LONG-RUN RELATION AMONG MOTOR FUEL USE, VEHICLE MILES TRAVELED, INCOME, AND GAS PRICE FOR THE US

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Overview

Energy used in transport is a particularly important focus for environment-development studies since such use is increasing in both developed and developing countries and is (given current technology) a carbon-intensive activity everywhere. Furthermore, understanding the long-run relationship among transport energy use, income, and fuel price in developed countries is important to project with any accuracy global transport fuel use and carbon emissions.

This paper examines whether a systemic, cointegrated relationship exists among gasoline price, income, and both (i) two definitions of transport demand (per capita motor fuel consumption and per capita vehicle-miles traveled), and (ii) transport technology choice (miles per gallon) over the long-run in the US. This paper expands on previous work in two important ways. First, focusing on transport in the US allows for the consideration of much longer data sets (as long as from 1919 to present) than previous work (most analyses are on the order of only 30-40 years). Not having sufficiently long series is a well-known source of spurious results in these types of time series analyses. Second, this paper also considers price and is a multivariate analysis (much earlier work was bivariate, considering only various aggregations of GDP and energy use).

Methods

The data series used in this study are annual data, converted to natural logs. The series are: real per capita GDP, 1919-2004 from Johnston and Williamson; vehicle-miles traveled per capita, 1936-2004, and motor fuel use per capita, 1919-2004, both from the US Department of Transportation, Federal Highway Administration's Highway Statistics; miles per gallon, 1936-2004 (vehicle-miles traveled divided by motor fuel use); and real retail gasoline price from US Department of Energy, Energy Information Agency. Population data (to convert measures to per capita) is from the US Census Bureau.

The first step is to test for unit roots in each series since all variables in a cointegration test should be of the same order. It is expected, as others have found, that these series (all of which contain noticeable trends) will be nonstationary in levels, but stationary in first differences. To test for unit roots, I use both the Elliott, Rothenberg, and Stock Dickey-Fuller test with GLS detrending (DF-GLS), and the Ng-Perron test, also with GLS detrending.

Engle and Granger pointed out that a linear combination of two or more nonstationary series may be stationary. If such a stationary linear combination exists, the nonstationary time series are said to be cointegrated. The stationary linear combination is called the cointegrating equation and may be interpreted as a long-run equilibrium relationship among the variables. The purpose of the cointegration test is to determine whether a group of non-stationary series are cointegrated or not. To test for cointegration, I use Johansen and Juselius' test for multivariate cointegration. The Johansen cointegration approach produces two statistics (the trace and maximum eigenvalue statistics), which can conflict—although they do not in the results presented here. To determine the number of cointegrating relations, r, one proceeds sequentially from $r = 0$ to $r = k – 1$, where k is the number of endogenous variables, until one fails to reject. The two tests of the null hypothesis of r cointegrating relations against the alternative of k cointegrating relations, for $r = 0, 1, \ldots, k - 1$ are reported in the results tables.

Results

The results of the unit root tests did not provide convincing evidence to reject my prior belief that all of these series are I (1). Three sets of cointegration tests were run: one involving each definition of mobility demand (motor fuel use and vehicle-miles traveled) and one involving technology choice (miles per gallon). Tables 1 and 2 show that, for the two sets of transport demand variables—GDP per capita, price, and motor fuel use in Table 1, and GDP per capita, price, and vehicle-miles traveled in Table 2—both the trace and max-eigenvalue test statistics indicate one cointegrating equation at the one percent significance level. Table 3 shows that, for technology choice (miles per gallon), price, and GDP per capita, both the trace and max-eigenvalue test statistics indicate one cointegrating equation at the five percent significance level. These findings of cointegration confirm a long-run, systemic relationship among price, income, and transport demand or technology choice in the US.

Table 1. Johansen and Juselius cointegration test for GDP per capita, prices, and motor fuel use, 1919-2004

Null	Alternative	Statistic	Critical values	
			5 %	1 %
Variables: LGDP, LPRICE, LMFU				
Trace statistic				
r = 0	r > 0	37.08**	29.68	35.65
r <= 1	r > 1	9.61	15.41	20.04
r <= 2	r = 3	2.13	3.76	6.65
Maximum eigenvalues				
r = 0	r > 0	27.46**	20.97	25.52
r <= 1	r > 1	7.48	14.07	18.63
r <= 2	r = 3	2.13	3.76	6.65

Table 2. Johansen and Juselius cointegration test for GDP per capita, prices, and vehicle-miles traveled, 1936-2004

Null	Alternative	Statistic	Critical values	
			5 %	1 %
Variables: LGDP, LPRICE, LVMT				
Trace statistic				
r = 0	r > 0	39.00**	29.68	35.65
r <= 1	r > 1	13.23	15.41	20.04
r <= 2	r = 3	4.42	3.76	6.65
Maximum eigenvalues				
r = 0	r > 0	25.77**	20.97	25.52
r <= 1	r > 1	8.81	14.07	18.63
r <= 2	r = 3	4.42	3.76	6.65

Table 3. Johansen and Juselius cointegration test for GDP per capita, prices, and miles per gallon, 1936-2004

Null	Alternative	Statistic	Critical values	
			5 %	1 %
Variables: LGDP, LPRICE, LMPG				
Trace statistic				
r = 0	r > 0	32.69*	29.68	35.65
r <= 1	r > 1	7.90	15.41	20.04
r <= 2	r = 3	0.05	3.76	6.65
Maximum eigenvalues				
r = 0	r > 0	24.78*	20.97	25.52
r <= 1	r > 1	7.85	14.07	18.63
r <= 2	r = 3	0.05	3.76	6.65

Notes for all tables: r Indicates the number of cointegrating relationships. Trace test and maximum eigenvalue statistics are compared with the critical values from Johansen and Juselius. * Indicates rejection of the null hypothesis of no cointegration at the 5% level.

Conclusions

Transport is a major consumer of energy and an important source of carbon dioxide emissions everywhere. The demand for mobility increases strongly with income. Although gasoline price and gasoline consumption are correlated across countries, it may be too simplistic to assume that higher gasoline taxes in high consuming countries would result in much lower fuel consumption, and thus carbon emissions. The analysis here showed that in the US mobility demand (proxied by either motor fuel use or vehicle-miles traveled) has a long-run systemic relationship with gasoline price and income, as does technology choice (miles per gallon) with gasoline price and income. And thus, these variables cannot be easily disentangled in the short-run. This paper's finding of a cointegrating relationship has two important implications for policy. First, in countries like the US, higher standards for vehicle efficiency are preferable to higher gasoline taxes since (i) the former may lead to a faster change in overall vehicle fleet efficiency; and (ii) the level of taxes necessary for the latter approach to cause a sufficient change in vehicle fleet efficiency via the market would be quite painful. Second, countries like China and India would be wise to develop a system of prices, technology, and mobility options that help them avoid the difficult choice that the US now faces.