	1.8
San Jose	7.4	1.8
Detroit	1.3	1.6
Phoenix	3.4	1.8
San Diego	5.1	1.7
Denver	3.9	2.0
Portland	1.7	2.0
Baltimore	3.3	1.4

* These point estimates are calculated under the circumstance that the national cycle phase and the regional cycle phase do not coincide.

Table 7.

Factor Loadings of MSAs

Cities	Lagged Factor			National Factor			Standard Deviation		
	α_{exp}^{r}	α_{con}^{r}	$\alpha_{exp}^{r} - \alpha_{con}^{r}$	β_{exp}^{r}	β_{con}^{r}	$\beta_{exp}^{r} - \beta_{con}^{r}$	σ_{exp}^{r}	σ_{con}^{r}	$\sigma_{exp}^{r} - \sigma_{con}^{r}$
New York	-0.05	0.07	-0.12	1.96*	0.72*	1.25	1.02**	1.58**	-0.58**
Los Angeles	-0.08	0.15	-0.23	1.55	1.26**	0.29	0.97**	1.09**	-0.13
Chicago	-0.19**	0.30**	-0.50**	2.86**	0.96**	1.90**	0.88**	0.86**	0.02
Washington	-0.12	0.06	-0.17	3.00**	0.54**	2.46**	1.06**	1.16**	-0.12
Houston	0.05	-0.03	0.08	-0.23	0.83**	-1.06	0.82**	1.16**	-0.35**
Dallas	-0.16**	0.40**	-0.56**	1.49	0.46**	1.03	0.90**	0.97**	-0.08
Philadelphia	-0.12	-0.04	-0.08	1.24	1.01**	0.23	1.06**	1.12**	-0.07
San Francisco	-0.07	0.58**	-0.65**	-0.23	0.44*	-0.67	0.87**	1.03**	-0.17
Boston	-0.20**	0.18	-0.38**	0.55	0.22	0.33	0.97**	1.19**	-0.24**
Atlanta	0.03	-0.06	0.10	1.45*	1.00**	0.44	0.84**	0.75**	0.08
Miami	-0.09	0.28	-0.38*	1.43	0.67**	0.76	1.01**	0.87**	0.13
Seattle	-0.11	0.12	-0.23	1.30	0.97**	0.33	0.96**	0.87**	0.07
Minneapolis	0.00	0.25	-0.25	0.88	0.84**	0.04	1.02**	0.97**	0.03
San Jose	0.26**	0.63**	-0.37**	-0.52	0.29	-0.81	0.81**	1.08**	-0.28**
Detroit	0.08	0.11	-0.03	1.18	0.76**	0.43	0.89**	1.03**	-0.16
Phoenix	0.22**	0.09	0.14	1.53*	0.82**	0.71	0.95**	0.94**	0.00
San Diego	0.05	-0.06	0.10	0.56	1.25**	-0.69	0.93**	0.94**	-0.03
Denver	-0.18**	0.42**	-0.60**	1.11	0.63**	0.47	0.95**	1.13**	-0.19
Portland	-0.05	0.18	-0.23	1.90**	0.86**	1.04	1.04**	1.23**	-0.22
Baltimore	-0.22**	-0.24	0.02	1.08	0.69**	0.39	0.95**	1.19**	-0.26*
National	0.12*	0.69**	-0.57**	-	-	-	0.56**	0.81**	-0.27**

- exp : expansion phase, con : contraction phase

- **: significant at 5% confidence interval, *: significant at 10% confidence interval

Figure 1.

Dependency Structure of Regional Economy on National Economy

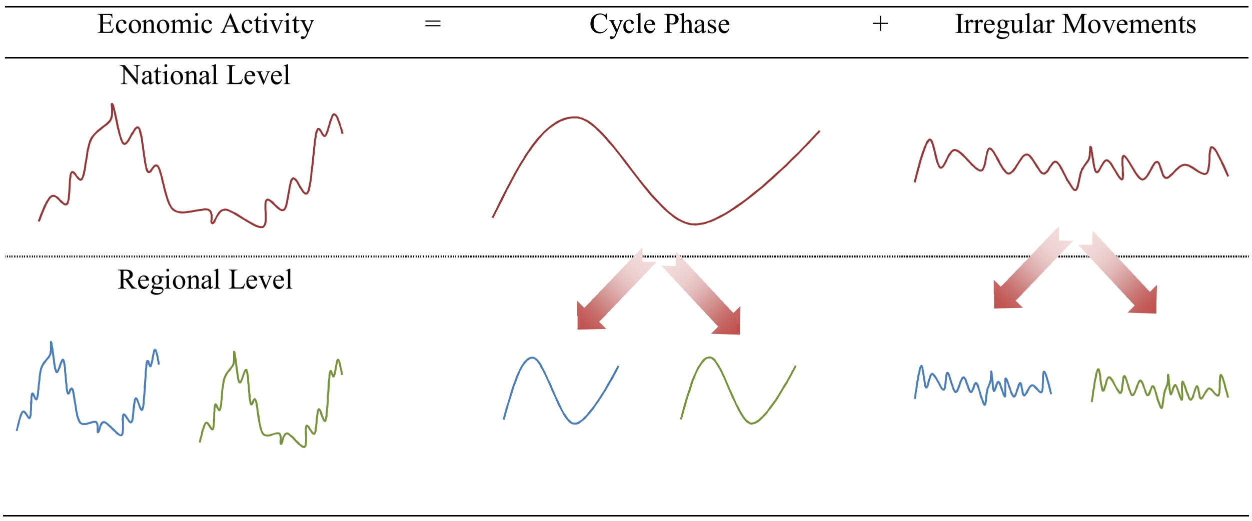


Figure 2.

Conceptual Comparison of Regional Shock vs. National Shock

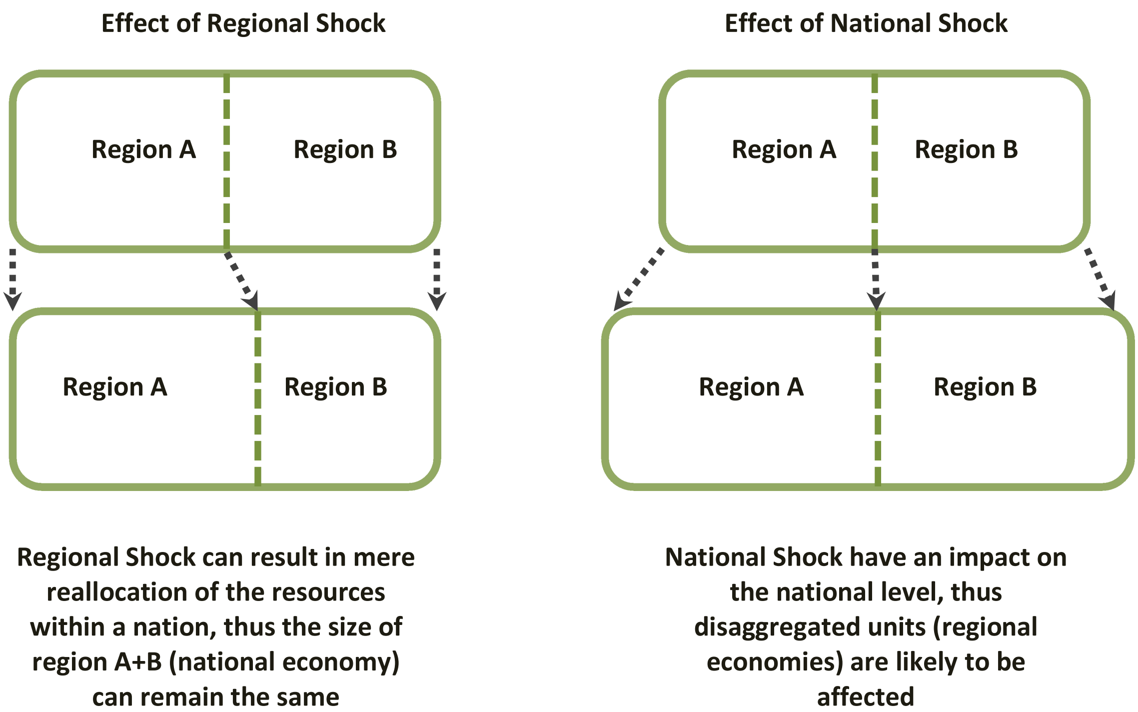


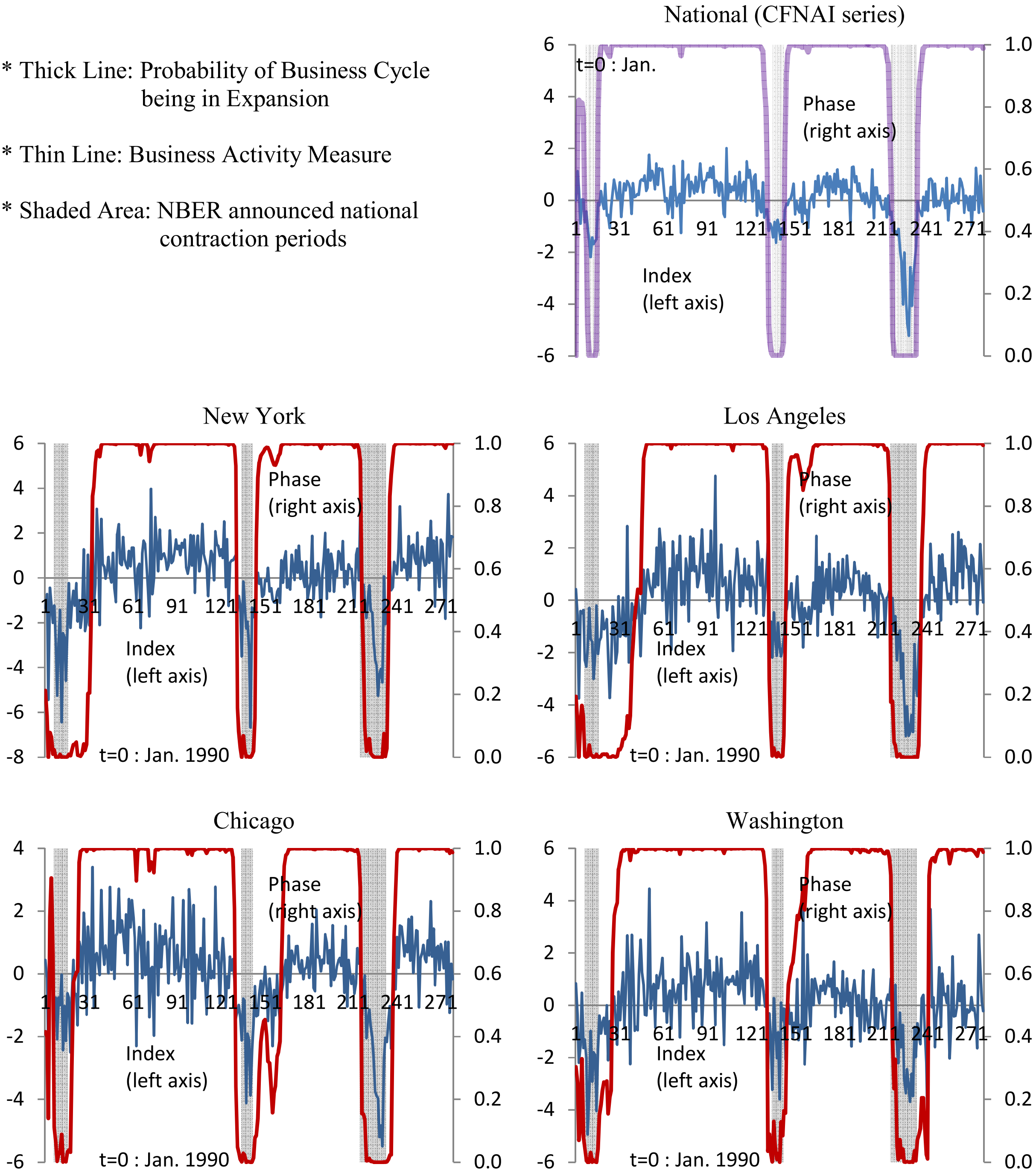
Figure 3.

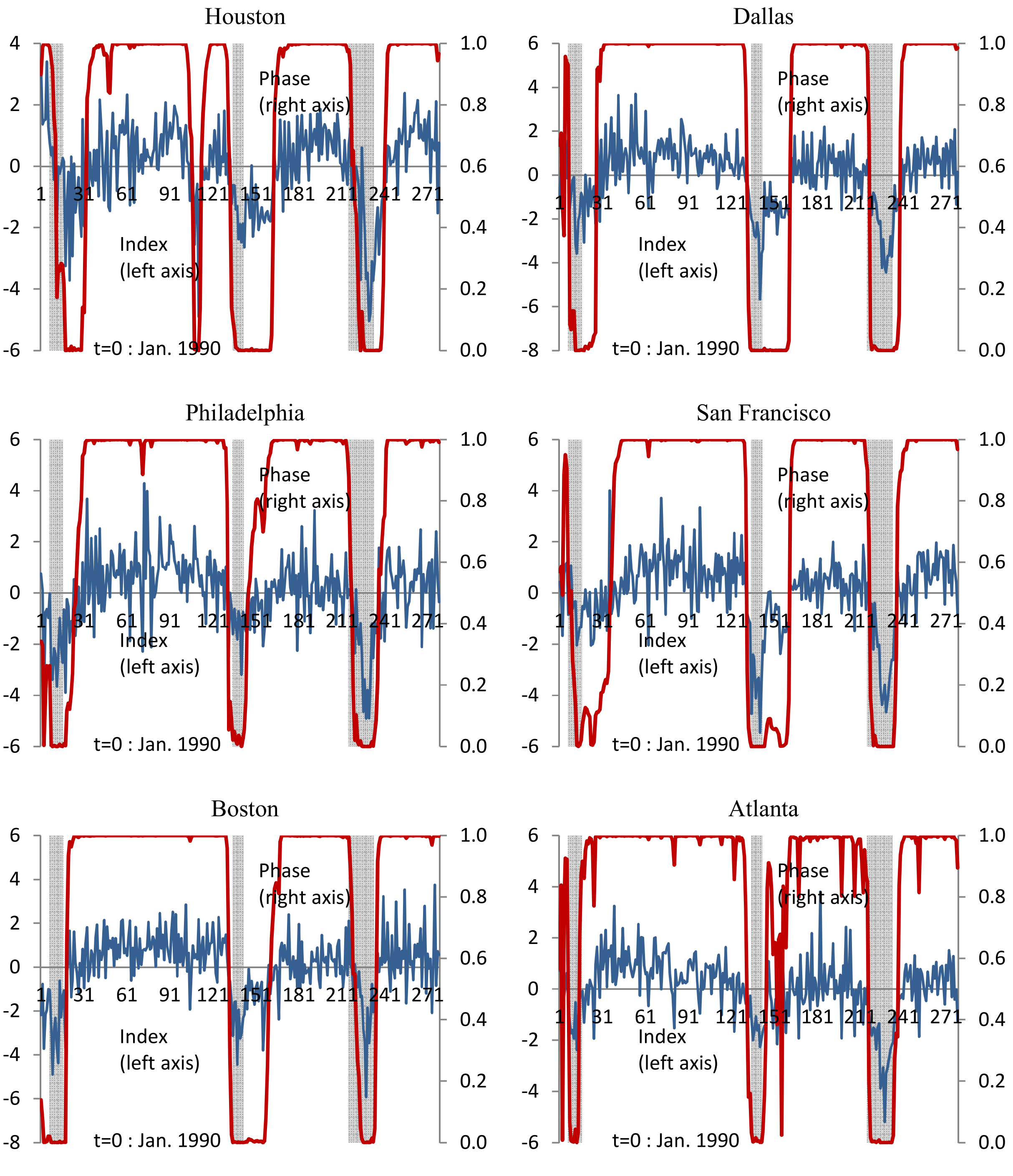
<u>Phase Identification Results</u>

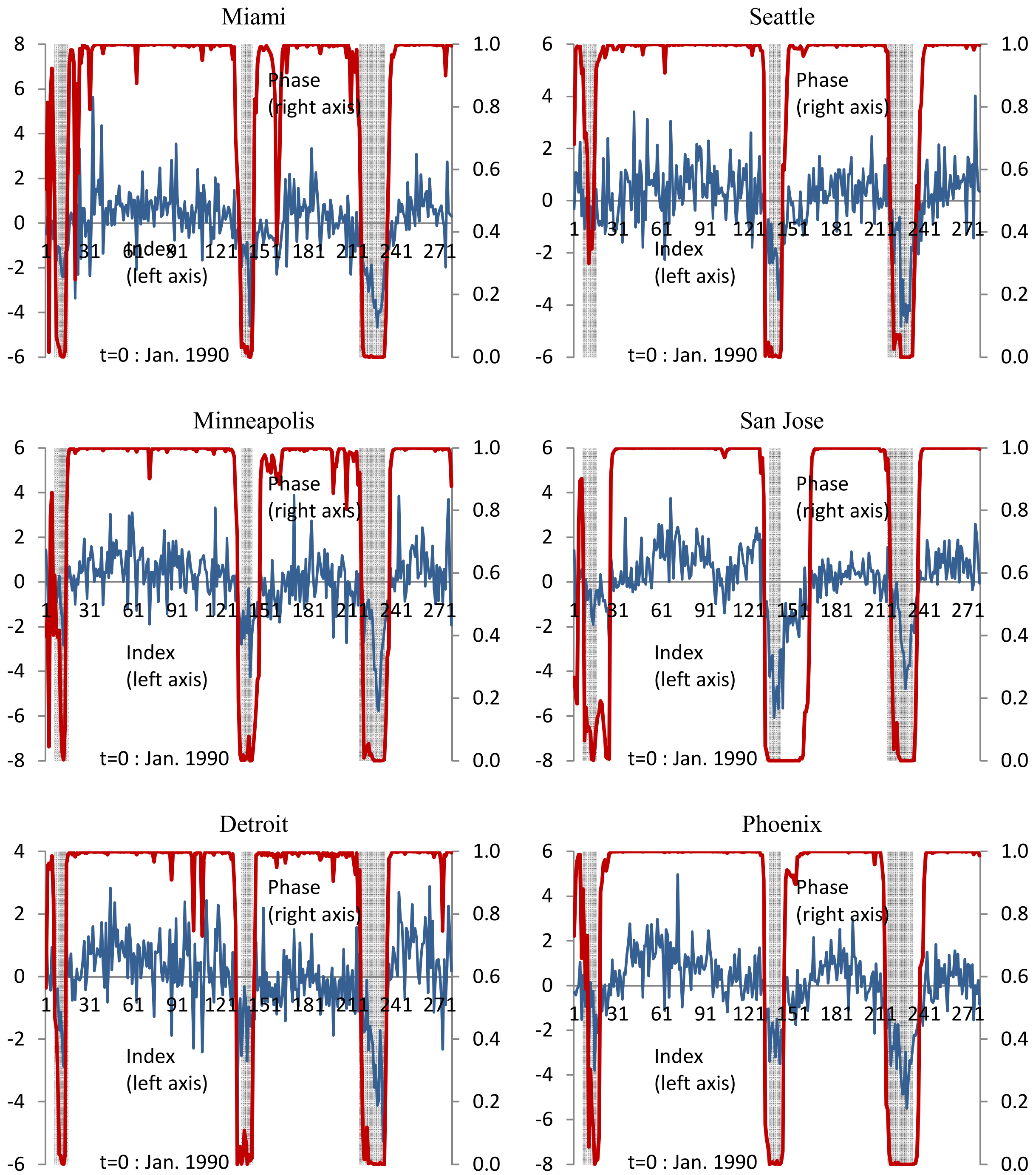
* Thick Line: Probability of Business Cycle being in Expansion

* Thin Line: Business Activity Measure

* Shaded Area: NBER announced national contraction periods




Houston
Phase
(right axis)
Index
(left axis)
t=0 : Jan. 1990
Dallas
Phase
(right axis)
Index
(left axis)
t=0 : Jan. 1990
Philadelphia
Phase
(right axis)
Index
(left axis)
t=0 : Jan. 1990
San Francisco
Phase
(right axis)
Index
(left axis)
t=0 : Jan. 1990
Boston
Phase
(right axis)
Index
(left axis)
t=0 : Jan. 1990
Atlanta
Phase
(right axis)
Index
(left axis)
t=0 : Jan. 1990


Miami
Seattle
Minneapolis
San Jose
Detroit
Phoenix
Phase
(right axis)
Index
(left axis)
t=0 : Jan. 1990
1
31
61
91
121
151
181
211
241
271

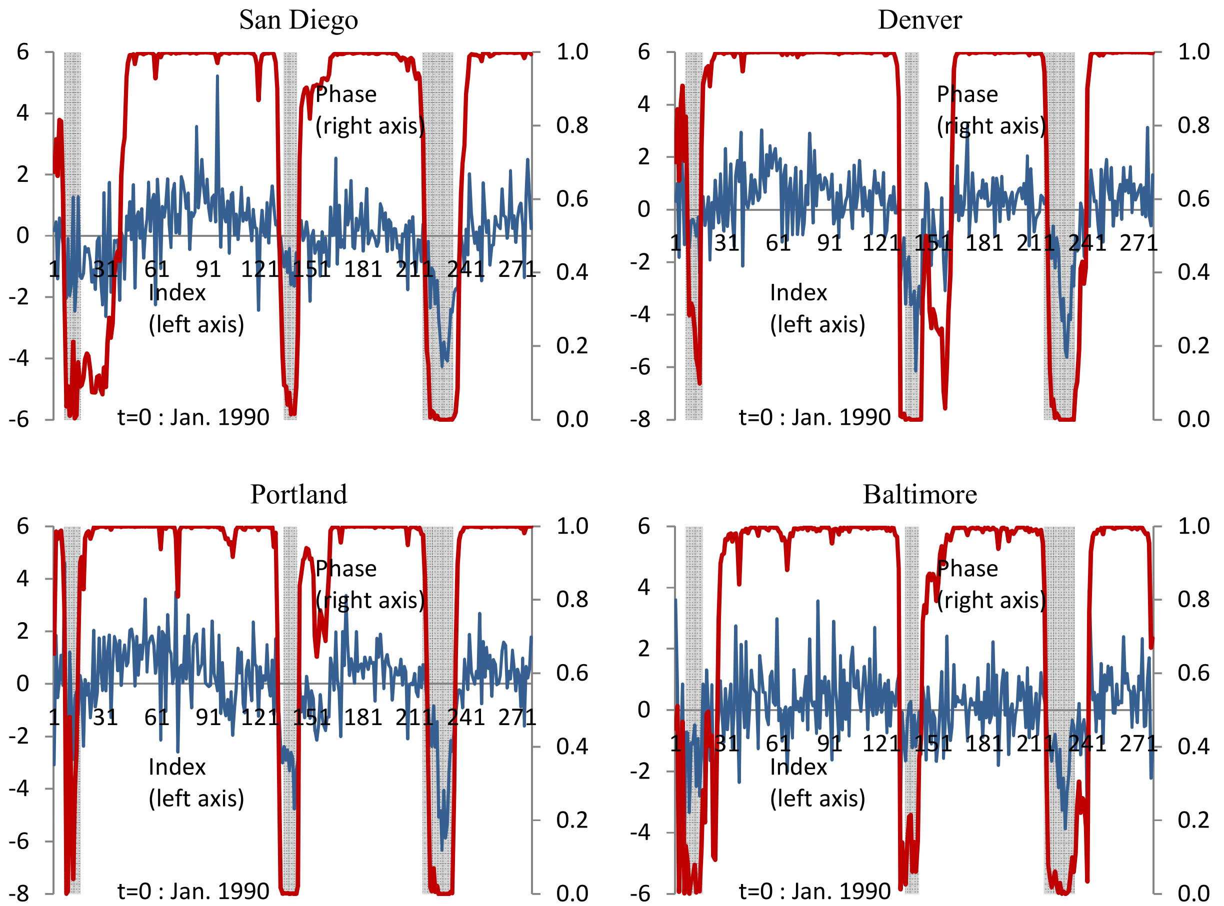
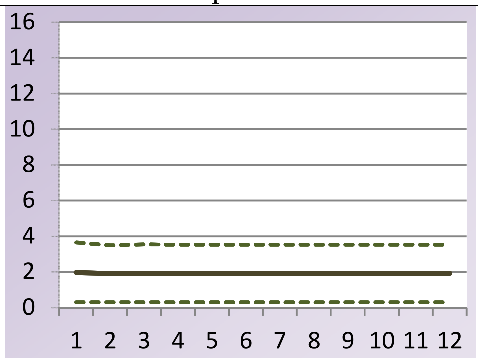
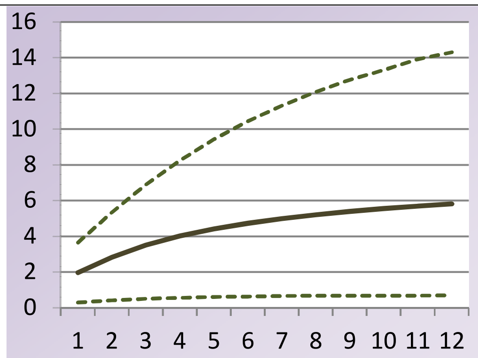
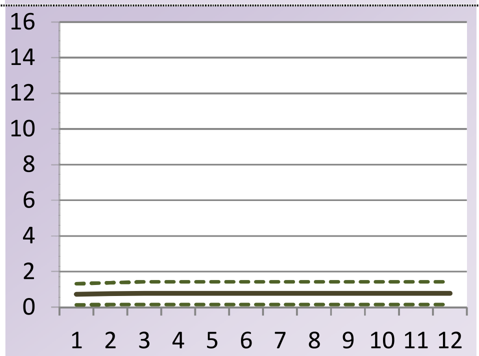
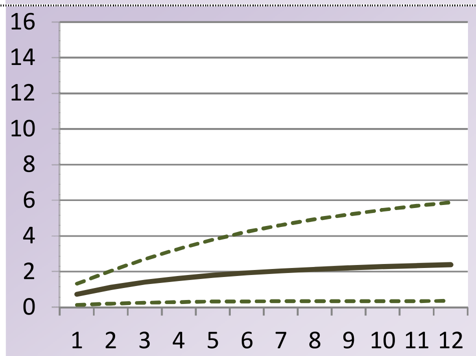
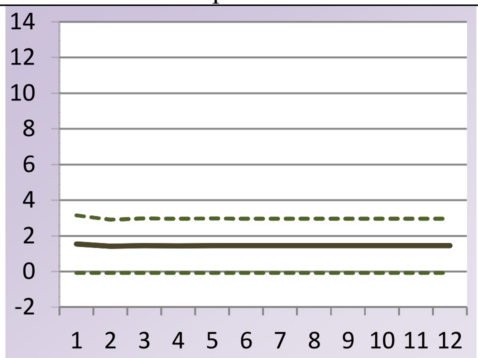
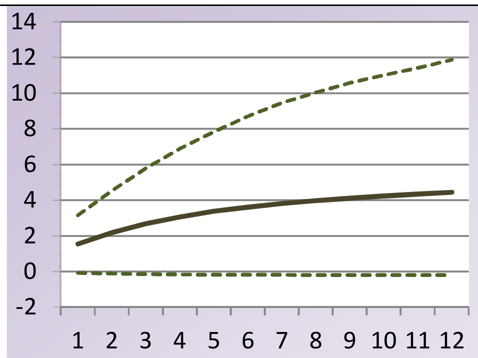
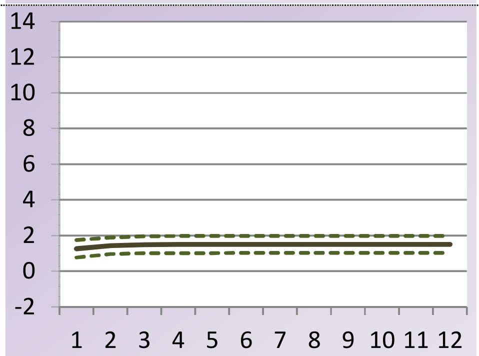
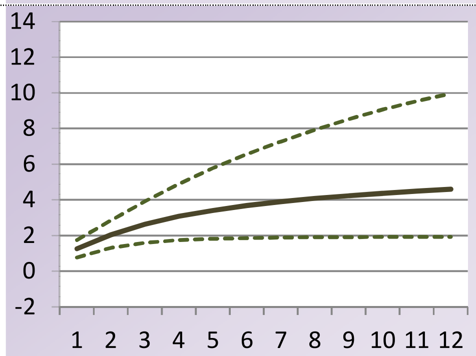

San Diego
Phase
(right axis)
Index
(left axis)
t=0 : Jan. 1990
Denver
Phase
(right axis)
Index
(left axis)
t=0 : Jan. 1990
Portland
Phase
(right axis)
Index
(left axis)
t=0 : Jan. 1990
Baltimore
Phase
(right axis)
Index
(left axis)
t=0 : Jan. 1990
1 31 61 91 121 151 181 211 241 271

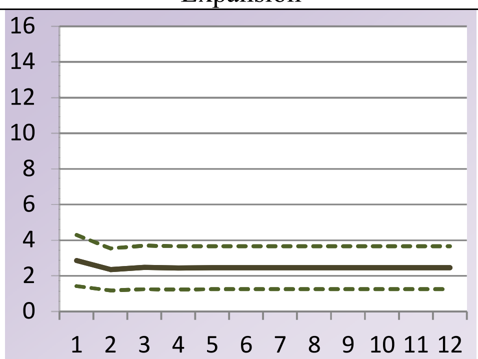
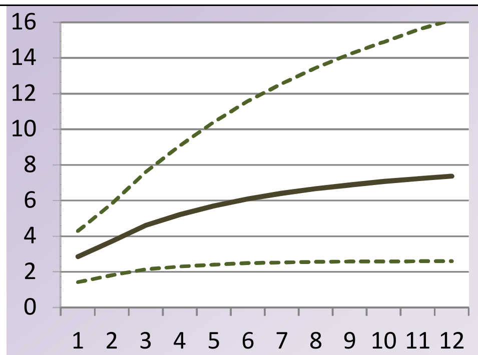
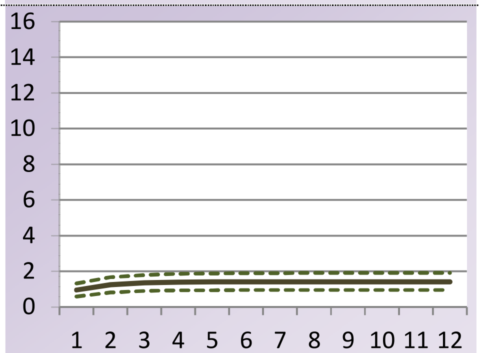
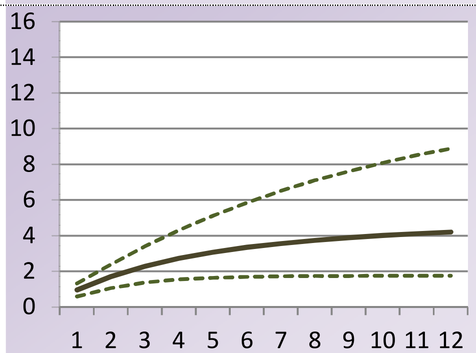
Figure 5.

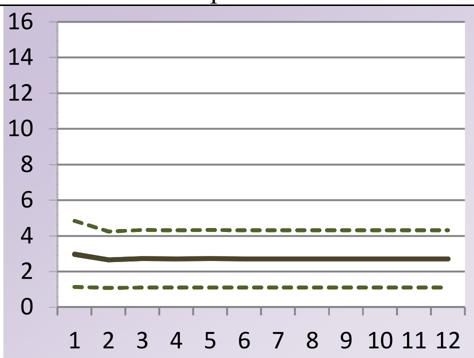
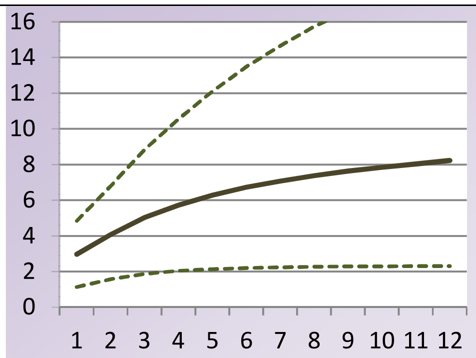
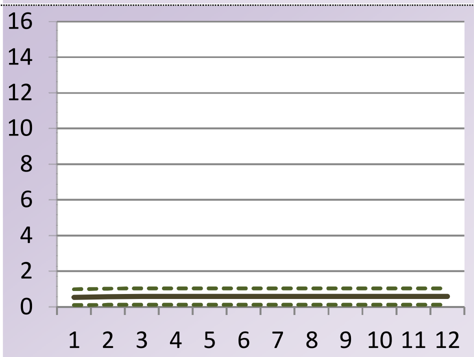
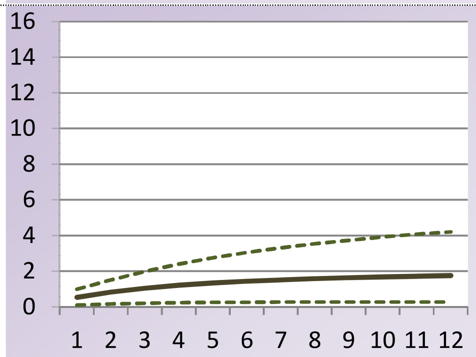
<u>Phase Dependent Impulse Response Functions for 20 MSAs</u>

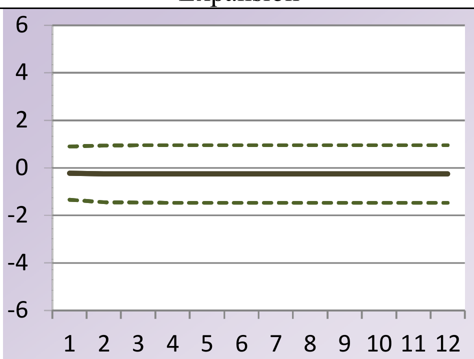
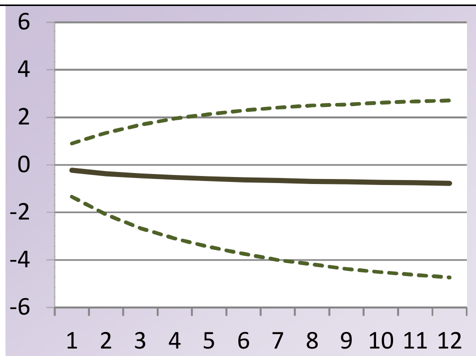
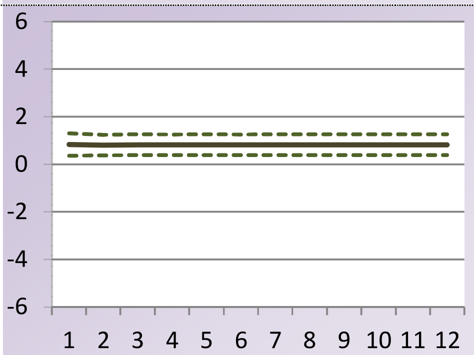
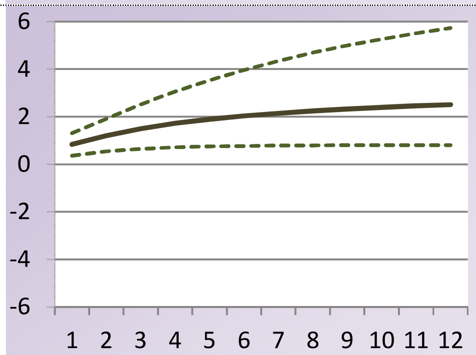
* Impulse: One standard deviation amount of positive shock at the national level

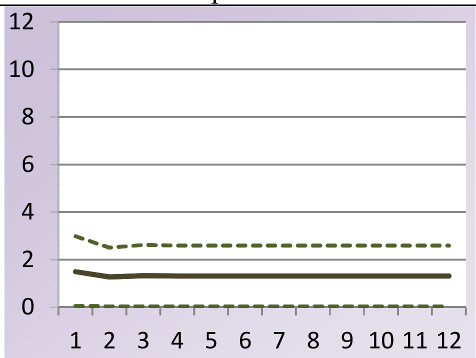
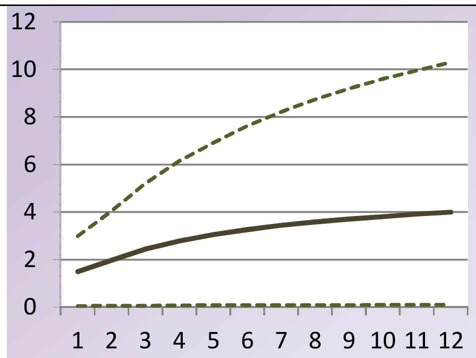
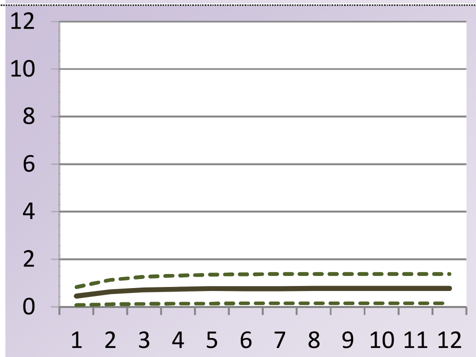
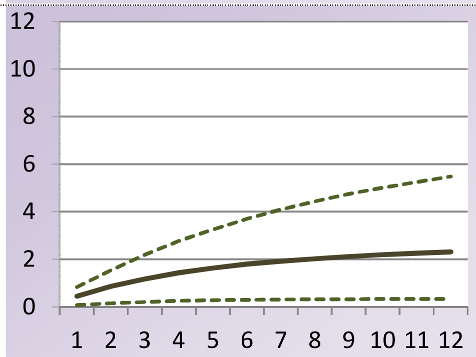
New York	National Phase: Expansion		National Phase: Contraction
Expansion		<	
Contraction		<	

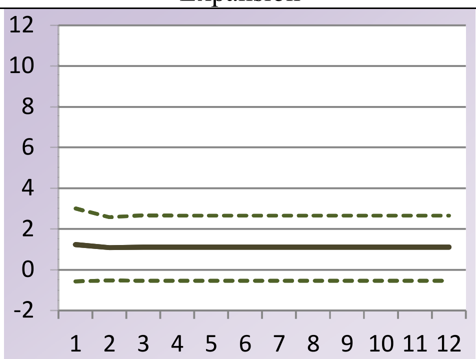
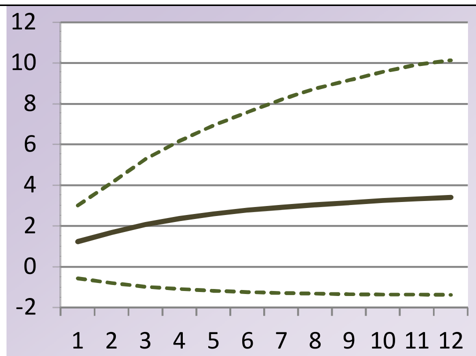
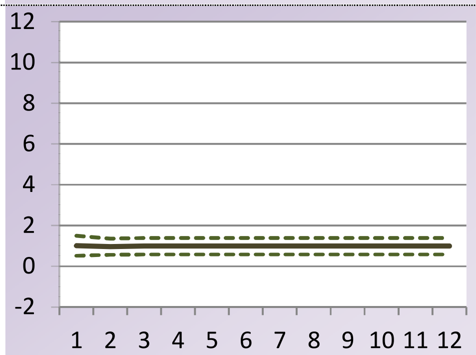
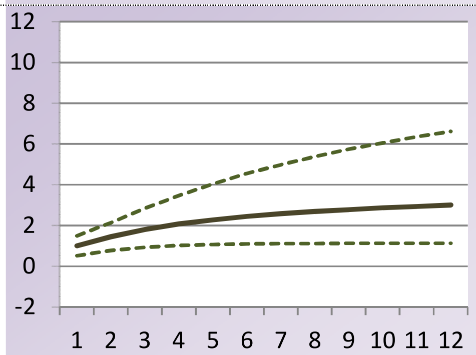
Los Angeles	National Phase		
	Expansion		Contraction
Expansion		<	
Contraction		<	

Chicago	National Phase		
	Expansion		Contraction
Expansion		<	
Contraction		<	

Washington	National Phase: Expansion		National Phase: Contraction
Expansion		<	
Contraction		<	

Houston	National Phase: Expansion		National Phase: Contraction
Expansion		?	
Contraction		<	

Dallas	National Phase Expansion		National Phase Contraction
Expansion		<	
Contraction		<	

Philadelphia	National Phase Expansion		National Phase Contraction
Expansion		<	
Contraction		<	

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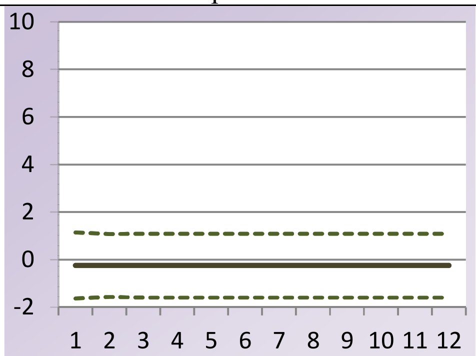
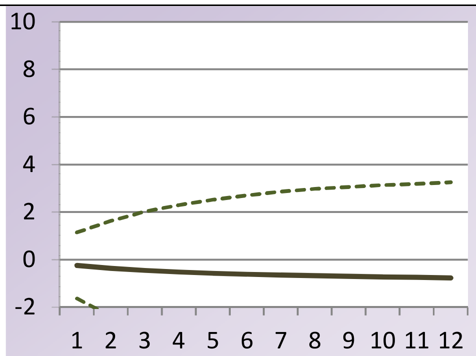
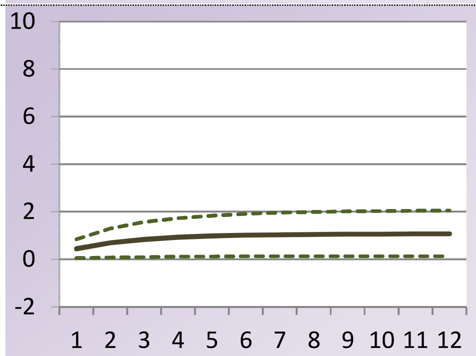
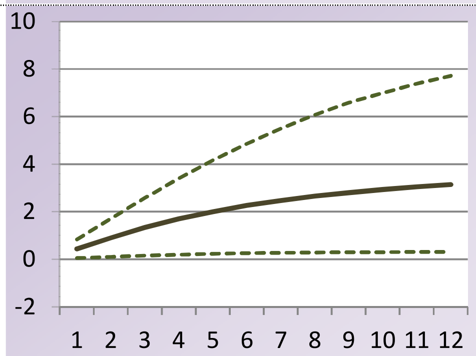
Expansion		?	
Contraction		<	

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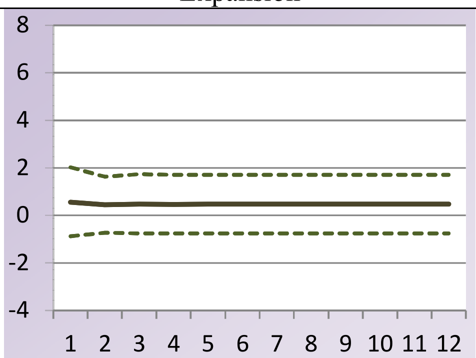
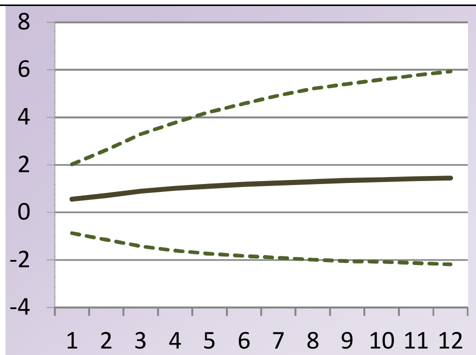
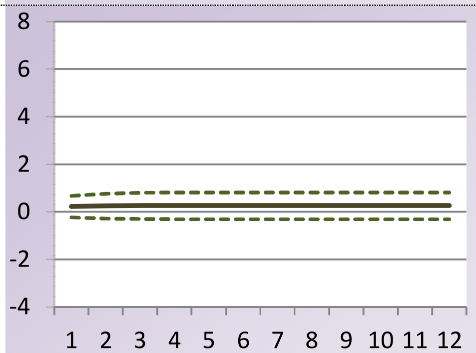
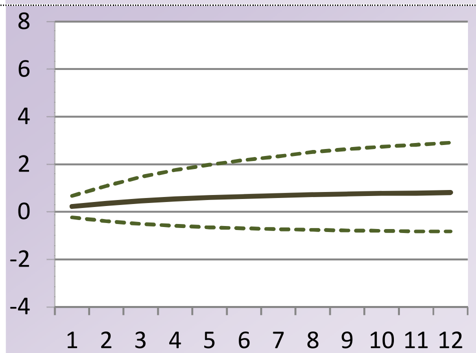
Expansion		<	
Contraction		<	

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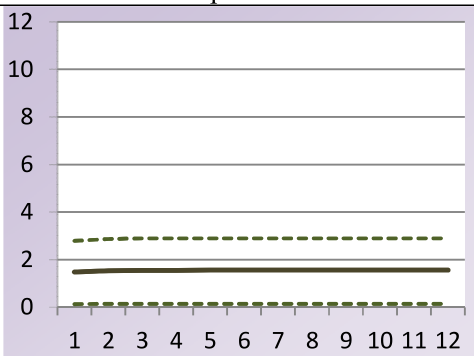
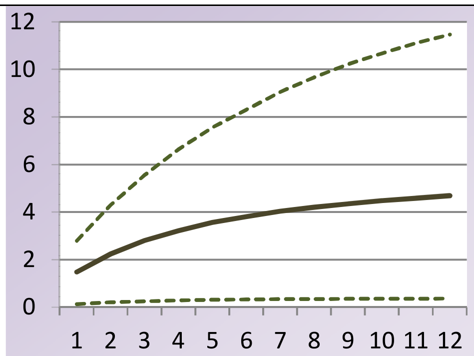
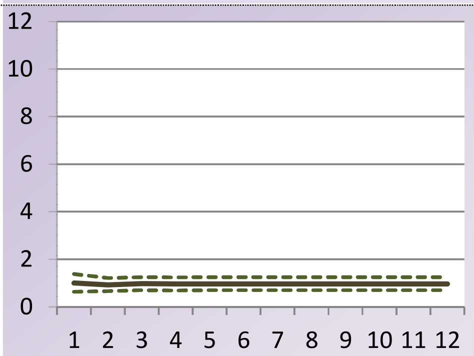
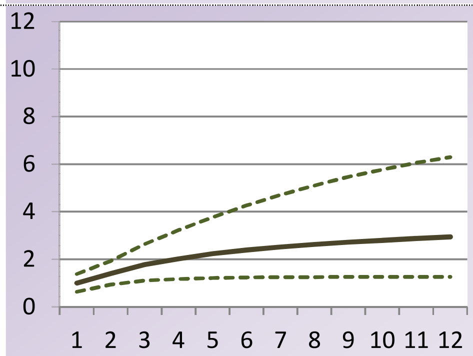
Expansion		<	
Contraction		<	

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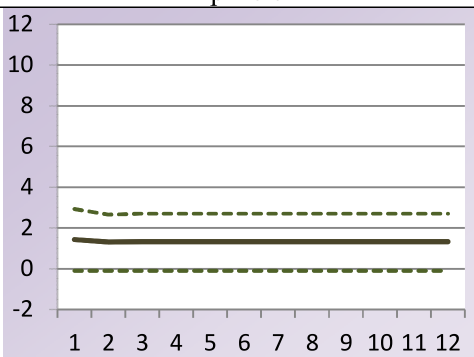
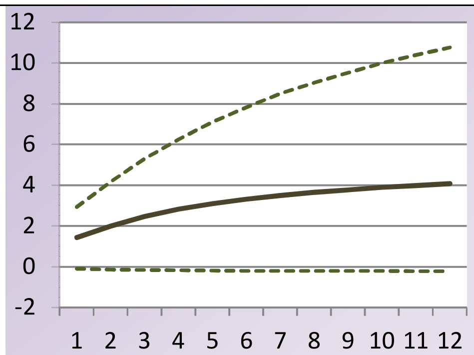
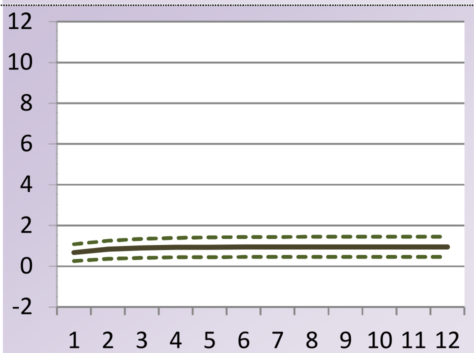
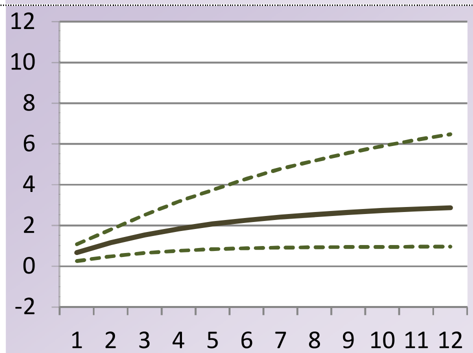
Expansion		<	
Contraction		<	

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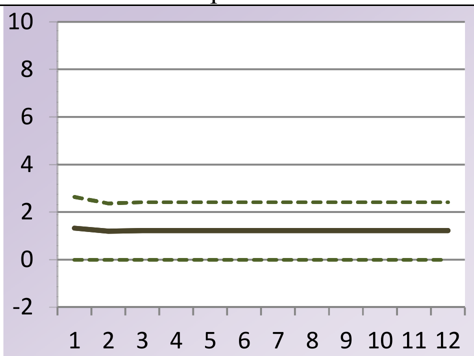
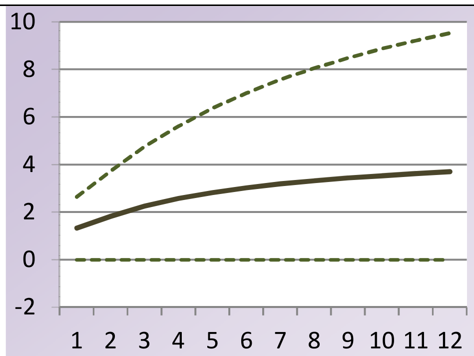
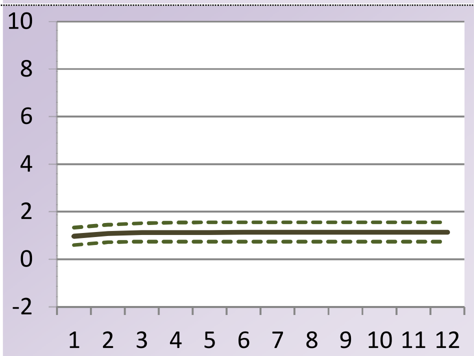
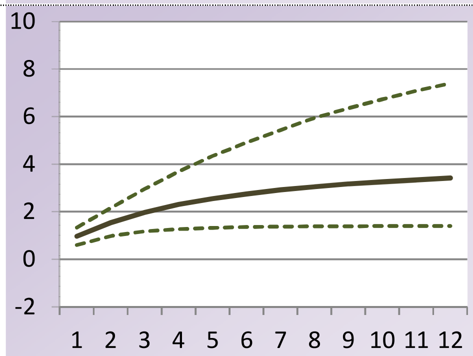
Expansion		<	
Contraction		<	

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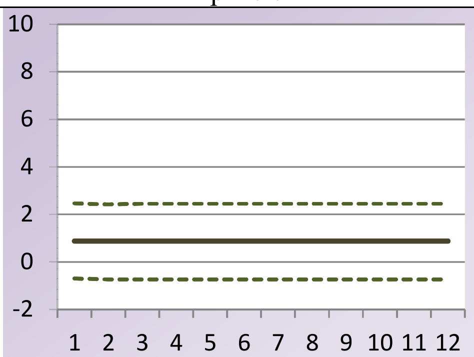
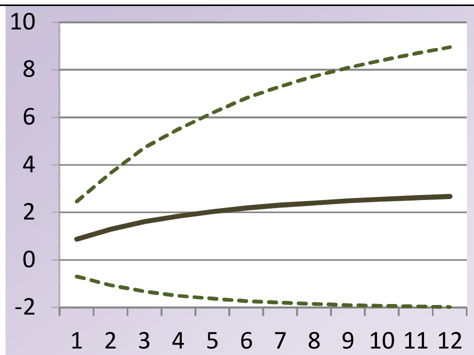
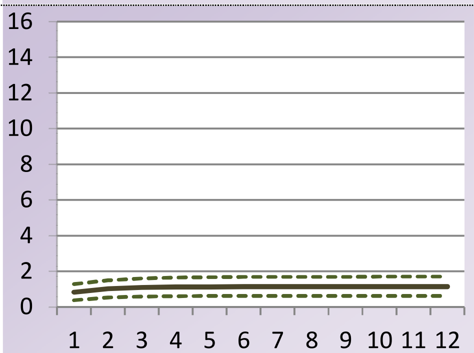
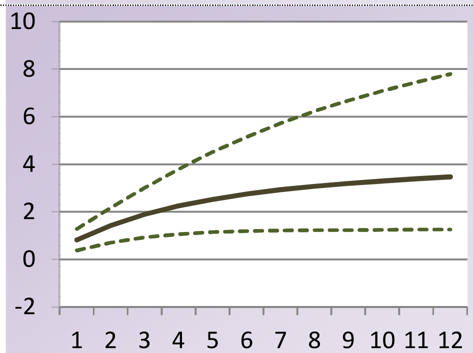
Expansion		<	
Contraction		<	

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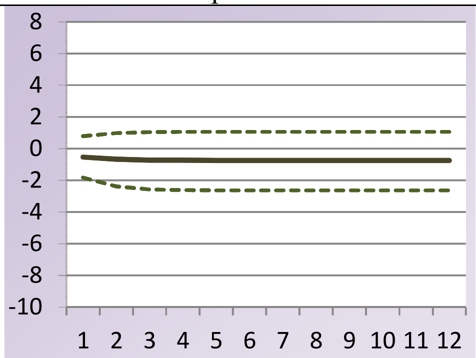
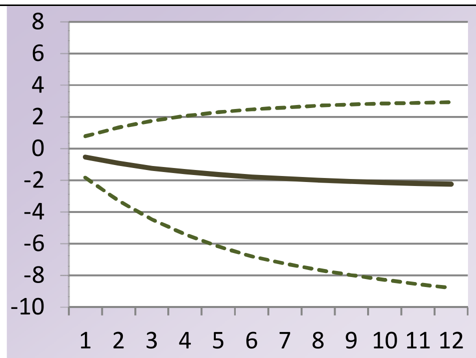
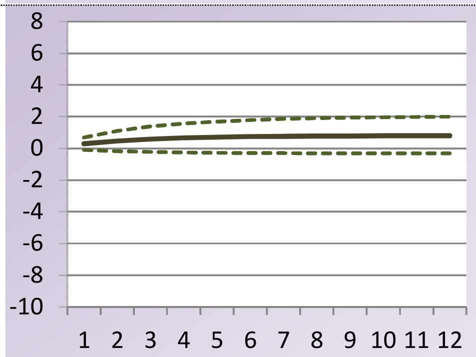
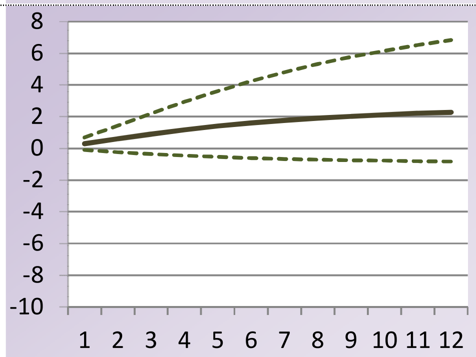
Expansion		?	
Contraction		<	

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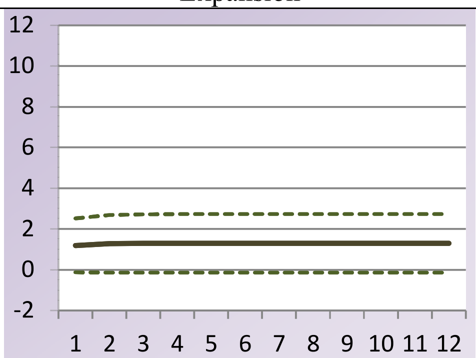
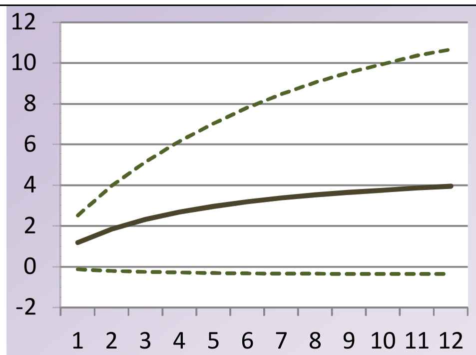
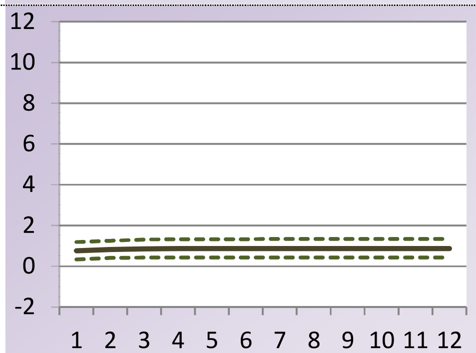
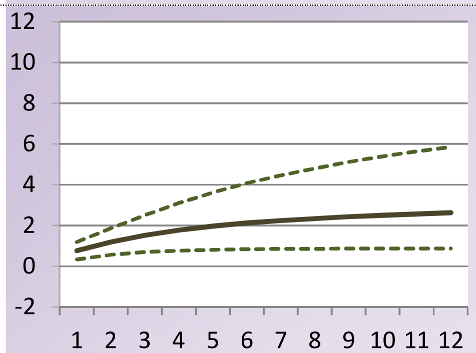
Expansion		<	
Contraction		<	

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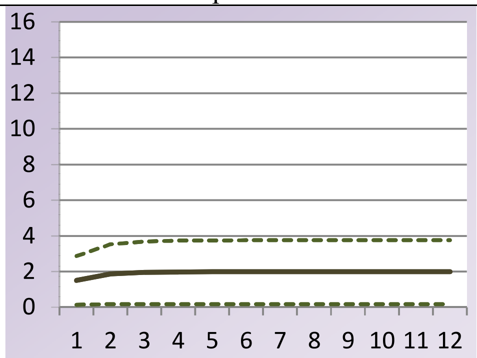
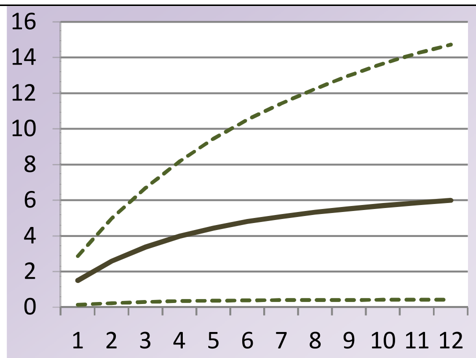
<tr><td>Expansion</td><td>
</td><td><</td><td>
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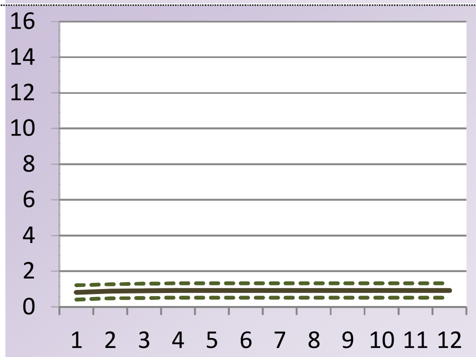
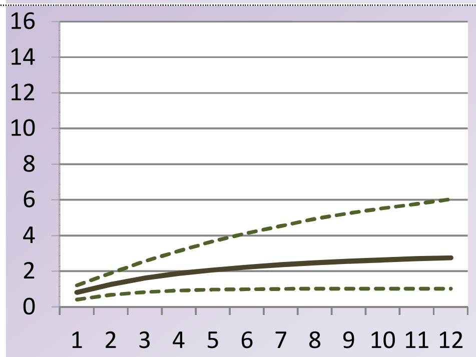
<tr><td>Contraction</td><td>
</td><td><</td><td>
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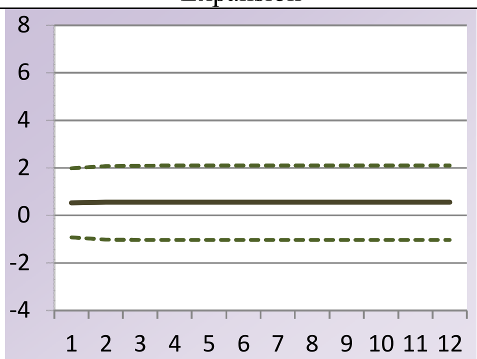
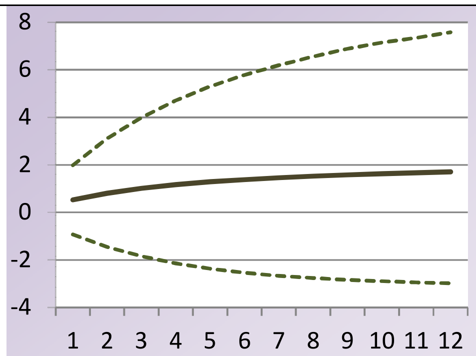
<tr><td>Expansion</td><td>
</td><td><</td><td>
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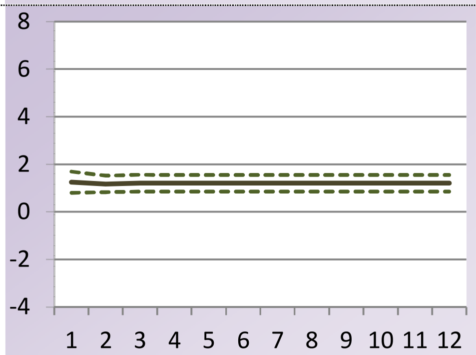
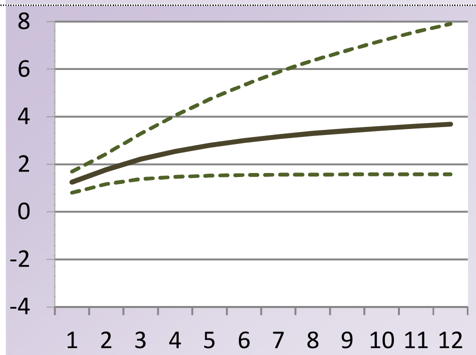
<tr><td>Contraction</td><td>
</td><td><</td><td>
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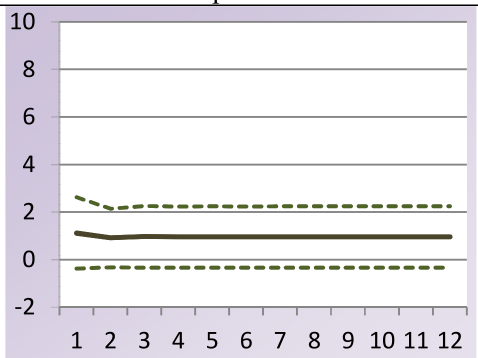
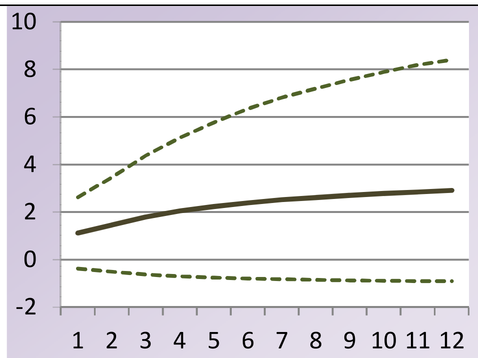
<tr><td>Expansion</td><td>
</td><td><</td><td>
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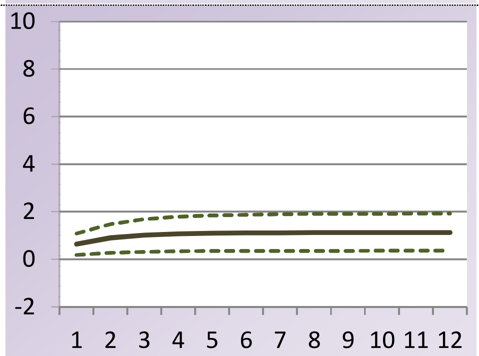
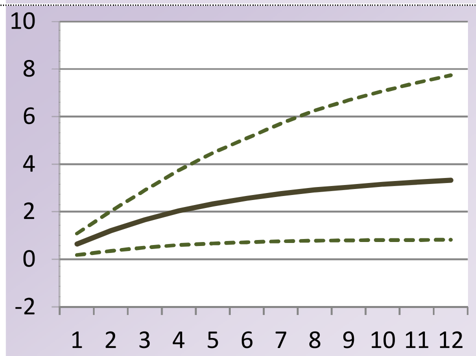
<tr><td>Contraction</td><td>
</td><td><</td><td>
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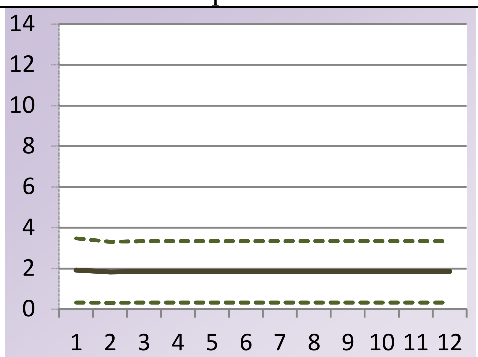
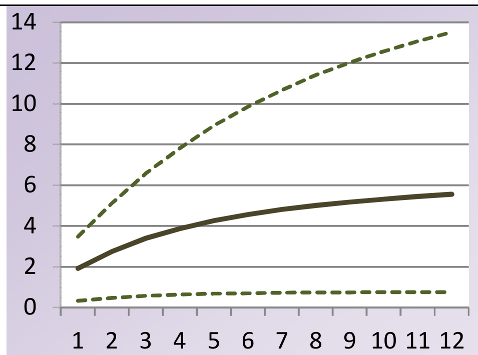
<tr><td>Expansion</td><td>
</td><td><</td><td>
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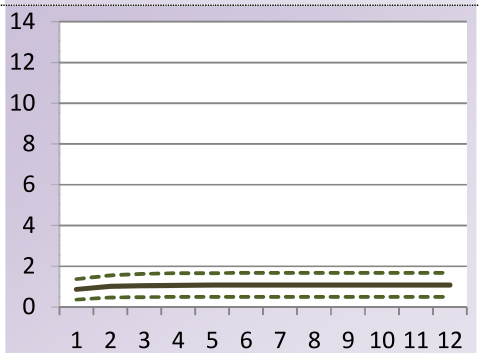
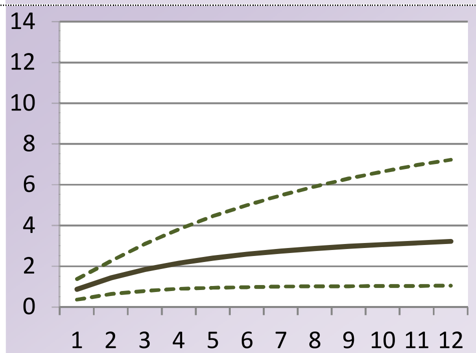
<tr><td>Contraction</td><td>
</td><td><</td><td>
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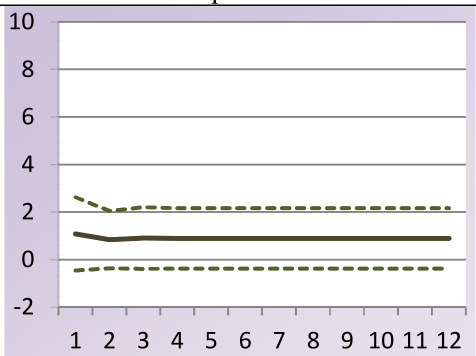
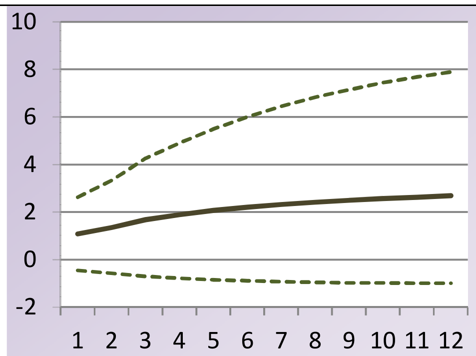
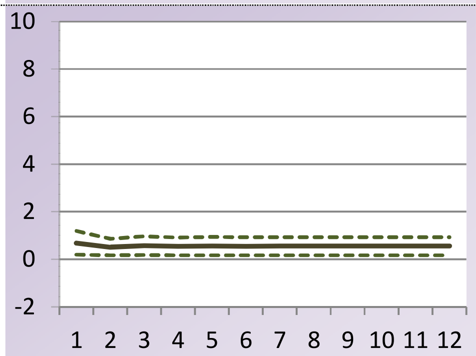
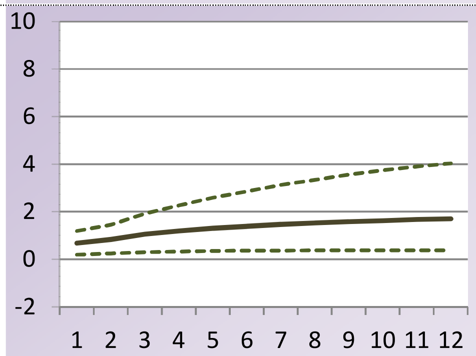
Expansion		<	
Contraction		<	

Appendix 1. Sample Monthly Report

REGIONAL | ECONOMICS | APPLICATIONS | LABORATORY

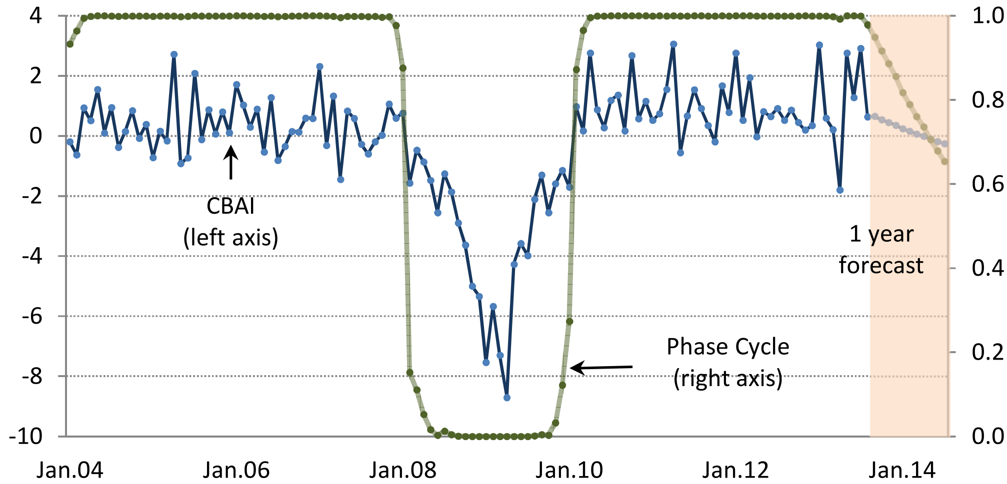
CHICAGO BUSINESS ACTIVITY INDEX

(Release Date: Sep 13)

July Index indicates the Chicago economy still in expansion phase

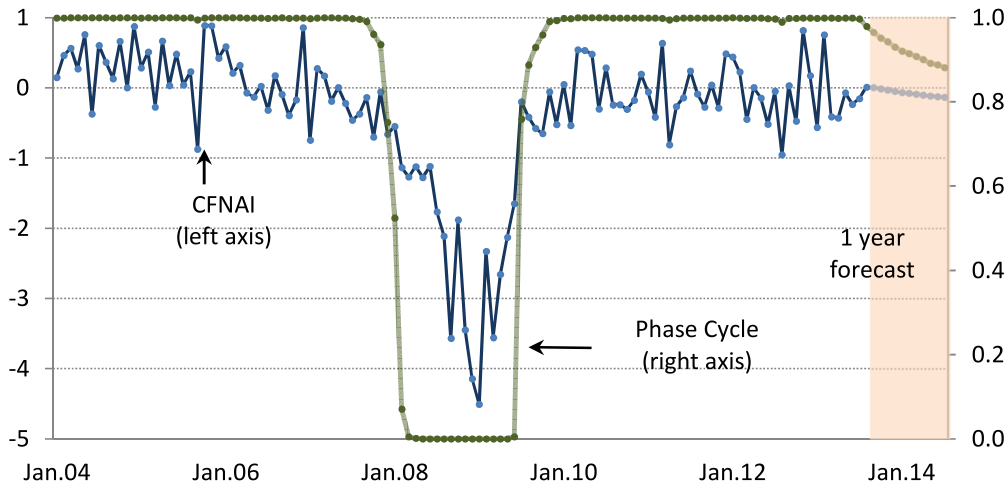
The Chicago Business Activity Index (CBAI) increased to 2.91 in July from 1.27 in June. The increase is attributed to the increase in manufacturing employment and activities in the retail sector in the Chicago region.

Chicago Metropolitan Area (CBAI)



	Historical (ago)	Forecast (ahead)
CBAI (Current:2.91)		
1m	1.27	0.63
3m	-1.79	0.54
6m	3.03	0.24
1y	0.91	-0.26
Phase (Current: 0.999)		
1m	1.000	0.979
3m	0.992	0.917
6m	1.000	0.817
1y	1.000	0.654

U.S. (CFNAI)

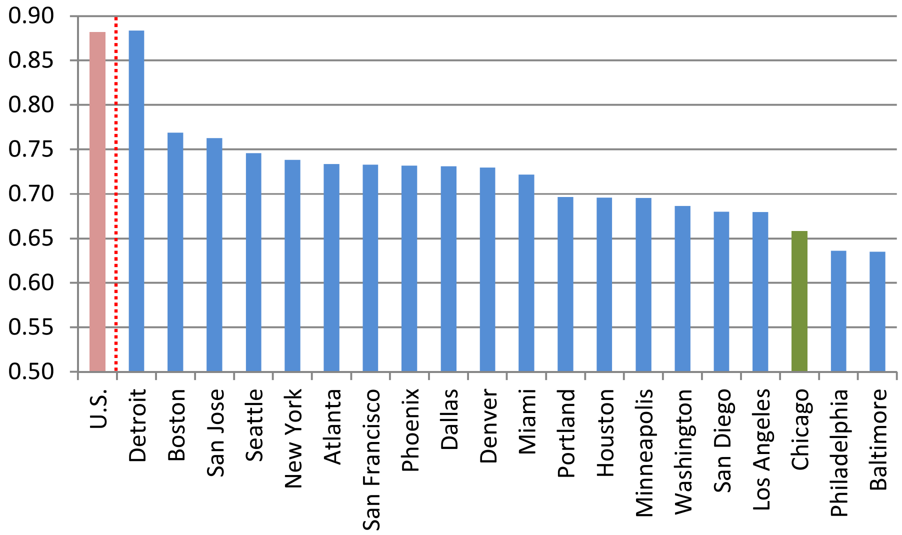


	Historical (ago)	Forecast (ahead)
CFNAI (Current:-0.15)		
1m	-0.23	0.01
3m	-0.43	-0.01
6m	-0.56	-0.07
1y	-0.05	-0.13
Phase (Current: 0.997)		
1m	0.999	0.980
3m	0.998	0.980
6m	0.999	0.921
1y	0.997	0.882

In July, the national and regional economy shared mixed features. The Chicago Fed reported that the Chicago Fed National Activity Index (CFNAI) increased to -0.15 in July from -0.24 in June due to positive contributions of sales and employment. The unemployment rate also fell to 7.4 percent in July from 7.6% in June. In the Chicago region, employment in non-durable goods manufacturing and durable goods manufacturing increased 1.63% and 0.59% respectively after seasonal adjustment. The decreasing trend in unemployment rate also continued in July also.

In coming months, the national economy is likely to maintain its modest recovery trend. The economic growth reflected in CFNAI suggests that the national economic activity was below its historical trend, but the cycle phase indicates that the probability of the national economy being in an expansion phase is 99.7% in July, a slight decrease from 99.9% in June. Considering recent national economic conditions and movements of projected CBAI, the Chicago economy is expected to continue its modest improving trend over the next several months. The probability of the Chicago economy being in an expansion phase was 99.9% in July, but the probability is expected to fall to 97.9% next month due to the slight decrease of the national phase indicator and the Chicago phase indicator.

1-yr-ahead Forecast of the Probability being in an Expansion Phase for 20 Cities



Comparison of the one-year-ahead forecast of the Chicago business cycle phase with other cities indicates that the expansionary force of Chicago area is weaker than other cities. Although, the probability for the Chicago business cycle being in an expansion phase is high (65.4%), it is still below the national average (88.2%) and other 17 cities.

About CBAI
The index is constructed from 10 indicators of Chicago Metropolitan Area provided by Bureau of Labor Statistics using Principal Component Analysis. A positive value indicates that the Chicago economy is growing at above its historical trend rate of growth, and a negative value indicates below-average growth. The current CBAI was constructed using data available as of September 13, 2013. At that time, July data are preliminary.

About Cycle Phase Indicator
The indicator provides additional information on which cycle phase the Chicago economy is in. A value 1 indicates that the Chicago economy is in expansion phase with probability 100%, and a value 0 indicates that the Chicago economy is in a contraction phase with probability 100%.