A note on the diffusion of business cycles

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Abstract: For over five decades, diffusion indexes have been widely used by statistical and economic agencies as an instrument to summarize the dynamics of a group of disaggregated time-series economic data. In this note we revise the methods for constructing diffusion indexes, propose a novel generalized diffusion index and apply it to the U.S. State Coincident Indexes published by the Federal Reserve Bank of Philadelphia. We show that the proposed index is more informative and conclusive regarding the stage of the aggregate business cycle than the traditional indexes used by some statistical agencies. Moreover, one of the unique properties of the generalized diffusion index is that it allows a consistent reading of the contributions of its constituent units.
Keywords: Diffusion indexes, coincident indexes, business cycles, monitoring.
JEL Classification: C1, C5, E3.

Resumen: Desde hace más de cinco décadas, los índices de difusión han sido aplicados ampliamente por agencias estadísticas y económicas como un instrumento para resumir la dinámica de un grupo desagregado de series de tiempo económicas. En esta nota revisamos los métodos para construir índices de difusión, proponemos un nuevo índice de difusión generalizado y lo aplicamos a los Índices Coincidentes Estatales de Estados Unidos publicados por la Reserva Federal de Filadelfia. Mostramos que el índice propuesto es más informativo y concluyente sobre el estado del ciclo económico agregado que los índices tradicionales utilizados por algunas agencias estadísticas. Más aún, una de las características únicas del índice generalizado es que permite una lectura consistente de las contribuciones de sus unidades constituyentes.
Palabras Clave: Índices de difusión, índices coincidentes, ciclos económicos, monitoreo.

1 Introduction

It is well known that the dynamics of local business cycles contain relevant information regarding the evolution of the aggregate business cycle. Summarizing the dynamics of local business cycles typically relies on a statistical method for dimensionality reduction of time-series data. Back in the early 50's, the diffusion index proposed by Alexander (1958) was used and adopted in practice by many government and statistical agencies. With the advent of new methods for time-series analysis, more sophisticated methods for dimensionality reduction have been proposed, such as dynamic factor models (Stock and Watson, 1990), which have received a considerable attention by academics and statistical agencies. It is worth noting that despite the simplicity of the earlier methods and the complexity of some other more recent approaches, both methodologies are currently applied in practice by government and statistical agencies. Actually, among statistical agencies it is still very common to use the earlier version of the diffusion index to summarize the dynamics of local business cycles. In this note we focus on the original concept of diffusion indexes and generalize it to allow for a more accurate and informative reading of local business cycles. As it will be argued, the generalized diffusion index can be more informative for reading the dynamics of local business cycles of heterogeneous economies, where their local components differ among each other in terms of their contribution to the aggregate economic cycle.

The diffusion index proposed originally by Alexander (1958), termed by us as conventional diffusion index (CDI), is defined as the difference between the proportion of a group of series that are in an expansion phase and the proportion of the same group that is in a contraction phase. Diffusion indexes of business cycles are built using sectoral or local economic indicators of business cycles (its constituent units). Table 1 in Appendix A lists some applications of the CDI used by statistical and government agencies throughout the world. One of their main uses is to describe and anticipate turning points in the aggregate business cycle (see, Broida, 1955; Moore, 1955). Another important use, which motivates this note, is that to describing the rhythm of expansion and contraction of the aggregate economic activity.

The CDIs are useful instruments to approximate the rates of change of the aggregate business cycle. Since CDIs only consider the direction in which their constituent units move, alternatives to compute the index considering the weights of those units have been proposed in the past. The weighted diffusion indexes (WDIs), studied by Hickman (1958), take into account two dimensions of the business cycle: the direction in which its units move (as the conventional diffusion index does), and the contribution of each unit to the aggregate activity of the economy. Since CDIs and WDIs

exhibited a fairly similar behavior in practice when applied to the US economy (Hickman, 1958), the use of WDIs has been limited. However, as Guerrero Escobar and Martínez-Ovando (2014) note, the relative share of local economies may be more important in the context of heterogeneous economies, such as developing countries.[1]

With the aim of conceiving a more informative and accurate diffusion index of business cycles, we develop a generalized diffusion index (GDI) that takes into account three dimensions of disaggregate business cycles: the direction of change of its constituent units, their contribution (weights) to the aggregate economic activity and the magnitude of their changes. Adding the magnitude of local business cycles allows us to disaggregate the GDI by its constituent units in an informative way since, at each point in time, we can observe the relative contribution of each local business cycle to the aggregate business cycle.

The structure of this note is as follows: Section 2 develops the methodology for constructing three diffusion indexes: conventional, weighted and generalized; Section 3 applies the GDI to the US economy using the coincident indexes developed by the Federal Reserve Bank of Philadelphia; and Section 4 concludes with a discussion and some open questions for further research.

2   Diffusion Indexes of Business Cycles

The CDIs are computed as the difference between the proportion of trend-cycle components of economic series that exhibit a positive change minus the proportion of trend-cycle components of those series that registered a negative change at a given time period t. As such, diffusion indexes of business cycles are constructed using J time series of trend-cycle components of business cycles, $(c_{j,t})_{j=1}^{J}$, where J usually represents the number of business cycles of local units (*e.g.* state coincident indexes or sectoral coincident indexes).[2] Formally, the CDI at time period t is defined as,

$$\text{CDI}_t \quad = \quad \frac{\sum_j \mathbb{I}(\Delta c_{j,t} > 0) - \sum_j \mathbb{I}(\Delta c_{j,t} < 0)}{J}, \tag{1}$$

where $\Delta c_{j,t} = (c_{j,t} - c_{j,(t-1)})/c_{j,(t-1)}$, for $j = 1, \ldots, J$. The CDI typically exhibits lack of smoothness since it is highly sensitive to lack of synchronicity between local cycle movements, given each

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[1]Comparing GINI coefficients for state GDP shares for the US and Mexico we find that Mexican states are 1.3 times more concentrated in their participation to total GDP than are US states, implying Mexico is a more heterogeneous economy than the US.

[2]In general, since, to our knowledge, there is no methodology to simultaneously estimate local and national business cycles, the sum of the J trend-cycle components of the economic activity does not necessarily equals the trend-cycle component of the aggregate business cycle c_t.

movement of its constituent parts has an equal weight in the index. The lack of smoothness is larger when local business cycles are less synchronized. In general, in heterogeneous economies the lack of smoothness is much more notorious than in more homogeneous economies.

Diffusion indexes are meant to serve two purposes (Moore, 1961): first, to summarize the dynamics of disaggregate business cycles and, second, to identify sub-groups of its constituent units that lead changes in the aggregate business cycle. Concerning the second purpose, the CDI does a relative poor job since it only takes into account the direction of change of local dynamics, disregarding the relative importance (both in terms of the magnitude of change and the weights) of its constituent units.

With the aim of providing a more accurate reading of the aggregate business cycle dynamics Hickman (1958) proposed a weighted diffusion index (WDI), that incorporates measures of the relative contributions of local business cycles to the aggregate business cycle. The WDI that he studied was computed as a variant of (1) in which each local expansion and contraction was re-scaled with respect to a collection of fixed or adaptive weights, $(w_{j,t})_{j=1}^{J}$, which represent the relative contribution of each disaggregate component to the aggregate economic activity at time period t. The underlying idea behind weighting is that of acknowledging the underlying heterogeneity of the units involved; CDIs assign the same weight, $1/J$, to every unit, whereas WDIs weight the units heterogeneously, according to objective or subjective judgments. For the sake of simplicity, it is assumed that theses weights are known, such that, $w_{j,t} \geq 0$, for any j and t, and $\sum_{j=1}^{J} w_{j,t} = 1$, for any time period t. One objective way to construct the weights is by using the relative contribution of each local component to aggregate output (GDP) at a given baseline period t_0. Accordingly, weights can change or remain fixed over time. Thus, the WDI at time period t is defined as,

$$\text{WDI}_t = \frac{\sum_{j=1}^{J} w_{j,t} \mathbb{I}(\Delta c_{j,t} > 0) - \sum_{j=1}^{J} w_{j,t} \mathbb{I}(\Delta c_{j,t} < 0)}{\sum_{j=1}^{J} w_{j,t}}, \tag{2}$$

which also considers the general case where the local weights are positive but not normalized, *i.e.* $\sum_{j=1}^{J} w_{j,t} > 0$.

The WDI recognizes that each constituent unit of the diffusion index may contribute differently to the aggregate business cycle. In this sense the WDI provides a more accurate representation of the aggregate business cycle. It is worth noting that dynamic weights $(w_{j,t})$, if computed as described above, are typically stable over time mainly due to the stability underlying the composition of the economic activity; strong changes in the composition of $(w_{j,t})$ would imply strong and pervasive shocks to the economy. Hence, in practice, constructing WDI with dynamic or static weights produce fairly similar results.

There is another variant of the WDI that partially takes into account the magnitude of local

changes, which is obtained if the weights are assigned not in terms of the composition of the econ-omy nor in terms of their local disaggregated components, but in terms of subjective considerations. These, in general, refer to three possible scenarios that the dynamics of local business cycles may ex-hibit: contraction, expansion or neutrality. For instance, in the context of employment analysis, Getz and Ulmer (1990) explored the assignment of different weights to the aforementioned three scenarios. Their criteria to assigning the weights to different economic units associates a contraction with a neg-ative arbitrary number, $-y$, neutrality with no change, 0, and an expansion with a positive arbitrary number, x. In practice, there are no rules to assigning the weights in a similar context.

Although the WDI is able to produce a more accurate reading of the aggregate business cycle than the CDI (in the sense that it takes into consideration the composition of the economy in its disaggre-gated units), it does not take into account the magnitude of the rates of change of local economies. Thus, it does not make any distinctions between large or small changes in local dynamics of business cycles. These changes provide an extra piece of information to the aggregate business cycle that both CDI and WDI ignore.

Any indicator of business cycles should be relatively robust to (non-relevant) idiosyncratic or local shocks to their components not to provide false signals of the state of the economy and thus, be as smooth as possible. The CDI is sensitive to changes in any given local business cycle that are not synchronized with the rest of the economy. The WDI is sensitive to changes in any given local business cycle that are not synchronized with the rest of the economy and that has larger weights in the aggregate economy. Hence, the WDI is a more informative index than the CDI, since it is less sensitive to units that are not synchronized and do not have an important participation in the economy.

As we mentioned before, the generalized diffusion index (GDI) proposed in this note simultane-ously takes into consideration three dimensions of the business cycles that are relevant for the determi-nation of the aggregate business cycle: direction of local changes, magnitude of those changes and the relative contribution of local business cycles to the aggregate. In this way, the GDI provides us with a a proper and accurate reading of disaggregate and aggregate dynamics of business cycles in terms of the total economic activity. This idea is motivated by the decomposition of the aggregate business cycle into the weighted sum of its components, *i.e.* $c_t = \sum_{j=1}^{J} w_j c_{j,t}$. Inspired by that decomposition, we look at the notion of total activity of the economy (TotAct), which at time period t is expressed as the weighted sum of changes of local business cycles, weighted by their corresponding (static or dynamic) contribution to the economy according to the decomposition of the aggregate rate of change as $\Delta c_t = \sum_{j=1}^{J} w_{j,t} \Delta c_{j,t}$, where Δc_t is defined as above. The normalized weights used in the above decomposition are given by $w_{j,t} = w_{j,t_0} c_{j,(t-1)} / \sum_{i=1}^{J} w_{i,t_0} c_{i,(t-1)}$ at any time and baseline periods t and

t_0, respectively. According to the above decomposition, one can think of the intuitive notion of TotAct in the economy at time t, as the weighted sum of absolute contractions and expansions experienced by business cycles in the same time period,

$$\text{TotAct}_t \quad = \quad \sum_{j=1}^{J} w_{j,t} |\Delta c_{j,t}|. \tag{3}$$

Derived from this, the GDI at time period t is defined as,

$$\text{GDI}_t = \frac{\sum_{j=1}^{J} w_{j,t} \Delta c_{j,t} \mathbb{I}(\Delta c_{j,t} > 0) - \sum_{j=1}^{J} w_{j,t} |\Delta c_{j,t}| \mathbb{I}(\Delta c_{j,t} < 0)}{\text{TotAct}_t}. \tag{4}$$

The GDI is comparable with the CDI and WDI (and its variants). However, the GDI provides us with an extra piece of information, the magnitude of local business cycle changes, which makes it more informative and more robust (less sensitive to unsynchronized movements of local business cycles that have little weight and which movements are relatively small) than its counterparts. In practice, this translates into having a smoother index. In the next section we compute the CDI, WDI and GDI using the state coincident indexes published by the Federal Reserve Bank of Philadelphia.

3   A Generalized Diffusion Index for the US Economy

Recently, Crone and Clayton-Matthews (2005) developed coincident indexes for every state in the US economy.[3] Since their publication, the Federal Reserve Bank of Philadelphia publishes these indexes on a monthly basis[4], which are widely followed by local governments and businesses to track the state of local economies. In its monthly State Coincident Indexes Report, the Federal Reserve Bank of Philadelphia reports the diffusion index of state coincident indexes. We use data from the Philadelphia Fed to construct four diffusion indexes according to the methodologies exposed in Section 2, from yearly variations of state coincident indexes.

Figure 1 plots the conventional, weighted and generalized diffusion indexes from July 1980 to August 2013, as well as the NBER recession dates. Although the four indexes move similarly, the main difference between the GDI and the traditional alternatives is that the former is smoother and moves less erratically than the others, providing us with a more robust reading of the state of the economy at a given point in time. In general, we can observe that the indexes move similarly. However there are

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[3]It is worth noting that the methodology used by Crone and Clayton-Matthews adapts the one proposed by Stock and Watson (1990) based on dynamic factor models.

[4]Refer to website, `http://www.philadelphiafed.org/research-and-data/regional-economy/indexes/coincident/`.

some slight differences. For example, from January 1985 to July 1986, the CDI and the WDI dropped in a similar magnitude they generally do in recessions. From looking at those indexes we would probably have anticipated a recession in the coming months. In contrast, the GDI moved slower, indicating a lower possibility of a large recession approaching. In that period (between 1985Q1 and 1988Q3) the economy grew 13.7% in real terms. As explained earlier, the CDI and the WDI are less smooth due to the fact that they are more sensitive to unsynchronized local economies and this may make them less robust as aggregate business cycle indicators compared to the GDI. The GDI also preserves all of the notable characteristics of the other indexes: continuous negative changes in its path almost always lead NBER recession periods (except for the recession of 1981, where all the indexes seem to increase at the month the recession started), and strong stability around positive levels of the business cycle. While all indexes seem to anticipate recession periods several months in advance, they all do lack anticipating recoveries (again except for the 1981 recession). Finally, it is notable that state weights in the national economy have not experienced large enough changes over time to produce significant differences between the dynamic and the static weighted diffusion indexes, as discussed earlier in the paper.

We claim that the GDI is more informative than alternatives, in the sense that it combines all the sources of variability among and across local business cycles. Figure 2 exemplifies that. In that figure, it is shown the relative contribution of four representative state business cycles to the three diffusion indexes. Plots are drawn in the same scale for comparability purposes. The illustration is made for California, New York, Tennessee and Texas. These are chosen because they represent archetype behaviors of the states business cycle in the US economy: California's GDP represents 15% of total US GDP, whereas New York and Texas approximately represent 9% each, and Tennessee nearly 2%. The purpuse of this figure is to show the information that is used for the computation of the three types of diffusion indexes of business cycles. The blue lines in the four panels show the local contribution to the CDI, with values alternating between 1/50 and -1/50, according to the period of expansion or contraction, respectively. As claimed before, the weighted diffusion index considers another layer of information by means of differentiating the states contribution to the diffusion in terms of their relative weights on the aggregate GDP. Accordingly, the green line shows the trayectories of the states' contribtion to the WDI. Finally, the red line shows the relative contribution of states business cycles to the generalized diffusion index. As can be noted, the red line considers the magnitude of expansions and contractions of local business cycles. Moreover, those magnitudes are moduled according to the relative share of the local economy to the aggregate. Comparing the blue, green and red lines, it is evident that the GDI components are telling us that not all expansion or recession periods are the

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same for a given economy. For example, according to the GDI, the expansion period that California experienced from 1993 to 2000 was stronger than the one it experienced during the second part of the 2000's decade. This reflects the information technology boom that originated in California during the 1990's. Neither the CDI or the WDI reflect that heterogeneity. In this sense, we claim our index is more informative than the existing ones, since it conveys more information regarding the evolution of local economies.

Figure 1: Diffusion indexes of the US economy for the period July 1980-August 2013.
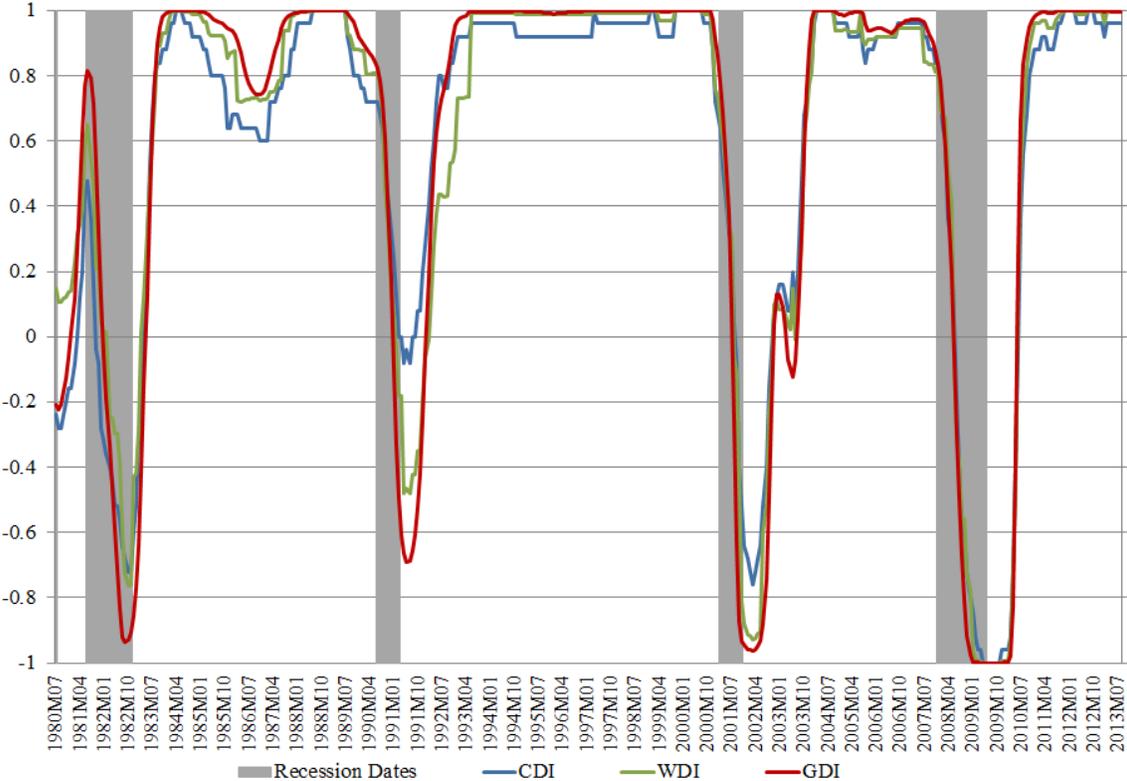
Perhaps the most relevant and unique characteristic of the GDI is that it properly reads the contribution of the local parts to the sum of their aggregate. And such a reading is informative, in the sense that it permits to observe the contribution of each of its components to the aggregate business cycle.

In Figure 3 we decompose the index by the contributions of each of the 8 Bureau of Economic Analysis (BEA) Regions over time from July 1980 to August 2013 [5]. Interestingly, declines in the

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[5]The BEA Regions are defined as follows: Great Lakes (Illinois, Indiana, Michigan, Ohio and Wisconsin), Far West (Alaska, California, Hawaii, Nevada, Oregon and Washington), Mideast (Delaware, District of Columbia, Maryland, New Jersey, New York and Pennsylvania), New England (Connecticut, Maine, Massachusetts, New Hampshire, Rhode Island

Figure 2: States contribution to diffusion indexes for the period July 1980-August 2013.

(a) California

(b) New York

(c) Tennessee

(d) Texas
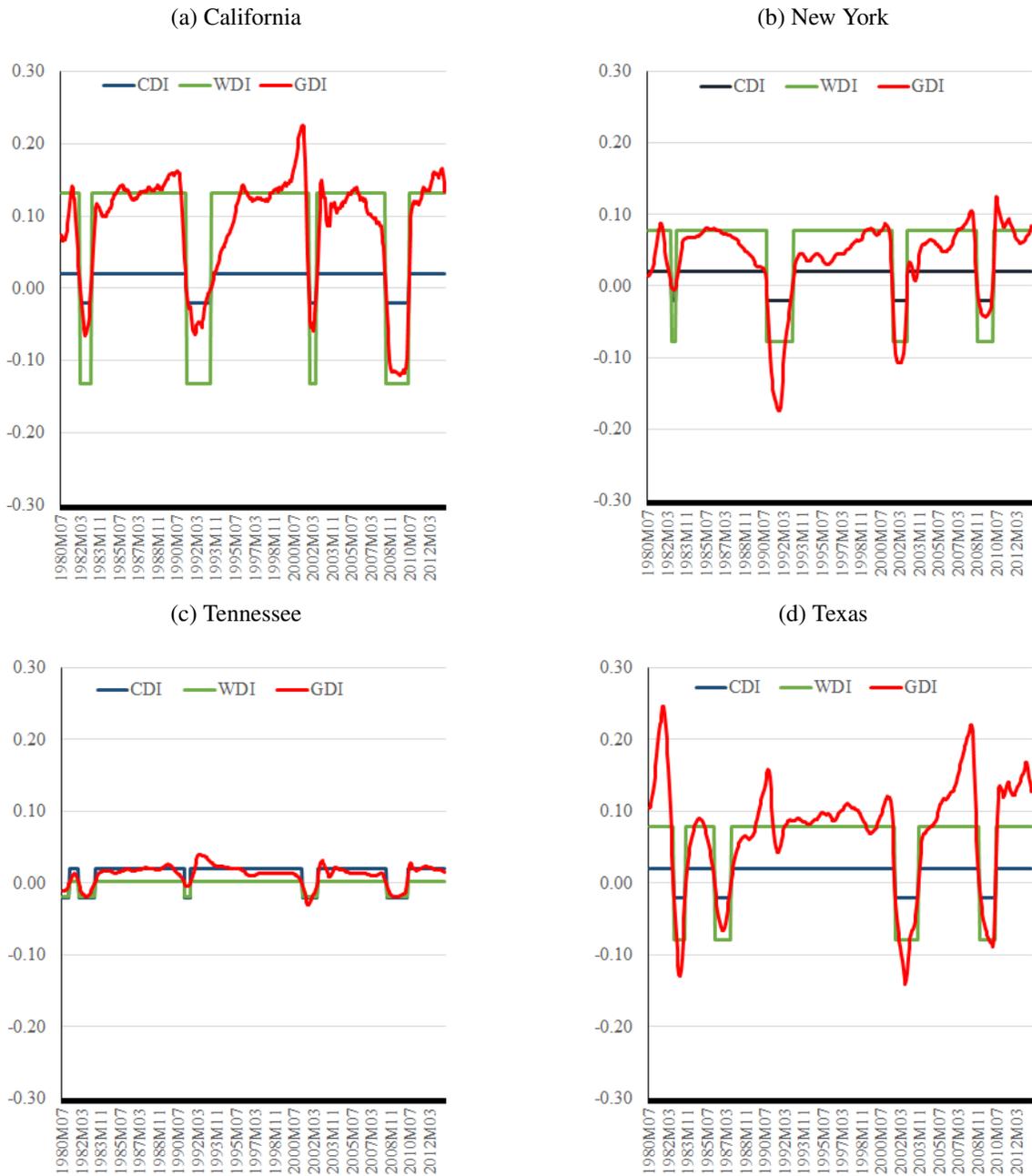
and Vermont), Plains (Iowa, Kansas, Minnesota, Missouri, Nebraska, North Dakota and South Dakota), Rocky Mountain (Colorado, Idaho, Montana, Utah and Wyoming), Southeast (Alabama, Arkansas, Florida, Georgia, Kentucky, Louisiana, Mississippi, North Carolina, South Carolina, Tennessee, Virginia and West Virginia) and Southwest (Alabama, Arizona, Arkansas, Florida, Georgia, Kentucky, Louisiana, Mississippi, New Mexico, North Carolina, Oklahoma, South Carolina, Tennessee, Texas, Virginia and West Virginia)

Great Lakes region preceded three of the last four recessions: notice how the green bars locate in negative territory before other regions in the 1981 and 2000 recessions. In the 2008 recession, both the Green Lakes and the Southeast regions GDIs registered negative numbers almost at the same time. In contrast, the Southwest region fell into recession slower than other regions in three of the 1980, 1990 and 2008 recessions, indicating that this region is less synchronized with the other regions. Beyond its use to describe regional trends, the decomposition property of the GDI can be a useful tool for policy makers since it can help to direct public efforts in trough periods to areas that precede national recessions.

Figure 3: Generalized diffusion index of the US economy and regional contributions for the period July 1980-August 2013.
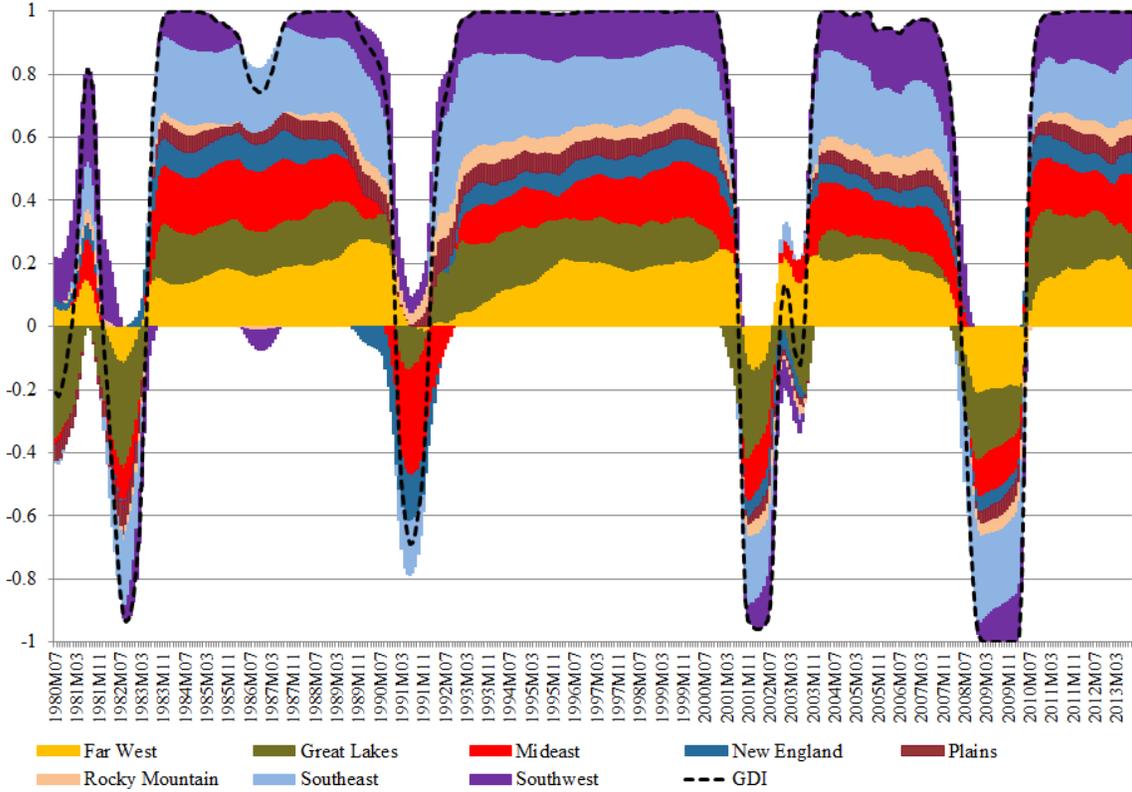
4   Concluding Remarks and Discussion

We emphasize in this note that a more informative and concluding reading of business cycles dynamics can be obtained through the use of the proposed generalized diffusion index. The proposed index

takes simultaneously into account the magnitudes of changes of local business cycles, their direction and relative contribution to the economy. Including these three dimensions of local business cycles provides us with a more informative and accurate reading of the aggregate business cycle. The components of the proposed index can be grouped in order to identify sub-groups of components that lead or follow movements of the aggregate business cycle. We apply the index to the US economy using the US states coincident indexes produced by the Philadelphia Fed.

The construction of the generalized diffusion index highly depends on a consistent and accurate reading of the trend-cycle components of local business cycles. In this respect, the proposal of this new index also motivates the need to develop new and more robust methodologies to construct coincident and leading indicators of disaggregate business cycles that are consistent with the aggregate business cycles.

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A Complementary Table

Table 1: Diffusion Indexes used by statistical and government agencies

Country	Agency	Indicator
Indonesia, Malaysia, the Philippines, Singapore and Thailand	OECD Development Centre Asian Business	Diffusion Index for the Association of Southeast Asian Nations (ASEAN) Economies
Japan	Bank of Japan	Japan Business Conditions Leading Diffusion Index
Mexico	Mexican Institute of Financial Executives	Mexican Business Environment Indicator
Mexico	National Institute of Statistics and Geography	Public Safety Perception Index
Norway	Statistics Norway	Diffusion Indexes of Business Tendency Survey for Manufacturing, Mining and Quarrying
Spain	National Institute of Statistics	Employment Diffusion Index
Spain	Ministry of Employment and Social Security	Diffusion Indexes of Social Security Activities
U.S.A.	Bureau of Labor Statistics-US Department of Labor	Diffusion Index for Industries with Employment
U.S.A.	National Bureau of Economic Research	Diffusion Index of Eight Leading Indicators, Three-Six Month Span for United States
U.S.A.	National Bureau of Economic Research	Diffusion Index, Employment In Non-agricultural Establishments, Thirty-Two Industries, One Month Span for United States
U.S.A.	Institute for Supply Management (ISM)	ISM Manufacturing Index
U.S.A.	Board of Governors of the Federal Reserve System	Diffusion Indexes of Industrial Production
U.S.A.	The Conference Board	The Conference Board Leading Economic Index (LEI)-Diffusion Index

Table 1 Continued: Diffusion Indexes used by statistical and government agencies

United Kingdom	The Institute of Credit Management (ICM)	The Institute of Credit Management (ICM) UK Credit Managers Index
United Nations Organization (Index for 180 Countries)	United Nations Organization	ICT (Information and Communication Technology) Diffusion Index
Uruguay	Chamber of Industries of Uruguay	Industrial Diffusion Indicator