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Cycles in the Transportation Sector and the Aggregate Economy

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Abstract

Transportation plays a central role in facilitating economic activities across sectors and between regions, and is thus essential to business cycle research. Using four coincident indicators representing different aspects of the transportation sector that include an index of transportation output, payroll, personal consumption and employment, we define the classical business cycle and growth cycle chronologies for this sector. We find that, relative to the economy, business cycles in the transportation sector have an average lead of nearly 6 months at peaks and an average lag of 2 months at troughs. Similar to transportation business cycles, growth slowdowns in this sector also last longer than the economy-wide slowdowns by a few months. This study underscores the importance of transportation indicators in monitoring cyclical movements in the aggregate economy.

***Keywords*:** Business cycle, Composite coincident index, Dynamic factor model, Regime switching, Growth cycle.

I. INTRODUCTION

Relative to the good-producing sectors, the service-providing sectors have become increasingly more important in most countries. Thus, information from the service sectors is now essential to the study of business cycles in a contemporary economy. Moore (*1*) points out that the ability of the service sectors to create jobs has differentiated business cycles since the 1980s from their earlier counterparts, and has led economy-wide recessions to be shorter and less severe. Layton and Moore (*2*) suggest two factors that can account for less severity in service sector recessions – i) the increased importance of non-manufacturing labor market relative to that of the manufacturing sector, and ii) services are non-storable and thus, these sectors do not hold inventories. Since inventory movement is the dominant feature of business cycles, we can appreciate why recent business cycle research has not paid much attention to the service sectors. This also partly explains the absence of service sector indicators in NBER Committee's deliberations in dating U.S. business cycles over last forty years.[1]

However, transportation as a service sector is different. Almost all the intermediate goods are moved through the transportation system to build business inventories. Thus, transportation activity itself is expected to be highly correlated with inventory cycles. This relationship, in turn, suggests a strong linkage between transportation and the aggregate economy. In a recent research sponsored by the U.S. Department of Transportation, Lahiri *et al*. (*7*) have developed a monthly experimental index to measure the aggregate output of the transportation sector. This transportation services output index (TSOI) utilizes eight series on freight and passenger movements from the airlines, rail, waterborne, trucking, transit and pipelines (NAICS codes 481-486) covering around 90% of total for-hire transportation during 1980-2000. Lahiri and Yao (*8*) records the business cycle characteristics of TSOI in monitoring the current state of aggregate economy; they find that it leads at peaks but almost coincident at troughs of the economy-wide business cycles. Lahiri and Yao (*9*) further explain these features through TSOI's central role in inventory cycles and industrial production in a stage of fabrication

[1] Interestingly, in the early part of the last century, the NBER scholars considered transportation to be central to the study of business cycles, see Burns and Mitchell (*3*), Dixon (*4*), Hultgren (*5*), and Moore (*6*). Later on, research on transportation was hampered due to the discontinuation of many transportation series in the 1960's.

model. In so far as inventory cycles and fluctuations in the manufacturing production are central to fluctuations in the aggregate production, transportation activities, particularly freight movements, are crucial in the propagation of economy-wide business cycles.[2]

TSOI is a chained Fisher-ideal index,[3] and is methodologically similar to the Industrial Production (IP) index, which is one of the four coincident indicators of the aggregate economy.[4] Thus, TSOI together with other coincident indicators from transportation can be used to study business cycles characteristics of this sector, and its relationship to the aggregate economy. It should also be noted that understanding of the cyclical characteristics in transportation activities is important for the purposes of planning and resource allocation in the sector. This paper applies dynamic factor models and the nonparametric NBER procedure to estimate the composite coincident index (CCI) for the transportation sector, and to study its cyclical features in relation to the aggregate economy.

The paper is organized as follows: After *Introduction,* we select four standard coincident indicators from the transportation sector, and experiment with alternative procedures to construct CCI for the U.S. transportation sector in *Section II*. These include the conventional NBER nonparametric and two parametric approaches by Stock-Watson (*13*) and Kim-Nelson (*14*). *Section III* studies the business and growth cycle characteristics of the transportation sector based on its CCI's. The relationship between cycles in this sector and those in the aggregate economy are also explored. The last section summarizes main conclusions of this study.

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[2] Ghosh and Wolf (*10*), in examining the importance of geographical and sectoral shocks in the U.S. business cycles, find that transport sector is highly correlated with intra-state and intra-sector shocks, and is thus crucial in the propagation of business cycles.

[3] In constructing TSOI, we used value-added weights from NIPA. During 1980 - 2000, the weights for air and rail changed from 18.8% to 33.0%, and from 21.5% to 8.1%, respectively. The trucking has the maximum weight among all subsectors throughout the period, always in excess of 40.0%. The weights for the others (*i.e.,* rail passenger, air freight, pipelines, water transportation and public transit) were always below 8.0% and changed little over this period. The weights also reflect the fact that economy has become less freight-intensive in that the total weight for freight movements relative to the total transportation activities has steadily shrunk from 72.3% to 61.1% in past two decades.

[4] Gordon (*11*) and Bosworth (*12*) have provided valuable insights into the different methodologies and data that BEA and BLS use to construct alternative annual transportation output series. A comparison suggests that these annual output measures reflect the long-term trends of TSOI, and that the latter is superior in reflecting the cyclical movements in the transportation sector, see Lahiri *et al.* (7).

II. INDEX OF COINCIDENT INDICATORS OF THE TRANSPORTATION SECTOR

1. Comovement among the Four Coincident Indicators

Burns and Mitchell's (*3*) definition of business cycles has two key features. The first is the comovement or concurrence among individual economic indicators; the other is that business cycle is governed by a switching process between different regimes or phases. Extracting the comovement among coincident indicators leads to the creation of the so-called composite coincident indicator, which is the basis to define the current state of the aggregate economy.

Following the NBER tradition and Layton and Moore (*2*), we use four conventional coincident indicators from the transportation sector to define its the current state. They are: TSOI (Y_{1t}) as defined earlier, real aggregate payrolls of workers employed in the transportation sector (Y_{2t}), real personal consumption expenditure on transportation services (PCE, Y_{3t}), and all employees (Y_{4t}) of this sector. These indicators, plotted in Figure 1, reflect information on output, income, sales, and labor usage in the transportation sector. Given these four available data series, the existence of comovement among them should be tested for their statistical significance. That is, we should check for the synchronization between them in terms of their underlying business cycle regimes (expansion or recession). This topic has been the subject of considerable research in recent years because the economic cost associated with forecast errors around turning points of business cycles is considerably more than that during other times, see Pesaran and Timmermann (*15*).

The concept of comovement between a pair of indicators can be illustrated with four outcomes in Table 1 adapted from Granger and Pesaran (*16*). With such a contingency table, various χ^2 tests were designed based on the proportion of correct directional forecasts for both positive and non-positive growth ($P_1 + P_2$), see Henriksson and Merton (*17*), Schnader and Stekler (*18*), and Pesaran and Timmermann (*19*) for further discussions. Using this information, Harding and Pagan (*20*) propose an index of concordance for two series x_t and y_t with sample size T:

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

S_{xt} and S_{yt} are the underlying states (0 or 1) of each series based on turning points defined using the NBER procedure. The degree of concordance defined in (1) between two variables is quantified by the fraction of times that both series are simultaneously in the same state of expansion (S_t = 1) or contraction (S_t = 0) such that the value I ranges between 0 and 1. The index can be further re-parameterized as

$$I = 1 + 2\rho_S \sigma_{S_x}\sigma_{S_y} + 2\mu_{S_x}\mu_{S_y} - \mu_{S_x} - \mu_{S_y}\ , \tag{2}$$

where μ_{S_x} and μ_{S_y} are the means of S_{xt} and S_{yt} respectively, σ_{S_x} and σ_{S_y} are their standard deviations, and ρ_S is the correlation coefficient. When the correlation coefficient ρ_S = 0, $I = 1 + 2\mu_{S_x}\mu_{S_y} - \mu_{S_x} - \mu_{S_y}$ = 0.46 for μ_{S_x} = 0.3 and μ_{S_y} = 0.6. So this concordance index is determined not only by the correlation between the two series but also their average fraction of times in expansion.

The binary state variable (S_{xt} or S_{yt}) corresponding to each indicator is defined based on the turning points (peak or trough) identified using the NBER dating procedure (BB algorithm), which is documented in Bry and Boschan (*21*). 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 trough (phase) cannot be shorter than six months and a complete cycle must be at least fifteen months long. The resulting turning points define a "specific cycle" of each component series. The peaks and troughs of four selected coincident indicators of the transportation sector are reported in Table 2 in terms of lead (-) or lag (+) relative to the transportation reference cycle chronology that we will introduce later.

The synchronization of cycles among coincident indicators can be measured and tested based on the index of concordance between four specific cycles and the reference cycle. We have tabulated the concordance measures and the test statistics in Table 3. In the first part of the table (3A), the concordance statistics I's are reported above the diagonal while ρ_S's are reported below the diagonal, and μ_S and σ_S are given in the bottom. All the pairs of transportation coincident indicators have positive correlations ranging between 0.5 ~ 0.7 and concordance indexes between 0.8 ~ 0.9. With the reference cycle, the figures are even higher. These statistics suggest strong evidence of synchronization between cycles underlying the selected transportation coincident indicators. Also, based on reported μ_S 's, none of the series is dominated by either of the states (0 or 1). Hence the high concordance indexes are associated with the high correlations between them. Harding and Pagan (*20*) have also developed a test to see if synchronization of cycles is statistically significant. A simple way to do so is the *t*-test for H_0: $\rho_S = 0$, where $\hat{\rho}_S$ is obtained from the regression

$$\frac{S_{yt}}{\sigma_{S_y}} = a_1 + \rho_S \frac{S_{xt}}{\sigma_{S_x}} + u_{t.} \qquad (3)$$

Standard *t*-statistics is based on OLS regression. We use Newey-West heteroskedasticity and autocorrelation consistent (HAC) standard errors (lag truncation = 5) to account for possible serial correlation and heteroskedasticity in errors u_t. In Table 3B, standard *t*'s are reported below the diagonal while the robust *t*'s are reported above it. All these statistics significantly reject $H_{0.}$ The large t-values also suggest the existence of comovement of the four transportation coincident indicators and the reference cycle. Thus, they are qualified coincident indicators for this sector.

2. *Transportation CCI*

A CCI can be constructed non-parametrically by assigning fixed standardization factors as weights to each of the four coincident indicators. The following four steps characterize the NBER nonparametric approach: 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 as reported in Table 4; 3) the level of the index is computed using the symmetric percent change formula; and 4) the index is re-based to be 100 in 1996 to make a formal NBER index. See Conference Board (*22*) for the complete methodology. An alternative would be using techniques of modern time-series analysis to develop dynamic factor models with regime switching (Kim-Nelson, (*14*)) or without (Stock-Watson, (*13*)). The resulting single indexes would represent the underlying state of their constituent time series, namely the Kim-Nelson index and the Stock-Watson index. Thus, dating turning points could be based on the probabilities of the recessionary regime implied by the time series models.

Given a set of coincident indicators Y_{it} (i = 1, 2, 3, 4), their growth rates can be explained by an unobserved common factor ΔC_t, interpreted as growth in CCI, and some idiosyncratic dynamics e_{it}.[5] This defines the measurement equation for each component:

$$\Delta Y_{it} = \gamma_i \Delta C_t + e_{it}, \qquad (4)$$

where ΔY_{it} is logged first difference in Y_{it} and γ_i is the coefficient for the index ΔC_t for each individual indicator. 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 term w_t and ε_{it} respectively.

$$\Phi(L)\ (\Delta C_t - \mu_{St} - \delta) = w_t, \qquad (5)$$

$$\Psi(L)\ e_{it} = \varepsilon_{it}, \qquad (6)$$

where μ_{St} is the regime-dependent average growth rate, binary state variable S_t = 0 (recession) or 1 (recovery), and δ is used to demean $\Delta C_t - \mu_{St}$. The two noise terms are assumed to be independent of each other. The transitions of different regimes (μ_{St}), incorporated in (2), are governed by a hidden Markov process:

$$\mu_{st} = \mu_0 + \mu_1 S_t,\ S_t = \{0, 1\},\ \mu_1 > 0, \qquad (7)$$

$$Prob\ (S_t = 1 \mid S_{t-1} = 1) = p,\ Prob\ (S_t = 0 \mid S_{t-1} = 0) = q, \qquad (8)$$

Equation (4) ~ (6) defines the Stock-Watson model (dynamic factor model) while the Kim-Nelson model includes all five equations (dynamic factor model with regime switching). To implement the Kim-Nelson model, we used priors from the estimated Stock-Watson model. Priors for regime switching parameters were obtained using sample information from the NBER index. Both models were estimated using computer routines described in Kim and Nelson (*14*). Unlike the Stock-Watson (*13*) model specification for the aggregate economy, personal consumption expenditure in transportation appears 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 generally 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

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[5] For further details, see Kim and Nelson (*14*), Diebold and Rudebusch (*23*), and Stock and Watson (*13*).

difference is complemented by a much larger role of employment and a smaller role of personal consumption in the Kim-Nelson model. As a result, the Stock-Watson index appears to be smoother than the Kim-Nelson index (see Figure 4). The latter model also distinguishes between two clear-cut regimes of positive (0.745) and negative (-0.869) growth rates. Based on the estimated transitional probabilities (P_{00} = 0.926 and P_{11} = 0.985), expected durations of recessions and expansions are calculated as $(1- P_{00})^{-1}$ = 13.5 and $(1- P_{11})^{-1}$ =66.7 months respectively. These estimated average durations of recessions and expansion in the transportation sector compare favorably with the actual durations of 13 and 68 months respectively over our sample. The estimated transportation CCI's from these two models are plotted against the NBER index in Figure 2. Compared to Kim-Nelson index, the Stock-Watson index agrees more closely with the NBER index throughout the period. Despite differences in model formulations and in minor details, their cyclical movements appear to be very similar to one another, and synchronized well with the NBER-defined recessions for the economy (the shaded areas).

III. RELATION WITH THE AGGREGATE ECONOMY

1. Comparison with Business Cycles

The BB algorithm is employed to identify the turning points in the NBER index. The NBER procedure to define recessions for the economy involves visually identifying clusters of turning points of the individual indicators and that of the constructed NBER index, and minimizing the distance between the turning points in each cluster (Layton and Moore, *2*). Following the standard steps, we defined the chronology of cycles in the U.S. transportation sector for the period since January 1979. They are reported in Table 2. There are clearly four major recessions: 1979:03~1980:08, 1981:01~1983:02, 1990:05~1991:06, and 2000:11~2001:12. Determining the peak and the trough for the latest recession in the transportation turned out to be little difficult. Among four coincident indicators, TSOI, personal consumption and payrolls had signs of recessions back in 1998 while the employment became weak only after January 2001. We determined the peak for this transportation recession to be in November 1999 based on the peak of the composite NBER index. Identifying the trough is even more difficult due to the profound impact of 9/11 event. Both TSOI and personal consumption were so dramatically affected that that the two series started recovering immediately from October 2001. The payrolls series reached its trough two month later. Employment in this sector, like that in total non-farm sectors used by NBER, has been weak throughout the sample period. As a result, we determined the trough of the latest transportation recession to be December 2001 based on the trough of the NEBR index.

The recessionary periods in the transportation sector during 1979 to 2002 are pitted against the NBER-defined business cycles of the aggregate economy in Table 6. Overall, there is a one-to-one correspondence between cycles of the transportation sector and those of the economy. However, the relationship between transportation and the economy is asymmetric at peaks and troughs.[6] Specifically, the transportation sector peaks ahead of the economy by almost 6 months on the average, while at troughs it lags by two months. In other words, recessions in the transportation sector last longer that the economy-wide recessions by almost 8 months. Thus, the cycles of this sector can potentially be used to confirm the NBER dating of U.S. recessions.

The above analysis is based on the nonparametric procedure practiced by the NBER Dating Committee. Alternatively, reference cycles can be defined from the probability of recessions implied by the regime-switching model of Kim and Nelson (*14*). Figure 3 depicts the posterior probability that transportation sector is in a recession as inferred from the Kim-Nelson model estimation. The darker shaded areas represent the NBER-defined recessions for the U.S. economy, while the lightly shaded areas represent recessions in the U.S. transportation sector as given in Table 2. If we define the transportation recessions by taking the first month that the probability begins to rise (drop) as the trough (peak), the resultant chronology would be very similar to the shaded areas representing transportation recessions defined earlier using NBER approach. The probabilities in Figure 3 show that, corresponding to each of the four economy-wide recessions defined by NBER, there is a recession in the transportation sector. The Kim-Nelson recession probabilities also indicate that the transportation recessions are consistently longer in duration than the economy-wide recessions. Figure 3 suggests that the latest recession in the U.S. transportation sector ended in December 2001, which is

[6] Interestingly, a similar asymmetry also exists between inventory and business cycles; see Zarnowitz (*24*, p. 336) and Humphreys *et al.* (*25*).

just one month after the recently announced NBER trough of the economic recession that began in March 2001. Interestingly, the finding on the longer duration of transportation recessions is very similar to that in Moore (*6*, pp. 48-51), who used only railway freight data for his conclusion.

Comparisons of lead/lag relationship of the transportation reference cycle in this study and transportation output index that we reported in Lahiri and Yao (*8*) relative to the NBER reference cycle of the aggregate economy suggest importance differences between the two. The TSOI leads the economic reference cycle by almost 16 months at peaks and is roughly coincident at troughs, but with two extra turns that correspond to stand-alone economic slowdowns of 1984~1985 and 1995~1996. The TSOI is more synchronized with growth cycles than the full-fledged business cycles of the aggregate economy. Based on the transportation CCI constructed from four coincident indicators including TSOI, the business cycles in the transportation sector seem to have a one-to-one correspondence with those of the aggregate economy with no extra turns. Thus, the cycles in the transportation sector and those of the aggregate economy become a lot more synchronized when indicators from other aspects of the sector such as employment, consumption and income are also considered.

2. Comparison with 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 (*26*). These are the periods when the economy undergoes alternating periods of decelerations and accelerations of growth that may not culminate into full-fledged recessions. Growth cycles cover both business cycles and growth slowdowns, and a recession usually starts with a slowdown and is 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 tends. Depending how one estimates the trend from a time series, estimated growth cycles could be different.

1) Estimation of the Trend

The conventional NBER algorithm to estimate the secular trend and identify the growth cycles is the Phase Average Trend (PAT) method (*27*). The PAT starts with determining preliminary turning points based on the deviation from 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 on 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.

Since the calculation of PAT can be tedious, a good alternative would be the Hodrick-Prescott (*28*) filer. HP filter chooses the trend value τ_t of the deseasonalized data y_t to minimize:

$$\sum_{t=1}^{T}(y_t - s_t)^2 + \lambda\sum_{t=2}^{T-1}((\tau_{t+1} - \tau_t) - (\tau_t - \tau_{t-1}))^2 . \qquad (9)$$

The penalty parameter λ controls the smoothness of the series.[7] The larger the value of λ is, the smoother will be the trend. Zarnowitz and Ozyildirim (*26*) point out that the selection of the trend is inevitably associated with considerable arbitrariness, which has long been a source of puzzle in the literature of growth cycle. However, they found that estimated trends are generally similar between PAT and HP 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 λ=108,000, the two estimated trends based on PAT and HP filter were found to be very similar. By its very nature, however, PAT attributes a somewhat bigger part of the cyclical movements to trend.

The other alternative is the so-called band-pass filter. It was developed from the theory of spectral analysis, which provides a rigorous foundation that there are different frequency component of the data series. Spectral Representation theorem also enables us to decompose any time series into different frequency components, using ideal band pass filter proposed by Baxter and King (*29*). Note that business cycles differ from growth cycles in that the former require absolute decline in economic activity. The band pass

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[7] The first term in equation (9) represents the cyclical movement (difference between a time series and its trend), and the second term represents the second order change or smoothness of the trend. Thus the minimization of equation (9) amounts to balancing between the closeness of y_t to its to-be-estimated trend, and the smoothness of this trend. λ is the weighting parameter emphasizing smoothness of trend relative to closeness, so it is a unit-free number relative to 1 (weight emphasizing the closeness).

filter simply makes no distinction between classical business cycles and growth cycles. Thus the estimated series from the band pass filter actually corresponds to the growth cycles. In practice, the narrower the bands are, the more numerous and the smaller are the fluctuations in the filtered series. Like λ in the HP filter, selection of band is crucial to the band pass filter estimates.

2) Growth Cycles in U.S. Transportation Sector

With various estimated trends, growth cycles are obtained as the deviation of original seasonally adjusted data series from its trend. Following NBER approach, we defined growth cycles in the transportation sector based on PAT. Figure 4 depicts cyclical movements based on PAT, HP and band-pass filters, where the shaded areas represent growth cycles based on PAT. Deviation from PAT and deviation from HP trend appear to be similar. They are less smooth, but the different phases are clearly identified with the assistance of zero line. With a band ranging from 9 to 96 months, the series from band pass filter has a surprising match with PAT-defined growth recessions as depicted in the Figure 4. This series is smoother than either the deviation from the PAT or HP trend due to the exclusion of the irregular movements (less than 9 months) and inclusion of pure trend (frequencies up to 96 month). The growth cycles based on the PAT are reported in Table 6 as well. Over the entire period, there were six such growth slowdowns in the U.S. transportation sector. Four of them developed into full-fledged recessions; the other two are just stand-alone slowdowns. Like business cycles, these slowdowns in the transportation sector are also longer than those in the aggregate economy; they peak ahead of the economy by almost 3 months on the average, while at troughs they lag by 2 months. Again, growth cycles of this sector are well synchronized with those of the economy, but with slightly longer durations.

IV. CONCLUSIONS

We have pointed out that it is useful to distinguish between growth slowdowns and full-fledged recessions of the aggregate economy in order to understand fully the role of transportation in business cycle analysis. Typically, a recession is bordered by periods of slow growths, but there are stand-alone growth slowdowns that do not culminate into full-fledged recessions. We found that transportation output is highly sensitive to both recessions and slowdowns in the economy. The cyclical movements in TSOI are dominated by for-hire freight, which is used to deliver inventories of materials & supplies for the manufacturing. It is well known that inventory cycles especially those of materials & supplies are the dominant features of modern business cycles. This makes transportation a key sector in understanding the business cycle dynamics in a contemporary economy.

This paper studies both business and growth cycles in the U.S. transportation sector using the economic indicators analysis approach and modern time series models. Four coincident indicators are selected to represent different aspects of the transportation sector, including a newly developed index of transportation output (TSOI), payrolls, personal consumption expenditure and employment in this sector. Three alternative composite indexes (CCI) are created representing the current state of the transportation sector. Based on the NBER index, chronologies of both classical business cycles and those of growth slowdowns are determined. Methodologically, a comforting result is that CCI obtained using nonparametric NBER procedure yields almost same turning point chronology as those using parametric time series models. We find that, relative to the economy, business cycles in the transportation sector have an average lead of 6 months at peaks and an average lag of nearly 2 months at troughs. Thus, the recessions in this sector last longer by nearly 8 months than those of the overall economy. Similar to business cycles, growth cycles in the sector also last longer by a few months. This study underscores the importance of transportation indicators in monitoring cycles in the aggregate economy.

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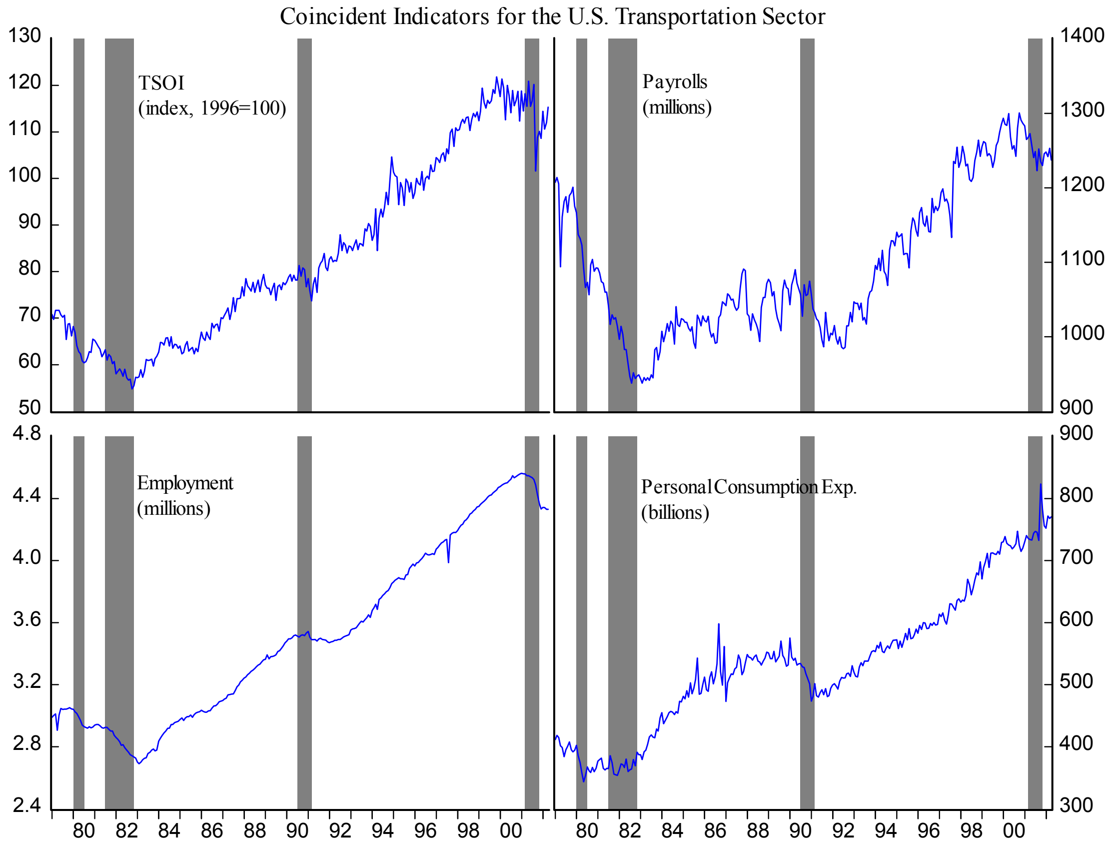

FIGURE 1

*Shaded areas represent NBER-defined recessions for the U.S. economy

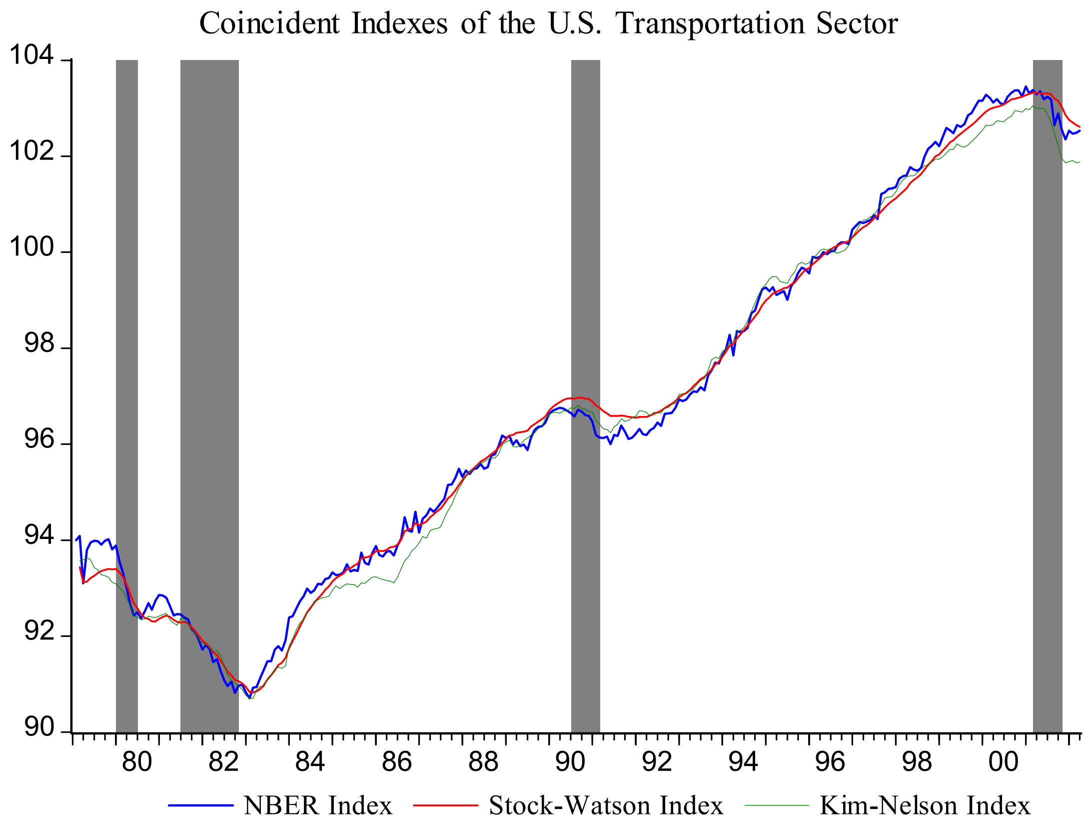

FIGURE 2

*Shaded areas represent NBER-defined recessions for the U.S. economy

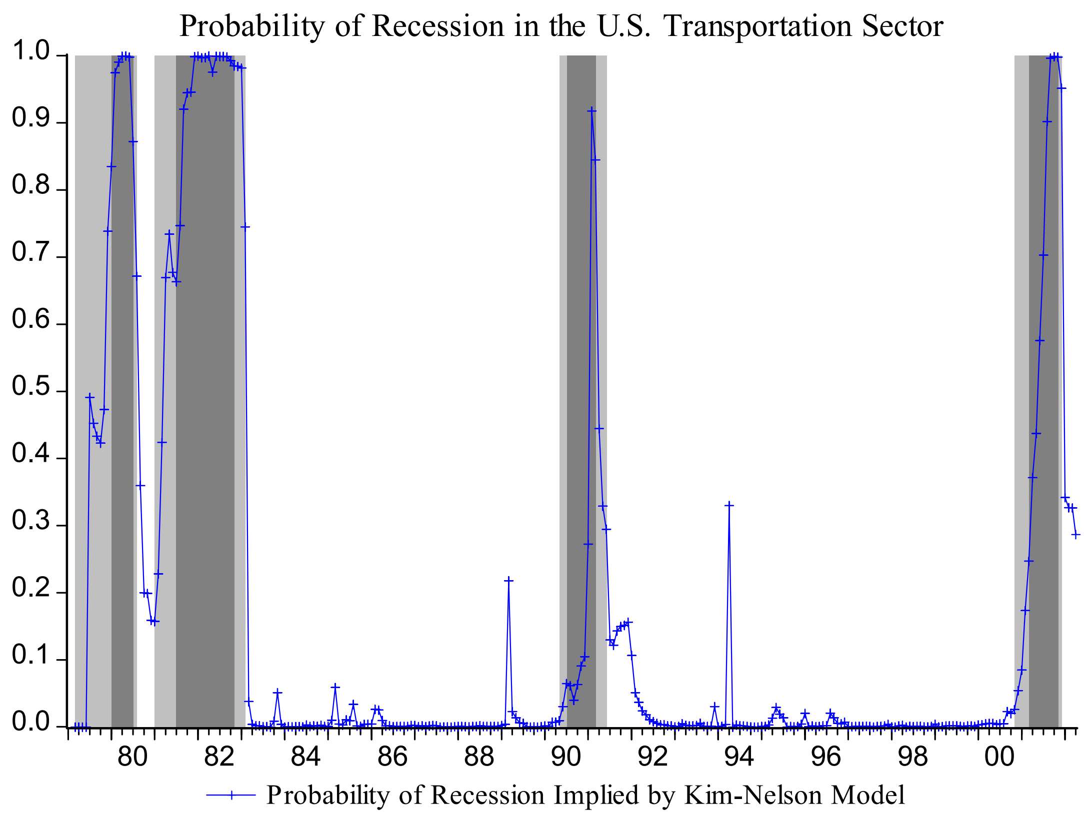

FIGURE 3

* Darker shaded areas represent NBER-defined recessions for the U.S. economy; lightly shaded areas represent recessions of the U.S. transportation sector.

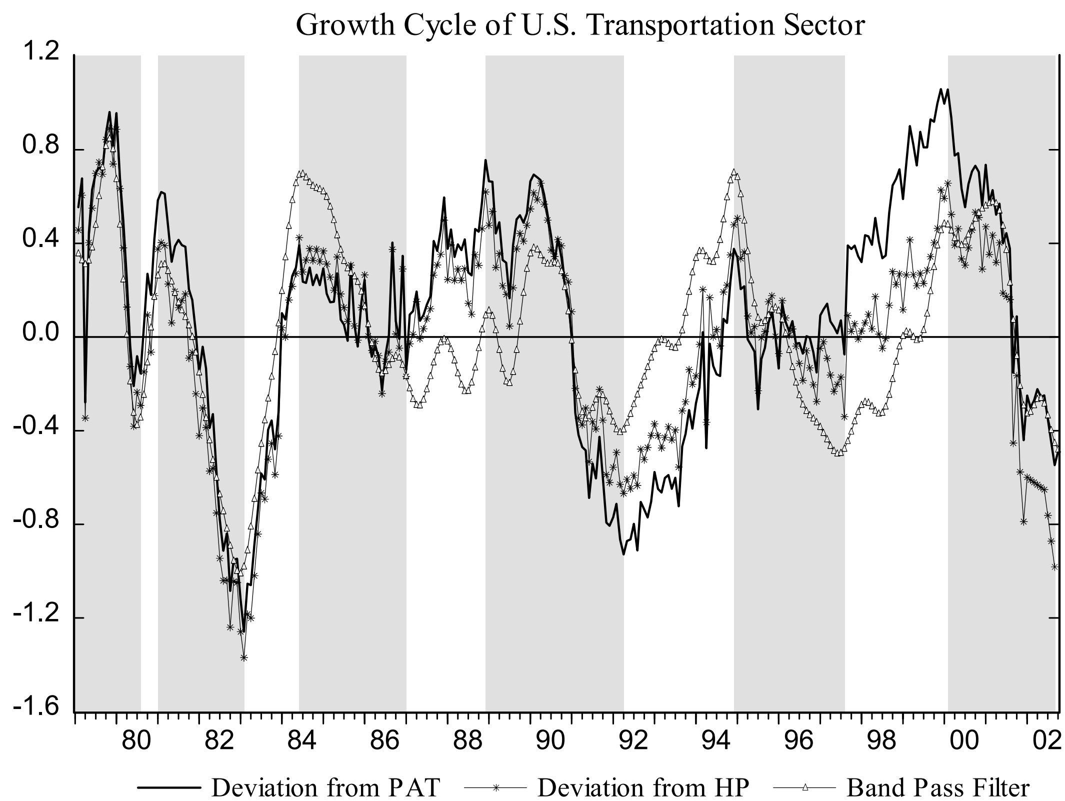

FIGURE 4

*Shaded areas represent growth cycle recessions in U.S. transportation sector based on its CCI

TABLE 1 Contingency Table for Concordance Analysis

		Actual Change	
		> 0	≤ 0
Forecasted Change	> 0	Correct (P_1)	False ($1- P_2$)
	≤ 0	False ($1- P_1$)	Correct (P_2)

TABLE 2 Business Cycle Chronologies in U.S. Transportation Sector, 1979 – 2002

Transportation Reference Cycles		Leads (-) and Lags (+), in months, relative to Transportation reference cycle									
		NBER Index		Output		Employment		Real PCE		Real Pay	
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	-2	+2	-	-12	-2	-13	-1
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

TABLE 3 Measuring and testing of synchronization of cycles

A. Concordance indexes and correlations of cycles among transportation coincident indicators

	Employment	Payrolls	Output	PCE	Reference Cycle
Employment	--	0.8	0.8	0.8	0.9
Payrolls	0.6	--	0.8	0.8	0.8
Output	0.5	0.6	--	0.8	0.8
PCE	0.6	0.5	0.5	--	0.9
Reference Cycle	0.8	0.7	0.6	0.7	--
$\hat{\mu}_S$	0.7	0.6	0.6	0.7	0.7
$\hat{\sigma}_S$	0.4	0.5	0.5	0.5	0.4

B. Standard and robust t-statistics for H_0: $\rho_S = 0$

	Employment	Payrolls	Output	PCE	Reference Cycle
Employment	--	6.2	4.0	5.1	9.6
Payrolls	14.2	--	6.4	4.8	12.9
Output	9.2	12.1	--	4.8	7.8
PCE	13.0	9.8	10.1	--	7.8
Reference Cycle	23.4	16.2	12.7	16.8	--

TABLE 4 Standardization Factors for Constructing Transportation CCI (NBER)

U.S. transportation coincident indicators	Factors (01/79 ~ 04/02)
1. TSOI	0.108
2. Real aggregate payrolls	0.175
3. Real personal consumption expenditure	0.106
4. All employees in transportation	0.611

TABLE 5 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	Φ_1	0.775	0.167	0.775	0.127	0.119	0.114
(State Variable)	Φ_2	0.107	0.162	0.107	0.121	0.085	0.124
ΔY_{1t}	γ_1	0.171	0.057	0.1	0.136	0.028	0.136
(Output)	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}	γ_2	0.148	0.048	0.1	0.173	0.042	0.172
(Payrolls)	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}	γ_3	1.485	0.631	1.5	0.059	0.060	0.059
(Personal	γ_{31}	-1.364	0.626	-1.4	-0.041	0.059	-0.039
Consumption	φ_{31}	-0.149	0.122	-0.1	-0.388	0.060	-0.388
Exp.)	σ_3^2	2.443	1.831	2	0.849	0.076	0.844
ΔY_{4t}	γ_4	0.110	0.021	0.1	0.548	0.081	0.557
(Employment)	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

TABLE 6 Comparison of Transportation Cycles with Economic Cycles

<table>
<tr><td colspan="3" rowspan="2">Transportation Business Cycles</td><td colspan="3">Leads (-) and Lags (+), in months, of Transportation Business Cycles relative to</td><td colspan="2" rowspan="2">Transportation Growth Cycles</td><td colspan="2">Leads (-) and Lags (+), in months, of Transportation Growth Cycles relative to</td></tr>
<tr><td colspan="3">NBER Business Cycles</td><td colspan="2">NBER Growth Cycles</td></tr>
<tr><td>P</td><td>T</td><td>Duration</td><td>P</td><td>T</td><td>Duration</td><td>P</td><td>T</td><td>P</td><td>T</td></tr>
<tr><td>03/79</td><td>08/80</td><td>17</td><td>-10</td><td>+1</td><td>6</td><td>01/79</td><td>08/80</td><td>-2</td><td>+1</td></tr>
<tr><td>01/81</td><td>2/83</td><td>25</td><td>-6</td><td>+3</td><td>16</td><td>01/81</td><td>02/83</td><td>-6</td><td>+2</td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td><td>06/84</td><td>01/87</td><td>-3</td><td>0</td></tr>
<tr><td>05/90</td><td>06/91</td><td>13</td><td>-2</td><td>+3</td><td>8</td><td>12/88</td><td>04/92</td><td>-1</td><td>+4</td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td><td>12/94</td><td>08/97</td><td>-1</td><td>+19</td></tr>
<tr><td>11/00</td><td>12/01</td><td>13</td><td>-4</td><td>-1</td><td>8</td><td>02/00</td><td>-</td><td>-4</td><td>-</td></tr>
<tr><td colspan="2">Mean</td><td>18</td><td>-6</td><td>+2</td><td>10</td><td></td><td></td><td>-3</td><td>+2</td></tr>
<tr><td colspan="2">Median</td><td>17</td><td>-3</td><td>+3</td><td>8</td><td></td><td></td><td>-3</td><td>+5</td></tr>
<tr><td colspan="2">Std Dev.</td><td>6</td><td>3</td><td>1</td><td>5</td><td></td><td></td><td>2</td><td>8</td></tr>
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