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Economic indicators for the US transportation sector

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Abstract

Since the transportation sector plays an important role in business cycle propagation, we develop indicators for this sector to identify its current state, and predict its future. We define the reference cycle, including both business and growth cycles, for this sector over the period from 1979 using both the conventional National Bureau of Economic Research (NBER) method and modern time series models. A one-to-one correspondence between cycles in the transportation sector and those in the aggregate economy is found; however, both business and growth cycles of transportation often start earlier and end later than those of the overall economy. We also construct an index of leading indicators for the transportation sector using rigorous statistical procedures, and is found to perform well as a forecasting tool.

Keywords: Transportation; Business cycles; Leading indicators; Index of concordance; Dynamic factor models

1. Introduction

Business cycle studies play an important role in the decision-making processes of government agencies and private sectors. For instance, recessions and expansions dated by NBER are often utilized as an important input for macroeconomic policies or business planning (Zarnowitz, 1992). In the current NBER indicators system, information from services sectors is significantly underrepresented. Among the current four coincident and ten leading indicators, there is not a single series specifically measuring services sectors, and most of the attention in business cycle studies has remained focused on manufacturing sectors since the beginning of NBER. Yet services have become increasingly more important in the contemporary economy and business cycles. For instance, in the US over the period 1953:I–2003:II, the share of goods in the GDP has declined from 54% to 35%, compared with an increase in the share of services from 34% to 56%. Moore (1987) points out that the ability of the service sectors to create jobs has differentiated business cycles since the 1980s from their earlier counterparts, and thus led economy-wide recessions to be shorter and less severe.

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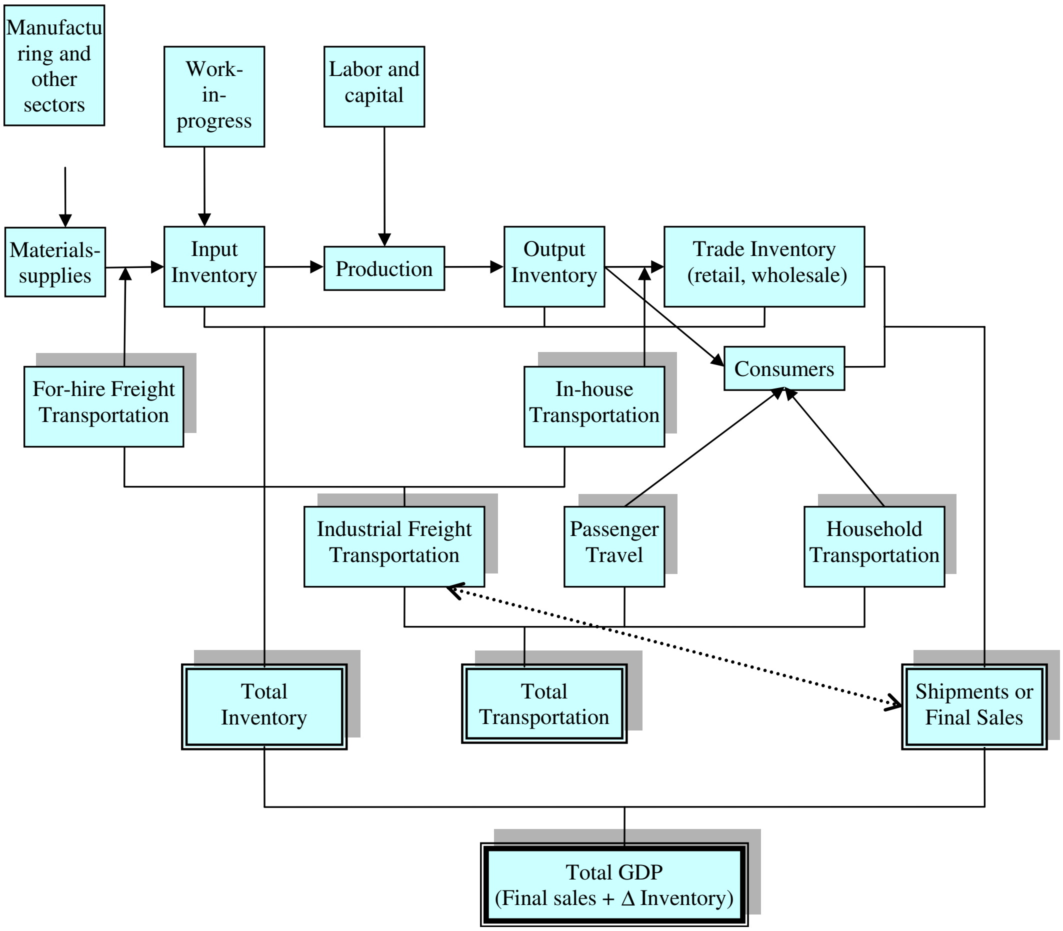

Fig. 1. Stage-of-fabrication model with transportation.

This paper studies business cycles of an important services sector, namely transportation services.[1] Besides the sizable proportion of US Gross Domestic Product (GDP)[2] it represents, transportation plays a crucial role in facilitating economic activities between sectors and across regions. Fig. 1 provides a schematic illustration of the stage-of-fabrication production process employed by a typical firm to transform input inventories (purchased materials/supplies and work-in-progress) into output inventories (finished goods). The middle and lower parts illustrate that the role of freight transportation in the overall economy is closely related to input inventories, which account for 65% of total manufacturing inventories by value and 67% by variance (Blinder and Maccini, 1991). Since it is well known in the economics literature since Abramovitz (1950) that inventory cycles have been the dominant feature of economic fluctuations in GDP, information from transportation sector should be useful to help discover the mystery of the fluctuations and learn how to control them better; see Humphreys et al. (2001) for more recent studies on inventory cycles. NBER scholars had also noticed the pervasive influence of transportation on all sectors of the economy and paid attention to the recurrent feature of

[1] There are three transportation-related industries in the economy: transportation services (NAICS codes 48–49), transportation equipment (NAICS code 336) and transportation infrastructure. NAICS represents the North American Industrial Classification System, which replaced US Standard Industrial Classification (SIC) in 1997 to define each industry. The above three industries belong to three different product categories in the National Income and Product Account (NIPA), namely, services, goods (more accurately manufacturing) and structure respectively. Transportation services sector is what is being studied in this paper.

[2] Using different concepts about the scope of the transportation industry would yield different measures of its importance in aggregate output, varying anywhere from 3.09% (Transportation GDP) to 16.50% (Transportation-driven GDP). See Han and Fang (2000).

business cycles from the perspective of transportation.[3] However, further efforts to study the role of transportation in monitoring modern business cycles were largely hindered due to the discontinuation, in the 1960s, of many monthly transportation indicators.

We thus study the classical and growth cycles for this sector using the economic indicator analysis (EIA) approach. This effort would help us to track the ups and downs in the transportation sector and to explore its relationship with the aggregate economy. The former can be used for planning and economic policies in transportation while the latter would be useful in understanding the role of transportation in economic development and monetary policies. The EIA was originally developed in Burns and Mitchell (1946) and revised by Moore (1961), Zarnowitz (1992) and many others, where a business cycle is defined to "consist of expansions occurring at about the same time in many economic activities, followed by similarly general recessions, contractions, and revivals...". These concurrent movements can be captured by a single underlying unobservable variable or index from many cyclical indicators, which is the rationale behind NBER business cycle chronology. The cyclical indicators are often grouped into leading, coincident, and lagging categories according to their tendency to change direction before, during or after a corresponding change in the general state or reference cycles of the macroeconomy. The composite indices constructed from leading and coincident indicators are named composite leading index (CLI) and composite coincident index (CCI) respectively. CCI is used to define the reference cycles and CLI is used mostly to forecast CCI.

Following the NBER tradition, Section 2 studies the reference cycles of the transportation sector using transportation coincident indicators and an estimated CCI. We use both the NBER non-parametric method and modern time series models. Section 3 then selects a total of seven leading indicators, and constructs transportation CLI to predict the reference cycles defined in Section 2. In both sections, selection of indicators is done with rigorous statistical tests in addition to the standard EIA criteria. Section 4 studies the growth cycles for this sector. The last section summarizes the conclusion of the paper.

2. Transportation coincident indicators and reference cycles

2.1. Co-movement among four coincident indicators

Burns and Mitchell's (1946) definition of business cycles consists of two key features. One is the co-movement or concurrence among individual economic indicators, and the other is a switching process between different regimes, i.e. expansions and recessions. The existence of co-movement is one of the criteria for selecting or testing qualified coincident indicators. Extracting the co-movement among coincident indicators leads to the creation of the CCI, which is the basis for defining the current state of the aggregate economy or of a single sector. The CCI usually reflects the concurrent transitions between recessions and expansions of the coincident indicator.

Following the NBER tradition, we use four conventional coincident indicators to define the current state of the US transportation sector: transportation services index (TSI, Y_{1t}),[4] real aggregate payrolls in transportation (Y_{2t}), real personal consumption expenditure on transportation (Y_{3t}), and employment (Y_{4t}) in this sector. These indicators, plotted in Fig. 2, reflect the information on output, income, sales, and labor usage in the transportation sector. In the NBER tradition, these four are the most important aspects of the current economy.[5] The turning points of each series are defined using an NBER procedure documented in Bry and Boschan (1971), namely, the BB algorithm. In practice, the BB algorithm is supplemented by censoring procedures to distinguish the real peaks and troughs from spurious ones, e.g., a movement from a peak to a

[3] Burns and Mitchell (1946, p. 373) and Hultgren (1948) found that the cyclical movements in railroads coincided with the prosperities and depressions of the economy at large. Moore (1961, vol. I, pp. 48–50), based on updated data through 1958, found that railway freight car loading, while still being coincident at troughs, showed longer leads at peaks after the 1937–1938 recession.

[4] For details on construction of this index and discussions of its characteristics, see Lahiri et al. (2003) and Lahiri and Yao (2004).

[5] The four monthly coincident indicators currently used by NBER are employment, personal income less transfer payments, industrial production, and manufacturing and trade sales. In addition to monthly chronology, NBER also defines quarterly chronology based on quarterly GDP. The two chronologies are normally consistent with each other. However, the CCI constructed out of four monthly indicators represents the underlying state of the economy or the co-movement emphasized by Burns and Mitchell (1946), while GDP is only a single series representing aggregate output.

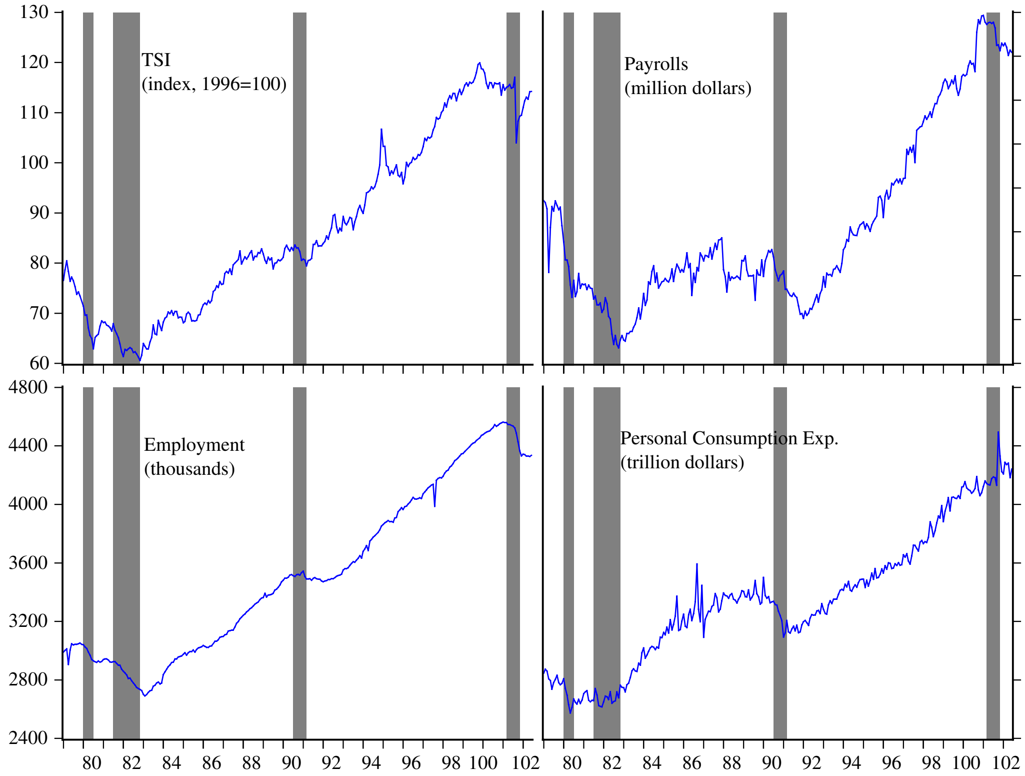

Fig. 2. Coincident indicators for the US transportation sector.

Table 1
Business cycle chronologies in US transportation sector, 1979–2002

Transportation reference cycles		Leads (−) and lags (+), in months, relative to transportation reference cycle											
		NBER index		Output		Employment		Personal consumption exp.		Payrolls			
P	T	P	T	P	T	P	T	P	T	P	T		
03/79	08/80	0	−1	0	−1	3	+1	0	−3	0	0		
01/81	02/83	0	0	−1	−4	+2	0	0	−9	−3	0		
05/90	06/91	−3	+3	+3	−3	+8	+7	−18	+5	−1	+1		
11/00	12/01	0	0	−12	−3	+2	–	−12	–	−13	–		
Mean		−1	+1	−3	−3	+4	+3	−8	−2	−4	0		
Median		0	0	0	−3	3	1	−6	−3	−2	0		
Std dev.		1.5	2.1	2.1	1.5	2.9	3.8	9.0	7.0	6.0	0.6		
Extra turns				06/84	09/85					09/84	08/85		
				12/88	07/89					11/87	08/88		
				12/94	07/95					01/95	08/95		

trough (phase) cannot be shorter than six months and a complete cycle must be at least 15 months long. These specific cycles of individual component series, i.e. peaks (P) and troughs (T), are listed in Table 1.

Given the data and their specific cycles, the existence of co-movement among them can be tested for its statistical significance. That is, how well are they synchronized with each other in terms of directional change to qualify for inclusion in the list of coincident indicators? This topic has been the subject of considerable research in recent years because the economic costs of forecast errors around business cycle turning points compared to other times are considerably asymmetric (Pesaran and Timmermann, 2003). This concept of

Table 2
Contingency table in directional analysis

	Actual/realization	
	$\leqslant 0$	>0
Forecast/action		
$\leqslant 0$	Hits (P_1)	False alarms ($1 - P_2$)
>0	Misses ($1 - P_1$)	Correct rejections (P_2)

co-movement can be illustrated with four outcomes in Table 2, adapted from Granger and Pesaran (2000). With such a contingency table, various χ^2 tests were designed based mainly on the information on $P_1 + P_2$ to test the statistical relevance between two events or series. For instance, Harding and Pagan (2002) propose an index of concordance for two series, x_t and y_t, with sample size T

$$\widehat{I} = \frac{1}{T}\left\{\sum_{t=1}^{T} S_{xt}S_{yt} + \sum_{t=1}^{T}(1 - S_{xt})(1 - S_{yt})\right\}. \tag{1}$$

S_t is the underlying state (0 for recession or 1 for expansion) of each series based on defined turning points using the BB algorithm. The degree of concordance between the two variables is quantified by the fraction of time that both series are simultaneously in the same states of expansion ($S_t = 1$) or contraction ($S_t = 0$). The concordance is determined not only by the correlation between series but also their average fraction of time in state 1.

The synchronization of cycles among coincident indicators can be measured and tested using the index of concordance among four specific cycles. We have tabulated the concordance measures and the test statistics in Table 3. In the first part of the table, the concordance statistic $\widehat{I}$ is above the diagonal while $\hat{\rho}_S$ is below the diagonal; $\hat{\mu}_S$ and $\hat{\sigma}_S$ are in the bottom of the table. All the pairs of transportation coincident indicators have positive correlations ranging between 0.5 and 0.7 and concordance indexes between 0.8 and 0.9. These statistics suggest strong evidence of synchronization of cycles between them. None of the series is dominated by either of the states. Hence, the high concordance indexes are significantly associated with the high correlations. Statistics can also be developed to test whether synchronization of cycles is significant between indicators and the reference cycle. A simple way to do so is by the t-test for H_0: $\rho_S = 0$. $\hat{\rho}_S$ is obtained from the regression

$$\frac{S_{yt}}{\hat{\sigma}_{S_y}} = a_1 + \rho_S \frac{S_{xt}}{\hat{\sigma}_{S_x}} + u_t. \tag{2}$$

Standard t-statistics is based on ordinary least squares (OLS) regression. We used Newsy–West heteroskedasticity and autocorrelation consistent standard errors and covariance (lag truncation = 5) to account for serial

Table 3
Measuring and testing of synchronization of cycles

	Employment	Payrolls	TSI	Personal consumption exp.	Reference cycle
(1) Concordance indexes and correlations of cycles among transportation coincident indicators					
Employment	–	0.8	0.8	0.8	0.9
Payrolls	0.6	–	0.8	0.8	0.8
TSI	0.5	0.6	–	0.8	0.8
Personal consumption exp.	0.6	0.5	0.5	–	0.9
Reference cycle	0.8	0.7	0.6	0.7	E
$\hat{\mu}_S$	0.7	0.6	0.6	0.7	0.7
$\hat{\sigma}_S$	0.4	0.5	0.5	0.5	0.4
(2) Standard and robust t-statistics for H_0: $\rho_S = 0$					
Employment	–	6.2	4.0	5.1	9.6
Payrolls	14.2	–	6.4	4.8	12.9
TSI	9.2	12.1	–	4.8	7.8
Personal consumption exp.	13.0	9.8	10.1	–	7.8
Reference cycle	23.4	16.2	12.7	16.8	–

correlation. In the second part of Table 3, standard t is below the diagonal while the robust t is above it. All those statistics significantly reject H_0. These provide strong evidence for the existence of common cycles among four transportation coincident indicators. Thus, they are qualified coincident indicators for this sector.

2.2. NBER index and transportation reference cycles

There are two ways to create a CCI from coincident indicators in order to study the reference cycles: the non-parametric NBER method and parametric dynamics factor models. The NBER index is created by assigning a fixed standardization factor to the growth rate of each component and taking their average.[6] By using the inverse of the standard deviation as weight, the contribution of change in each series to the final index is well balanced. The turning points of the NBER index, defined based on the BB algorithm, are also reported in Table 1. Together with specific cycles of the four individual indicators, the chronology of business cycles in the US transportation sector is defined for the period since January 1979.[7]

Over the sample period, there are clearly four major recessions: 3/79–8/80, 1/81–2/83, 5/90–6/91, and 11/00–12/01. Overall, there is a one-to-one correspondence between the business cycles of the transportation sector and those of the overall economy. The comparison of these two is reported in Table 4. Cycles in the transportation sector lead peaks in the economy-wide business cycles on the average by 6 months, while being lagging by 2 months at troughs. As a result, the duration of transportation recessions is 8 months longer than general economic recessions. Interestingly, these findings are very similar to those in Moore (1961), who used only railway freight data on a much earlier period for his conclusion. Lahiri et al. (2003) show that transportation output alone (namely, TSI) is more sensitive to business cycle shocks and thus has more downturns that not only signal fully-fledged recessions, but also even some mild slowdowns. The output also has a large lead over every single economy-wide business cycle. Therefore, cycles in the transportation services sector are more synchronized with those of the aggregate economy when information from labor usage, sales, and income is considered.

2.3. Dynamic factor models

An alternative to the conventional NBER method would be using techniques of modern time-series analysis to develop dynamic factor models with regime switching (Kim and Nelson, 1998) or without (Stock and Watson, 1991). The common factor to be estimated from the model represents the underlying state in its constituent time series. Thus, the dating of turning points could be based on the probabilities of the recessionary regime implied by the model. Given a set of coincident indicators Y_{it}, their growth rates can be explained by an unobserved common factor ΔC_t, interpreted as growth in the CCI, and some idiosyncratic dynamics. This defines the measurement equation for each component

$$\Delta Y_{it} = \gamma_i \Delta C_t + e_{it}, \tag{3}$$

where ΔY_{it} is logged first difference in Y_{it}. In the state-space representation, ΔC_t itself is to be estimated. In the transition equations, both the index ΔC_t and e_{it} are processes with AR representations driven by noise terms w_t and ε_{it} respectively.

$$\Phi(L)(\Delta C_t - \mu_{st} - \delta) = w_t, \tag{4}$$

$$\Psi(L)e_{it} = \varepsilon_{it}. \tag{5}$$

[6] More specifically, four steps are involved: (1) month-to-month changes (x_t) are computed for each component (X_t) using the conventional formula: $x_t = 200 * (X_t - X_{t-1})/(X_t + X_{t-1})$. (2) The month-to-month changes are adjusted to equalize the volatility of each component using the standardization factors, which is the inverse of standard deviation over the sample period, then normalized to sum = 1. (3) The level of the index is computed using the symmetric percent change formula. (4) The index is re-based to be average 100 in 1996 to make a formal NBER index. See Conference Board (2001).

[7] A recession refers to the period from one peak to the next trough while an expansion is the period from a trough to the next peak. A complete cycle includes one recession and the subsequent expansion.

Table 4
Estimates of the transportation coincident index models

Variables	Parameters	Stock–Watson Model		Kim–Nelson Model			
				Prior	Posterior		
		Estimate	s.e.		Mean	s.e.	Median
ΔC_t (State variable)	Φ_1	0.775	0.167	0.775	0.127	0.119	0.114
	Φ_2	0.107	0.162	0.107	0.121	0.085	0.124
ΔY_{1t} (Output)	γ_1	0.171	0.057	0.1	0.136	0.028	0.136
	ϕ_{11}	−0.519	0.067	−0.2	−0.637	0.057	−0.638
	ϕ_{12}	−0.067	0.017	0	−0.401	0.057	−0.401
	σ_1^2	5.181	0.480	2	0.652	0.057	0.648
ΔY_{2t} (Payrolls)	γ_2	0.148	0.048	0.1	0.173	0.042	0.172
	ϕ_{21}	−0.162	0.077	−0.1	−0.216	0.061	−0.216
	σ_2^2	2.107	0.210	2	0.782	0.071	0.778
ΔY_{3t} (Personal consumption exp.)	γ_3	1.485	0.631	1.5	0.059	0.060	0.059
	γ_{31}	−1.364	0.626	−1.4	−0.041	0.059	−0.039
	ϕ_{31}	−0.149	0.122	−0.1	−0.388	0.060	−0.388
	σ_3^2	2.443	1.831	2	0.849	0.076	0.844
ΔY_{4t} (Employment)	γ_4	0.110	0.021	0.1	0.548	0.081	0.557
	ϕ_{41}	−0.006	0.357	−0.1	−0.025	0.084	−0.026
	σ_4^2	0.072	0.015	2	0.125	0.081	0.120
	P_{00}			0.967	0.926	0.066	0.945
	P_{11}			0.986	0.985	0.012	0.988
	μ_0			−0.869	−1.822	0.554	−1.727
	μ_1			0.745	2.208	0.580	2.110
	δ			–	0.356	0.038	0.359
	$\mu_0 + \mu_1$			–	0.385	0.132	0.385

These two noise terms are assumed to be independent of each other. Eqs. (3)–(5) define the Stock–Watson model, which can be estimated using maximum likelihood. Adding a regime-switching feature into the model forms the Kim–Nelson model. The transitions of different regimes (μ_{st}), incorporated into (4), are governed by a hidden Markov process

$$\mu_{st} = \mu_0 + \mu_1 S_t, \quad S_t = \{0, 1\}, \ \ \mu_1 > 0, \tag{6}$$

$$\text{Prob}(S_t = 1|S_{t-1} = 1) = p, \qquad \text{Prob}(S_t = 0|S_{t-1} = 0) = q. \tag{7}$$

This model can be estimated using Gibbs-sampling. To implement the Kim–Nelson model, I used priors from the estimated Stock–Watson model. Priors for regime switching parameters were obtained from sample information from the NBER index. Both models were estimated using computer routines described in Kim and Nelson (1998). Unlike the original Stock–Watson model specification for the aggregate economy, personal consumption expenditure and employment in transportation both appear to be somewhat lagging to the current state of transportation.

The final specification and parameter estimates from Stock–Watson and Kim–Nelson models are reported in Table 5. The two sets of estimates are close, except that the sum of the AR coefficients for the state variable in the Stock–Watson model is significantly higher, implying more state-dependence in the resulting index. This difference is complemented by the much larger role that employment plays in the Kim–Nelson model. The latter model also distinguishes between two clear-cut regimes of positive and negative growth rates. Based on transitional probabilities (P_{00} and P_{11}), expected durations of recessions and expansions are calculated as $(1 - P_{00})^{-1}$ and $(1 - P_{11})^{-1}$ respectively. This would give us 13.5 and 66.7 months on average of recession and expansion in the transportation sector in contrast to the actual durations of 13 and 68 months.

The estimated transportation CCIs from these two models are plotted against the NBER index in Fig. 3. Compared to Kim–Nelson index, the Stock–Watson index agrees more closely with the NBER index throughout the period, while the NBER index picked up some additional details of the cyclical movements that would

Table 5
Business cycles in the US transportation sector

Transportation business cycles			Leads (−) and lags (+), in months, of transportation business cycles relative to			Leads (−) and lags (+), in months, of transportation leading index relative to	
			NBER business cycles			Transportation business cycles	
P	T	Duration	P	T	Duration	P	T
03/79	08/80	17	−10	+1	6	−4	−1
01/81	2/83	25	−6	+3	16	−1	−13
05/90	06/91	13	−2	+3	8	−16	−6
11/00	12/01	13	−4	+1	8	−20	−3
Mean		17	−6	+2	10	−10	−6
Median		15	−5	+2	8	−10	−5
Std dev.		6	3	1	4	9	5

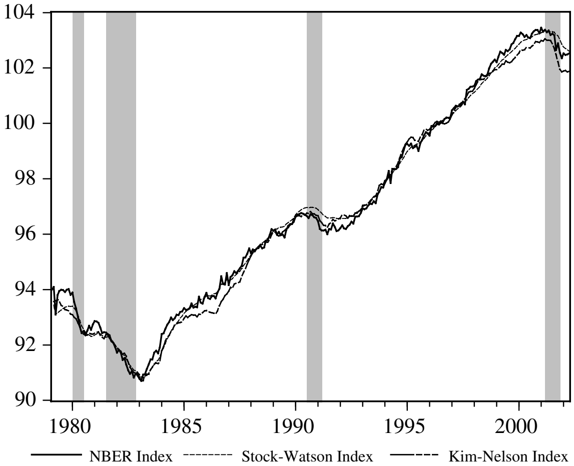

Fig. 3. Coincident indexes of the US transportation sector. Shaded areas represent NBER-defined recessions for the US economy.

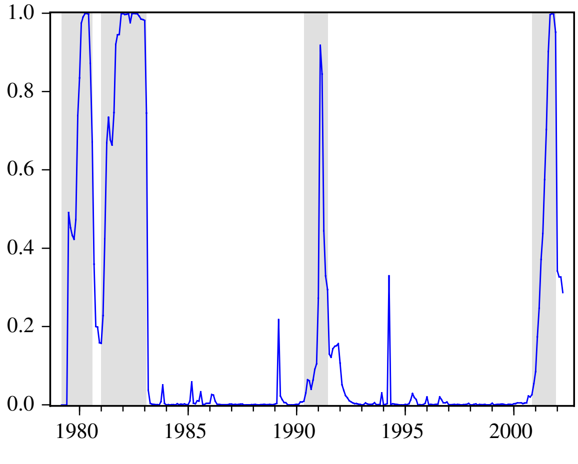

Fig. 4. Probability that transportation is in recession implied from Kim and Nelson Model. Shaded areas represent recessions defined for the US transportation sector.

not have been identified in two alternative indexes, such as the distinction between the 1980 and 1981 recessions. Despite differences in their model formulations and in minor details, their cyclical movements appear to be very similar to one another, and are well synchronized with the NBER-defined recessions for the economy (the shaded areas).

Fig. 4 depicts the posterior probability that the transportation sector is in recession as inferred from the Kim–Nelson model estimation. This gives the parametric dating in contrast to the NBER non-parametric dating algorithm. The darker shaded areas represent the NBER-defined recessions for the US economy, while the lightly shaded areas represent recessions in the US transportation sector as implied by probabilities from the Kim–Nelson model. In defining the transportation sector recessions, we take the first month that the probability begins to rise (or drop) as the trough (or peak). The resulting chronology would be very similar to that using the non-parametric NBER index. The recession probability in Fig. 4 also suggests that the latest recession in the US transportation sector ended in December 2001, which is just one month after the recently announced NBER trough of the economic recession beginning in March 2001.

3. Transportation leading indicators

3.1. Selection of leading indicators

In practice, determining turning points (peaks or troughs) based on coincident indicators usually involves the resolution of difficulties such as substantial lag or data revision. For instance, the NBER did not confirm the latest recession, which began in March 2001, until November 26, 2001; and the latest recovery, which began in November 2001, was not confirmed until July 17, 2003. Leading indicators generally have the advantage of early signaling, timely availability, and freedom from revision. The leading economic indicator approach has also survived repeated testing over time and has been found to be a very effective technique for predicting economic recessions in other countries (Moore, 1961; Zarnowitz, 1992). Therefore, developing leading indicators is an integral component of business cycle studies. To do this, we examined a number of indicators conceptually similar to those currently used leading indicators for the overall economy. These leading indicators for the aggregate economy cover the following aspects of the economy: the degree of tightness in the labor market due to employer hiring and firing; new orders in manufacturing for future production; financial information related to short-term and long-term interest rate differentials that indicate the effect of monetary policies; stock market performance that indicates investors' pessimism or optimism about the future; and consumer expectations of future household spending. Economic theory states that profit is the prime mover in a private enterprise economy and that the recurrence of business cycles of expansion and recession are caused by changes in expectations of profits (De Leeuw, 1991). The CCI and its components measure movements in production and sales; hence, they are concurrent with the current state of the economy. The CLI and its components represent business commitments and expectations regarding labor markets, product markets, and financial markets; thus, they point to future profit outlook.

For the transportation sector, we included all the possible transportation-related as well as economy-wide leading indicators. This produced an initial list of 22 variables: average weekly working hours of transportation and public utilities, seven leading or coincident indicators for transportation equipment (shipment, production, new orders, employment, change in unfilled orders, payrolls, average weekly hours), change in price of spot oil, Dow Jones industrial average and Dow Jones transportation average (DJTA), five currently-used economic leading indicators (consumer sentiment index of the University of Michigan, new orders, interest rate spread between 10-year treasury bonds and federal fund, M2, and new housing starts), purchasing managers' index (PMI) of the Institute of Supply Management and its five component diffusion indexes, and change in business inventories. Among these, transportation equipment provides supplies and equipment to the transportation services sector and is considered a "manufacturing sector" for the latter. The current DJTA includes a total of 20 common stocks associated with transportation: six airlines, five trucking companies, four railroads, two airfreight service providers, and one each for marine transportation, transportation services, and industrial services. These indicators from the economy are all useful barometers for general market conditions, and thus should be predictive of the current state of the transportation sector. For further discussion on the individual indicators, see Batchelor (2001), Klein and Moore (1991), Moore (1961), and Zarnowitz (1992).

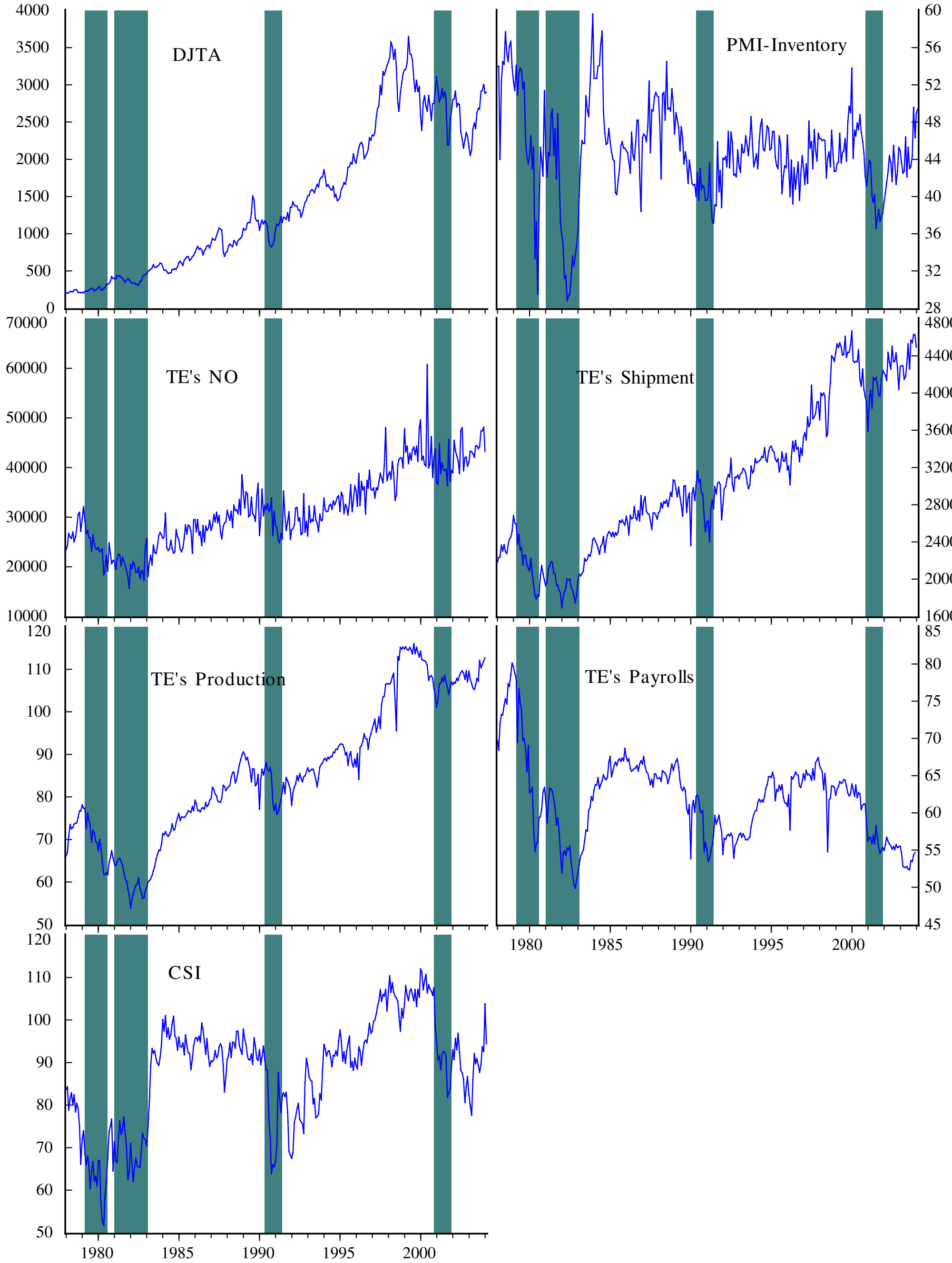

Fig. 5. Leading indicators for the US transportation sector. Shaded areas represent recessions defined for the US transportation sector.

By applying six indicator selection criteria, the initial list of leading indicators was reduced to 14 indicators (see Zarnowitz and Boschan, 1977, pp. 171–173; US BEA, 1984, for discussions on these criteria).[8] They were further screened using Granger-causality tests (Granger, 1969) to test their predictive content for the transportation CCI in both bivariate and multivariate environments. This method is consistent with Zarnowitz and

[8] These criteria include: (a) economic significance, (b) statistical adequacy, (c) conformity to historical business cycles, (d) consistency of timing during cycles, (e) smoothness, and (f) currency.

Braun (1989) in discussing leading indicators for the economy. Finally, these tests had five more variables removed from the list to leave nine indicators remaining.

The last procedure was, as with coincident indicators, to test for the existence of co-movement among the remaining indicators using the *index of Concordance*. We calculated the standard and robust t-statistics to test whether H_0: $\rho_S = 0$ was true. Considering the high serial correlation among the variables, robust t is preferable. At the 5% significance level, t-statistics of interest-rate spread with other variables cannot reject H_0 against H_1. At the 1% level of significance, t-statistics for new housing starts with other variables cannot reject H_0 except for its relationship with TEs production. The correlation between CSI and DJTA is very close to the 1% critical value, but all their other correlations are very significant. Therefore, interest-rate spread and new housing starts are removed from the list for lack of common cycles with the other seven series. The remaining seven variables are, thus, the leading indicators to be used to predict a coincident index for the US transportation sector. They are plotted in Fig. 5, where shaded areas represent the recessions we have defined earlier for the US transportation sector.

3.2. The transportation CLI

Based on these seven leading indicators, a leading index was constructed using the conventional NBER method. Standardization factors of leading indicators used for constructing an NBER index are the inverse of the standard deviation of each series, as reported in Table 6. Following the Conference Board (2001), the constructed transportation CLI is a weighted average of their transformed symmetric month-to-month change then converted back to a level index. It is plotted in Fig. 6.

Table 6
Standardization factors for constructing transportation CLI

US transportation leading indicators	Factors (up to 12/2003)
DJTA (20 stocks)	0.098
PMI-inventory diffusion index (PMI-inventory)	0.091
NO (TE)	0.058
Shipments (TE)	0.140
IP (TE)	0.256
Payrolls (TE)	0.220
Consumer sentiment index (CSI)	0.137

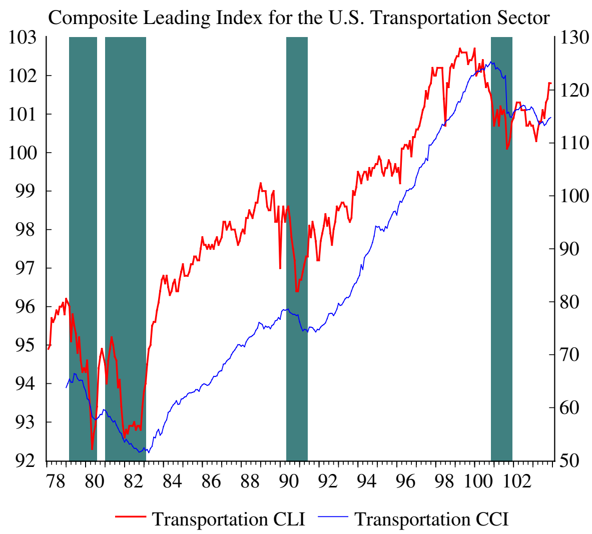

Fig. 6. CLI for the US transportation sector. Shaded areas represent recessions defined for the US transportation sector.

The exact lead–lag relation of the transportation CLI relative to transportation business cycle chronologies is also reported in Table 4. For the latest recession, which started in November 2000, the leading index led the transportation coincident index by 20 months. As the trough for the transportation sector has been determined as having occurred in December 2001, the CLI clearly reached its trough three months earlier. Overall, the leading index of the US transportation sector leads its CCI by 10 months at peaks and 6 months at troughs, on average. The CLI also gives two short false signals in 2/95–2/96 and 5/98–7/98. However, these extra turns are very short and mild and could easily be ignored using the censoring rule in the BB algorithm. The extra turn in 1995 is associated with a growth cycle recession instead of a fully-fledged recession in the transportation sector. The other one might have been caused by a sector-wide temporary shock, as seen in most other transportation indicators as well.

We should, however, point out that the lead-time analysis presented above does not take into account either the lag involved in obtaining the data necessary to construct the series or the delay in identifying a turning point. After all, a leading indicator is only as good as the filter rule (e.g., three consecutive decline rule for signaling a downturn) that interprets its movements. These rules typically involve timeliness trade-offs between accuracy and missing signals or false alarms (see Lahiri and Wang, 1994).

4. Growth cycles of transportation sector

4.1. Defining transportation growth cycles

In addition to identifying economy-wide recessions, the NBER has a long-standing tradition of also identifying growth cycles (see Zarnowitz and Ozyildirim, 2002). These are the periods when the economy undergoes alternating periods of decelerations and accelerations of growth that may not culminate in fully-fledged recessions. Growth cycles usually pick up both business cycles and growth slowdowns and a recession usually starts with a slowdown, followed by a slow recovery. Technically, the growth cycle refers to the cyclical component of a typical time series. The concept measures the movements in aggregate economic activities adjusted for their secular trends.

The conventional NBER algorithm to estimate the secular trend and identify the growth cycles is the Phase Average Trend (PAT) method (Boschan and Ebanks, 1978). The PAT starts by determining preliminary turning points based on the deviation from a 75-month moving average (first approximation) of a deseasonalized time series. Then, values at the turning points are averaged to obtain ‘‘phase averages’’ (each phase is defined by two turning points). The 3-item moving averages of these phase averages are subsequently computed to obtain the so-called ‘‘triplets’’. The midpoints of the triplets are connected, and the connected level series is further adjusted to match the level of the original series. Then, a 12-month moving average (second approximation) of the adjusted series yields the estimated secular trend.[9]

Fig. 7 depicts deviation from PAT where the different phases are clearly identified with the assistance of the zero line. In the figure, lightly shaded areas represent NBER-defined growth cycle recessions for the US economy and dark shaded areas represent NBER-defined recessions for the US economy. The fully-fledged recessions can be clearly distinguished from growth cycles with some hypothetical growth rate in the transportation CCI around ±0.5%, except for the economic recession of 1/80–7/80. The growth recession of 12/88–4/92 in the transportation sector covers both economic recession and growth slowdown in that period with longer swings. The deviation from PAT started to move up and down from late 1988 but only in early 1991 did it show true decline. We then defined the growth cycle recessions based on PAT using the BB algorithm. The dated growth

[9] Since the calculation of PAT can be tedious, a good alternative would be the use of Hodrick and Prescott (1997). The H-P filter chooses the trend value s_t of the deseasonalized data y_t to minimize: $\sum_{t=1}^{T}(y_t - s_t)^2 + \lambda\sum_{t=2}^{T-1}((s_{t+1} - s_t) - (s_t - s_{t-1}))^2$. The penalty parameter λ controls the smoothness of the series. The larger the value of λ is, the smoother will be the trend. Currently, the H-P filter can be implemented using most econometric software (such as EViews).

Zarnowitz and Ozyildirim (2002) point out that the selection of the trend is inevitably associated with considerable arbitrariness, which has long been a source of confusion in the literature of growth cycles. However, they found that estimated trends are generally similar between PAT and the H-P filter when the value of λ is around 108,000 for monthly data, and PAT is superior to its alternatives in the matter of details. Consistent with their finding, with the value of $\lambda = 108{,}000$, the two estimated trends based on PAT and the H-P filter were very similar. By its very nature, however, PAT attributes a somewhat bigger part of the cyclical movements to trend.

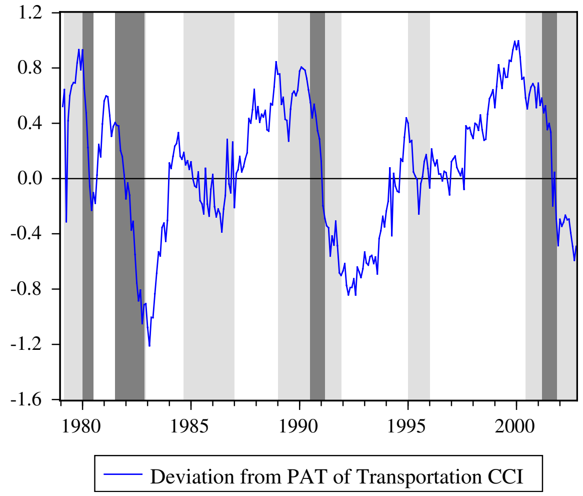

Fig. 7. Growth cycles of US transportation sector. Dark shaded areas represent the NBER-defined recessions for the US economy; lightly shaded areas represent the NBER-defined growth cycle recessions for the US economy.

cycles of the US transportation sector together with their lead/lag relative to the NBER-defined growth cycle are reported in Table 7. Over our sample period, there are six such growth cycle recessions in the US transportation sector. Four of them have developed into fully-fledged recessions; the other two are stand-alone slowdowns. There is also a one-to-one correspondence between growth cycles in the transportation sector and in the aggregate economy. On average, there is a 3-month lead at peaks and a 5-month lag at troughs in the transportation growth cycles relative to economic growth cycles. This gives growth recessions that are 8 months longer in this sector, which is consistent with the longer recession in transportation in the previous analysis.

Layton and Moore (1989) observed two interesting features of services growth rate chronology. One is the typical sequence between cycles in services and the overall economy: peak in services chronology → peak in economy-wide growth chronology → peak in business cycles, while the troughs of the three are simultaneous. The other is that contractions in services-growth chronology have become systematically shorter than the preceding expansion since 1970. Previously, the opposite was the case. Both Fig. 7 and Table 7 suggest a similar sequence, where the peak in transportation growth precedes that in economic growth, followed by economic recessions. The business cycle characteristic of transportation, as a service sector, is consistent with that of general services. But the growth chronology of transportation distinguishes between growth cycles and busi-

Table 7
Growth cycles of the US transportation sector

Transportation growth cycles		Leads (−) and lags (+), in months, of transportation growth cycles relative to		Leads (−) and lags (+), in months, of transportation leading index relative to	
		NBER growth cycles		Transportation growth cycles	
P	T	P	T	P	T
01/79	08/80	−2	+1	−2	−3
01/81	02/83	−6	+2	−2	−4
06/84	01/87	−3	0	−6	−20
12/88	04/92	−1	+4	−1	−16
12/94	08/97	−1	+19	−11	−17
02/00	–	−4	–	−12	9/01
Mean		−3	+5	−6	−12
Median		−3	+3	−4	−16
Std dev		2	8	5	8

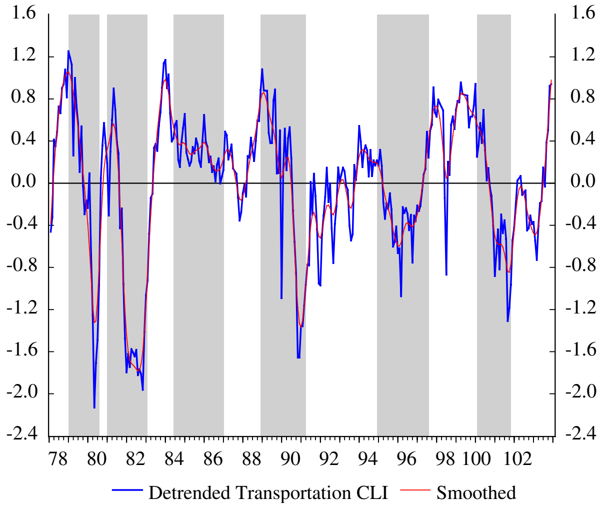

Fig. 8. Growth cycles of transportation CLI. Shaded areas represent growth cycle recessions defined for the US transportation sector.

ness cycles. Troughs in the transportation growth chronology usually lag behind those in economic growth cycles preceded by a trough in economic recessions.

Based on transportation growth chronology, durations of contractions and expansions in growth were calculated, where contractions have been systematically longer than either preceding or subsequent expansions. This, though inconsistent with general services, is consistent with Moore's (1961, vol. I, pp. 48–50) findings with railway freight carloadings after the 1937–1938 recession. Moore attributed the longer contractions in railways to a declining trend, and this explained the failure of railway freight movements as a roughly coincident indicator for the aggregate economy.

4.2. Predicting transportation growth cycles

Growth cycles of the transportation sector were defined based on the deviation from PAT of the transportation CCI. Then, transportation CLI was used to predict them based on its deviation from the H-P trend, as plotted in Fig. 8. The exact lead–lag relationship of growth cycles of transportation CLI relative to those of the transportation sector is reported in the last column of Table 7. The transportation CLI gives early signals of the peaks and troughs of the transportation growth cycles, on average by 6 and 12 months respectively, without any false signal or missing any turn. As a result, growth slowdowns in the transportation sector are longer than those in the aggregate economy on average by 18 months. The minimum lead the leading index has shown is a one-month lead while forecasting the peak of the 1988 growth recession. For the latest growth cycle recession, beginning in February 2000, the leading index started to decline in April 1999, about 12 months earlier. Though the trough of this growth slowdown has not yet been determined, the growth cycle of the leading index reached its trough in September 2001.

5. Conclusion

This paper studies both the classical business cycles and the growth cycles of the US transportation sector using economic indicators. These cycles are useful in diagnosing the ups and downs in the aggregate economy and ultimately can help improve transportation planning and macroeconomic policies. Based on the four selected coincident indicators, a composite coincident index was created using both the NBER non-parametric method and dynamic factor models. We defined reference cycle chronologies for this sector using the selected transportation coincident indicators. The leading indicators were selected to predict future states in this sector. The similar practice can be repeated on a regular basis to monitor this sector and make inferences on the overall economy in real time. Reference cycles we defined for transportation sector are synchronized with those in aggregate economy as dated by NBER, but the transportation recessions are found to be longer than those of the overall economy. In other words, recessions in this sector often starts earlier and ends later. The selected leading indicators perform fairly well over the sample period as a forecasting tool for this sector.

The relationship between transportation and the aggregate economy reflects complex linkages between sectors. First, as a derived input, transportation demand often reflects the producers' expectation towards future profits. Second, due to deregulation and the adoption of just-in-time inventory control methods, productivity improvements in US economy have been largely contributed by the transportation modes (Bosworth, 2001). Third, this sector is also very sensitive to monetary policy tightening and oil price shocks due to its heavy usage of capital equipments and fuel consumption. These are the most common shocks noted in the economics literature to have caused recessions in various periods (Temin, 1998). Therefore, these factors can explain why transportation output has substantial leading value (on average 17 months at peaks) to economy-wide business cycles (Lahiri et al., 2003), and why transportation cycles always peak earlier (on average 2 months at peaks). On the other hand, demand for transportation services is also affected by the current state of economy, especially in terms of employment and consumption expenditure. This can explain a much shorter lead-time of transportation reference cycles compared with transportation output. The conclusion we draw for transportation growth cycles is consistent with Layton and Moore's (1989) study on the general services sector, where they found that general services sector enters growth recessions earlier than overall economy. Although they did not find regular relationship between cycles in general services and overall economy at troughs, this paper suggests that transportation, as one of the services sectors, recovers later than general economy.

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