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An Analysis of the Causal Relationship Between Transportation and GDP: A Time-Series Approach for the United States

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ABSTRACT. Time-series analysis using monthly data from January 2000 to December 2015 is used to investigate the relationship between transportation and real GDP, controlling for the price of diesel, the amount of money invested in infrastructure, the inflation rate, and the real effective exchange rate. Transportation is proxied with the freight Transportation Services Index. Using Granger-causality, I find that changes in transportation Granger cause changes in real GDP, but not vice versa. It is a one-directional relationship where past values of transportation lead changes in real GDP.

I. Introduction

The transportation industry is as an integral part of the economy. Nearly all businesses use some form of transportation to connect people, goods, and resources. Improvements in the transportation industry support and create jobs, increase household disposable income, and improve business productivity (Maryland Department of Transportation 2015). When evaluating the state of the economy and the contribution transportation makes to GDP, it would be useful to know the relationship between these variables.

Given how important transportation is to economic activity, it begs the question whether changes in transportation cause changes in real GDP, or if changes in GDP lead changes in the transportation industry. The relationship could also be bidirectional. Although unlikely, they may even have no influence on each other. One method to test the relationship is with Granger-causality. Don't let the name fool you; Granger-causality is not a test for causality. Granger-causality means past values of one variable have predictive power about future values of another variable.

The null hypothesis is non-Granger causality, that is, changes in one variable do not consistently precede changes in the other. To test the hypothesis, one must use lagged variables. The alternative hypothesis is Granger causality, which means changes in the lagged variables precede

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changes in the variable being tested. An F-test is then run on the lagged variables to see if they provide statistically significant information about the future values of another variable. In other words, do past values of X, the lagged variables, provide additional information to predict the future values of Y? If X does Granger cause Y, then the null hypothesis will be rejected.

By controlling for economic variables such as the price of diesel, the amount of money invested in infrastructure, the inflation rate, and the real effective exchange rate, the relationship between the freight Transportation Services Index (TSI) and GDP can be analyzed. Both variables serve as dependent variables in the economic models presented. Monthly data from January 2000 to December 2015 is used for the regression analysis. Lags of four months and twelve months are created to see if past data about one variable provides additional information to forecast the other variable. After running the regressions, it is found that changes the Transportation Services Index Granger cause changes in real GDP.

II. Background

The United States has the world's largest economy, producing over 18 trillion dollars in nominal GDP. GDP can be broken into four components: consumption, investment, government purchases, and net exports. Combined, these represent the total dollar value of all final goods and services produced during a given period. Changes in real GDP, which adjusts nominal GDP for inflation, avoids the effects of price and wage increases; it represents the real size of the US economy.

This transportation industry made up approximately 9% of GDP in 2015 (Bureau of Transportation Statistics 2016). In 2013, transportation assets totaled 7.7 trillion dollars. The for-hire transportation sector in 2013 employed over 4.6 million people. The Bureau of Transportation Statistics, an agency of the United States Department of Transportation, created an index called the Transportation Services Index (TSI) to measure aggregate changes in the transportation sector.

The Transportation Services Index is the broadest monthly measure of domestic transportation services. The three components of the TSI are freight index, passenger index, and combined index, which is a combination of freight and passenger index data. The indexes move in conjunction with other economic indicators. The focus of this paper will be on the freight component, as it is the best TSI measure of economic growth. It measures monthly changes in shipments by mode of transportation in tons and ton-miles. Within the freight component are five modes of transportation: trucking, air, rail, water, and pipeline (U.S. Department of Transportation 2014).

III. Literature Review

There have been several studies on the effects of transportation on GDP. One such study, mirroring my own, is by Gao et al (2016). Their analysis is on the relationship between the comprehensive Transportation Freight Index and GDP in China. They analyzed the relationship from 1978 to 2014 to better detect early changes in transportation to use as a basis for predicting downturns in GDP. It was found that the volume of freight traffic and turnover of freight traffic in China are positively correlated with GDP. The model below represents the basis for the relationship (Gao et al. 2016, 571-576).

$Q = Q\,(GDP, Y_1, ...T_j, ...Y_m)$

Q = The cargo demand of transportation;

GDP = Gross domestic product;

Y_j = Other factors except GDP, for example: PPI, CPI, and so on, j = 1,2..., m.

Using their data, they concluded that the relationship was linear and derived the following regression results:

Freight Traffic = 669074.419 + 6.134GDP

Ln(Turnover of Freight Traffic) = 2.138 + 0.523ln(GDP)

They found that GDP growth came before growth of freight volume. They were not testing for Granger-causality, but they did conclude that GDP drives growth of freight volume. When the economy is growing rapidly, so too is freight volume and vice versa. Between 1978 and 2014, the average growth rate of GDP was 9.5% compared to the average freight growth rate of 8.6% (Gao et al. 2016, 577).

A similar study conducted by Beyzatlar, Karacal, and Yetkiner (2014) analyzed the relationship between transportation and GDP in Europe.

This study investigated the Granger-causality relationship between income and transportation of the then 15 European Union countries. Using a panel-data approach, they assessed the 1970 to 2008 period using data from OECD Stat Extracts Database. Income was measured by GDP; three indexes represented transportation: inland freight transportation per capita in ton-km (TRP), inland passenger transportation per capita in passenger-km (PAS), and road sector gasoline fuel consumption per capita in kg of oil equivalent (GAS). The models below represent the approach taken for the study (Beyzaltar, Karacal, and Yetkiner 2014, 43-47).

$$y_{i,t} = \sum_{k=1}^{p} \beta_k y_{i,t-k} + \sum_{k=0}^{p} \theta_k x_{i,t-k} + u_{i,t}$$

$$\Delta GDP_{i,t} = \sum_{k=1}^{p} \beta_k \Delta GDP_{i,t-k} + \sum_{k=0}^{p} \theta_k \Delta TRP_{i,t-k} + u_{i,t}$$

$$\Delta TRP_{i,t} = \sum_{k=1}^{p} \beta_k \Delta TRP_{i,t-k} + \sum_{k=0}^{p} \theta_k \Delta GDP_{i,t-k} + u_{i,t}$$

u is assumed to be normally distributed with ui,t = αi + εi,t; p is the number of lags; and εi,t are independent and identically distributed (0, σ2). It is assumed that βk and the regression coefficients θk's are identical for all countries.

The autoregressive coefficients and regression coefficient slopes were treated as constants. Assuming that the Granger-causality model is linear enabled them to implement a time-stationary vector autoregression (VAR) model. To test the direction of the relationship, two models were presented, one with GDP and one with Transportation as the dependent variable; the natural logarithms were taken for both models. As this was a cross-country analysis, the results varied by country. The predominant result was that Granger-causality is bidirectional; this was the result for 8 of the 15 countries. It was one-directional or non-Granger causality for countries with the lowest income per capita (Beyzaltar, Karacal, and Yetkiner 2014, 51).

Another such study looks at the impact of infrastructure investment in South Africa on long-run economic growth. Fedderke, Perkins, and Luis (2006) used a time-series approach to look at data from 1875 to 2001. Using a Johansen and Vector Error Correction Mechanism (VECM), they conclude that investment in infrastructure does lead economic growth (Fedderke, Perkins, and Luiz 2006, 1037-1045). Badalyan et al did a similar study that looked at the relationship between transport infrastructure and economic growth. Instead of a time-series approach, they used panel-data to analyze the relationship in Armenia, Georgia, and Turkey from 1982 to 2010. Their model was a Vector Error Correction Model (VECM) which allowed them to look at short-run and long-run implications. They concluded that there was bidirectional causality between economic growth and infrastructure investment, in both the short-run and the long-run (Badalyan, Herzfeld, and Rajcaniova 2014). These studies demonstrate the variability in results on the relationship between transportation and GDP.

IV. Model

Two models are needed to determine the relationship between transportation and GDP. The first model has transportation, proxied by freight Transportation Services Index, as the dependent variable. Freight TSI is set as a function of real GDP, as well as other variables that serve as controls. These variables include the price of diesel, the amount of money invested in infrastructure, the inflation rate, and the real effective exchange rate. The second model has the same control variables, but now real GDP is the dependent variable and freight TSI is an independent variable. Data is monthly ranging from January 2000 to December 2015. The dependent variables are the natural logarithms of the changes in each variable.

To test whether freight TSI or real GDP lead one another, lags are created for both models. The first two models have four lags. Removing four monthly observations from freight TSI and real GDP allows us to see if changes in one of those variables accurately forecasts future changes in the other variable. Furthermore, two additional models are created with twelve lags to see if the relationship identified with four lags holds with twelve lags. The models are represented below. In the linear regression equations, i = 1-4 and i = 1-12 represent the length of each lag. For example, when i = 1, the data is lagged one month; when i = 2, the data is lagged two months, etc.

$$\Delta \ln TSI_t = \sum_{i=1-4}^{4} \propto i \ GDP_{t-i} + \sum_{i=1-4}^{4} \propto i \ TSI_{t-i} + \beta_1 GDP + \beta_2 Diesel + \beta_3 Construction + \beta_4 \ Inflation + \beta_5 \ Exchange + \epsilon_t$$

$$\Delta \ln \mathrm{GDP}_t = \sum_{i=1-4}^{4} \propto \mathrm{i}\ \mathrm{GDP}_{t-i} + \sum_{i=1-4}^{4} \propto \mathrm{i}\ \mathrm{TSI}_{t-i} + \beta_1 \mathrm{TSI} + \beta_2 \mathrm{Diesel} + \beta_3 \mathrm{Construction} + \beta_4 \mathrm{Inflation} + \beta_5 \mathrm{Exchange} + \epsilon_t$$

$$\Delta \ln \mathrm{TSI}_t = \sum_{i=1-12}^{12} \propto \mathrm{i} \propto_i\ \mathrm{GDP}_{t-i} + \sum_{i=1-12}^{12} \propto \mathrm{i}\ \mathrm{TSI}_{t-i} + \beta_1 \mathrm{GDP} + \beta_2 \mathrm{Diesel} + \beta_3 \mathrm{Construction} + \beta_4 \mathrm{Inflation} + \beta_5 \mathrm{Exchange} + \epsilon_t$$

$$\Delta \ln \mathrm{GDP}_t = \sum_{i=1-12}^{12} \propto \mathrm{i} \propto_i\ \mathrm{GDP}_{t-i} + \sum_{i=1-12}^{12} \propto \mathrm{i}\ \mathrm{TSI}_{t-i} + \beta_1 \mathrm{TSI} + \beta_2 \mathrm{Diesel} + \beta_3 \mathrm{Construction} + \beta_4 \mathrm{Inflation} + \beta_5 \mathrm{Exchange} + \epsilon_t$$

*ϵ_t is a random error term at time t

V. Variables

As the economy grows, we would expect freight TSI to grow as well. This positive relationship is expected to occur because freight TSI is a large component of GDP. Also, if freight TSI is increasing, we would expect a positive relationship with increases in GDP. Increases in freight TSI means more raw materials or finished goods are moving, which could signal economic expansion.

The first of the other variables, serving as controls, is the price of diesel. Over half of domestic transportation is done by trucking, so the price of fuel is a major cost in the transportation industry. Tractor-trailers generally run at five to seven miles per gallon. Higher fuel costs directly reduce the profitability of the trucking industry. The freight rail component of transportation also contracts because, historically, fuel accounts for approximately 20% of operating costs. Similarly, higher fuel costs reduce profits for air and water transportation. Higher fuel prices also mean increased costs for consumers, which prevents them from spending money elsewhere (Tipping, Schmahl, and Duiven 2015). This reduces profits and demand, so one would expect a negative relationship with fuel costs and TSI.

The amount of money invested in infrastructure is the next control variable. Increased spending on public construction can increase the productivity of transportation services. Truckers can get from point A to point B quicker, thus reducing fuel costs and decreasing transportation time. In 2013, traffic congestion cost the U.S., directly and indirectly, \$124 billion dollars (Federico 2014). Increased spending on infrastructure can reduce congestion and improve transportation efficiency, so one would expect a positive relationship. With regards to GDP, infrastructure connects businesses to workers, consumers to shopping areas, and suppliers to customers. Efficient infrastructure also increases aggregate demand because of lower transportation costs and quicker service (Badalyan, Herzfeld, and Rajcaniova 2014). Therefore, we would expect increases in public spending on construction to lead to increases in real GDP.

The inflation rate is used to capture the ongoing rise in the price level. Inflation occurs as the nominal supply of dollars grows faster than the real supply of final goods and services. Using the equation of exchange, we see the relationship between money supply and the price level represented as the formula below. The quantity theory of money shows us that a larger money supply equates to a higher price level in the long run (Mishkin 2015). Inflation can occur as consumer demand increases faster than firms meet demand. This leads to increased prices, and consequently, increased wages for workers. They then have more money to spend on goods and services, many of which may be imported due to higher domestic prices. Unemployment also can temporarily decrease with increased inflation. Therefore, with increased demand and employment, we would expect a positive relationship, up to a certain level, with freight TSI and real GDP.

$$MV=PY.$$

Where:

M= money supply

V= income-velocity

P= price level

Y= real GDP

The real effective exchange rate is the last control variable. As the dollar appreciates, the exchange rate increases. The real effective exchange rate is the relative price of goods when comparing countries; it is sometimes called the terms of trade. It is equal to the number of foreign goods acquired by one domestic good and can be calculated using the formula below (Mankiw 2015). A rising exchange rate means domestic goods are more expensive, so consumers may import more goods. Therefore, we would expect increases in freight TSI.

$$\frac{\text{Nominal exchange rate x domestic price}}{\text{foreign price}} = \text{real exchange rate}$$

Exchange rate>1, domestic goods are relatively expensive

Exchange rate<1, domestic goods are relatively cheap

VI. Data

The data used to conduct this study came from a broad range of sources. The TSI was created by the US Department of Transportation, Bureau of Transportation, which compiles data on the five components of freight TSI from the following resources: Trucking - American Trucking Association; Air - Bureau of Transportation Statistics; Rail - Association of American Railroads and Federal Railroad Administration; Water - US Army Corps of Engineers; Pipeline - Energy Information Administration (Bureau of Transportation Statistics 2017). One potential limitation of this data is that it only accounts for the for-hire component of transportation, which means the overall value of transportation may be understated.

Real GDP is typically calculated on an annual or quarterly basis, but monthly data was needed to coincide with the other variables. One resource that had monthly GDP data is YCharts, a modern day financial data research platform (YCharts 2017). GDP can either be calculated by adding what everyone earned in a year, the income approach, or by adding what everyone spent in a year, the expenditure approach. As complicated as it is to calculate GDP for a longer period, it can be even more difficult to do so accurately monthly.

US diesel retail prices are in dollars per gallon provided by the US Energy Information Administration (EIA). The EIA collects, analyzes, and disseminates independent and impartial energy information (US Energy 2017). A limitation with this data is that one price is given each month, but diesel prices can vary across the country. These unaccounted-for variations restrict the data from being representative.

The data on the amount of money spent on infrastructure is available through the United States Census Bureau. The Value of Construction Put in Place Survey (VIP) provides monthly estimates of the total dollar value of construction work done in the US. It covers both work on new structures and improvements to current structures. The data used in the study is seasonally adjusted (US Census 2017). One item to note is that infrastructure investment often has a lag. Although some months may have higher investment totals, it can take months and years to finish a project, so the benefit of the infrastructure can be delayed.

Data concerning the inflation rate is published through the US Department of Labor, Bureau of Labor Statistics (BLS). The BLS is responsible for measuring labor market activity, working conditions, and price changes in the economy. Data from the BLS is objective, timely, accurate, and relevant (Bureau of Labor Statistics 2017). A potential drawback to the inflation rate is that the typical basket of goods and services may not be representative, so some people are more influenced by the inflation rate than others.

Lastly, data on the real effective exchange rate is available through the Bank for International Settlements (BIS). The BIS indices cover 61 economies, including individual euro countries, and the euro area as an entity. The real effective exchange rates are weighted averages of bilateral exchange rates adjusted by relative consumer prices (Bank for International Settlements 2017). There are, however, some limitations to the real effective exchange rate. Given international product differentiation, the elasticity of substitution between imports from different economies may vary. Furthermore, the varying elasticities of substitution between goods are not accounted for when the weights are assigned (Klau and Fung 2006).

VII. Regressions

TABLE 1. Linear regression results with freight TSI as the dependent variable and a lag of 4.

Linear regression	Number of obs = 188
	F(11, 174) = .
	Prob > F = .
	R-squared = 0.0939
	Root MSE = 1.6e-07

$\Delta lnTSI_t$	Coef.	Robust Std. Err.	t	P>|t|	[95% Conf.	Interval]
TSI_{t-1}	6.87e-10	9.23e-09	0.07	0.941	-1.75e-08	1.89e-08
TSI_{t-2}	1.57e-08	1.20e-08	1.31	0.193	-8.01e-09	3.94e-08
$TSI3_{t-3}$	-4.39e-09	1.09e-08	-0.40	0.687	-2.59e-08	1.71e-08
TSI_{t-4}	-1.22e-08	9.02e-09	-1.35	0.179	-3.00e-08	5.64e-09
GDP_{t-1}	-1.20e-07	1.46e-07	-0.82	0.413	-4.09e-07	1.69e-07
GDP_{t-2}	5.44e-09	1.83e-07	0.03	0.976	-3.56e-07	3.66e-07
GDP_{t-3}	2.41e-07	1.64e-07	1.47	0.143	-8.23e-08	5.65e-07
GDP_{t-4}	-1.20e-07	1.20e-07	-1.00	0.321	-3.57e-07	1.18e-07
GDP	.059633	.124914	0.48	0.634	-.1869087	.3061747
Diesel	-1.840919	.5896702	-3.12	0.002	-3.004746	-.6770923
Construction	-1.42e-13	6.85e-13	-0.21	0.836	-1.49e-12	1.21e-12
Inflation	5.75e-07	1.41e-06	0.41	0.684	-2.21e-06	3.36e-06
Exchange	1.75e-09	2.58e-09	0.68	0.499	-3.34e-09	6.84e-09
_cons	2.781286	1.009091	2.76	0.006	.7896522	4.77292

TABLE 2. Corresponding F-test to Table 1 above.

test GDP_{t-1} GDP_{t-2} GDP_{t-3} GDP_{t-4}

(1) $GDP_{t-1} = 0$
(2) $GDP_{t-2} = 0$
(3) $GDP_{t-3} = 0$
(4) $GDP_{t-4} = 0$

F(4, 174) = 0.72
Prob > F = 0.5788

TABLE 3. Linear regression results with real GDP as the dependent variable and a lag of 4.

Linear regression

Number of obs	=	188
F(10, 174)	=	.
Prob > F	=	.
R-squared	=	0.1010
Root MSE	=	8.8e-08

$\Delta \ln GDP_t$	Coef.	Robust Std. Err.	t	P>|t|	[95% Conf. Interval]	
TSI_{t-1}	-1.57e-08	5.33e-09	-2.95	0.004	-2.63e-08	-5.22e-09
TSI_{t-2}	1.83e-08	6.97e-09	2.62	0.009	4.53e-09	3.20e-08
TSI_{t-3}	3.09e-09	6.01e-09	0.51	0.607	-8.77e-09	1.50e-08
TSI_{t-4}	-3.31e-09	5.05e-09	-0.66	0.513	-1.33e-08	6.66e-09
GDP_{t-1}	2.95e-08	7.96e-08	0.37	0.711	-1.28e-07	1.87e-07
GDP_{t-2}	7.97e-08	9.54e-08	0.84	0.404	-1.09e-07	2.68e-07
GDP_{t-3}	-1.21e-07	9.85e-08	-1.23	0.220	-3.16e-07	7.31e-08
GDP_{t-4}	-9.50e-09	8.63e-08	-0.11	0.912	-1.80e-07	1.61e-07
TSI	.0191902	.0450142	0.43	0.670	-.0696539	.1080343
Diesel	.3292431	.8101176	0.41	0.685	-1.269679	1.928165
Construction	-1.17e-14	3.68e-13	-0.03	0.975	-7.38e-13	7.15e-13
Inflation	-1.33e-06	7.22e-07	-1.84	0.067	-2.75e-06	9.66e-08
Exchange	-3.67e-09	1.53e-09	-2.40	0.017	-6.68e-09	-6.58e-10
_cons	.6515672	.5859027	1.11	0.268	-.5048239	1.807958

TABLE 4. Corresponding F-test to Table 3 above.

test TSI_{t-1} TSI_{t-2} TSI_{t-3} TSI_{t-4}

(1) $TSI_{t-1} = 0$
(2) $TSI_{t-2} = 0$
(3) $TSI_{t-3} = 0$
(4) $TSI_{t-4} = 0$

F(4, 174) = 3.32
Prob > F = 0.0119

TABLE 5. Linear regression results with freight TSI as the dependent variable and a lag of 12.

Linear regression

Number of obs	=	180
F(24, 150)	=	.
Prob > F	=	.
R-squared	=	0.1914
Root MSE	=	1.5e-07

$\Delta lnTSI_t$	Coef.	Robust Std. Err.	t	P>|t|	[95% Conf.	Interval]
TSI_{t-1}	-3.94e-09	1.11e-08	-0.35	0.724	-2.59e-08	1.80e-08
TSI_{t-2}	1.87e-08	1.52e-08	1.23	0.219	-1.12e-08	4.87e-08
$TSI3_{t-3}$	-8.56e-09	1.18e-08	-0.73	0.469	-3.18e-08	1.47e-08
TSI_{t-4}	-4.99e-09	1.15e-08	-0.43	0.666	-2.78e-08	1.78e-08
TSI_{t-5}	-8.15e-09	1.46e-08	-0.56	0.576	-3.69e-08	2.06e-08
TSI_{t-6}	2.22e-08	1.30e-08	1.71	0.090	-3.47e-09	4.78e-08
TSI_{t-7}	-2.05e-08	1.30e-08	-1.57	0.118	-4.63e-08	5.25e-09
TSI_{t-8}	-1.38e-08	1.27e-08	-1.09	0.278	-3.88e-08	1.12e-08
TSI_{t-9}	9.42e-09	1.44e-08	0.65	0.514	-1.90e-08	3.79e-08
TSI_{t-10}	9.71e-09	1.38e-08	0.70	0.484	-1.77e-08	3.71e-08
TSI_{t-11}	-2.43e-09	1.30e-08	-0.19	0.852	-2.82e-08	2.33e-08
TSI_{t-12}	-4.72e-09	1.10e-08	-0.43	0.667	-2.64e-08	1.69e-08
GDP_{t-1}	-8.52e-08	1.59e-07	-0.54	0.592	-3.99e-07	2.28e-07
GDP_{t-2}	-1.02e-07	1.91e-07	-0.54	0.593	-4.79e-07	2.74e-07

$\Delta lnTSI_t$	Coef.	Robust Std. Err.	t	P>|t|	[95% Conf. Interval]	
Continued from page 28						
GDP_{t-3}	3.47e-07	1.82e-07	1.90	0.059	-1.33e-08	7.07e-07
GDP_{t-4}	-1.11e-07	1.64e-07	-0.68	0.500	-4.36e-07	2.14e-07
GDP_{t-5}	3.94e-08	1.78e-07	0.22	0.825	-3.11e-07	3.90e-07
GDP_{t-6}	-1.03e-07	1.78e-07	-0.58	0.563	-4.55e-07	2.49e-07
GDP_{t-7}	1.82e-7	1.68e-07	1.08	0.280	-1.49e-07	5.13e-07
GDP_{t-8}	2.16e-07	1.61e-07	1.34	0.181	-1.02e-07	5.34e-07
GDP_{t-9}	-2.87e-07	1.70e-07	-1.69	0.093	-6.23e-07	4.83e-08
GDP_{t-10}	-4.40e-08	1.71e-07	-0.26	0.797	-3.82e-07	2.94e-07
GDP_{t-11}	-3.40e-08	1.82e-07	-0.19	0.852	-3.94e-07	3.26e-07
GDP_{t-12}	7.71e-09	1.62e-07	0.05	0.962	-3.12e-07	3.27e-07
GDP	.1101167	.146755	0.75	0.454	-.1798574	.4000907
Diesel	-1.759748	.671945	-2.62	0.010	-3.087448	-.4320482
Construction	1.71e-13	7.83e-13	0.22	0.827	-1.37e-12	1.72e-12
Inflation	8.37e-07	1.50e-06	0.56	0.579	-2.13e-06	3.81e-6
Exchange	3.04e-09	2.46e-09	1.24	0.218	-1.81e-09	7.90e-09
_cons	2.649631	.6642526	3.99	0.000	1.337131	3.962132

TABLE 6. Corresponding F-test to Table 5 above

test GDP_{t-1} GDP_{t-2} GDP_{t-3} GDP_{t-4} GDP_{t-5} GDP_{t-6} GDP_{t-7} GDP_{t-8} GDP_{t-9} GDP_{t-10} GDP_{t-11} GDP_{t-12}

(1) $GDP_{t-1} = 0$
(2) $GDP_{t-2} = 0$
(3) $GDP_{t-3} = 0$
(4) $GDP_{t-4} = 0$
(5) $GDP_{t-5} = 0$
(6) $GDP_{t-6} = 0$
(7) $GDP_{t-7} = 0$
(8) $GDP_{t-8} = 0$
(9) $GDP_{t-9} = 0$
(10) $GDP_{t-10} = 0$
(11) $GDP_{t-11} = 0$
(12) $GDP_{t-12} = 0$

$F(11, 150) = 1.27$
$Prob > F = 0.2455$

TABLE 7. Linear regression results with real GDP as the dependent variable and a lag of 12

Linear regression	Number of obs	=	180
	F(27, 150)	=	.
	Prob > F	=	.
	R-squared	=	0.1761
	Root MSE	=	8.9e-08

$\Delta \ln GDP_t$	Coef.	Robust Std. Err.	t	P>|t|	[95% Conf.	Interval]
TSI_{t-1}	-1.43E-08	6.68e-09	-2.14	0.034	-2.74e-08	-1.06e-09
TSI_{t-2}	2.15e-08	7.05e-09	3.05	0.003	7.55e-09	3.54e-08
$TSI3_{t-3}$	7.46e-09	7.18e-09	1.04	0.301	-6.73e-09	2.17e-08
TSI_{t-4}	-9.76e-09	7.77e-09	-1.26	0.211	-2.51e-08	5.60e-09
TSI_{t-5}	2.53e-10	8.80e-09	0.03	0.977	-1.71e-08	1.76e-08
TSI_{t-6}	1.14e-09	7.26e-09	0.16	0.875	-1.32e-08	1.55e-08
TSI_{t-7}	5.79e-09	7.92e-09	0.73	0.466	-9.86e-09	2.14e-08
TSI_{t-8}	7.22e-09	8.03e-09	-0.90	0.370	-2.31e-08	8.65e-09
TSI_{t-9}	-9.50e-09	7.51e-09	-1.26	0.208	-2.43e-08	5.34e-09
TSI_{t-10}	4.86e-09	7.63e-09	0.64	0.525	-1.02e-08	1.99e-08
TSI_{t-11}	2.24e-09	7.04e-09	0.32	0.751	-1.17e-08	1.62e-08
TSI_{t-12}	2.86e-09	5.03e-09	0.57	0.570	-7.08e-09	1.28e-08
GDP_{t-1}	3.51e-08	7.93e-08	0.44	0.659	-1.22e-07	1.92e-07
GDP_{t-2}	8.93e-08	9.62e-08	0.93	0.355	-1.01e-07	2.79e-07
GDP_{t-3}	-2.27e-07	1.02e-07	-2.24	0.027	-4.28e-07	-2.67e-08
GDP_{t-4}	-8.68e-08	9.91e-08	-0.88	0.382	-2.83e-07	1.09e-07
GDP_{t-5}	5.94e-08	9.49e-08	0.63	0.532	-1.28e-07	2.47e-07
GDP_{t-6}	3.49e-08	1.17e-07	0.30	0.766	-1.97e-07	2.67e-07
GDP_{t-7}	-3.98e-08	1.16e-07	-0.34	0.732	-2.69e-07	1.89e-07
GDP_{t-8}	8.07e-08	1.21e-07	0.67	0.505	-1.58e-07	3.19e-07
GDP_{t-9}	-5.08e-09	1.04e-07	-0.05	0.961	-2.11e-07	2.00e-07
GDP_{t-10}	9.03e-08	9.89e-08	0.91	0.363	-1.05e-07	2.86e-07
GDP_{t-11}	-7.24e-08	1.10e-07	-0.66	0.510	-2.89e-07	1.45e-07

$\Delta \ln GDP_t$	Coef.	Robust Std. Err.	t	P>|t|	[95% Conf. Interval]	
continued from page 31						
GDP_{t-12}	1.45e-08	9.22e-08	0.16	0.875	-1.68e-07	1.97e-07
TSI	.0374916	.0487563	0.77	0.443	-.0588464	.1338295
Diesel	.3650317	.7568213	0.48	0.630	-1.130375	1.860439
Construction	-1.18e-13	4.55e-13	-0.26	0.796	-1.02e-12	7.82e-13
Inflation	-1.15e-06	7.55e-07	-1.52	0.130	-2.64e-06	3.43e-07
Exchange	-3.87e-09	1.62e-09	-2.40	0.018	-7.07e-09	-6.80e-10
_cons	597477	.9952935	0.60	0.549	-1.369129	2.564083

TABLE 8. Corresponding F-test to Table 7 above.

test TSI_{t-1} TSI_{t-2} TSI_{t-3} TSI_{t-4} TSI_{t-5} TSI_{t-6} TSI_{t-7} TSI_{t-8} TSI_{t-9} TSI_{t-10} TSI_{t-11} TSI_{t-12}

(1) $TSI_{t-1} = 0$
(2) $TSI_{t-2} = 0$
(3) $TSI_{t-3} = 0$
(4) $TSI_{t-4} = 0$
(5) $TSI_{t-5} = 0$
(6) $TSI_{t-6} = 0$
(7) $TSI_{t-7} = 0$
(8) $TSI_{t-8} = 0$
(9) $TSI_{t-9} = 0$
(10) $TSI_{t-10} = 0$
(11) $TSI_{t-11} = 0$
(12) $TSI_{t-12} = 0$

F(12, 150) = 2.09
Prob > F = 0.0209

In each of the models, the null hypothesis is that there is no Granger-causality. This is demonstrated by setting the alphas equal to zero. The alternative hypothesis is that at least one of the alphas is not equal to zero, which means Granger-causality is present. If freight TSI does not Granger cause changes in real GDP, then the null hypothesis will not be rejected. If it does Granger cause changes in real GDP, then the null hypothesis will be rejected. An F-test is used to test if a group of variables, the lagged variables in the model, are statistically significant. In other words, it demonstrates whether the variables are significantly different from zero. The Prob > F numbers given for each of the linear regressions represent the highest significance level at which the null hypothesis can be rejected. If a value is 0.0750, then the null hypothesis can be rejected at the 10% level, but not the 5% level. The models are represented below.

Four Lags- Null: TSI Non-Granger causality: $\sum_{i=1-4}^{4} \propto i \ GDP_{t-i} = 0$

Alternative: TSI Granger-causality: $\sum_{i=1-4}^{4} \propto i \, GDP_{t-i} \neq 0$

Null: GDP Non-Granger causality: $\sum_{i=1-4}^{4} \propto i \, TSI_{t-i} = 0$

Alternative: GDP Granger causality: $\sum_{i=1-4}^{4} \propto i \, TSI_{t-i} \neq 0$

Twelve Lags- Null: TSI Non-Granger causality: $\sum_{i=1-4}^{4} \propto i \, GDP_{t-1} = 0$

Alternative: TSI Granger-causality: $\sum_{i=1-4}^{4} \propto i GDP_{t-i} \neq 0$

Null: GDP Non-Granger causality: $\sum_{i=1-4}^{4} \propto i TSI_{t-i} = 0$

Alternative: GDP Granger-causality: $\sum_{i=1-4}^{4} \propto i \, TSI_{t-i} \neq 0$

VIII. Results

Starting with the model with four lags and freight TSI as the dependent variable, the F-value is given as 0.5788. This means that the lagged GDP variables are not statistically significant at the 10% or the 5% level. Real GDP does not Granger cause changes in freight TSI. The other model with four lags has real GDP as the dependent variable. The F-value is given as 0.0119. This means that the lagged TSI variables are significantly different from zero and do have explanatory power on changes in real GDP. It is statistically significant at the 10% and 5% levels that changes in freight TSI Granger causes changes in real GDP.

The model with twelve lags and freight TSI as the dependent variable has an F-value of 0.2455. This is similar to the model with four lags because the lagged coefficients on the GDP variables again are not statistically different from zero; they do not have any explanatory power on changes in freight TSI at both the 10% and 5% significance levels. The model with real GDP as the dependent variable has an F-value of 0.0209. Like the model with four lags, the coefficients on the lagged TSI variables are statistically different from zero. They have explanatory power on changes in real GDP at the 10% significance level and the 5% significance level.

The control variables were included in the model because without them, the estimated relationship between TSI and GDP could suffer from omitted variable bias. This would have caused the model to compensate for the variables not included by overestimating or underestimating the effects of the included variables.

The data in Table 9 below summarizes the regression results and shows that changes in freight TSI can be used to forecast changes in GDP; freight TSI is a leading indicator. The relationship is one-directional; freight TSI Granger causes changes in real GDP but real GDP does not Granger cause changes in freight TSI. Monthly data was used, so at least four months in advance, changes in TSI predict changes in real GDP. This opens the realm of studying transportation data to see how the economy is doing. Two consecutive quarters of negative GDP growth signify that the economy is entering a recession. Having freight TSI data could act as an early warning system.

Table 9. Granger-causality summary

Variable	Lag Length	H0: Null Hypothesis	H1: Alternative Hypothesis	F-Value	10% Significance Level	5% Significance Level
GDP to TSI Cauality	4	Non-Granger causality	Granger-causality	0.5788	Fail to reject H0	Fail to reject H0
TSI to GDP Causality	4	Non-Granger causality	Granger-causality	0.0119	Reject H0	Reject H0
GDP to TSI Causality	12	Non-Granger causality	Granger-causality	0.2455	Fail to reject H0	Fail to reject H0
TSI to GDP Causality	12	Non-Granger causality	Granger-causality	0.0209	Reject H0	Reject H0

IX. Conclusion

What is the relationship between transportation and real GDP? The direction of this relationship, whether one causes the other, they both cause each other, or neither cause the other, is analyzed and it is found that freight TSI Granger causes changes in real GDP. Monthly freight TSI served as a proxy for transportation; it was the dependent variable in one model while monthly real GDP data was the dependent variable in the other model. Control variables were diesel prices, the amount of money invested on infrastructure, the inflation rate, and the real effective exchange rate.

The data shows that changes in freight TSI do lead changes in real GDP. Past values of freight TSI, the lagged values of four months and twelve months, were shown to have predictive power over changes in real GDP. Lags of four and twelve were both statistically significant at the 10%

and 5% level. This study suggests that transportation is a leading indicator. Nearly all facets of business deal with transportation in some way, so it is reasonable that changes in this sector might predict changes in the overall economy.

This study adds to the literature on the relationship between transportation and GDP. As previously noted, findings have not been consistent across studies. Beyzatlar, Karacal, and Yetkiner (2014), found that higher income countries were more likely to have a bi-directional Granger-causality result. However, that explanation did not hold for the US. Differences in results could be due to the time periods chosen. Some countries advance quicker than others, so the relationship between transportation and GDP may be influenced by technological advancements. Last, numerous proxies are used to represent transportation. Because transportation encompasses a large part of the economy, it can be difficult to assess its true value; therefore, some measures of transportation may be better than others. Overall, more research is needed.

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