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Vehicle Fuel Economy And Vehicle Miles Traveled: An Empirical Investigation Of Jevons' Paradox

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(Under review at *Energy Policy*)

Research Focus

- Policy responses to the energy crisis (Jimmy Carter and the moral equivalent of war, MEOW)
- The commonly held notion: Increased efficiency reduces demand/consumption
  - Part of rational for energy efficiency standards (e.g. SB221)
  - Rationale for Corporate Average Fuel Economy (CAFE) standards
- Jevons' Paradox
- The question: *does Jevons' Paradox hold in regards to automobile transportation, i.e, is increase in fuel economy associated with increase in vehicle miles travelled (VMT) when controlling for all other available factors that can affect VMT?*

The Theoretical Foundation; Jevons' Paradox

"It is wholly a confusion of ideas to suppose that the economical use of fuel is equivalent to a diminished consumption. The very contrary is the truth…" (Jevons, 1865)

- Williams Stanley Jevons (1865; Figure 1) "The Coal Question: An Inquiry Concerning the Progress of the Nation, and the Probable Exhaustion of Our Coalmines"

Figure 1: William Stanley Jevons
Source: Popular Science Monthly, 1877

The Theoretical Foundation; Khazzoom—Brookes Postulate

- Daniel Khazzoom

  Microeconomic scale

- Len Brookes

  Macroeconomic scale

  - a more restrictive application of Jevons Paradox
  - specific to energy efficiency

The KB Postulate: "energy efficiency improvements that, on the broadest considerations, are economically justified at the microlevel lead to a higher level of energy consumption at the macrolevel" (Saunders, 1992).

The Theoretical Foundation; Neoclassical economics and the question of "Rebound"

- Rebound;

R = (PES-AES/PES)*100

Where;

R = Rebound

PES = Potential Energy Savings

AES = Actual Energy Savings

- Can be direct, indirect or economy-wide (Figure 2)

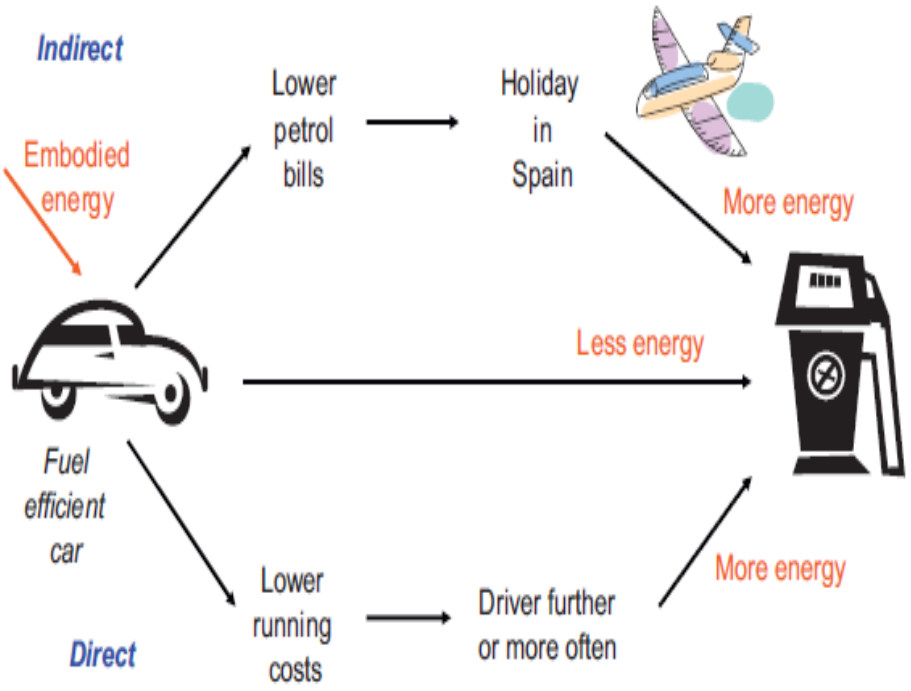


Figure 2
Source: Sorrell, (2009)

Application of Theory to a Current Issue; Vehicle Fuel Economy and VMT

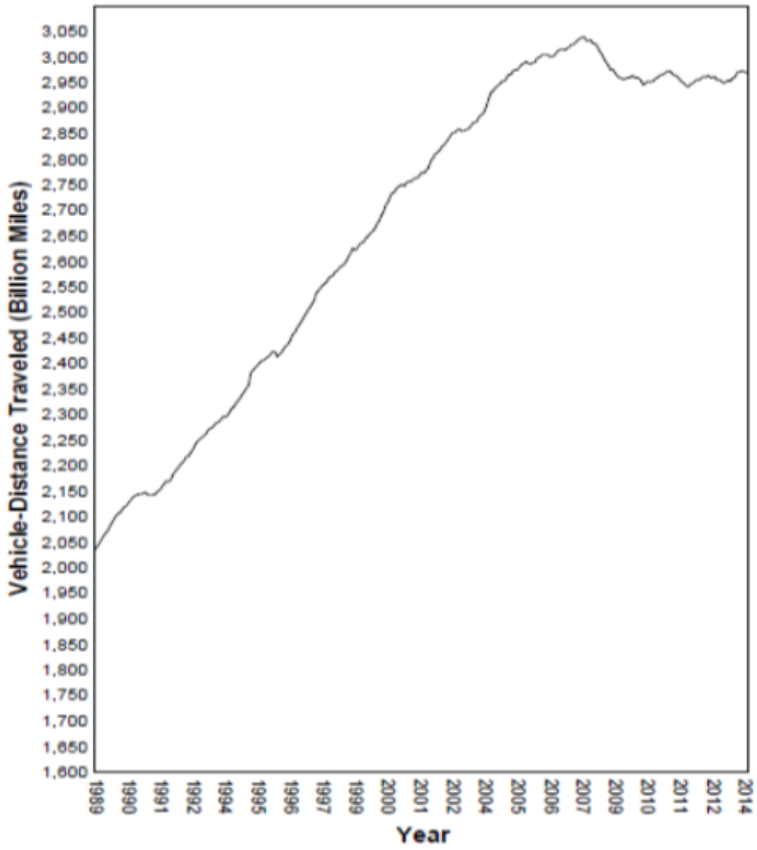


Figure 3: VMT, 1989—2014, billion miles

Source: USDOT, 2014.

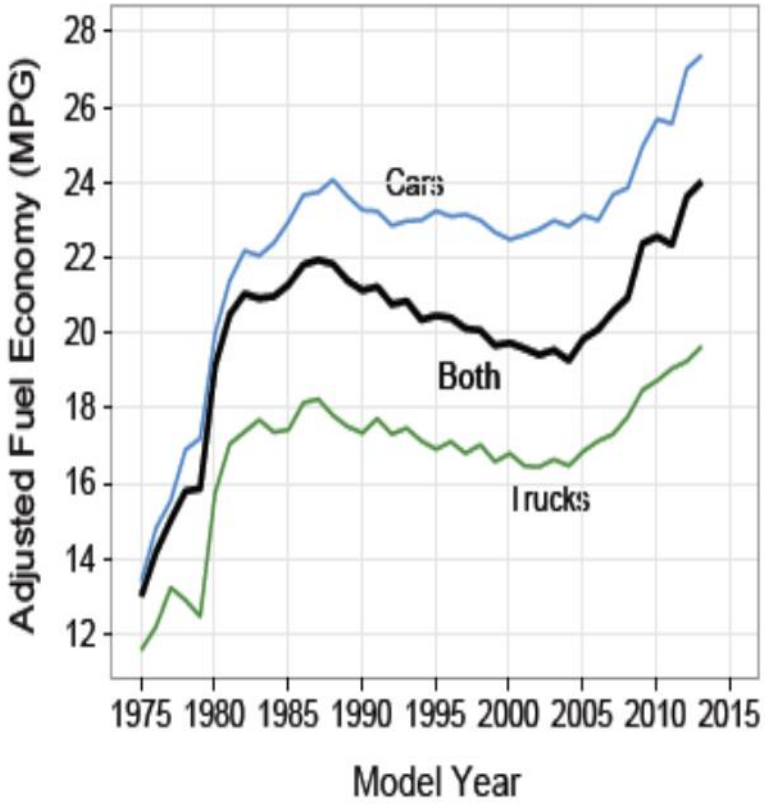


Figure 4: Adjusted Fuel Economy for Model Year, 1975—2013

Source: EPA, 2013

The paradox: the US light vehicle stock was on average 50% more efficient in 2005 than in 1975, however, VMT continued to increase until 2007 (Figure 5; USDOT, 2014)

Literature Review

1. **Macroeconomic scale**

a. Very few in number

b. largely theoretical and anecdotal (based on historical estimates)

c. when empirical, based on indirect, proxy measures

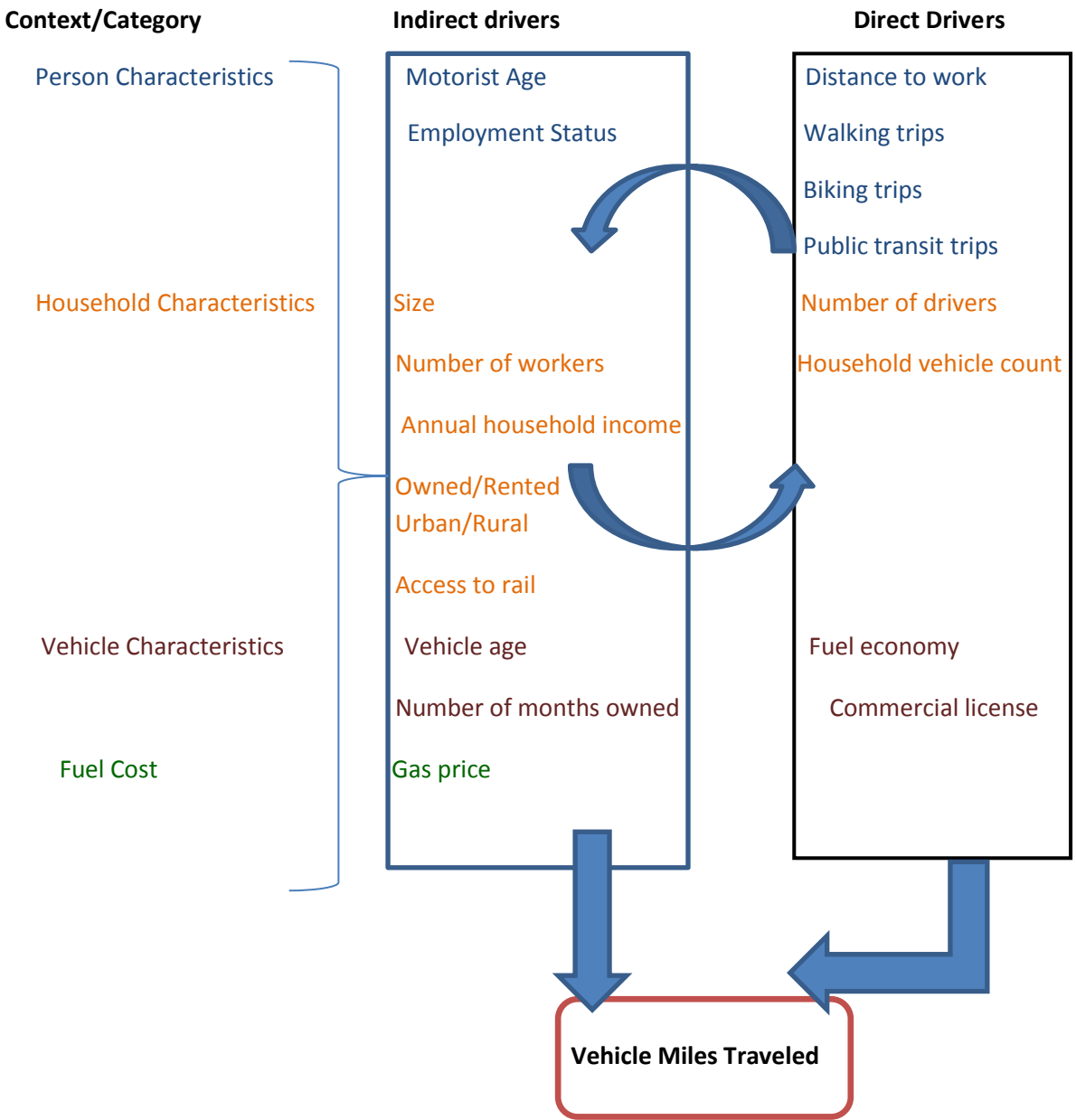
2. **Microeconomic**

a. large number of studies (relative to those on the macroeconomic scale)

b. focused primarily on estimating rebounds for different efficiency improvements in different sectors

Brookes (2000) “The claims of what might be called the Jevons school are susceptible only to suggestive empirical support since estimating the macroeconomic consequences of individual improvements in energy efficiency is practically impossible”.

Conceptual Framework



Category	Variable	Expected Direction	Comments
Person Characteristics			
	Motorist Age		
	<20	-	Limited by age of obtaining driver's license
	20—64	+	Economically productive and socially active age group
	>64	-	Limited mobility due to advanced age
	Walking Trips	-	Inversely Correlated
	Biking Trips	-	Inversely Correlated
	Public Transit Trips	-	Inversely Correlated
	Employment Status		
	Employed	+	Mobility associated with work, income
	Unemployed	-	
	Distance to Work	+	Directly Correlated as a function of commute distance

Category	Variable	Expected Direction	Comments
Household Characteristics			
	Household Size	+	Magnitude is expected to increase with increases in household size
	Worker Count	+	Increase with increase in adults
	Driver Count	+	Increase with increase in drivers
	Household Vehicle Count	+	Increase with increase in vehicles
	Personal Income		
	<$40,000 p.a.	-	Disposable income is correlated with VMT
	$40,000—120,000	+	
	>$100,000	-/+	Greater income reduces the significance of fuel costs in decisions about travel; on the other hand it could be expected that with greater income comes; a) greater mobility, b) desire to live in exurbs

	Housing type		
	Owned	+	Greater magnitude expected for owned as a function of distance to work
	Rented	+	
	Urban/Rural		
	Urban	-	Density effect
	Rural	+	
Vehicle Characteristics			
	Vehicle owned, months	-	Function of age
	Vehicle Age	-	Function of age
	Commercial license	+	Travel for work
	Hybrid	+	Greater efficiency (Jevons' Paradox)
	Vehicle fuel economy	+	Jevons' Paradox
Fuel cost			
	Cost in nominal US dollars per gasoline equivalent Gallon	-	Function of cost of travel

Data

- National Household Travel Survey 2009 (NHTS)
- 13-month period, 50 states and the District of Columbia
- Micro-level dataset; travel and transportation behaviors
- Cross-sectional data collected using list-assisted Random Digit Dialing (RDD) method
- Data for all 150,147 completed households with 309,163 vehicles (vehicles that have all the required data = 197,454)
- Final N=82,485

Mathematical Model

- $\ln(MILEs = \alpha + \beta_1 R\_AGE + \beta_2 OCCAT + \beta_3 NWLKTRP + \beta_4 NBKTRP + \beta_5 PTUSED + \beta_6 HHSIZE + \beta_7 INCDUMMY + \beta_8 HHVEHCNT + \beta_9 DRVRCNT + \beta_{10} NUMADLT + \beta_{11} WRKCNT + \beta_{12} HOMEOWN + \beta_{13} URBRUR + \beta_{14} RAIL + \beta_{15} VEHOWNMO + \beta_{16} VEHAGE + + \beta_{17} \ln(EIADMPG) + \beta_{18} GSCOST + \beta_{19} HYBRID + \varepsilon$

- R_AGE = Respondent age; OCCAT = Occupational category; NWALKTRP = Number of walking trips; NBKTRP = Number of biking trips; PTUSED = Number of public transit trips; HHSIZE = Household size; INCDUMMY = Annual household income; HHVEHCNT = Household vehicle count; DRVRCNT = Driver count; WRKCNT = Worker Count; URBRUR = Urban or Rural location; RAIL = Access to Rail in MSA; VEHOWNMO = Number of months vehicle owned; VEHAGE = Age of the vehicle; VEHCOMM = Commercial license plates; EIADMPG = EIA derived miles per gallon (vehicle fuel economy); GSCOST = Fuel cost; Hybrid = Vehicle is hybrid or uses alternative fuel.

Results

- Variables of interest

Term	Coef	SE Coef	T-Value	P-Value	VIF
lnEIADMPG; EIA derived miles per gallon estimate (fuel economy)	1.20514	0.00992	121.55	0.000	1.13
GCCOST; fuel cost	-0.1711	0.0195	-8.76	0.000	1.19
HYBRID; hybrid or alternative fuel vehicle	-0.2357	0.0118	-20.02	0.000	1.06

The primary hypothesis was that a vehicle with greater fuel economy, would, all things being equal, be associated with greater VMT than a less fuel efficient vehicle. The results of the analysis indicated that this was indeed the case.

Results

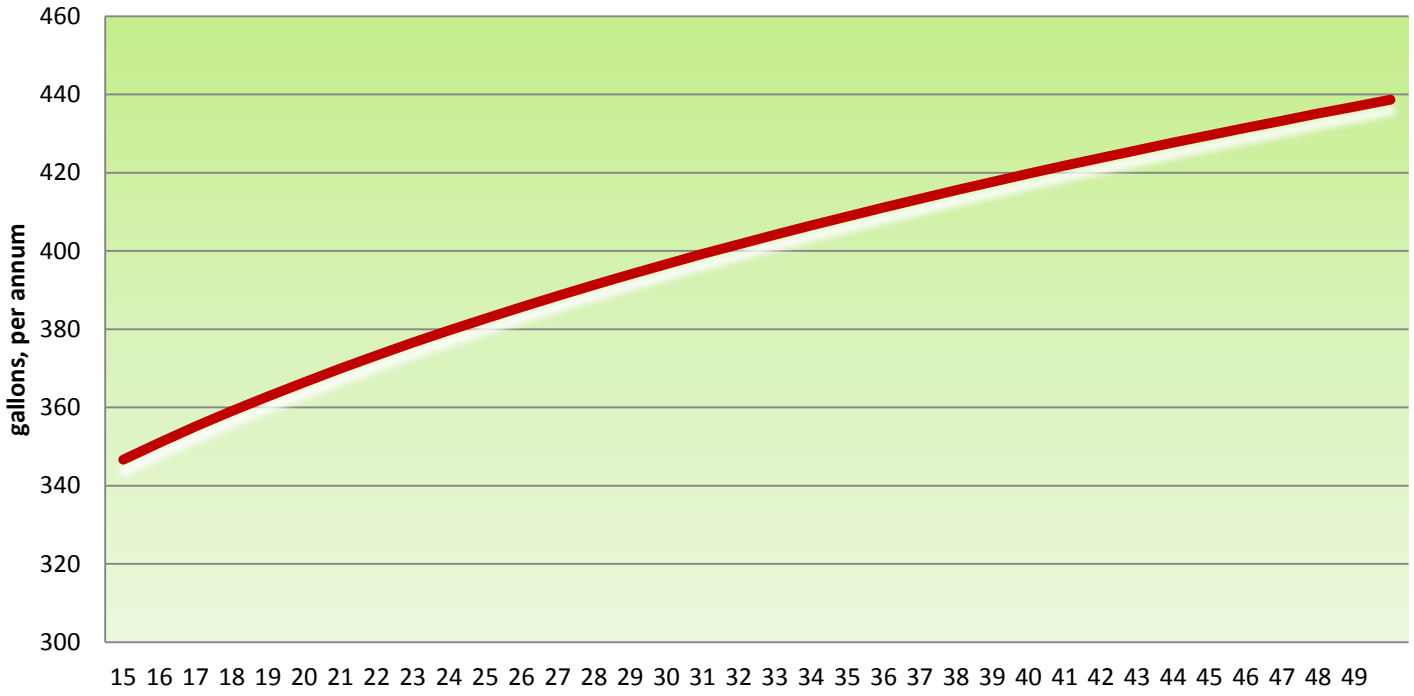
- What does “a 1% increase in fuel economy is associated with a 1.2% increase in VMT” really mean?

mpg	1% increase	VMT	Miles, week	Gallons, week	Gallons, Year
15			100	6.666666667	346.6666667
16	6.66666667	1.08	108	6.75	351
17	6.25	1.075	116.1	6.829411765	355.1294118
18	5.88235294	1.0705882	124.295294	6.905294118	359.0752941
19	5.55555556	1.0666667	132.581647	6.977981424	362.8550341
20	5.26315789	1.0631579	140.955225	7.047761238	366.4835844
21	5	1.06	149.412538	7.114882774	369.9739042
22	4.76190476	1.0571429	157.950398	7.179563526	373.3373034
23	4.54545455	1.0545455	166.565874	7.241994514	376.5837147
24	4.34782609	1.0521739	175.256267	7.302344468	379.7219123
25	4.16666667	1.05	184.019081	7.360763224	382.7596876
26	4	1.048	192.851996	7.417384479	385.7039929
27	3.84615385	1.0461538	201.752858	7.472328068	388.5610595
28	3.7037037	1.0444444	210.719652	7.52570184	391.3364957
29	3.57142857	1.0428571	219.750494	7.577603232	394.0353681
30	3.44827586	1.0413793	228.843618	7.628120587	396.6622705
31	3.33333333	1.04	237.997362	7.677334268	399.2213819
32	3.22580645	1.0387097	247.210163	7.725317607	401.7165156
33	3.125	1.0375	256.480545	7.772137714	404.1511611
34	3.03030303	1.0363636	265.80711	7.817856171	406.5285209
35	2.94117647	1.0352941	275.188537	7.862529635	408.851541

Results

mpg	1% increase	VMT	Miles, week	Gallons, week	Gallons, Year
35	2.94117647	1.0352941	275.188537	7.862529635	408.851541
36	2.85714286	1.0342857	284.623573	7.906210355	411.1229385
37	2.77777778	1.0333333	294.111025	7.948946627	413.3452246
38	2.7027027	1.0324324	303.649761	7.990783188	415.5207258
39	2.63157895	1.0315789	313.238701	8.031761564	417.6516013
40	2.56410256	1.0307692	322.876815	8.071920372	419.7398593
41	2.5	1.03	332.563119	8.111295593	421.7873708
42	2.43902439	1.0292683	342.296674	8.14992081	423.7958821
43	2.38095238	1.0285714	352.076579	8.187827418	425.7670258
44	2.3255814	1.027907	361.901972	8.225044816	427.7023304
45	2.27272727	1.0272727	371.772026	8.261600571	429.6032297
46	2.22222222	1.0266667	381.685946	8.297520573	431.4710698
47	2.17391304	1.026087	391.642971	8.332829171	433.3071169
48	2.12765957	1.0255319	401.642366	8.367549293	435.1125632
49	2.08333333	1.025	411.683425	8.401702555	436.8885329
50	2.04081633	1.0244898	421.765468	8.435309365	438.636087

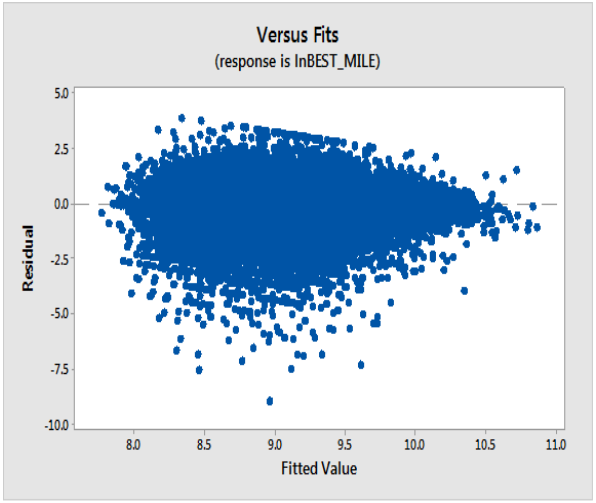
Fuel Economy vs Gallons of Gasoline Consumed

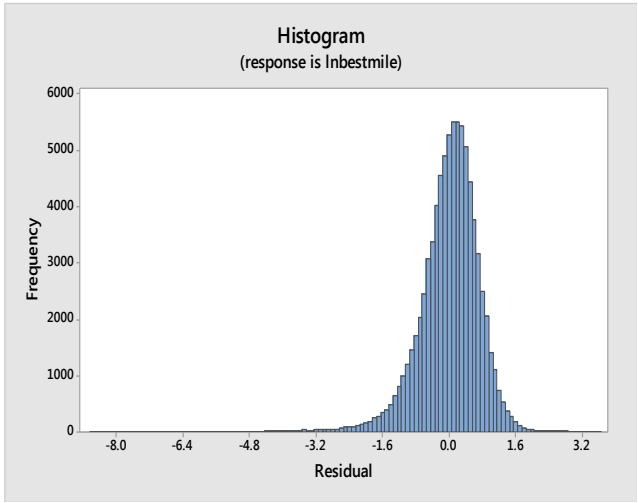


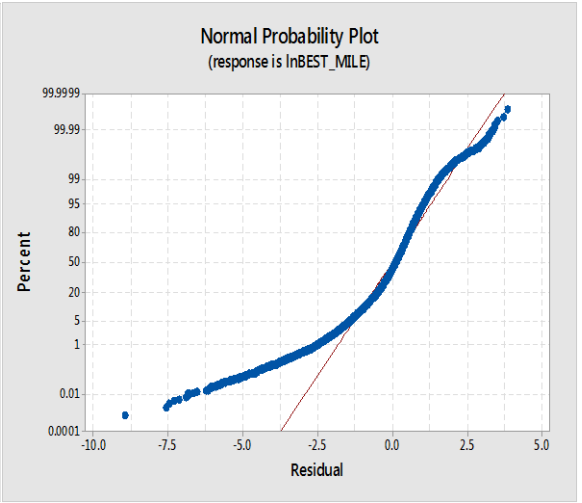
Results

❑ Model Summary

S	R-Sq	R-Sq (Adj)	R-Sq (Pred)
0.733483	25.67%	25.63%	25.59%







Limitations of the Study

- Limitations of the Dataset
- The Question of Consumer/Producer Behavior Modification
- The Vehicle Choice Question
- External Validity/Generalizability
- Validity of Statistical Conclusions

Policy Implications and Future Directions

- ❑ Pricing Policies
- ❑ Shift to multi-person modes of transit
- ❑ Historic change in VMT trends
- ❑ Scale effects and Substitution effects

There is evidence that Jevons' paradox holds. There is also evidence that increase in fuel price drives down fuel consumption and consequently VMT. The current trend toward less driving coupled with vehicle fuel efficiency may not result in the paradoxical increased macro-level consumption that Jevons' paradox posits, after all.

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Presentation Overview

- Study focus and need
- Theoretical foundations
- Application of the theory to a current issue
  - Vehicle fuel economy and vehicle miles traveled
- Literature review
  - Findings and directions
- Conceptual framework
- Data and treatment
- Results
- Limitations
- Policy implications and future directions

Application of Theory to a Current Issue; Vehicle Fuel Economy and Vehicle Miles Travelled

- In the case of motor vehicles,

  efficiency = fuel economy,

  the service derived =VMT

  resource consumed = fuel

- This research looked at passenger vehicle fuel economy and VMT and empirically examined whether Jevons' paradox holds, *ceteris paribus*.

Category	Variable	Direction Predicted by Literature	Direction Observed in the Study Results
Person Characteristics			
	Respondent Age	+ with age until 50 decreases after	-
	Walking trips	-	+
	Public transit	-	-
	Biking trips	-	-
	Occupational Category		
	Employed	+	+
	Unemployed	-	-
	Distance to Work	+	+
Household Characteristics			
	Household Size	+	+
	Worker Count	+	-
	Driver Count	+	+
	Household Vehicle Count	+	+
	Household Income		
	<$40,000 p.a.	-	-
	$40,000—120,000	+	-

Category	Variable	Direction Predicted by Literature	Direction Observed in the Study Results
	Housing type		
	Owned	+	+
	Rented	+	-
	Urban/rural		
	Urban	-	-
	Rural	+	+
	Rail	-	-
Vehicle Characteristics			
	Vehicle Owned, months	-	-
	Vehicle Age	-	-
	Commercial license	+	+
	Hybrid	+	-
	Vehicle fuel economy	+	+
Fuel cost			
	Cost in nominal US dollars per gasoline equivalent Gallon	+/-	-