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METHODOLOGY
FOR CONSTRUCTING AN ECONOMIC INDEX FOR THE COLLEGE STATION-BRYAN METROPOLITAN STATISTICAL AREA

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Introduction

Economic variables such as the United States' Gross Domestic Product (GDP) provide quarterly updates of the country's total economy. Each release of the GDP numbers receives considerable media attention, and that attention is heightened when the economy is booming or when growth is slowing or turning negative. Such movements indicate the coincident occurrence of recoveries or recessions. Unfortunately, GDP is only released quarterly, and with a lag. For example, as we write this, it is October 19, 2018 after the end of third quarter of 2018 (also called 2018Q3). At this time, we have a value for the 2018Q2 GDP. Our first estimate of 2018Q3 will be what is called the "advanced estimate" released on October 26 2018, almost one month after the end of the third quarter on September 30 2018. These "advanced estimates" are noisy and subject to large revisions. The so-called "second estimate" of GDP for 2018Q3, sometimes called the preliminary estimate, will be released on November 28, almost two months after the end of the third quarter. The "third estimate" of GDP for 2018Q3, often called, somewhat erroneously, the final estimate, will be released on December 21 2018, almost three months after the end of the third quarter. After this estimate, further changes to the estimate of GDP for 2018Q3 will occur infrequently and not on a fixed schedule.

What this means is that our information on the state of the U.S. GDP is dated, and our final estimate is only available with about a one-quarter lag. For GDP, we are always looking at data that tells us what happened in the past, not what is happening today.

In response to this information lag, economists and policy makers have developed indexes of economic performance that use information available on a more timely basis, including measures of monthly labor market activity and sales data. Information in these variables is used to supplement data that is otherwise only available quarterly.

There are numerous indexes that provide up-to-date information about the state of the national economy. Such indexes, designed to reflect the state of an economy at a point in time, are known as coincident indexes. Coincident indexes are often estimated based on economic indicators such as the unemployment rate, the employment level, and real earnings. The goal is to provide information on the current state of the economy, or to get as close to the current state as possible.

There are other indexes that are designed to provide an early indication of where the economy is heading, and these are known as leading indexes. Common in these indexes are variables such as housing starts, construction spending, manufacturers' supply orders, and initial unemployment claims.

The usefulness of a coincident index for local economies such as Metropolitan Statistical Areas is perhaps even greater than it is for the United States. GDP at the local level is only available annually, and with a very long lag. GDP for our area for 2017 was just released on September 18, 2018. At the release date, the data was about nine months old. Just before the release date, the most recent GDP estimate was for 2016, a lag of well over 1.5 years. Next year, the lag will increase – the Bureau of Economic Analysis plans to release estimates of 2018 GDP by metropolitan area in December 2019. For local areas, having a coincident indicator based on more frequently available data from labor market observations and sales data is even more useful than it is for the U.S.

Here we present the methodology and the data used to estimate a coincident business-cycle Index for the College Station-Bryan Metropolitan Statistical area, which is comprised of Brazos, Burleson and Robertson Counties.

A Coincident Index for the College Station-Bryan MSA

The CSB Business-Cycle Index is patterned after the Federal Reserve Bank of Dallas' (FRBD's) economic indexes for the major Texas Metropolitan Statistical areas (MSAs). The FRBD's methodology is an application of a well-established model used to estimate state and MSA level economic indexes. The original methodology is presented by Stock and Watson (1989).[1] The methodology we employ in estimating the business-cycle for CSB is an update to the established procedures that was presented in Banbura and Modugno (2014).[2] Their method allows estimation of indexes with missing data and mixed frequencies. This is particularly helpful in our context because our data series are both monthly and quarterly.

Methodology

We obtain our business-cycle index based on a dynamic factor model, where the dynamic co-movement of a set of observed data series is summarized by a small number of unobserved factors. The first of these unobserved factors constitutes the business-cycle index.

The estimation methodology relies on Banbura and Modugno (2014), who propose an expectation maximization algorithm that can work in a fairly general setting, i.e. when you have observed data series of different length, frequency and publication delays. The estimation relies on a maximum likelihood approach, which is more efficient in small samples and can be easily adapted to data with arbitrary patterns of missing data relative to some of the non-parametric alternatives.

More specifically, let y_t be a stationary n−dimensional vector process, which has been standardized such that it has a mean of zero and a variance of one. Suppose y_t has the following factor model representation:

$$y_t = \Lambda f_t + \epsilon_t, \qquad t = 1, \ldots, T, \tag{1}$$

Here f_t is the unobserved common factor, while ϵ_t is the normally distributed, cross-sectionally uncorrelated idiosyncratic component, which is uncorrelated with f_t in all leads and lags.[3]

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[1]James H. Stock and Mark W. Watson, "New Indexes of Coincident and Leading Economic Indicators," in *NBER Macroeconomics Annual 1989,* Volume 4, edited by Olivier J. Blanchard and Stanley Fischer, MIT Press, pp. 351-394.

[2]Banbura and Modugno "Maximum Likelihood Estimation of Factor Models on Datasets with Arbitrary Pattern of Missing Data," *Journal of Applied Econometrics*, Volume 29 (2014): 133-160.

[3] The results are asymptotically valid also in the case of the approximate factor models, i.e. when the idiosyncratic components can be weakly correlated.

The elements of the error term ϵ_t on the other hand, are assumed to be serially correlated and follow an AR(1) process. This assumption makes the idiosyncratic component predictable and can improve the efficiency of factor estimates in small samples and in applications where the dataset at the end of the sample is incomplete. More specifically, let $\epsilon_t = [\epsilon_{1,t}, \epsilon_{2,t}, \ldots, \epsilon_{n,t}]'$ and

$$\epsilon_{i,t} = \alpha_t \epsilon_{i,t} + e_{i,t}, \qquad e_{i,t} \sim i.i.d. N(0, \sigma_i^2). \tag{2}$$

The factor is assumed to also follow an AR(1) process, i.e.

$$f_t = \beta f_{t-1} + u_t, \qquad u_t \sim i.i.d. N\left(0, \sigma_f^2\right). \tag{3}$$

The parameters of the model in equations (1) - (2) are cast in a state space framework, where equation (1) is the observation equation, while equations (2) and (3) are jointly modeled as state equations, guiding the autoregressive dynamics of the latent variables in the system.

As noted earlier, the model is estimated based on the EM (expectation maximization) algorithm of Banbura and Modugno (2014), which makes maximum likelihood estimation with incomplete and latent data feasible. This procedure is a two-step procedure, where (i) in the first step, we obtain estimates of the latent variables given the most recent data and parameter estimates using Kalman filtering/smoothing techniques and form the expected likelihood; (ii) in the second step, we pick new parameter estimates which maximize the expected likelihood. We iterate the two-step procedure until the algorithm converges.

The maximum likelihood estimation highlighted here makes it possible to restrict some of the parameters of the model. In fact, given that we use a mix of monthly and quarterly variables, we utilize certain restriction on the parameters of the model in order to make the growth rates of the quarterly variables consistent with the underlying monthly ones. More specifically, given our three monthly and one quarterly variables in the system, the state space considered above has the following form:

$$
\begin{bmatrix} y_t^m \\ y_t^q \end{bmatrix} = \begin{bmatrix} \Lambda_m & 0 & 0 & 0 & 0 & I_m & 0 & 0 & 0 & 0 & 0 \\ \Lambda_q & 2\Lambda_q & 3\Lambda_q & 2\Lambda_q & \Lambda_q & 0 & 1 & 2 & 3 & 2 & 1 \end{bmatrix} \begin{bmatrix} f_t \\ f_{t-1} \\ f_{t-2} \\ f_{t-3} \\ f_{t-4} \\ \varepsilon_t^m \\ \varepsilon_t^q \\ \varepsilon_{t-1}^q \\ \varepsilon_{t-2}^q \\ \varepsilon_{t-3}^q \\ \varepsilon_{t-4}^q \end{bmatrix} + \begin{bmatrix} \xi_t^m \\ \xi_t^q \end{bmatrix}
$$

$$
\begin{bmatrix} f_t \\ f_{t-1} \\ f_{t-2} \\ f_{t-3} \\ f_{t-4} \\ \varepsilon_t^m \\ \varepsilon_t^q \\ \varepsilon_{t-1}^q \\ \varepsilon_{t-2}^q \\ \varepsilon_{t-3}^q \\ \varepsilon_{t-4}^q \end{bmatrix} = \begin{bmatrix} \beta & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & \alpha_m & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & \alpha_q & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 \end{bmatrix} \begin{bmatrix} f_{t-1} \\ f_{t-2} \\ f_{t-3} \\ f_{t-4} \\ f_{t-5} \\ \varepsilon_{t-1}^m \\ \varepsilon_{t-1}^q \\ \varepsilon_{t-2}^q \\ \varepsilon_{t-3}^q \\ \varepsilon_{t-4}^q \\ \varepsilon_{t-5}^q \end{bmatrix} + \begin{bmatrix} u_t \\ 0 \\ 0 \\ 0 \\ 0 \\ \varepsilon_t^m \\ \varepsilon_t^q \\ 0 \\ 0 \\ 0 \\ 0 \end{bmatrix},
$$

where I_m indicates an $m \times m$ identity matrix, while ξ_t is cross-sectionally uncorrelated noise with a very small variance, which is added to the system to make estimation and inference simpler.

The size of the state vector and the restriction on the loading matrix Λ are motivated by the objective to ensure that the sequential monthly real wage growth series, which in our case is the quarterly variable in the system, remains consistent with the observed quarterly growth rate. To achieve that, motivated by Mariano and Murasawa (2003), we impose the [1 2 3 2 1] weighting structure on the model implied monthly growth rates.

For instance, let y_t^q be the growth rate of the quarterly variable Y_t^Q. Then, using the approximation provided by Mariano and Murasawa (2003), we obtain:

$$
y_t^Q = Y_t^Q - Y_{t-3}^Q \approx (Y_t^M + Y_{t-1}^M + Y_{t-2}^M) - (Y_{t-3}^M + Y_{t-4}^M + Y_{t-5}^M)
$$

$$y_t^Q = y_t + 2y_{t-1} + 3y_{t-2} + 2y_{t-3} + y_{t-4},$$

where the y_t would be the underlying month-to-month growth rate of the real wage series. In practice, what is being aggregated is the model-implied monthly growth rate.

As noted, once the algorithm converges, the estimated common factor f_t is the series from which we build the business-cycle index.

Data

We use four economic variables to estimate the College Station-Bryan business-cycle index. The four variables are the MSA's monthly unemployment rate and non-farm employment count, quarterly real (inflation-adjusted) wages, and monthly total taxable sales. These are chosen to be closely similar to the data series used by the FRBD in its construction of the business cycle indexes for the major Texas MSAs. The main difference is that the FRBD uses quarterly retail sales rather than monthly total taxable sales. We opted to use the monthly taxable sales because of its monthly frequency and because we were able to obtain a longer historical series for taxable sales than for quarterly retail sales. The four series for the College Station-Bryan MSA are discussed next.

Unemployment Rate

The seasonally adjusted unemployment rate for the CSB MSA is available monthly from the Bureau of Labor Statistics (BLS). Monthly data for this series is released with a one-month lag. Figure 1 presents two series. The first series, with the noticeable discontinuity during the 1990s, is the BLS's seasonally adjusted unemployment rate series for the CSB MSA from January 1990-August 2018.[4] The BLS already accounts for the redefinition of Metropolitan Statistical Areas and has reconstructed the unemployment series back to January 1990. This "raw" series exhibits two significant breaks between December 1990 and January 1991 and between December 1999 and January 2000. The break is due to redesigns of the Local Area Unemployment Statistics (LAUS) program that affects the BLS methodology used to estimate sub-state area employment and unemployment figures.

Our adjustment of the BLS unemployment rates for the period up to December 1999 is also presented in Figure 1. The model used to predict replacement values for the adjusted series can be written as:

$$\Delta UER_t = a_1 + a_2 D_1 + a_3 D_2 + b_1 \Delta UER_{t-1} + b_2 \Delta UER_{t-1} * D_{1t-1} + b_3 \Delta UER_{t-1} * D_{2t-1}$$

where:

$\Delta UER_t = Unemployment\ Rate\ in\ period\ t$

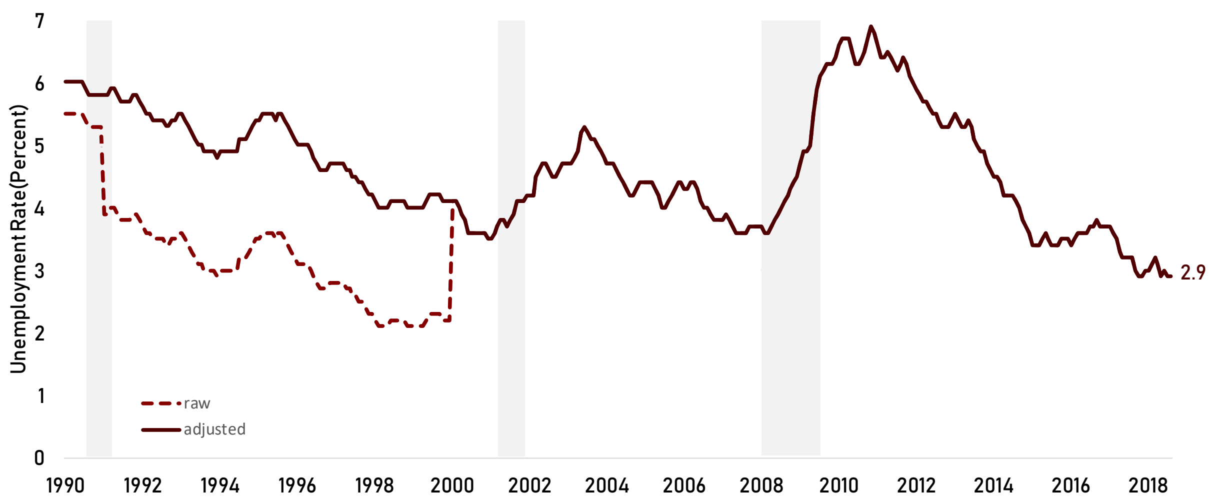
[4]Bureau of Labor Statistics (BLS), State and Metro Area Employment, Hours, & Earnings https://www.bls.gov/sae/

$D_1 = 1\ on\ January\ 1991, 0\ in\ all\ other\ months$

$D_2 = 1\ on\ January\ 2000, 0\ in\ all\ other\ months$

We estimate this model on the seasonally adjusted unemployment rate series for January 1990 to July 2018. The adjusted series is based on the predicted values from January 1990 to December 1999 and the data from the BLS thereafter.

Figure 1. Unemployment Rate in College Station-Bryan MSA



Source: Bureau of Labor Statistics. (Monthly) Seasonally Adjusted. Last reported data point August 2018.

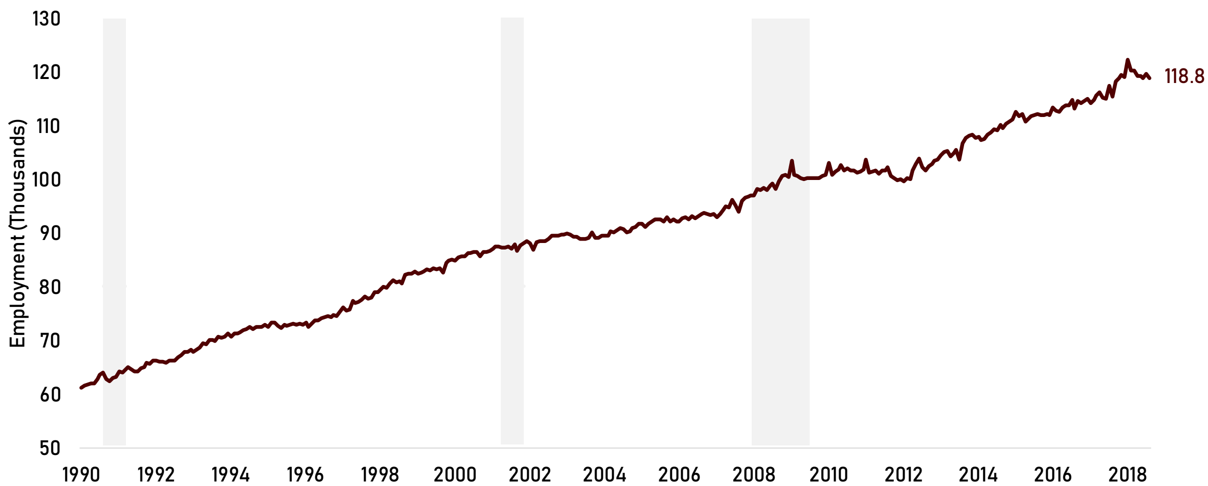
The adjusted series indicates movements in the underlying business cycle and the magnitude of its fluctuations. The unemployment rate in the CSB MSA declined during 1990s and up to the beginning of 2001. This turning point was at approximately the same time as the March 2001 peak prior to the 2001 recession, (recessions are identified by the shaded areas) as dated by the National Bureau of Economic Research.[5] The rate then rose until it reached 5.3% in June of 2003. From that point until March of 2008, the rate declined to 3.6%. The rate rose in conjunction with the Great Recession and reached a peak of 6.9% in November of 2010. After this peak, the rate declined to 3.4% by January 2015, but then stalled and actually rose to 3.8% in September 2016 – this period will show up the business-cycle index as a temporary slowdown in the local economy. The 2.9% unemployment rate in August of 2018 is tied for the lowest in the adjusted series.

[5] *US Business Cycle Expansions and Contractions,* National Bureau of Economic Research, https://www.nber.org/cycles/US_Business_Cycle_Expansions_and_Contractions_20120423.pdf

Non-Farm Employment

The non-farm employment count for the CSB MSA is also available monthly from the BLS. Non-farm employment counts are also released with a one-month lag. We source the seasonally adjusted non-farm employment count for CSB from the FRBD because the FRBD series uses a superior two-step seasonal adjustment process which overcomes a data issue that arises at the turn of each year with BLS data.[6] The non-farm employment series for CSB from January 1990 to August 2018 is presented in Figure 2.

Figure 2. Non-Farm Employment in College Station-Bryan MSA



Source: Bureau of Labor Statistics; Federal Reserve Bank of Dallas for two-step seasonal adjustment (Monthly). Last reported data point August 2018.

The periods of relatively slow or negative employment growth in the CSB MSA usually coincide with the timing of national recessions, but with a delay. In particular, as seen with The Great Recession, the employment response to the recession in the CSB MSA were delayed and lingered into the first the months of 2012. This delayed response is driven by seasonally adjusted government employment levels that continued to rise in the CSB MSA, up to 43.8 thousand by January 2010 and then declined for the succeeding 30 months down to 38 thousand in July of 2013. As we will see, the CSB Business-Cycle's peaks and troughs are delayed relative to the national cycle's peaks and troughs.

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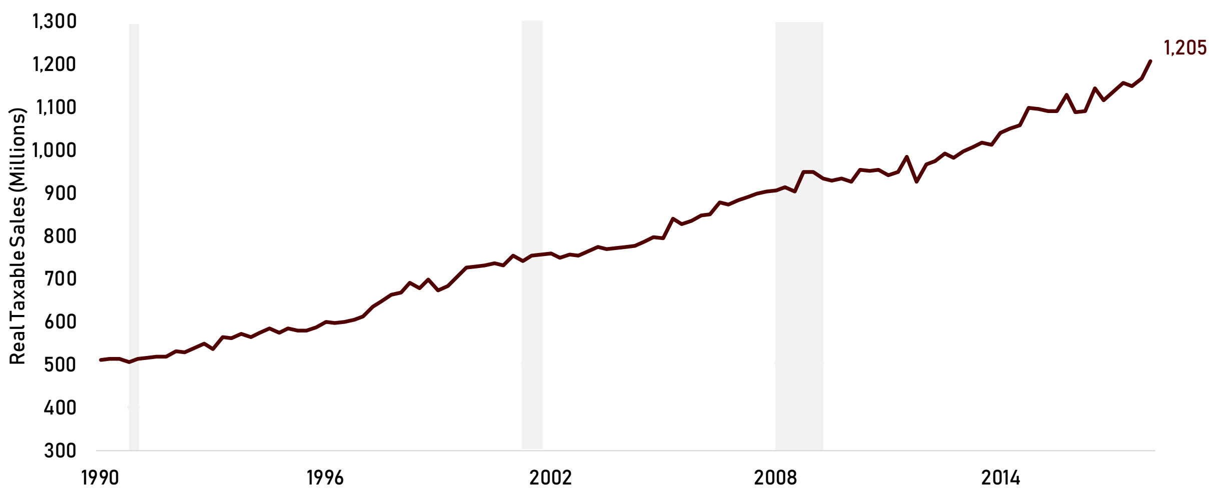
[6]See the Dallas Federal Reserve's discussion of the two-step process used to adjust the nonfarm employment series at: https://www.dallasfed.org/research/basics/twostep.aspx

Real Wages

Our source for quarterly seasonally adjusted total wages in the College Station-Bryan MSA is the St. Louis Federal Reserve Bank. The raw data is from the BLS, but is seasonally adjusted by the St. Louis Fed. This series reflects total wage compensation paid in the MSA. The wages are converted to real, inflation-adjusted, wages using the consumer price index for all urban consumers. This data is released with a fairly long lag: the most recent data was released on September 5, 2018 and reflected total wages for the 1st quarter of 2018. Data for Quarter 2 of 2018 will be released three months later, a six month lag, on December 6, 2018.

Figure 3. Real Wages in College Station-Bryan MSA



Sources: Bureau of Labor Statistics; Federal Reserve Bank of St. Louis for seasonal adjustment (Quarterly). Last reported data point 2018:Q1. Adjusted for inflation using CPI-U (2018:Q3=100).

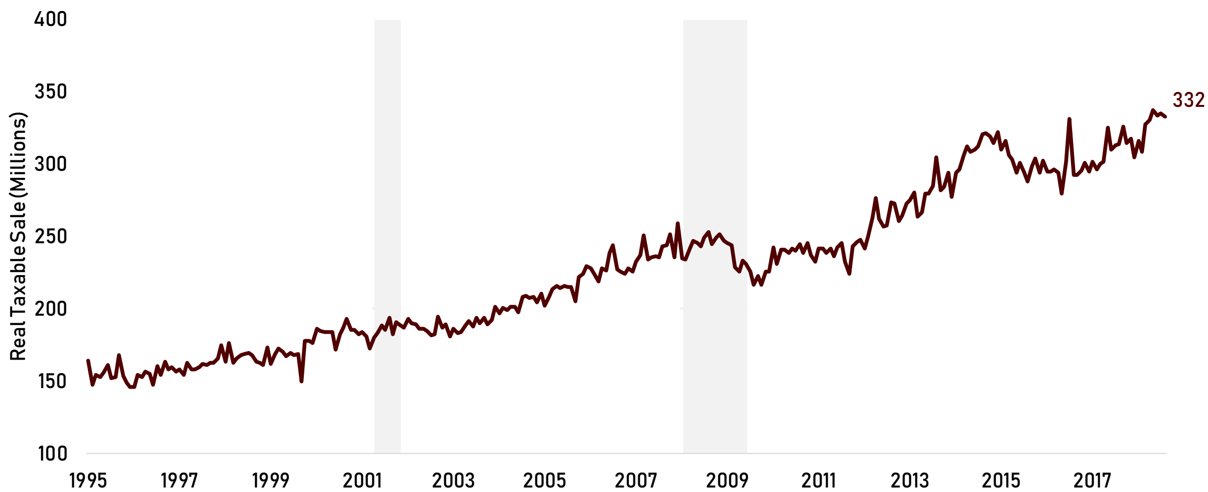
This series illustrates that the total wage bill associated with all employment exhibits a delayed period of static real wages well after the recent recession.

Real Taxable Sales

We use monthly sales taxes allocated to Brazos and Burleson Counties, and because Robertson County does not collect a separate sales tax, we use the tax allocations reported for Bremond, Calvert, Franklin and Hearne to arrive at the total sales taxes collected in the CSB MSA. We combine these data with the respective sale tax rates to produce a series of gross sales subject to the sale tax. Using the Census Bureau's X-13 software, we seasonally adjust the real taxable sales series. The monthly series from January 1995 to the August 2018 is presented in Figure 4.

Again, this series illustrates that the business-cycle in the CSB MSA is delayed relative to the national cycle. As was noted in the discussion of the unemployment rate, there was a period of declining economic activity, here revealed as a decline in real taxable sales during 2015 and the beginning of 2016.

Figure 4. Real Taxable Sales in College Station-Bryan MSA



Source: Texas Comptroller of Public Accounts; Private Enterprise Research Center for aggregation to the CSB MSA and for seasonal adjustment. Last reported data point August 2018. Adjusted for inflation using CPI-U (August 2018=100).

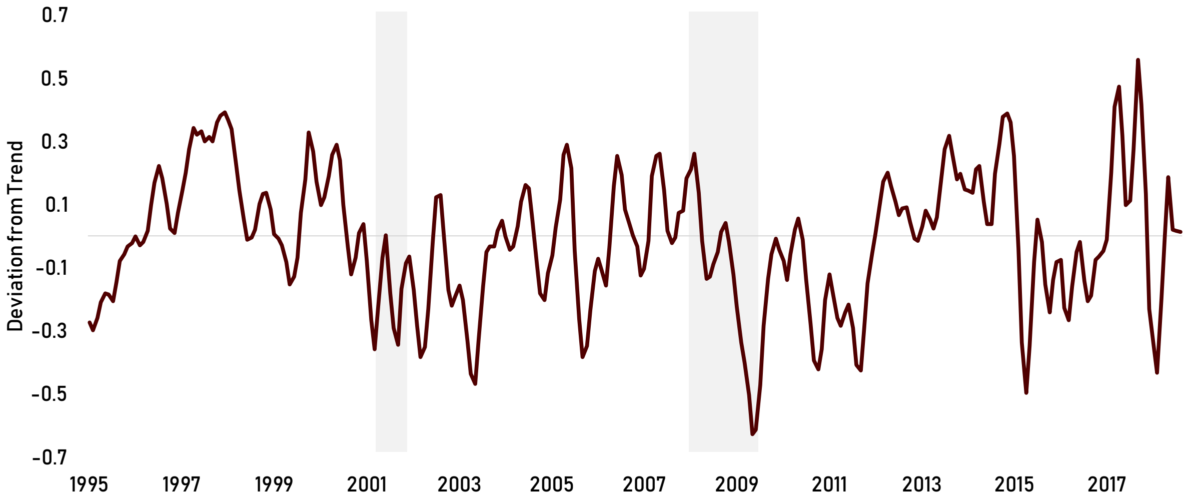
The four series are transformed before estimating the model. The inverse of the unemployment rate is entered as a 5-month centered moving average. The real taxable sales series is also smoothed with the 5-month centered moving average.[7] Finally, we transform the series to stationarity by differencing the unemployment series and by taking the difference of the logs of the other three.

The College Station-Bryan Business Cycle

The output from the model is the common factor f_t presented in Figure 5 for the period January 1995 to the August 2018. The series fluctuates above and below zero indicating the movements relative to the College Station-Bryan economy's underlying economic growth. The delayed movements in the cycle show in the figure were indicated by the timing of the movements of the component series relative the US business-cycle.

[7]Both the unemployment rate and the real taxable sales series are 5-month smoothed weighted centered moving averages of the following form: $\bar{x}_t = 1x_{t-2} + 2x_{t-1} + 3x_t + 2x_{t+1} + 1x_{t+2}$.

Figure 5. Estimated Common Factor Series for the College Station-Bryan MSA



Source: Private Enterprise Research Center. Last reported data point August 2018 (Monthly).

Scaling and Transforming the Estimated Common Factors to Produce the Business-Cycle Index

The common factor show in Figure 5 is used to build the business-cycle index as follows. We begin with some notation. We redefine the notation of the common factor f_t in month *t* as $\Delta \ln C_t^a$. This series has mean μ^a and standard deviation d^a. We standardize the series as follows:

$$\Delta \ln C_t^b = (\Delta \ln C_t^a - \mu^a) / d^a .$$

Next we scale this standardized series to match the growth rate and standard deviation of MSA-level real GDP. Annual real GDP series is produced for the CSB MSA by the Bureau of Economic Analysis for the years 2001 to 2017.[8] We transform real GDP, Y, into growth rates by defining y = $\Delta \ln(Y)$. The mean of this annual series is μ_y^A and the standard deviation is σ_y^A. The monthly equivalent growth rate is $\mu_y^M = \mu_y^A / 12$ and the monthly equivalent standard deviation is $\sigma_y^M = \sigma_y^A / \sqrt{12}$. We use these monthly equivalent means and standard deviations to transform $\Delta \ln C_t^b$ Let $\Delta \ln C_t = \mu_y^M + \Delta \ln C_t^b / \sigma_y^M$. This gives us a transformed version of our estimated common factor that has the same mean and standard deviation as real GDP. This series $\Delta \ln C_t$ is what we label the "business cycle." To create our trending index, we cumulate the series we label the business cycle as follows:

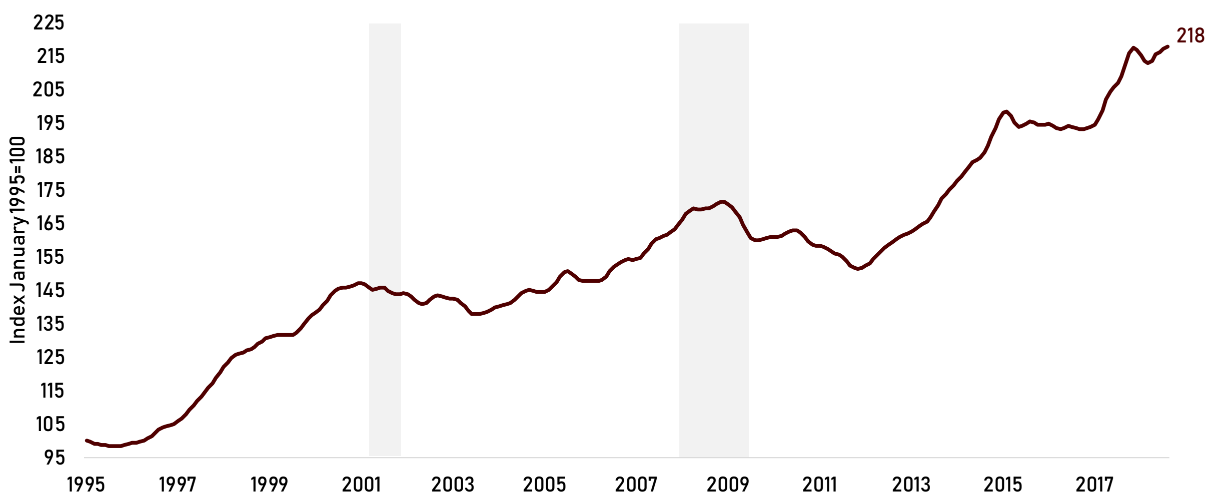
[8]The Bureau of Economic Analysis, GDP by Metropolitan Area, https://www.bea.gov/data/gdp/gdp-metropolitan-area.

$$I_t = I_0 + \sum_{i=1}^{t} \Delta \ln C_t \quad \text{for t = 1, 2, …, T, and where } I_0 = 0.$$

Then finally we define the published index, B, as $B_t = 100 * \exp(I_t)$.

Figure 6 presents the College Station-Bryan Business-Cycle Index beginning with January 1995=100. As expected, the peaks and troughs in the CSB Business-Cycle Index are staggered relative to the national cycle. This is also the case when the CSB Business-Cycle Index is compared to the indexes produced by the FRBD for Texas and the larger Texas MSAs. The more recent period of slower growth in the CSB economy corresponds to a similar period identified in the FRBD business-cycle for the Houston-The Woodlands-Sugar Land MSA.[9]

Figure 6. College Station-Bryan Business-Cycle Index



Source: Private Enterprise Research Center. Last reported data point August 2018 (Monthly).

Our index shows the CSB MSA responding with a long lag to the national economic situation. That is, our index value continues to decline well after the recession is over at the national level. This delayed response lasts longer than many other MSA's in Texas. However, Fullerton and Subia (2017) developed a business-cycle index for Lubbock, Texas and find that Lubbock's business cycle is also delayed relative to the national cycle. They suggest that this was due to that Lubbock's large manufacturing sector. In the case of the College Station-Bryan economy, the significant role of Texas A&M University in the local economy through the labor market variables in the model influences the relative timing of the business-cycle's movements.

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[9] See Houston-The Woodlands-Sugar Land- Business-Cycle Index, https://www.dallasfed.org/research/econdata/houcoini.aspx.

Conclusion

The College Station-Bryan Business-Cycle Index is based on a dynamic factor model developed by Banbura and Modugno (2014) that accommodates data series with differing lengths, frequencies and publication delays. We implement their model utilizing three monthly and one quarterly data series. The monthly series include the seasonally adjusted unemployment rate, seasonally adjusted non-farm employment, and seasonally adjusted real taxable sales. Total real seasonally adjusted wages are the lone quarterly series.

Given that GDP measures for local economies are only available annually, with significant delays, the CSB Business-Cycle Index is a coincident index that provides a much more timely indication of the overall movements in the local economy. Our estimates indicate that this MSA's economy's peaks and troughs are delayed relative to the national business cycle.

Data Sources

Unemployment Rate
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Inflation
U.S. Bureau of Labor Statistics, Consumer Price Index for All Urban Consumers: All Items [CPIAUCSL], retrieved from FRED, Federal Reserve Bank of St. Louis; https://fred.stlouisfed.org/series/CPIAUCSL. Wages and Taxable Sales are converted to real dollars (inflation-adjusted) using the CPI-U.

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