Federal Reserve Bank of Dallas

Texas Manufacturing Outlook Survey: Survey Methodology, Performance and Forecast Accuracy

Jesus Cañas, Aparna Jayashankar, Emily Kerr and Diego Morales-Burnett

Working Paper 2402 **March 2024**

Research Department

https://doi.org/10.24149/wp2402

Texas Manufacturing Outlook Survey: Survey Methodology, Performance and Forecast Accuracy*

Jesus Cañas†, Aparna Jayashankar‡, Emily Kerr§ and Diego Morales-Burnett±

March 8, 2024

Abstract

The Texas Manufacturing Outlook Survey (TMOS) is a monthly survey of area manufacturers conducted by the Federal Reserve Bank of Dallas. TMOS indexes provide timely information on manufacturing activity in Texas, which is useful for understanding broader changes in regional economic conditions. This paper describes the survey methodology and analyzes the explanatory and predictive power of TMOS indexes with regard to other measures of state economic activity. Regression analysis shows that several TMOS indexes successfully track changes in Texas employment, gross domestic product and consumer price index. Forecasting exercises show that several TMOS indexes are also useful in predicting future changes in some of these regional economic indicators.

Keywords: Manufacturing, Surveys, Forecasting

JEL Classifications: L60, C83, C53

*We thank Pia Orrenius and Anil Kumar for valuable comments. This paper was initiated while Aparna Jayashankar (McKinsey & Co.) was working at the Federal Reserve Bank of Dallas. This paper is related to "Texas Manufacturing Outlook Survey: Survey Methodology and Performance." The views expressed here are those of the authors and do not necessarily reflect those of the Federal Reserve Bank of Dallas or the Federal Reserve System.

†Jesus Cañas, Federal Reserve Bank of Dallas, jesus.canas@dal.frb.org.

‡Aparna Jayashankar, McKinsey & Co., aparna_jayashankar@mckinsey.com.

§Emily Kerr, Federal Reserve Bank of Dallas, emily.kerr@dal.frb.org.

±Diego Morales-Burnett, Federal Reserve Bank of Dallas, diego.morales-burnett@dal.frb.org.

Table of Contents

1. Introduction

Business surveys such as the Dallas Fed's Texas Manufacturing Outlook Survey (TMOS) are used to monitor economic activity and expectations about future growth. They typically also provide timelier information than other regional data sources. In the U.S., several of these surveys focus on the manufacturing sector since its trends are particularly useful for understanding changes in the general economy. This is because manufacturing is more cyclically sensitive and tends to lead overall economic growth.[1] One such business survey is the Institute for Supply Management's (ISM) Report on Business, which has reported its monthly national manufacturing Purchasing Managers' Index (PMI) index since 1948.[2] Other monthly U.S. manufacturing surveys include regional surveys published by a number of the Federal Reserve banks, including Philadelphia (started in 1968), Richmond (started in 1993), New York (started in 2001), Kansas City (started in 2001) and Dallas (started in 2004).

These Fed surveys can provide an early look at economic conditions within the Banks' respective geographic regions before official statistics become available. Since its inception in 2004, TMOS has become widely used by analysts and commonly cited by local and national business media outlets, including the *Dallas Morning News*, the *Austin American-Statesman*, *Wall Street Journal*, *Fortune*, Reuters and Bloomberg. TMOS provides real-time information on changes in activity in Texas' manufacturing sector, which, as noted above, has implications for

[1] See Stock, James H. & Watson, Mark W., 1999. "Business cycle fluctuations in U.S. macroeconomic time series," in: J. B. Taylor & M. Woodford (ed.), Handbook of Macroeconomics, edition 1, vol. 1, chapter 1, pp. 3-64. See also Zarnowitz, Victor, 1992. "Composite Indexes of Leading, Coincident, and Lagging Indicators," in: Zarnowitz, Victor (ed.), Business Cycles: Theory, History, Indicators, and Forecasting, chapter 11, pp. 316-356.

[2] The ISM PMI index has proven a valuable tool in forecasting U.S. gross domestic product growth. See Koenig, Evan F. (2002), "Using the Purchasing Managers' Index to Assess the Economy's Strength and the Likely Direction of Monetary Policy," Federal Reserve Bank of Dallas Economic and Financial Policy Review, vol. 1, no. 6.

broader economic activity in the region. In 2022, manufacturing accounted for 6.9% of Texas employment.

The most important gauge of TMOS' value is whether its indexes are correlated with economic activity in Texas. Berger (2010) shows that the TMOS production, employment, and new orders indexes each help explain monthly changes in Texas manufacturing employment, Texas manufacturing industrial production and the Texas manufacturing business-cycle index. This paper updates an earlier working paper, Canas and Kerr (2014), that built on Berger's research to explore how well TMOS indexes correlate with changes in overall Texas employment, Texas gross domestic product (GDP) and the headline consumer price index (CPI) for Texas. In addition, we do a forecast evaluation.

2. TMOS Methodology

TMOS is one of several Dallas Fed surveys which include TMOS's two sister surveys, the Texas Service Sector Outlook Survey and the Texas Retail Outlook Survey, as well as the Banking Conditions Survey, the Energy Survey and the Agricultural Survey.[3] The surveys provide information that helps the Dallas Fed fulfill its role as part of the nation's central bank system, providing valuable insight into regional economic conditions and informing monetary policy decisions. The survey data fill a gap in regional economic data, which are limited, not generally timely, and are also subject to large and delayed revisions. For example, state employment data from the Bureau of Labor Statistics are released with a three-week lag and are extensively

[3] These surveys can be found on the Dallas Fed website at www.dallasfed.org/research/surveys.

revised in subsequent months and years. State level GDP data from the Bureau of Economic Analysis are also available with a substantial lag and are subject to revision.

Manufacturing executives responding to TMOS report on how business conditions have changed for a number of indicators, such as production, new orders, prices and employment. Respondents are also asked to report on how they perceive broader economic conditions have changed, such as general business activity. All questions ask whether the indicator has increased, decreased or remained unchanged over the prior month.[4] Survey responses are used to calculate diffusion indexes by subtracting the percentage of respondents reporting a decrease from the percentage reporting an increase. When the share of firms reporting an increase exceeds the share reporting a decrease, the index will be greater than zero, suggesting the indicator has increased over the prior month. If the share of firms reporting a decrease exceeds the share reporting an increase, the index will be below zero, suggesting the indicator has decreased over the prior month. In addition to asking about month-to-month changes, the survey also asks about expectations six months ahead for the same group of indicators.

Survey Design and Implementation

The Dallas Fed began collecting TMOS data in June 2004. The original sampling frame was drawn from Reference USA, a business database that listed over 45,000 Texas manufacturing firms. Solicitations to participate went out to single-location companies or company headquarters in Texas; branches were excluded to avoid duplicate responses from affiliated operations. We

[4] The sample survey form can be found on the Dallas Fed website at www.dallasfed.org/~/media/documents/research/surveys/tmos/documents/form.pdf.

focused on firms with more than 100 employees, although for some industries it was necessary to include smaller entities (Sigalla, et. al 2007). Letters of invitation were sent to 2,500 randomly selected Texas manufacturing firms meeting the criteria in April 2004, and executives from 130 firms agreed to participate. There were roughly 65 to 80 survey responses received each month during the first three years. The survey sample was expanded in January 2007 with a second round of invitation letters, and smaller-scale recruitment efforts have taken place on an ongoing basis since. As of January 2023, nearly 140 firms receive the survey, and about 100 respond each month.

TMOS is sent via email mid-month to executives at Texas manufacturing firms, and participants have seven business days to submit their survey responses. The diffusion indexes calculated from the survey responses are seasonally adjusted in order to discern underlying economic trends. Full reports of results along with the collection dates and number of firms responding are published on the Dallas Fed website on the last Monday of each month. Comments from respondents' completed surveys are also published, anonymously, with permission. The Dallas Fed began releasing TMOS results to the public in November 2005. Survey results were reported on a seasonally adjusted basis starting in August 2009.

Seasonal Adjustment

The Dallas Fed uses the X12 seasonal-adjustment procedure, developed by the U.S. Census Bureau, to statistically remove seasonal effects. TMOS respondents are explicitly asked to take seasonal variations into account when assessing firm performance each month. However, as of January 2023, the X12 results indicate that 29 of the 33 indexes contained statistically significant

seasonality.[5] For these indexes, the increase, decrease and no change components are each adjusted. The indexes are then re-computed using the adjusted components. If the three adjusted component series (increase, decrease, and no change) do not sum to 100 percent, they are normalized to add up to 100. In January each year, the Dallas Fed revises historical data for TMOS by recalculating the seasonal factors to account for an additional year of data.

Representativeness of the TMOS sample

In order for the data received from TMOS to be generally representative of the Texas manufacturing sector, it is important that the industry composition of the survey panel be in line with the industry composition of manufacturing in Texas. The Dallas Fed uses employment shares for industries (using three-digit North American Industry Classification System (NAICS) codes) within the Texas manufacturing sector to set a target composition for the panel of TMOS participants. For example, if food manufacturing (NAICS 311) accounts for 12 percent of Texas manufacturing employment, ideally 12 percent of TMOS participants would be food manufacturers. A breakout of the industry distributions of Texas manufacturing employment and the TBOS sample are shown in Figures 1a and 1b. While not perfect, the industry composition of the TMOS sample very closely mirrors that of manufacturing in Texas, and efforts are always ongoing by Dallas Fed staff to better hone the representativeness of the TMOS sample by adding participants in underrepresented industries.

[5] A current list of the seasonal indexes is found at www.dallasfed.org/research/surveys/tmos/seasonal.

Figure 1a. Industry Distribution of Texas Manufacturing Employment, 2023

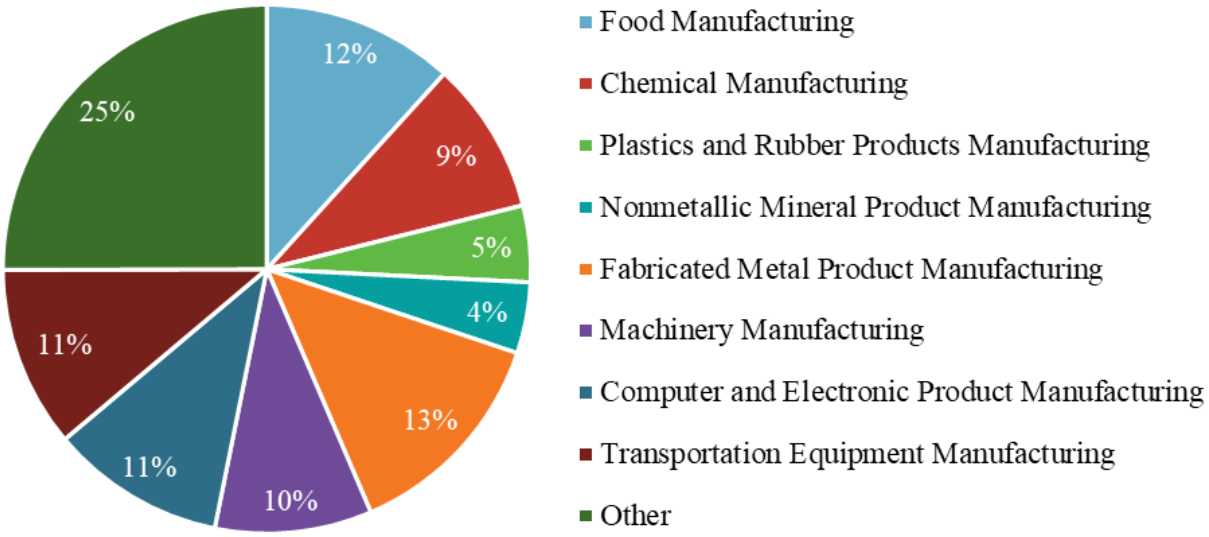
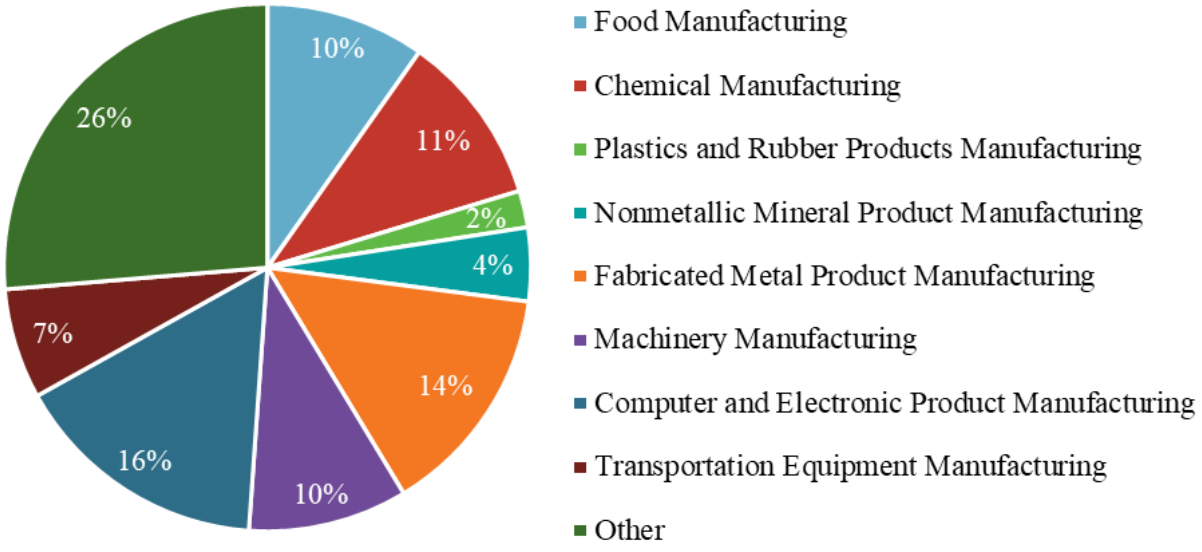


Figure 1b. Industry Distribution of TMOS Sample, 2023



NOTE: Shown in Figure 1a are Texas manufacturing employment shares for the top eight NAICS industries, which account for 75 percent of total Texas manufacturing employment.
SOURCE: Bureau of Labor Statistics.

Maintaining the TMOS Sample

Ongoing recruitment efforts are required to maintain a robust and representative survey panel. Firms discontinue involvement over time due to companies merging, changing the location or nature of their operations, going out of business, or due to participating executives changing roles, leaving the company or electing to no longer participate.

In the first quarter of each year, Dallas Fed economists analyze the representativeness of the existing TMOS panel. They identify target industries (by three-digit NAICS codes) where the survey panel is underrepresented. We also look at the sample distribution by geography and firm size, as well as how many are women and/or minority-owned firms. Recruitment efforts for the year focus on shoring up underrepresentation in any of these stratifications, so that the sample closely matches the distribution seen in Texas, as well as bolstering the overall sample size.

Methods of recruitment have included mailed letters of invitation, invitation emails or phone calls, as well as personal interactions at Dallas Fed events and when Dallas Fed economists give presentations to various groups (distributing a handout or providing a QR code on a presentation slide). New participants are enrolled for the next monthly survey on a rolling basis. In addition to adding new participants, it is also important to hold on to existing ones. Dallas Fed staff enacted procedure in 2012 to systematically follow-up with non-responding survey participants in an effort to minimize attrition and boost response rates.[6]

[6] Staff members call participants who do not respond to three consecutive monthly surveys to resolve any issues and encourage a resumption of participation. A similar follow-up call is placed to participants after six months in a row of non-response, and then an email is sent after nine months, followed by a letter after 11 months. These correspondences usually incite participation to resume, but if a participant does not respond to a survey for 12

3. TMOS Contribution to Regional Analysis

The Dallas Fed's TMOS adds considerable value to the existing body of U.S. business surveys, including other Fed manufacturing surveys.

Large Size of Manufacturing Sector

Texas accounts for almost 10 percent of U.S. manufacturing output, the highest share among the regions that Fed surveys cover, as shown in Table 1. Manufacturing output grew in Texas in the period 2017 to 2022, though not as fast as in the U.S. or as fast as Texas GDP overall.

Table 1. Comparison of Manufacturing GDP across Fed Survey Geographies

Region	Mfg. GDP, 2022 $2022 millions	Share of U.S. Mfg. GDP, 2022 percent	Mfg. GDP growth, 2017-2022 percent
Texas	164,923	9.2	5.7
New York	55,264	3.1	1.4
Third District*	112,858	6.3	4.1
Fifth District**	154,066	8.6	0.3
Tenth District***	103,224	5.8	13.6
U.S.	1,788,039	-	8.0

*Third District numbers include PA, NJ, and DE. **Fifth District numbers include MD, WV, VA, NC, SC, and DC. ***Tenth District numbers include MO, NE, KS, OK, WY, CO, and NM.
NOTES: These figures are not a perfect measure of the areas represented by each survey. The Third District includes only parts of PA and NJ, the Fifth District does not include all of WV, and the Tenth District includes only parts of MO and NM.
SOURCES: Bureau of Economic Analysis; Bureau of Labor Statistics.

consecutive months, they are removed from the panel. Participants are also removed from the panel at the request of the company or participant.

Survey Collection Period

TMOS data are collected in the latter half of the month to allow responding companies to get a real sense of business activity for that month. This adds unique value to the TMOS data, as most of the other Fed manufacturing surveys collect data early in the month (Table 2), and it is possible that respondents to these surveys could be responding based on the prior month's performance. Because of TMOS's later collection period, it is typically the last of the Fed manufacturing survey reports released. For almost half of the Federal Open Market Committee meetings, TMOS is the most recent Fed manufacturing survey data available.

Table 2. Collection Periods and Release Dates for Manufacturing Surveys, January 2023

	Dec. 2022			Jan. 2023																													
	Th	F	S	Su	M	T	W	Th	F	S	Su	M	T	W	Th	F	S	Su	M	T	W	Th	F	S	Su	M	T	W	Th	F	S	Su	M	T
New York Fed	29	30	31	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
Philadelphia Fed	29	30	31	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
Richmond Fed	29	30	31	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
Kansas City Fed	29	30	31	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
Dallas Fed	29	30	31	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31

NOTES: Shaded areas mark survey collection periods. Boxed dates mark survey release dates. January 2023 is used as an example of a typical month. Collection periods and release dates may vary from month to month.

Survey Indexes

TMOS includes data on production—a well-defined, quantifiable measure of manufacturing output that is not collected by most other Fed surveys. This adds value alongside measures of general business conditions, which tend to reflect perceptions of broad economic activity rather than actual output. While each of the Fed surveys asks about employment numbers, only TMOS and one other inquire about wages. Also, TMOS has four unique survey variables not available in the other Fed surveys: growth rate of orders, capital expenditures, company outlook and uncertainty regarding firms' outlook.

Survey Sample

TMOS receives about 100 survey responses each month—typically the highest among the Fed manufacturing surveys. In addition to a survey sample that is robust in number, it is also imperative that the composition of the sample be roughly in line with the composition of the sector it is intending to measure. The industry distribution of the TMOS sample is closely aligned with the industry distribution within Texas' manufacturing sector, as shown in Figures 1a and 1b, and the sample's geographical and size distribution is quite aligned as well.

4. TMOS Performance with Regional Economic Indicators

Monthly surveys of regional manufacturing activity can provide an early look at current economic conditions before official statistics become available. The most important gauge of their value, however, is whether the indexes are correlated with the economic activity they are intended to measure.

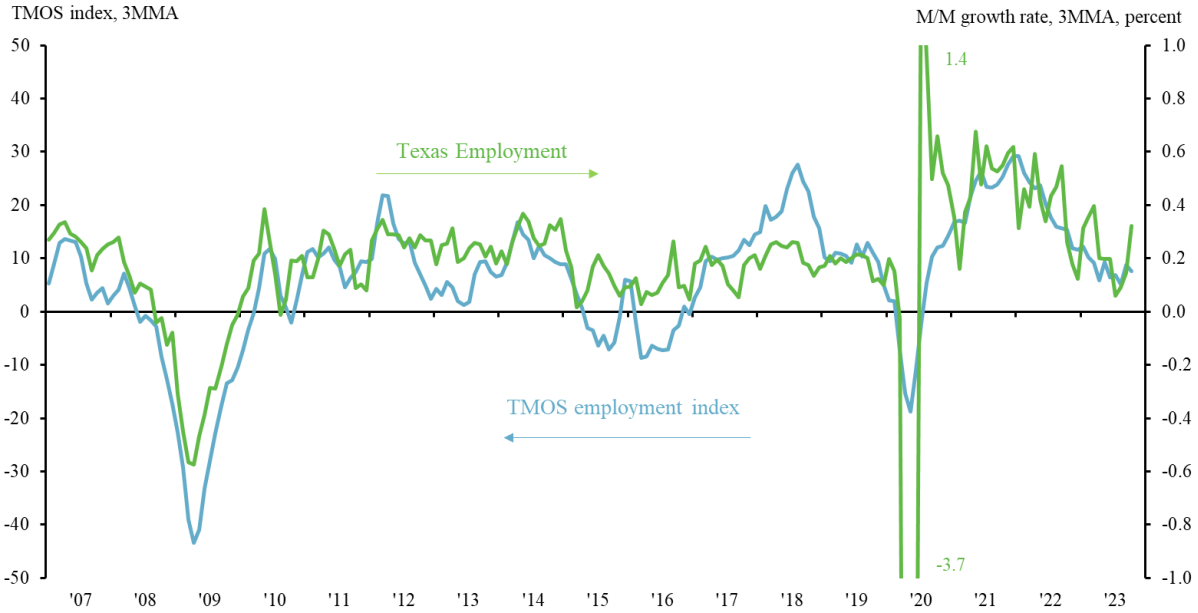
We examined the explanatory power of TMOS indexes for several state economic indicators—employment, gross domestic product, and headline CPI. We used autoregressive regression models to estimate how closely each index follows Texas economic activity. To avoid bias from the COVID-19 pandemic's impact, we excluded data from the year 2020.

Employment

Chart 1 plots the monthly change in Texas employment against the TMOS employment index. The index, like all TMOS indexes, is centered at zero, meaning that values greater than zero are consistent with growth. In general, the TMOS employment index tracks changes in Texas payroll

employment growth data from the Bureau of Labor Statistics, the timeliest and most comprehensive official indicator of state economic activity (even though the data are released with a lag and heavily revised in subsequent months).

Chart 1. TMOS Employment Index Tracks Monthly Changes in Texas Employment



NOTE: Data are monthly through October 2023.
SOURCES: Bureau of Labor Statistics; Texas Workforce Commission; Federal Reserve Bank of Dallas' Texas Manufacturing Outlook Survey.

Several studies have explored how well surveys of business activity correlate with regional economic indicators. Trebing (1998) finds that the Philadelphia Fed's Manufacturing Business Outlook Survey (MBOS) employment index was positively correlated with month-over-month changes in manufacturing employment and average manufacturing workweeks in the Third Federal Reserve District. Harris et al. (2004) show that the Richmond Fed's Fifth District Survey of Manufacturing Activity headline index highly correlates with Fifth District personal income. In addition, the authors find that the survey's employment index leads changes in the Fifth District's manufacturing employment by one quarter. Keeton and Verba (2004) show the Kansas

City Fed's employment indexes from the Survey of Tenth District Manufacturers provide substantial information about current and future growth in Tenth District manufacturing employment.

Survey indexes may also provide additional information about regional indicators beyond that contained in their past values. Trebing (1998) regressed monthly changes in U.S. manufacturing production index against 12 lagged values of change in the index plus Philadelphia's MBOS general activity index and finds that the model was able to account for 14 percentage points more of the monthly variation in U.S. manufacturing production when the MBOS diffusion index was added to the regression. Similarly, Keeton and Verba (2004) regressed monthly changes in Tenth Federal Reserve District employment on lagged values of changes in district employment plus the Kansas City Fed survey's manufacturing composite index and find that explanatory power substantially increases after including the survey index in the regression.

Following the steps of previous studies, we regressed monthly changes in Texas employment on its lagged values plus TMOS indexes to test if the survey indexes provide any information about current employment growth beyond that contained in past values of employment growth. The lag length of k=3 was chosen following the Akaike Information Criterion (AIC). We used the following equation:

$$\Delta TXEMPL_t = \beta_0 + \beta_1 TMOS_t + \sum_{j=1}^{k} \alpha_j \, \Delta TXEMPL_{t-j} + u_t \qquad (1)$$

where $\Delta TXEMP_t$ is the log difference in Texas employment and $TMOS_t$ is the index variable in levels. The expected sign of the $TMOS_t$ coefficient is positive and β_1 should be seen as the

change in the job growth rate that corresponds to a one-point increase in the value of the index. The year 2020 was excluded because of the initial disruption from the COVID-19 pandemic.

Regression results show that the three prior values of employment growth explain 33 percent of the change in a given month's employment growth. Adding TMOS variables to these lagged values of employment growth provides an additional 14 percentage points of explanatory power as evidenced by the adjusted R^2 values noted in Table 3. All coefficients are statistically significant and with the expected sign. According to the regression results, each one-point increase in the TMOS employment index, for instance, implies a 0.01 percentage point increase in the monthly change of Texas employment. The TMOS employment and capacity utilization indexes show the best fit.

Table 3 also shows the breakeven point, a value for the TMOS index that is consistent with no change in Texas employment growth. The breakeven point is equal to the negative of the ratio of the estimated intercept and slope coefficient. For example, if in equation (1) $\Delta TXEMP_t$ is zero—that is, no change in employment from the previous month—and β_0 is 5 and β_1 is 2, then the *TMOS* breakeven point should be -2.5 to be consistent with no change in state employment. Only values above the breakeven point suggest growth for the current month, and values below the breakeven point suggest a decline. Breakeven points for additional TMOS indexes can be found in Appendix A1.

Table 3. Texas Employment Growth Regressions

TMOS Index	Coefficient (t statistic)	Adjusted R^2	Breakeven point
No index		0.328	
Labor market indexes			
Employment	0.012 (7.105)	0.472	-8.168
Hours worked	0.010 (6.387)	0.449	-9.955
Future employment	0.006 (5.328)	0.416	5.810
Output indexes			
Capacity utilization	0.009 (6.593)	0.455	-6.048
Unfilled orders	0.010 (6.284)	0.446	-13.800
Growth rate of orders	0.007 (6.187)	0.443	-15.615
New orders	0.006 (6.116)	0.440	-10.563
Production	0.008 (5.895)	0.433	-5.040
Shipments	0.007 (5.803)	0.431	-7.435
Capital expenditures	0.009 (5.399)	0.418	-7.645

NOTES: Table displays the 10 TMOS indexes that are most highly correlated with Texas employment. The period is 2007:05 to 2023:10, excluding 2020 because of the initial disruption from the COVID-19 pandemic. Texas employment is in log difference. Regressions include three lags of employment growth.

Economic Activity

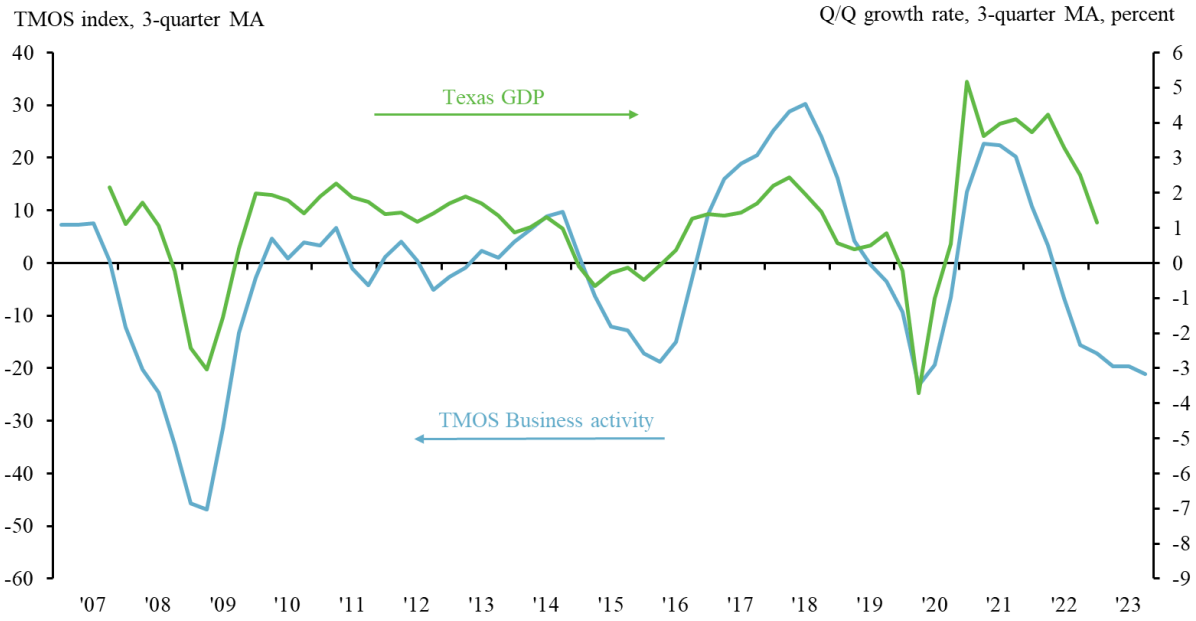
We also used regression analysis to ascertain whether TMOS indexes have statistically significant explanatory power for quarterly state real GDP growth, and we find that they do. The prior quarter's real GDP growth explains only 10 percent of the variation in real GDP growth in a given quarter. The addition of TMOS indexes pushes the adjusted R^2 up as high as 38 percent.

The model excludes 2020 and includes a one-quarter lag (k=1) to account for any variation explained by the previous quarter's real GDP growth and was as follows:

$$\Delta TXGDP_t = \beta_0 + \beta_1 TMOS_t + \sum_{j=1}^{k} \alpha_j \ \Delta TXGDP_{t-j} + u_t \qquad (2)$$

$\Delta TXGDP_t$ is real GDP growth from period t-1 to t, and $TMOS_t$ represents the level of a given TMOS diffusion index in period t. Table 4 lays out the regression results for the most relevant indexes. Business activity is the TMOS index with the most explanatory power for Texas real GDP, followed by company outlook and growth rate of orders. Chart 2 shows the three-month moving average of the TMOS business activity index alongside a three-quarter moving average of Texas real GDP growth and illustrates that they track each other closely.

Chart 2. TMOS Business Activity Index Correlates Well with Changes in Texas Real GDP



NOTES: Chart displays the TMOS index most highly correlated with Texas gross state product. Data through Q1 2023.
SOURCES: Bureau of Economic Analysis, Federal Reserve Bank of Dallas' Texas Manufacturing Outlook Survey.

A 1-point increase in the business activity index implies a 0.03 percentage point increase in Texas quarterly real GDP growth. For each regression, we also calculated a breakeven point, dividing the negative estimated intercept by the slope, to identify the level for the TMOS index that is consistent with no change in Texas real GDP growth. Breakeven points for additional TMOS indexes can be found in Appendix A2.

Table 4. Texas Real GDP Regressions

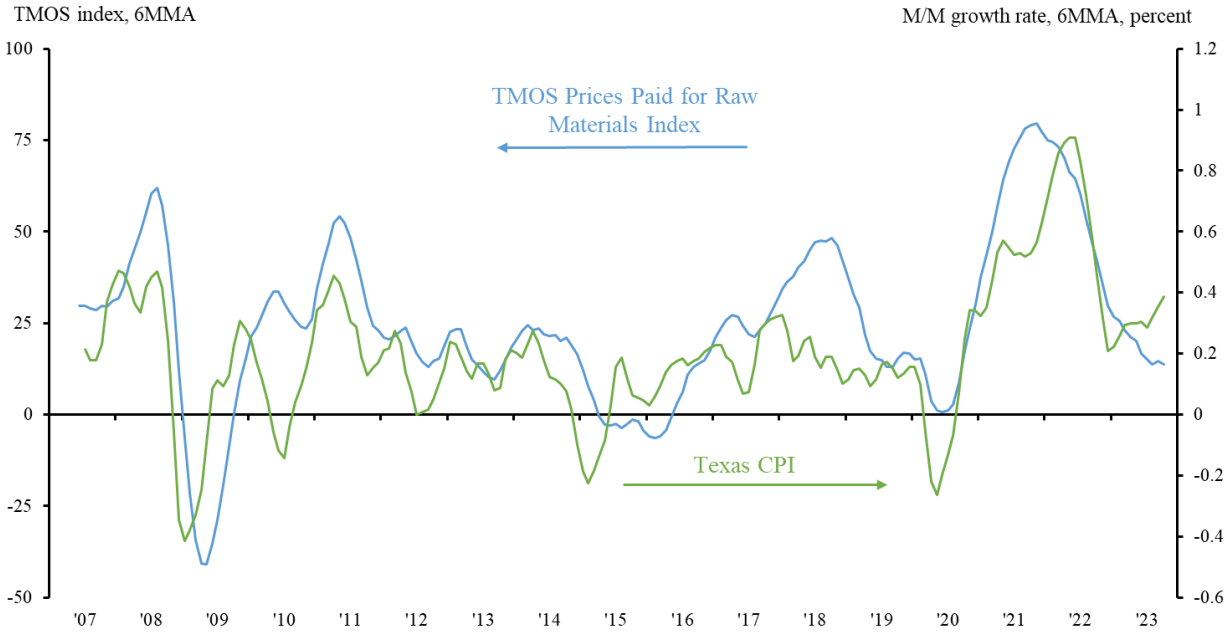
TMOS Index	**Coefficient** (t statistic)	**Adjusted R^2**	**Breakeven point**
No index		0.096	
Sentiment indexes			
Business activity	0.030 (5.165)	0.377	-28.095
Company outlook	0.036 (4.558)	0.329	-18.630
Output indexes			
Growth rate of orders	0.039 (4.525)	0.327	-21.390
Capacity utilization	0.045 (4.338)	0.312	-10.642
New orders	0.036 (4.314)	0.310	-17.386
Production	0.045 (4.307)	0.309	-9.301
Unfilled orders	0.051 (4.298)	0.309	-17.778
Shipments	0.043 (4.267)	0.306	-11.795
Labor market indexes			
Hours worked	0.043 (4.088)	0.292	-15.340
Employment	0.036 (3.725)	0.263	-15.755

NOTES: Table displays the 10 TMOS indexes most highly correlated with Texas real GDP. The period is 2007:Q3 to 2023:Q1, excluding 2020 because of the initial disruption from the COVID-19 pandemic. Texas real GDP is in log difference. Regressions include one lag of real GDP growth.

Inflation

Texas headline CPI—which is a weighted average by labor force of the metropolitan area CPIs for Houston and Dallas-Fort Worth—can be volatile, yet TMOS indexes are able to explain a significant amount of variation in it. As expected, the survey's price indexes are more highly correlated with CPI compared with output or labor market indicators. Chart 3 shows the six-month moving average of the prices paid for raw materials index, along with the six-month moving average of the monthly percent change in Texas headline CPI.

Chart 3. TMOS Prices Paid for Raw Materials Index Highly Correlated with Texas CPI



NOTE: Data through October 2023.
SOURCES: Bureau of Labor Statistics, Federal Reserve Bank of Dallas' Texas Manufacturing Outlook Survey.

As with employment and GDP, we conducted regression analyses to find the explanatory power of TMOS indexes and changes in state CPI. Our headline CPI model excludes 2020 and uses a two-month lag (k=2). The model was:

$$\Delta TXCPI_t = \beta_0 + \beta_1 TMOS_t + \sum_{j=1}^{k} \alpha_j \ \Delta TXCPI_{t-j} + u_t \quad (3)$$

$\Delta TXCPI_t$ represents the log change in the headline CPI. Table 5 displays the results. The baseline model explains 53 percent of CPI variation, then TMOS adds 15 percentage points to the explanatory power of the two prior CPI growth readings alone. Indexes for prices paid for raw materials and current and future prices received for finished goods perform best. A 1-point increase in the prices paid for raw materials index implies a 0.004 percentage point increase in Texas headline CPI growth.

Table 5. Texas CPI Regressions

TMOS Index	Coefficient (t statistic)	Adjusted R^2	Breakeven point
No index		0.529	
Price indexes			
Prices paid for raw materials	0.004 (5.451)	0.679	-7.512
Prices received for finished goods	0.006 (5.178)	0.674	-14.585
Future prices received for finished goods	0.005 (4.355)	0.662	-2.215
Labor market indexes			
Wages and benefits	0.006 (4.188)	0.659	2.460
Future wages and benefits	0.006 (4.184)	0.659	20.090
Hours worked	0.005 (3.633)	0.652	-17.823
Output indexes			
Delivery time	0.006 (3.491)	0.650	-16.947
Capacity utilization	0.004 (3.178)	0.646	-17.014
Capital expenditures	0.004 (2.994)	0.644	-17.929
Production	0.003 (2.951)	0.644	-17.425

NOTES: Table displays the 10 TMOS indexes most highly correlated with Texas headline CPI. Full results are shown in Appendix A3. The period is 2007:04 to 2023:10, excluding 2020 because of the initial disruption from the COVID-19 pandemic. Texas headline CPI is in log difference. Regressions include two lags of Texas headline CPI growth.

5. TMOS Indexes and Forecasting Regional Economic Indicators

In addition to analyzing the explanatory power of concurrent economic data, TMOS indexes can also be evaluated based on their ability to forecast economic data. Schiller and Trebing (2003) find the Philadelphia Fed's MBOS is as accurate as national surveys in predicting the monthly

change in the U.S. industrial production index for manufacturing.[7] Harris et al (2004) find that the Richmond Survey of Manufacturing Activity adds to the ability to forecast the manufacturing PMI from ISM, especially when combined with the Philadelphia Fed's Manufacturing Survey results. Kerr et al (2014) find that the Dallas Fed's Texas Manufacturing Outlook Survey performs well forecasting the ISM manufacturing index and U.S. industrial production.

Lagged models were used to forecast changes in Texas employment and headline CPI. In the case of Texas real GDP growth, the use of TMOS data does not result in a better forecast over the sample period—the basic model with one lag of GDP growth outperformed the indexes.

Employment

Multiple TMOS variables outperformed the baseline model (Table 6). The employment index contributed the most to improved accuracy of the forecast for monthly changes in Texas employment as indicated by the lowest root mean squared forecast error (RMSFE), followed by future employment and hours worked. There was a total of 14 TMOS indexes that outperformed the baseline model (full results shown in Appendix A4).

[7] More recently, the Philadelphia Fed released a 2018 article showing the current general activity index's predictive power of U.S. recessions.

Table 6. Forecasting Changes in Texas Employment

TMOS Index	RMSFE
Employment	0.851
Future employment	0.901
Hours worked	0.913
Capital expenditures	0.921
Unfilled orders	0.928
Baseline model	1

NOTES: A lower relative root mean squared forecast error (RMSFE) indicates better forecasting performance. The baseline model has three lags of Texas employment growth and no TMOS index. The sample period is May 2007 to March 2022, excluding 2020; forecasts run from April 2022 to March 2023. Each entry represents a separate regression, and all include three lags of the dependent variable (Texas employment growth). The top five best performing TMOS indexes with the lowest RMSFE are included.

Inflation

Current and future wages and benefits indexes are best suited for forecasting Texas CPI changes (Table 7). Prices received for finished goods and three other TMOS indexes are also useful in predicting changes in CPI (full results shown in Appendix A5).

Table 7. Forecasting Changes in Texas CPI

TMOS Index	RMSFE
Wages and benefits	0.826
Future wages and benefits	0.913
Prices received for finished goods	0.927
Employment	0.944
Delivery time	0.989
Baseline model	1

NOTES: A lower relative root mean squared forecast error (RMSFE) indicates better forecasting performance. The baseline model has two lags of Texas CPI growth and no TMOS index. The sample period is May 2007 to March 2022, excluding 2020; forecasts run from April 2022 to March 2023. Each entry represents a separate regression, and all include two lags of the dependent variable (Texas CPI). The top five best performing TMOS indexes with the lowest RMSFE are included.

6. Summary

The Texas Manufacturing Outlook Survey, a monthly survey of the state's manufacturing sector conducted by the Dallas Fed, tracks economic activity in Texas in a timelier manner than other data available. TMOS indexes help explain up to 47 percent of monthly changes in Texas total nonfarm employment, which is the best official measure of state economic conditions but is released with a three-week lag and subject to revision. They also help account for up to 38 and 68 percent of variation in quarterly Texas real GDP and monthly headline CPI, respectively.

Forecasting exercises show that several TMOS indexes, particularly employment and future employment, are powerful in predicting future changes in Texas employment. The TMOS wages and benefits index, as well as the future wages and benefits index, best help forecast state headline CPI movements.

7. References

Cañas, Jesús, and Emily Kerr. 2014 "Texas Manufacturing Outlook Survey: survey methodology and performance." Federal Reserve Bank of Dallas Working Paper 1416, URL: www.dallasfed.org/~/media/documents/research/papers/2014/wp1416.pdf

Harris, Matthew, Owens, Raymond E., and Pierre-Daniel G. Sarte. 2004. "Using Manufacturing Surveys to Assess Economic Conditions." Federal Reserve Bank of Richmond *Economic Quarterly* 90 (Fall 2004): 65-92. URL: www.richmondfed.org/-/media/richmondfedorg/publications/research/economic_quarterly/2004/fall/pdf/harrisowenssarte.pdf

Keeton, William R., and Michael Verba. 2004. "What Can Regional Manufacturing Surveys Tell Us? Lessons from the Tenth District." Federal Reserve Bank of Kansas City *Economic Review* 89, no. 3 (third quarter): 39-70. URL: www.kansascityfed.org/documents/1126/2004-What%20Can%20Regional%20Manufacturing%20Surveys%20Tell%20Us%3F%20Lessons%20from%20the%20Tenth%20District.pdf

Kerr, Emily, Orrenius, Pia, Wang, Jack and Jesús Cañas. 2014. "Regional Feds' Manufacturing Surveys Provide National Economy Insight." Federal Reserve Bank of Dallas *Economic Letter* (volume 9, number 12). URL: fraser.stlouisfed.org/title/economic-letter-6362/fed-manufacturing-surveys-provide-insight-national-economy-607700

Nakumura, Leonard, and Michael Trebing. 2008. "What Does the Philadelphia Fed's Business Outlook Survey Say About Local Activity?" Federal Reserve Bank of Philadelphia Research Rap Special Report (December 2008). URL: www.philadelphiafed.org/-/media/frbp/assets/economy/reports/research-rap/2008/business-outlook-survey-local-activity.pdf?la=en

Schiller, Timothy, and Michael Trebing. 2003. "Taking the Measure of Manufacturing." Federal Reserve Bank of Philadelphia *Business Review* (Q4 2003): 24-37. URL: www.philadelphiafed.org/-/media/frbp/assets/economy/articles/business-review/2003/q4/brq403tsmt.pdf

Sigalla, Fiona, Berger, Frank, Fomby, Tom, Phillips, Keith, and Mine Yucel. 2007. "Evaluating Alternative Index Designs for the Texas Manufacturing Outlook Survey." Paper prepared for the Third Joint European Commission-OECD Workshop on International Development of Business and Consumer Tendency Surveys (November 2007). URL: www.researchgate.net/profile/Keith-Phillips-2/publication/265157285_Evaluating_Alternative_Index_Designs_For_the_Texas_Manufacturin

g_Outlook_Survey/links/546f50a30cf24af340c0844f/Evaluating-Alternative-Index-Designs-For-the-Texas-Manufacturing-Outlook-Survey.pdf

Trebing, Michael. 1998. 'What's Happening in Manufacturing: "Survey Says…"' 1998. Federal Reserve Bank of Philadelphia *Business Review* (September/October 1998): 15-29. URL: www.philadelphiafed.org/-/media/frbp/assets/economy/articles/business-review/1998/september-october/brso98mt.pdf

8. Appendix

Table A1. Texas Employment Regressions

TMOS Index	Constant (t statistic)	Coefficient (t statistic)	Adjusted R^2	Break-even Point*
Employment	0.095 (4.911)	0.012 (7.105)	0.472	-8.168
Capacity utilization	0.054 (2.946)	0.009 (6.593)	0.455	-6.048
Hours worked	0.095 (4.768)	0.010 (6.387)	0.449	-9.955
Unfilled orders	0.140 (5.916)	0.010 (6.284)	0.446	-13.800
Growth rate of orders	0.105 (5.043)	0.007 (6.187)	0.443	-15.615
New orders	0.065 (3.454)	0.006 (6.116)	0.440	-10.563
Production	0.039 (2.045)	0.008 (5.895)	0.433	-5.040
Shipments	0.053 (2.796)	0.007 (5.803)	0.431	-7.435
Capital expenditures	0.066 (3.4)	0.009 (5.399)	0.418	-7.645
Future employment	-0.037 (-1.494)	0.006 (5.328)	0.416	5.810
General business activity	0.085 (4.19)	0.004 (5.246)	0.414	-21.039
Company outlook	0.062 (3.21)	0.005 (5.15)	0.411	-12.450
Prices received for finished goods	0.073 (3.693)	0.006 (5.011)	0.407	-12.060
Future capital expenditures	-0.016 (-0.669)	0.006 (4.801)	0.401	2.418
Delivery time	0.102 (4.448)	0.009 (4.47)	0.392	-11.566
Prices paid for raw materials	0.017 (0.8)	0.003 (4.382)	0.389	-5.338
Future finished goods inventories	0.084 (3.895)	0.007 (3.988)	0.379	-11.532
Future production	-0.084 (-2.153)	0.004 (3.903)	0.377	19.977
Future capacity utilization	-0.078 (-2.045)	0.004 (3.859)	0.376	17.775
Future shipments	-0.080 (-2.077)	0.004 (3.853)	0.376	18.908
Future prices paid for raw materials	-0.039 (-1.276)	0.003 (3.711)	0.372	11.247

Future prices received for finished goods	0.000 (-0.007)	0.004 (3.56)	0.369	0.037
Future new orders	-0.066 (-1.712)	0.004 (3.459)	0.367	17.858
Future growth rate of orders	-0.044 (-1.316)	0.004 (3.445)	0.366	10.688
Future general business activity	0.028 (1.372)	0.003 (3.371)	0.365	-10.439
Future company outlook	0.003 (0.11)	0.003 (3.366)	0.364	-0.819
Wages and benefits	-0.026 (-0.862)	0.006 (3.341)	0.364	4.320
Future hours worked	0.003 (0.133)	0.006 (3.19)	0.361	-0.529
Future wages and benefits	-0.116 (-1.988)	0.006 (2.989)	0.356	21.135
Future unfilled orders	0.032 (1.543)	0.005 (2.799)	0.353	-6.223
Future delivery time	0.072 (3.286)	0.007 (2.701)	0.351	-11.122
Finished goods inventories	0.075 (2.762)	0.003 (1.503)	0.333	-22.169

*The break-even point is defined as the level of the diffusion index consistent with no change in the underlying official statistic according to the regression model. It is equivalent to the negative of the ratio of the estimated intercept and slope coefficient.
NOTES: Indexes are ordered by adjusted R^2. Regressions are based on the estimation period 2007:05 to 2023:10, excluding 2020. Regressions include three lags of employment growth. Texas employment is in log difference.

Table A2. Texas Gross Domestic Product Regressions

TMOS Index	Constant (t statistic)	Coefficient (t statistic)	Adjusted R^2	Break-even Point*
Business activity	0.846 (6.197)	0.030 (5.165)	0.377	-28.095
Company outlook	0.674 (5.156)	0.036 (4.558)	0.329	-18.630
Growth rate of orders	0.841 (5.834)	0.039 (4.525)	0.327	-21.390
Capacity utilization	0.483 (3.73)	0.045 (4.338)	0.312	-10.642
New orders	0.626 (4.787)	0.036 (4.314)	0.310	-17.386
Production	0.419 (3.177)	0.045 (4.307)	0.309	-9.301
Unfilled orders	0.909 (5.841)	0.051 (4.298)	0.309	-17.778
Shipments	0.512 (3.953)	0.043 (4.267)	0.306	-11.795
Hours worked	0.659 (4.915)	0.043 (4.088)	0.292	-15.340
Employment	0.562 (4.21)	0.036 (3.725)	0.263	-15.755
Future business activity	0.430 (3.135)	0.023 (3.627)	0.255	-18.570
Capital expenditures	0.518 (3.849)	0.038 (3.571)	0.251	-13.731
Future hours worked	0.176 (1.038)	0.057 (3.513)	0.247	-3.079
Future capital expenditures	0.164 (0.951)	0.034 (3.478)	0.244	-4.824
Future employment	0.099 (0.526)	0.029 (3.363)	0.235	-3.414
Future finished goods inventories	0.769 (4.958)	0.050 (3.2)	0.223	-15.440
Future shipments	-0.293 (-0.965)	0.029 (3.059)	0.212	10.225
Future growth rate of orders	-0.090 (-0.364)	0.030 (3.039)	0.211	2.997
Future company outlook	0.261 (1.582)	0.024 (3.027)	0.210	-10.954
Future capacity utilization	-0.287 (-0.926)	0.030 (2.965)	0.205	9.724
Delivery time	0.689 (4.619)	0.039 (2.848)	0.197	-17.671
Future delivery time	0.730 (4.623)	0.055 (2.675)	0.185	-13.162

Future prices paid for raw materials	0.030 (0.125)	0.019 (2.617)	0.181	-1.602
Future production	-0.225 (-0.697)	0.025 (2.616)	0.181	8.968
Future new orders	-0.149 (-0.499)	0.024 (2.606)	0.180	6.311
Future unfilled orders	0.482 (3.375)	0.040 (2.518)	0.174	-12.162
Prices paid for raw materials	0.352 (2.205)	0.012 (2.48)	0.172	-30.087
Future prices received for finished goods	0.270 (1.413)	0.017 (2.095)	0.147	-15.845
Prices received for finished goods	0.517 (3.581)	0.014 (1.961)	0.140	-35.869
Future wages and benefits	-0.085 (-0.222)	0.018 (1.745)	0.128	4.646
Wages and benefits	0.351 (1.555)	0.011 (1.076)	0.099	-31.916
Finished goods inventories	0.600 (3.244)	0.011 (0.583)	0.086	-57.001

*The break-even point is defined as the level of the diffusion index consistent with no change in the underlying official statistic according to the regression model. It is equivalent to the negative of the ratio of the estimated intercept and slope coefficient.
NOTES: Indexes are ordered by adjusted R^2. Regressions are based on the estimation period 2007:Q3 to 2023:Q1, excluding 2020. Texas real GDP is in log difference. Regressions include one lag of real GDP growth.

Table A3. Texas Headline CPI Regressions

TMOS Index	Constant (t statistic)	Coefficient (t statistic)	Adjusted R^2	Break-even Point*
Prices paid for raw materials	0.029 (1.544)	0.004 (5.451)	0.679	-7.512
Prices received for finished goods	0.081 (4.983)	0.006 (5.178)	0.674	-14.585
Future prices received for finished goods	0.011 (0.493)	0.005 (4.355)	0.662	-2.215
Wages and benefits	-0.014 (-0.498)	0.006 (4.188)	0.659	2.460
Future wages and benefits	-0.113 (-2.316)	0.006 (4.184)	0.659	20.090
Hours worked	0.080 (4.786)	0.005 (3.633)	0.652	-17.823
Delivery time	0.095 (5.441)	0.006 (3.491)	0.650	-16.947
Capacity utilization	0.064 (3.663)	0.004 (3.178)	0.646	-17.014
Capital expenditures	0.068 (3.919)	0.004 (2.994)	0.644	-17.929
Production	0.059 (3.258)	0.003 (2.951)	0.644	-17.425
Employment	0.070 (4.049)	0.003 (2.925)	0.643	-21.126
Future prices paid for raw materials	0.006 (0.197)	0.003 (2.88)	0.643	-2.102
Growth rate of orders	0.094 (5.262)	0.003 (2.818)	0.642	-32.039
New orders	0.078 (4.606)	0.003 (2.808)	0.642	-28.276
Future employment	0.029 (1.17)	0.003 (2.659)	0.641	-10.392
Future finished goods inventories	0.091 (5.087)	0.004 (2.436)	0.638	-22.253
Finished goods inventories	0.099 (5.148)	0.004 (2.339)	0.638	-23.048
Future capital expenditures	0.042 (1.796)	0.003 (2.222)	0.637	-16.228
Unfilled orders	0.099 (5.052)	0.003 (2.165)	0.636	-30.333
General business activity	0.086 (4.91)	0.002 (2.087)	0.635	-56.102
Shipments	0.070 (3.946)	0.002 (2.059)	0.635	-30.818
Company outlook	0.077 (4.488)	0.002 (1.802)	0.633	-46.061

Future delivery time	0.088 (4.737)	0.003 (1.393)	0.631	-27.564
Future shipments	0.035 (0.928)	0.001 (1.308)	0.630	-24.654
Future general business activity	0.072 (3.944)	0.001 (1.017)	0.629	-89.630
Future company outlook	0.065 (2.956)	0.001 (0.946)	0.629	-73.960
Future capacity utilization	0.048 (1.277)	0.001 (0.943)	0.629	-44.839
Future hours worked	0.068 (3.133)	0.002 (0.835)	0.628	-42.031
Future production	0.052 (1.36)	0.001 (0.761)	0.628	-64.687
Future growth rate of orders	0.061 (1.926)	0.001 (0.677)	0.628	-76.780
Future new orders	0.057 (1.546)	0.001 (0.673)	0.628	-80.500
Future unfilled orders	0.080 (4.459)	-0.001 (-0.344)	0.627	129.694

*The break-even point is defined as the level of the diffusion index consistent with no change in the underlying official statistic according to the regression model. It is equivalent to the negative of the ratio of the estimated intercept and slope coefficient.
NOTES: Indexes are ordered by adjusted R^2. Regressions are based on the estimation period 2007:04 to 2023:10, excluding 2020. Texas headline CPI is in log difference. Regressions include two lags of Texas headline CPI growth.

Table A4. Texas Employment Forecasts

TMOS Index	RMSFE
Employment	0.851
Future employment	0.901
Hours worked	0.913
Capital expenditures	0.921
Unfilled orders	0.928
Prices received for finished goods	0.937
Future capital expenditures	0.951
Future finished goods inventories	0.956
Future wages and benefits	0.974
Prices paid for raw materials	0.981
Delivery time	0.981
Future prices received for finished goods	0.987
Wages and benefits	0.991
Future hours worked	0.994
Finished goods inventories	1.006
Future unfilled orders	1.007
Future delivery time	1.018
Capacity utilization	1.028
Future company outlook	1.042
Future prices paid for raw materials	1.048
Growth rate of orders	1.051
Future general business activity	1.054
General business activity	1.055
Future capacity utilization	1.057
Production	1.066
Future production	1.077
Shipments	1.085
Company outlook	1.086
New orders	1.095
Future growth rate of orders	1.116
Future shipments	1.148
Future new orders	1.165

NOTES: Forecasts were based on regressions estimated from 2007:05 to 2022:03, excluding 2020, and a forecasting period of 2022:04 to 2023:03. Texas employment is in log difference.

Table A5. Texas Headline CPI Forecasts

TMOS Index	RMSFE
Wages and benefits	0.826
Future wages and benefits	0.913
Prices received for finished goods	0.927
Employment	0.944
Delivery time	0.989
Finished goods inventories	0.996
Future unfilled orders	1.029
Hours worked	1.045
Capital expenditures	1.046
Capacity utilization	1.078
Future hours worked	1.083
Unfilled orders	1.096
Future capital expenditures	1.108
Future employment	1.126
Future finished goods inventories	1.127
Production	1.129
Shipments	1.140
Future prices received for finished goods	1.163
Prices paid for raw materials	1.166
General business activity	1.180
Future delivery time	1.185
Future general business activity	1.221
Company outlook	1.232
Future company outlook	1.238
Growth rate of orders	1.255
Future growth rate of orders	1.276
New orders	1.279
Future production	1.306
Future capacity utilization	1.320
Future prices paid for raw materials	1.393
Future new orders	1.395
Future shipments	1.446

NOTES: Forecasts were based on regressions estimated from 2007:05 to 2022:03, excluding 2020, and a forecasting period of 2022:04 to 2023:03. Texas headline CPI is in log difference.