

## What Do We Know about Gasoline Demand Elasticities?

Carol A. Dahl  
Colorado School of Mines  
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Numerous studies have been done on gasoline demand elasticities. Dahl (1995) summarizes previous survey work (Taylor (1977), Bohi (1981), Kouris (1983), Bohi and Zimmerman (1984), Dahl (1986), Dahl and Sterner (1991a,1991b), Goodwin (1992), and Dahl (1994)) with an update of studies through 1994. Summary statistics from these authors and more recent authors are shown in Table 1. I will highlight some of the other results from these studies below.

	# Studies	Study Years	Psr	Plr	Ysr	Ylr
Taylor (1977)	7	70-76	(0.10,-0.50)	(-0.25,-1.00)		
Bohi (1981)	11	74-78	-0.20	-0.70		near 1
Kouris (1983) Country CSTS	7	75-83	(-0.10,-0.20)			
Kouris (1983) US TS	7	72-83	(-.20,-.40)	-0.70		
Bohi and Zimmerman (1984)	10	79-82	-0.20	inelastic	0.40	elastic
Dahl (1986)	69	69-84	-0.12 (m,q)		0.31 (m,q)	
			-0.29 (a)	-1.02	0.47 (a)	1.38
Dahl and Sterner (1991a, 1991b)	~100	66-88	-0.26	-0.86	0.48	1.21
Goodwin (1992)	12		-0.27	(-0.71,-0.84)	nr	nr
Dahl (1995)	14	89-93	-0.20	-0.60		<1
Espey (1996) U.S.	41	69-90		-0.65		0.91
Espey(1998)	95	66-97	-0.16	-0.81	0.32	0.90
Graham and Glaister (2002)	113	66-00	(-0.20,-0.30)	(-0.60,-0.80)	(0.30,0.50)	(0.50,1.50)
Hanly, Dargay, Goodwin (2002)	69	72-01	-0.25	<-0.60	0.40	>1.00
Dahl (2006)	4					

Notes: Numbers in parenthesis indicate authors range of estimates (a) = annual, (m,q) = monthly and quarterly, CSTS = cross section time series dats, TS = time series data, <-0.60 means more elastic

Taylor (1977) suggests that evidence is mixed but comes up with ranges for the range of price elasticities shown in the Table but does not come up with summary income elasticities. Bohi (1981) finds elasticity consistency once studies are stratified by model --static, dynamic, and structural- and by data type - aggregate and disaggregate (household data). He finds summary price and long run income elasticities. He concludes that income elasticity is near one, except for

lower values on household data. Structural models with miles traveled and miles per gallon equations may have less elastic income and price elasticities.

Kouris (1983) considered 12 studies – international cross section time series and U.S. time series. He does not come up with summary income elasticities and finds more elastic price response on international panel data averaging -1.09. Otherwise his results resemble those of Taylor and Bohi. He finds wide variation on price elasticities using dynamic models.

Bohi and Zimmerman (1984) came up with summary price elasticities but found more inconsistency in results than in Bohi's earlier survey. Most unstable were the results on monthly or quarterly data. As cross sections increase and time series shorten in panel data, longer term adjustment may be captured.

Dahl (1986), after stratifying models, was able to report monthly to quarterly, annual, and long run price and income elasticities. She concluded that lag models capture long run income but not price elasticities. In panel data, as cross sections increase and time series get shorter, more long run adjustment appears to be captured. When a lagged endogenous variable and a vehicle stock variable are included only short run adjustments are captured.

Dahl and Sterner (1991a, 1991b) came up with summary statistics after stratifying by model and data type. Their model and data taxonomy are incorporated into later survey work. They find a third or less of short run price and income adjustment come from changes in vehicle characteristics. Goodwin (1992) stratifies his studies by time series estimates and panel data and only reports price elasticities. His long run panel studies find a more responsive price elasticity than do his time series estimates.

Dahl (1995) found less elastic income and price response than in her earlier survey. Some of the earlier large income effect might have resulted from baby boomers joining the labor force. Studies allowing asymmetric response to price increases and decreases found a larger price response to price increases for gasoline consumption, miles driven, and auto efficiency. Although CAFE standards may have contributed to lower price and income elasticities, she found no statistical evidence from studies on aggregate data that CAFE standards have been effective but one study on disaggregate data found CAFE had raised vehicle efficiencies. Higher income was found to raise vehicle efficiency as more wealthy drivers had newer and, hence, more efficient automobiles. Whereas earlier studies had found that raising income lowered efficiency as wealthier people bought bigger and more powerful vehicles.

Espey (1996) and (1998) performed meta-analysis on gasoline elasticities to determine whether functional form, lag structure, estimation technique and other study differences systematically affected elasticity estimates. Espey (1996) did the analysis on studies that include U.S. data (no studies on household panel data were included) and Espey (1998) includes all available studies. To do meta-analysis, she regressed income and price elasticities from the studies on a variety of study characteristics to determine their influence on estimated price and income elasticities. The elasticities in the above Table are from the constant terms in her regressions, which represent aggregate consumption for a lagged model on annual time series data not estimated with a random coefficient model.

For the U.S. elasticities, her regressions explain between one third and one half of the variation in long run price and income elasticities. Her conclusions for the U.S. study are as follows. For U.S. price elasticity, including any other variable but price and income does not have a

significant effect on elasticity, nor are price elasticities from static models significantly different from the long run estimates in dynamic models. Per capita or per household demand is significantly less elastic than total demand or demand per vehicle. There is no difference in long run estimates for monthly, quarterly, or annual data, linear or log linear models, nor is there a price elasticity difference between estimates on national time series or state cross section time series data. Studies that include cross section time series of other countries find a 50 per cent more elastic price response. Only random coefficient techniques find a significantly less elastic price response than other estimation techniques. Demand was more price elastic prior to 1974.

For U.S. income elasticity, including some measure of vehicle ownership lowers the elasticity but the inclusion of other variables beside price and income do not. Linear models are not found to have a significantly difference elasticity than non-linear models. Models on monthly and quarterly data find a smaller long run income response, and models on gasoline per capita, per household, per vehicle may find a higher income elasticity (10% significance level). Income elasticity may have been less elastic before 1974 (10% significance). There is no difference in elasticity between studies on national time series and cross section time series of states. Models using random coefficient find a more elastic income response.

Espey (1998) conducts meta-analysis in gasoline demand elasticities for all countries for both long and short run income and price elasticities. The elasticity estimates from her constant in the four regressions is for OLS estimation of total fuel consumption on a log-linear lagged endogenous model with annual, national U.S. time series data. The  $R^2$  for three of her regressions (long run price, short run income and long run income response) was around one fourth but  $R^2$  was closer to one third for the short run price elasticity. For price elasticity, including some measure of vehicle ownership or vehicle efficiency lessens short run price response and vehicle ownership lessens long run price response as well. Linear models find a lower long run price response. Estimates on monthly and quarterly data find a lower short run price response but find no difference for long run response. Static models pick up larger price response than short run estimates but lower price response than long run estimates. Partial and other lag structures did not pick up any difference across price elasticities. Studies on cross sectional data found the largest short run price response, while studies on cross sectional time series data found the smallest short run price response. There was no difference in the long run price elasticities over the three data types (cross section, cross section time series, and time series)

Estimates on state or provincial data (with no state or provincial dummies) were not different from those on national data, but studies using household panel data found a more elastic price response. Studies on state data with state dummies found a less elastic long run response. If U.S. data was combined with other country data the short but not the long run price response was larger. Over time the short run price response may have become smaller but the long run responses may have become larger.

For income elasticities, she found that the inclusion of vehicle ownership statistically lowered income elasticity but inclusion of vehicle characteristics such as efficiency did not. Static income elasticity estimates were statistically larger than short-run income elasticities but were not significantly difference from long run elasticities. Long income elasticities from monthly and quarterly data were no different than those from long run data although monthly short run elasticities were statistically smaller. Whether the data were cross section, time series, cross section time series or household did not tend to make much difference in the income elasticities. Results including state and regional dummies were mixed. Studies that pooled the U.S. with

.other countries found higher short run income elasticity but no difference in long run income elasticity. Studies on non-U.S. data tended to show more response to income. Short run income elasticity has not changed over time but long run elasticity may be falling.

Graham and Glaister (2002, 2004) (GG) survey an even larger set of studies that consider income and price elasticities of highway fuel demand. Since there is considerable overlap with Espey (1998) and Dahl and Sterner (1991a,1991b), the summary statistics for all of these studies are quite similar. GG include a survey of car travel elasticities, car ownership, and freight elasticities and have a nice methodological discussion in their comprehensive report. As time series techniques are getting more important in the recent studies, they are the first survey to explicitly discuss time series issues such as spurious regression, co-integration and error correction models.

GG also conduct a meta-analysis for short and long run price and income elasticities. They highlight the following findings from their meta-analysis. The use of non-dynamic modeling finds elasticities between long and short-run for both income and price. Studies on cross sectional data produce very elastic price response. Studies on cross section time series data often find less elastic price and income response. Studies that include vehicle ownership and characteristics often find less elastic income and price response. The elasticities are sensitive to geographic area included. They find long run income response is getting smaller, but unlike Espey (1998), they find short run price response getting larger over time.

Hanly, Dargay, and Goodwin (2002) (HDG) and Goodwin, Dargay, and Hanly (2004) survey studies only for OECD countries. They include studies that look at fuel demand, vehicle ownership, vehicle use, vehicle efficiency, and traffic induced from infrastructure expansion and reduced from traffic restrictions. They find the income elasticity to be 1.5 to 2 times greater than the absolute value of the price elasticity, while the long run price elasticities are 2 o 3 times larger than the short run elasticities. They pay a bit more attention to the composition of fuels and find that diesel may be less price In addition to coming up with summary elasticities similar to the other recent studies, they conduct a meta-analysis. They note that they do not find much systematic variation in their meta-analysis but conclude the following: studies on cross section time series find less elastic price and income responses, the U.S. has lower price and income responses than other countries, studies that end in the years 1974 to 1981 have a more elastic price response. One reason for this large price response might be expectations. At the time, many consumers believed that prices would go much higher and that there might be shortages. Thus, consumers were responding not only to current price run-up but the higher future prices and the crisis atmosphere. HDG02 do not find a systematic change in elasticities across time, except the long run income response may be getting smaller.

Most of the studies in the above surveys are for OECD countries. (For a survey on gasoline demand in developing countries, see Dahl (1994)). Unfortunately, none of the surveys includes studies beyond 2001 or the run up in real gasoline prices since 1999. I have found an additional seven studies done since 2000 and discuss the four of them that include data for 2000 and beyond. Summaries of these four studies are included in Appendix ?.

Small and van Dender (2006) (S&V06) build a model that looks at how vehicle miles traveled and auto efficiency change as price, income and other variables change for U.S. state data from 1966-2001. They include a dummy variable for each state. They compute fuel elasticities from their preferred estimation using 3SLS on miles traveled and vehicle efficiency equations. They

find the short and long run price and income elasticities of -0.089/-0.43 and 0.11/0.54, respectively. These elasticities seem less elastic compared to the summary statistics above, which is what Bohi (1981) found when elasticities were determined by structural models on miles and vehicle efficiency. Using data from the 1990s when prices tended to be falling, they find some statistical evidence that CAFÉ standards have had a significant effect but the result is sensitive to the way the CAFÉ standard is represented.

S&V06 also estimate their miles traveled equation on three sub periods – 1966-1977, 1978-89, and 1990-2001. They do not test whether the coefficients were significantly different over the three periods and only report results for price elasticities. They found that miles traveled were most price elastic in the earliest period and least elastic in the most recent period. Although they do not report enough information to determine fuel price elasticities, they are likely to have fallen some as well. Espey (1996) also found more elastic price response before 1974.

Wadad, Graham, and Noland (2006) (WGN06) use time series data for 20 years aggregated from the U.S. Consumer Expenditure Survey for 1984-2003. They do estimates on 5 income quintiles as well as aggregates for urban and rural households. Since they include a vehicle stock and a vehicle efficiency variable these results are likely to be shorter term adjustments reflecting how miles driven change with respect to price and income. Their estimates explain 75% or more of the variation in motor fuel consumption by quintile and the coefficients are found to be significantly different across quintiles.

Price is significantly different from zero at the 10% level or better and varies from -0.20 to -0.35. It is most elastic for the poorest quintile. Income is not significant for the lowest or highest income quintile but varies from 0.38 to 0.47 for the 2<sup>nd</sup> through 4<sup>th</sup> quintile. When miles per gallon (MPG) of the vehicle stock increases 1% gasoline consumption falls from 0.75% to almost 1%. The percentage decrease tends to be larger for lower quintiles. This result suggests that as MPG falls decreasing cost per mile, driving increases (called the rebound effect) from 0 to 0.25%. On average if income or the stock of auto increases 1%, gasoline consumption increases 0.4%.

Urban consumers are found to have more price elastic but less income elastic fuel response than rural households but there is no mention is the difference is significant.

I compare WGN06 estimates to earlier estimates for price/income/auto stock elasticities for annual models on aggregate data with a vehicle stock in them in Table 2. Since I do not have aggregate estimates from WGN06 we aggregate WGN estimates in three different ways. The first elasticities are a simple average of WGN06 elasticities across the quintiles (estimates not significant at 10% level or better are included as zero). The second elasticities are for WGN06s median quintile and the third are for a population weighted average of WGN06s estimates on U.S. urban (80%) and rural (20%) households. These are compared to estimates on models with vehicle stocks from two earlier surveys -- Dahl (1986) and Dahl and Sterner (1991b).

Earlier survey work suggested that demand may be getting less price elastic and more income elastic over time. Table 1 shows that WGN06s median quintile estimates suggest that demand may be less price elastic when more recent data are included but the two other aggregations of WGN06 results do not. The results on WGN06 aggregates suggest that income elasticity has likely remained the same or fallen since the earlier surveys. They also suggest that the intensity of vehicle use as the population has become more saturated has not risen.

Table 2 Gasoline Demand Elasticities with Respect to Price, Income and Auto Stock			
	Price	Income	Auto
WGN (2006) = quintile average	-0.27	0.24	0.41
WGN (2006) = median quintile	-0.20	0.38	0.48
WGN (2006) = 0.8*Urban+0.2*Rural	-0.28	0.49	0.28
Dahl (1986)	-0.26	0.46	not reported
Dahl and Sterner (1991b)	-0.31	0.52	0.52

The last study, I consider is by Hughes, Knittel, and Sperling (2006) (HKS06). Their study specifically considers whether there have been structural shifts in gasoline demand between the price run ups in the last half of the 1970's and the price run up in the early part of this century. They have estimates on dynamic models with a lagged endogenous variable to measure long and short run elasticities and static models. They compare estimates on monthly data for January, 1975 to January, 1980 and for March, 2001 to March, 2006. Models with one month lags have not performed well in the past and do not perform well in HKS06 (as the authors note) so I dismiss them. When the lagged endogenous variable has a 12 month lag, which has performed better in other studies, the results in HKS06 are disappointing. When the estimates on the lagged endogenous variable are well behaved, the coefficients on income are not, and when the coefficients on income are well behaved, the coefficients on the lagged endogenous variable are not. Although lagged endogenous models often provide large variations in long run elasticities it is unusual for the coefficient on the lagged endogenous variable to be less than 0.35 and it is highly unusual for them to be negative. I believe the likely culprit is multicollinearity between income and the lagged endogenous variable.

Thus, HKS06 were not able to estimate any long run price or income elasticities. Their static model is better behaved and measures a monthly price elasticity of around -0.30 from 1975-1980 and -0.04 from 2001 to 2006, which suggest that the short run price elasticity is less elastic than earlier. The only survey that specifically suggests a monthly price elasticity is Dahl (1986). She finds no difference between monthly and quarterly elasticities with a price elasticity of -0.12. The annual elasticity is over two times larger and the long run elasticity is over 8 times more elastic. Applying the same ratios to the HKS06 elasticity estimates suggests an annual elasticity of around -0.095 and a long run elasticity of -0.34. This is less elastic than other recent studies and is closer to short than long-run estimates of earlier studies.

So has the price elasticity really fallen so dramatically. Three of the recent studies suggest not but their data were before the big run up in prices hit. Has the price elasticity really fallen so dramatically? Sipe and Mendelsohn (2001) investigate demand elasticities on cross sectional data for individuals in California and Connecticut for 2000. Their data set is based on experimental survey data for 200 to 300 individuals and includes low price gasoline scenarios from \$1.70 to \$2.90 and high price scenarios from \$3.10 to \$5.80, which span high hurricane related and summer prices in the last year. Short run and long run response are based on how much the survey respondents say they would adjust driving and their auto stock in the short and long run. Both price and income elasticities are significant at the 5% level or better. California

residents, who drive on average about 5% more, say they are more price responsive (short run price elasticity equal to -0.55) than Connecticut residents (short run price elasticity of -0.37). In both cases, the long run price elasticity was between 20 and 30% higher than the short run elasticity. If we can trust Sipe and Mendelsohn's consumers, they say they would make substantial responses to permanent large price increases.

So why the small price response in HKS06. One of the big differences between the current price run up and that in the late 1970s is that then many consumers believed that gasoline prices would go ever higher, whereas today many consumers are not so sure that the run up is permanent. Other consumers may be taking a more wait and see attitude to whether political uncertainty in oil producing countries will subside, whether refining bottlenecks will be resolved, whether high oil prices will slow the growth of the world economy and whether high gasoline prices and slower economic growth will cool the markets.

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