

Revenue Forecasting Methods in Washington State

RALPH F. WILHELMI

ABSTRACT

A portion of the work performed in developing and using an econometric forecasting model of Washington State fuel tax revenue is reported. The administrative and legal frameworks within which the model was developed are outlined, and the administrative inputs to the final forecast are detailed. A three-equation model of fuel demand is developed. The first equation forecasts gasoline gallonage; the second equation forecasts diesel gallonage; and the third equation is an identity that defines total fuel gallonage. Each forecast is by quarter on a seasonally adjusted annual basis. The quarterly forecasts are averaged to yield annual forecasts for 8 years. The annual forecast is then spread to months with seasonal adjustments for the current fiscal year. A tax rate is determined and a revenue forecast is developed. The results of the model forecasts are compared to actual fuel demanded during forecast periods (months, quarters, and fiscal years).

Forecasting of fuel tax revenues has assumed increasing importance in Washington during the past decade because of the impacts of fuel supply interruptions and an increase in fuel prices. Since the first fuel crisis in 1973, considerable emphasis has been placed on devising forecast procedures that are responsive to anticipated changes in fuel supplies, fuel prices, and general economic conditions.

In Washington State the current administrative and legal forecasting frameworks originated in the mid-1970s and have changed over the years to accommodate new legislative and administrative requirements. Work on an econometric model began in the summer of 1981 when two disparate forecasts, one using a saturation process and one using an econometric equation of monthly gasoline consumption, were prepared and the final revenue estimates were more than \$100 million apart for a biennium. Although both forecasts had supporters, the decision was made to develop a new econometric model that would incorporate assumptions from each of these forecasts in a more orderly and technically defensible way.

Thus, the disparate forecasts, a new legislative requirement for quarterly forecasts for the current biennium, and the desire to interlock the fuel tax forecast with other Washington State economic forecasts, all prompted the decision to initiate a new forecasting methodology based on econometric modeling procedures.

The legal and administrative backgrounds of the Washington State fuel tax forecast are outlined in this paper followed by a description of the technical and pragmatic reasons for selection of model variables and equations. The paper ends with a comparison of forecast predictions with actual fuel consumption and revenue collections.

LEGAL FRAMEWORK

Washington State law requires quarterly estimates of future revenues for all state revenue sources for the current biennium. The Department of Licensing as the collector of fuel tax revenue has the legal responsibility to forecast this revenue. The Office of Financial Management (OFM) has the legal responsibility to forecast the economic conditions in the state for the same period as a basis for the forecast of revenues. The Washington State Department of Transportation (WSDOT) has the legal responsibility to manage the cash flow and expenditures from the Motor Vehicle Fund but does not have legal responsibility to estimate future revenues.

Thus, although WSDOT has no legal responsibility to estimate fuel tax revenues, the requirement to manage cash flow and expenditures from the Motor Vehicle Fund makes it fiscally prudent to estimate fuel taxes, which are the largest source of income for the Motor Vehicle Fund. To have input into the revenue forecast and at the same time meet cash management requirements, an interagency administrative framework was developed to provide direction to the overall forecast process.

ADMINISTRATIVE FRAMEWORK

When Washington State first adopted a variable fuel tax in 1977, a committee was appointed to certify, semiannually, the official price used to determine the tax rate. During the past 5 years, as changes in the law occurred (e.g., the requirement of quarterly forecasts) this committee was transformed into the Gas Tax Revenue Task Force. The original reason for the task force (the need to certify an official price) no longer exists because the legislature eliminated the variable fuel tax provision. The task force has seven organizational members:

1. Office of Financial Management (OFM)
2. Legislative Transportation Committee (LTC)
3. Department of Licensing (DOL)
4. Department of Revenue (DOR)
5. Washington State Patrol (WSP)
6. Department of Transportation (DOT)
7. Washington State Energy Office (SEO)

Two organizations have more than one member on the task force. OFM has members from both the budget and economic forecasting sections and DOT has members from the economics, comptrollers, and management and operations sections.

All task force members have fiscal, legal, or forecasting reasons for committee membership. For example, OFM provides coordination with statewide economic forecasting and the Department of Revenue provides specific statewide fuel price averages derived from tax data submitted by the state's 1,200 service stations. The role of the task force in preparing the forecast will be referred to in the forecast procedure section that follows.

METHODOLOGY

Data Availability

In order that the fuel tax revenue forecasts be

consistent with other state agency forecasts, it was determined that quarterly data series or data to construct quarterly series should be available for use in the model. With this constraint in mind, the 18 variables given in Table 1 were considered.

Those variables that were seasonally adjusted were adjusted using the Census X-11 variant procedure (1) as applied in the EPS system (2). Because seasonal adjustment was available and the ambient temperature variable captures mainly seasonal differences, it was decided not to use ambient temperature because of the impracticality of forecasts during an 8-year period of deviations from the average temperature. Variables for business cycles, recession, lumber and wood products, and retail trade were also dropped from consideration because it was decided that those variables would be more difficult to forecast correctly during an 8-year period than the dependent variable, diesel fuel. Finally, variables for the stock and distribution of vehicles were withheld from consideration until an econometric model of their future values in Washington State could be developed. The vehicle model's results would then be used as exogenous input for estimating future fuel consumption.

Model Specification

Economic theory justifies the demand for fuel as a derived demand. In this case, fuel demand is derived from consumer demand for the transportation services that both fuel and a vehicle provide. The demand for fuel can be modeled directly or indirectly (3). An indirect model would estimate the demand for vehicle miles traveled (VMT), that is, the transportation service provided, and then estimate fuel by dividing VMT by average miles per gallon of the fleet. Estimates of total VMT are available from the state department of transportation and are developed from traffic counts by automatic traffic recorders spread throughout the state. It was decided that tax reports that specified gallons of fuel taxed were a

more consistent data source than gallonage derived from VMT. This decision was based on the knowledge that forecasting gallonage derived from VMT implies the need to estimate changes in fleet miles per gallon by season under varying weather conditions.

A model of fuel demand simulates either a static or a dynamic process. A static form of model infers that all the adjustment of the dependent variable to changes in the independent variables occurs in one period. A dynamic form of model assumes the response of the dependent variable to changes in independent variables occurs over a period of time. It was decided that the model should be of dynamic form. The equation chosen to estimate fuel consumption in Washington State can be classified as a dynamic, state adjustment, direct-fuel consumption model (3).

The state adjustment form implies that current demand is a function of both past and current values of independent variables. The model infers that it is possible to identify the value of the current dependent variable with various proportions of past and current independent variables. This is a distributed lag effect. Generally distributed lags assume that more recent periods are of greater importance and thus receive larger values. However, because of the difficulties involved in explaining equations with polynomial distributed lag operators to task force members, it was decided that four-quarter moving averages of both price and income would be used because the reasoning for moving averages was more readily understood. A four-quarter moving average infers two assumptions about the lag operator: (a) that each lag operator is of equal weight and (b) that the adjustment process takes one year to complete. An incorrectly specified order or length of lag can bias least-squares estimators (4). However, when there is no known lag length or order, a priori, there are no tests that indicate either length or polynomial rank with any degree of certainty (4).

Under normal conditions there is no concern about availability of fuel. It is assumed, given the open economy of the United States, that fuel will flow

TABLE 1 Variables Considered

Variable	Historical Data Source
Miles per gallon	Environmental Protection Agency
Stock of cars and trucks	Federal Highway Administration State Department of Licensing
Distribution of cars by size and age	Department of Licensing
Price of gasoline	National Bureau of Labor Statistics State Department of Revenue/Department of Transportation
Population	Census
Driving age	
Household formation	
Age sex cohorts	
Personal income in Washington State	Bureau of Economic Analysis
Gas shortage dummy	Department of Transportation
Mt. St. Helens eruption dummy	Department of Transportation
Business cycle	National Bureau of Economic Research
Recession quarters dummy	National Bureau of Economic Research
Lumber and wood products	
Sales	Bureau of Economic Analysis
Employment	Washington State Employment Security Division
Retail trade	
Sales	Bureau of Economic Analysis
Employment	Washington State Employment Security Division
National gas consumption	Federal Highway Administration
Unemployment rate	Bureau of Labor Statistics
Ambient temperature	National Weather Service
Heating or cooling degree days	
Price indices	
CPI	Bureau of Labor Statistics
Implicit price deflator for personal consumption	Bureau of Economic Analysis
Fuel consumption	Department of Licensing
Gasoline	
Diesel	
Vehicle miles traveled	Department of Transportation

TABLE 2 Variables Defined

Variable	Definition
Dependent	
G1	Gallons of gasoline in Washington State by quarter at an annual rate
G2	Gallons of gasoline in Washington State by quarter at a seasonally adjusted annual rate
G3	G1 divided by driving age population
G4	G2 divided by population
G5	G2 divided by driving age population
Independent	
PG	The relative price of gasoline defined as a moving average over four quarters of the implicit price deflator for personal consumption-nondurables-gasoline and oil divided by the implicit price deflator for personal consumption
PN	A dummy variable that equals the nominal price of gasoline when the price exceeds its past nominal high and is zero at all other times when the nominal price of gasoline is defined as the implicit price deflator for personal consumption-nondurables-gasoline and oil
FM	Fleet miles per gallon approximated by a moving average over 14 quarters of the EPA MPG for new cars adjusted to reflect actual on-the-road experience
P1	Personal income defined as a moving average over four quarters at a seasonally adjusted annual rate of personal income for Washington State residents in 1972 constant dollars
P2	P1 divided by total population
P3	P1 divided by driving age population
C1	Gasoline crisis dummy variable that equals 1 for quarters (year : quarter) 1973:4, 1974:1, 1979:2, and 1979:3; zero at all other times
C2	Gasoline crisis dummy variable that equals 1 for quarters 1973:4, 1974 1 and 2, 1979:2, 3 and 4 and zero at all other times
C3	Gasoline crisis dummy variable that equals 2 in 1973:4, 1 in 1974:1, 2 in 1979:2, and 1 in 1979:3 and zero at all other times
MS	Mt. St. Helens dummy variable equals 1 in 1980:2, zero all other times
SD	Seasonal dummy variables—three seasonal dummy variables for winter, spring, and summer. Each variable was 1 for its respective season and zero for all other quarters

into Washington State as needed. However, because there were two periods of supply constraint for the entire United States during the period estimated, a dummy variable for gasoline crisis periods was used in all tested equations. A dummy variable is a binary variable that has the value of 1 when the condition exists (in this case a gasoline crisis period) and 0 when the condition does not exist.

Gasoline Demand Equations

In developing the forecast equation, 13 different gasoline-demand equations were analyzed. All of the equations were estimated over 40 quarters of observed data by an ordinary least-squares procedure (3). All of the variables used in any of the 13 equations are defined in Table 2. The variables used in each equation and the statistical results of each equation are given in Table 3.

All of the independent variables used in estimating each equation had theoretically proper signs even when the coefficients were not statistically significant (for instance, the coefficient of the Mt. St. Helens variable). Two variables, the past nominal high price of gasoline and the Mt. St. Helens dummy, were estimated at the request of members of the Gas Tax Revenue Task Force. Other task force members agreed not to include these variables in the forecast equation when they were found to have nonsignificant coefficients.

Ten of the 13 equations were eliminated from consideration as the forecast equation. The three reasons for elimination and the equations eliminated were (the letters refer to the equation column in Table 3):

1. Possible auto-correlation of error terms: Equations A, B, and M eliminated.
2. Nonsignificant variables included in the equations: Equations F, I, and L eliminated.
3. Inclusion of seasonal dummy variables in equation: Equations G and J eliminated.
4. Combinations of the foregoing three reasons: Equations C and K eliminated.

The three remaining equations (D, E, H) were ranked by their explanation of variance of the dependent variable. The equation with the best fit of the three (Equation H) was chosen to forecast future consumption.

FORECAST PROCEDURE

A fuel tax revenue forecast cycle begins with a meeting of the Gas Tax Revenue Task Force to determine the general economic assumptions for use in the forecast equations. The Department of Revenue provides the current statewide fuel price average semi-annually. All of the task force members discuss their views on future fuel prices and a consensus

TABLE 3 Variables and Statistical Results of Equations

Equation	Dependent Variable					Independent Variables										R ²	Durbin-Watson	Normalized Standard Error	
	G1	G2	G3	G4	G5	PG	PN	FM	P1	P2	P3	C1	C2	C3	MS				SD
A		D				X		X	X								.8445	.61	.028
B		D				X		X			X						.9391	1.31	.017
C		D				X	*	X	X			X					.9443	1.35	.017
D		D				X		X	X				X				.9490	1.98	.016
E				D		X		X		X			X				.9332	2.02	.016
F				D		X	*	X		X			X				.9339	1.96	.016
G		D				X		X	X				X				.9676	1.89	.017
H					D	X		X			X		X				.9512	2.04	.016
I					D	X	*	X			X		X				.9512	1.97	.016
J				D		X		X		X			X		X		.9650	2.01	.019
K		D				X	*	X	X				X		X		.9681	1.85	.017
L			D			X		X	X				X		*		.9531	2.21	.016
M			D			X		X	X					X			.9573	1.23	.015

Note: D = dependent variable for equation, X = independent variable used in equation significant, * = independent variable used in equation not significant.

price forecast is agreed on. The Office of Financial Management provides an official state forecast of the national and state economies based on the forecast of a national economic consulting firm (5). It also provides a short-term forecast of Washington State personal income, and the task force agrees to a long-term percentage increase to assume in the model. After these assumptions are made, the estimates are determined. Revisions in assumptions are possible if the fuel estimates are outside the range of outcomes held probable by a majority of the task force.

Gasoline Demand Equation

The equation used to forecast gasoline demand is given as Equation 1.

$$\begin{aligned} \text{GAS} = & +0.501 -0.173 \text{ PG} -0.014 \text{ MPG} -0.036 \text{ GC} \\ & (10.7) \quad (-13.59) \quad (-6.83) \quad (-5.4) \\ & +83.96 \text{ PI} \\ & (9.61) \end{aligned} \quad (1)$$

(t-statistics in parentheses all significant at 0.005 level)

where

- GAS = gallons of gasoline in Washington State per driving age population quarterly at a seasonally adjusted annual rate,
 PG = relative price of gasoline, a moving average over four quarters of the implicit price deflator for personal consumption-nondurables-gasoline and oil divided by the implicit price deflator for personal consumption,
 MPG = miles per gallon, a moving average over 14 quarters of Environmental Protection Agency (EPA) MPG for new cars adjusted for actual on-the-road experience,
 GC = a gasoline crisis indicator variable set at 1 during (year : quarter) 1973:4, 1974:1 and 2; and 1979:2, 3, and 4, at 0 all other times, and
 PI = personal income, a moving average over four quarters at a seasonally adjusted annual rate of personal income for Washington State residents in 1972 constant dollars per driving age population.

The gasoline price elasticity estimated by this equation is -0.36, which as an intermediate term price elasticity appears proper. A dynamic adjustment model for the state of Minnesota estimated a gasoline price elasticity as -0.34 (6). Also generally short-term price elasticity has been estimated at -0.20 and long-term price elasticity has been estimated from -0.65 to -0.85 (7), so -0.36 appears reasonable as an intermediate term (1 year) price elasticity.

Diesel and Total Demand Equations

The equation used to forecast diesel demand is given as Equation 2. The statistical information for that equation is also given. As noted earlier under the data availability section, there are ways to better estimate the historical diesel demand. However, it was decided that the difficulty of forecasting employment or sales in lumber and wood products or retail trade consistently would impart more variability to the estimate than using state personal income. Because diesel comprises only 10 percent of total fuel, the effect on the total fuel forecast of the variability of this estimate is mitigated.

$$\begin{aligned} \text{DSL} = & -85.501 +13.102 \text{ PI} \\ & (-5.69) \quad (18.08) \end{aligned} \quad (2)$$

Normalized standard error = .073

$R^2 = .8931$

Durbin-Watson Statistic = 1.85
 (t-statistics in parentheses all significant at .005 level)

where DSL is the gallons of diesel in Washington State by quarter at a seasonally adjusted annual rate and PI is the personal income, a moving average over four quarters at a seasonally adjusted annual rate of personal income in Washington State in 1972 constant dollars.

$$\text{TOT} = \text{GAS} + \text{DSL} \quad (3)$$

TOT = total taxable fuel gallons in Washington State

The identity used to forecast total fuel is given in Equation 3. This equation serves the purpose of collecting the total gallons of fuel forecast into one figure that can then be used to estimate total revenue when multiplied by the tax rate per gallon.

Monthly Forecast

Using the seasonal factors given in Table 4, a monthly forecast is derived for the current fiscal year. The seasonal factors were estimated using the seasonal adjustment procedure commonly known as the Census X-11 variant (1). These gasoline seasonal factors differ both in size and in rank order from those used in the short-term energy outlook model of national gasoline use (3). This difference was not deemed inappropriate because (a) the weather patterns in Washington State are somewhat different from national weather patterns, and (b) the Spearman rank correlation coefficient (0.7) is large enough to indicate a significant degree of similarity between the rankings, although the rankings were not equivalent.

TABLE 4 Seasonal Factors

Month	Gasoline Factor	Diesel Factor
January	0.8909	0.6361
February	0.8602	1.0358
March	1.0004	1.1887
April	0.9856	1.0834
May	1.0223	0.9752
June	1.0502	1.0581
July	1.0893	1.0181
August	1.0988	0.8289
September	1.0255	1.1908
October	1.0430	0.8402
November	0.9675	1.2467
December	0.9663	0.8980

Analysis of Forecast Versus Actual

Various representations of the percentage differences between forecast estimates and actual gallonage are given in Table 5. Because the normalized standard error of the gasoline equation is 1.6 percent and the error of the diesel equation is 7.3 percent, these two figures can be compared to those of the root mean squared error (RMSE) for the quarterly forecast.

TABLE 5 Forecast Error

Time Period	Forecast Estimate	Gasoline (%)	Diesel (%)	Total Fuel (%)
Monthly	RMSE	5.0	19.5	4.6
	Average	3.7	15.0	3.5
	Largest	11.0	44.0	11.0
Quarterly	RMSE	2.8	11.1	3.5
	Average	2.7	10.0	2.9
	Largest	6.0	17.0	5.0
Annual	RMSE	2.1	11.7	2.0
	Average	2.0	7.0	1.0
	Largest	3.0	11.0	2.0
Monthly for fiscal year to date	RMSE	2.0	11.3	1.7
	Average	1.3	9.8	1.4
	Largest	4.0	22.0	3.0

The average annual error for the total fuel equation is 1 percent. This annual error figure also applies to a total revenue figure for fuel tax and enables budget projections to be more precise than in the past. The average monthly error of 3.5 percent with the largest error of 11 percent of total fuel on a monthly basis makes it difficult to manage cash flow. But the error of 3.5 percent is lower than the monthly error before the current model. In addition, the monthly fiscal year-to-date error has the lowest RMSE from which it can be inferred that above-average months usually follow below-average months.

Legal codes that define when tax deposits should be made compound the cash flow difficulties. Cash flow deposits vary depending on administrative cut-off dates. In the past money deposits made in February have been as much as 75 percent below estimates and in March as much as 80 percent above estimates. The variation of mail deliveries and number of working days between the 25th of the month (the date taxes are required to be mailed) and the last day of the month will continue to cause difficulties in monthly cash flow estimates.

FUTURE APPLICATIONS

As the technical expertise of the members of the task force grows and their confidence in statistical procedures increases, further refinements of the model may be considered. Refinements that will be proposed for the gasoline equation are use of vehi-

cle stock attributes and a polynomial distributed lag operator on personal income.

The diesel forecast equation will be studied to find ways to reduce forecast error. This reduction will be important as the percentage of total fuel that is diesel fuel increases. The percentage of vehicles using diesel fuel and the split of the commercial versus personal-use diesel vehicles are possible variables for inclusion in the equation.

Extension of similar forecast procedures to vehicle registrations and fees forecasts will also be started. Past vehicle stocks, changes in age distribution and household size are variables that will be considered for use in the vehicle forecast model.

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