Matchmaking between vehicle miles traveled and fuel economy: the role of gasoline prices as the liaison

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Effects of gasoline prices

How do changes in gasoline prices affect behavior?

1. Utilization effect - changes gasoline consumption and hence changes VMT
2. Compositional effect - evolution of fleet towards more fuel-efficient vehicles

Previous literature

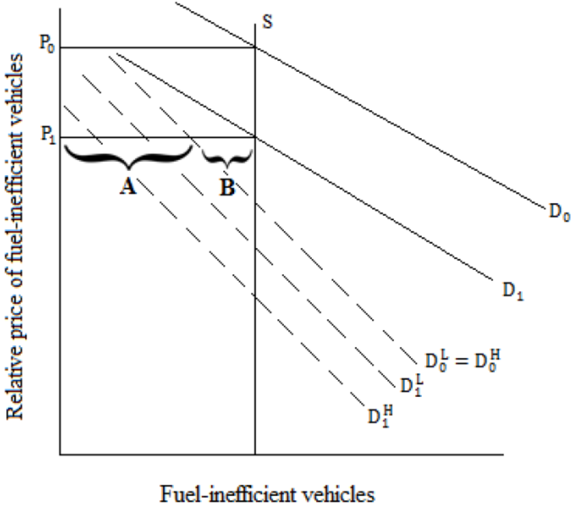
- Bento et al. (AER, 2009) - multi-market simulation model to evaluate efficiency and distributional implications of changes in gasoline prices
- Li et al. (2009) - explicitly look at the compositional effect.
- Busse et al. (AER, 2013) - study the role of gasoline prices in influencing individual's purchasing decisions and equilibrium prices in used and new car markets

Potential 3rd effect (ignored in the literature)

3. Matching effect - gasoline prices should particularly increase the demand for fuel efficiency among high-VMT households

- There is heterogeneity in demand among agents for VMT
  - households that drive more will be even more likely than other households to switch to a more fuel efficient car
- In equilibrium, after an increase in the gasoline prices there should be a stronger matching from households, based on the amount of driving they are likely to do, to the fuel economy of the cars they own.

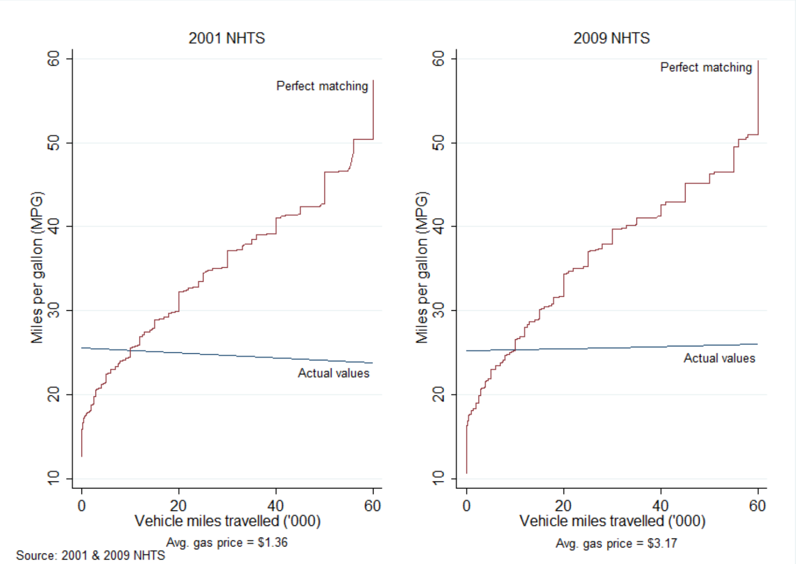
Matching effect explained



If $\frac{A}{A+B} > \frac{1}{2}$ ⇒market share of larger cars of low VMT increased

Is there a matching effect?

Figure : Matching effect



Data construction

- 2001 and 2009 National Household Travel Survey (NHTS) confidential data
- American Chamber of Commerce Cost of Living Index (COLI) database
- Department of Energy fuel economy files

Measuring the matching effect: approach 1

1. Difference-in-Difference-in-Differences (DDD) strategy:

$$MPG_{ijct} = \alpha + \beta Price^{gas}_{ct} + \gamma VMT_{ijct} + \theta \left[Price^{gas}_{ct} \times VMT_{ijct}\right] + \mathbf{X}_{\mathrm{ict}}\boldsymbol{\delta} + [Price^{gas}_{ct} \times \mathbf{X}_{\mathrm{ict}}]\boldsymbol{\varphi} + \eta_c + \lambda_t + \varepsilon_{ijct}$$

where λ are time fixed effects and η are city fixed effects

Measuring the matching effect: approach 1

Table : Difference-in-Difference-in-Differences Ordinary Least Squares (DDD - OLS)

	(1)	(2)	(3)	(4)	(5)
$Price^{gas}$	0.027	0.251***	-0.091***	-0.100***	-0.128
	(0.019)	(0.028)	(0.033)	(0.035)	(0.078)
VMT	-0.035***	-0.035***	-0.033***	-0.023***	-0.023***
	(0.004)	(0.004)	(0.005)	(0.006)	(0.005)
Matching effect	**0.019*** **	**0.019*** **	**0.018*** **	**0.019*** **	**0.019*** **
	(0.001)	**(0.001)**	**(0.002)**	**(0.003)**	**(0.002)**
Year FE		X	X	X	X
MSA FE			X	X	X
Demographic controls				X	X
$Price^{gas}$ × Demographic controls					X
N =	307,977	307,977	304,903	284,605	284,605

Measuring the matching effect: approach 2

2. Two-Stages Least Squares (2SLS)
   - VMT is endogenous to the fuel efficiency of the car: (VMT $\rightarrow$ MPG) *plus* (MPG $\rightarrow$ VMT)

$$VMT_{ijct} = a + \mathbf{X}_{\text{ict}}\mathbf{b} + cPrice^{gas}_{ct} + [Price^{gas}_{ct} \times \mathbf{X}_{\text{ict}}]\boldsymbol{d} + \eta_c + \lambda_t + \mu_{ijct}$$

$$\begin{aligned} MPG_{ijct} &= \alpha + \beta Price^{gas}_{ct} + \gamma \widehat{VMT_{ijct}} + \theta[Price^{gas}_{ct} \times \widehat{VMT_{ijct}}] \\ &\quad + \mathbf{X}_{\text{ict}}\boldsymbol{\delta} + \eta_c + \lambda_t + \varepsilon_{ijct} \end{aligned}$$

   - Use demographics and interactions of these with gasoline prices as instruments

Measuring the matching effect: approach 2

Table : Difference-in-Difference-in-Differences w/ linear instruments (DDD - 2SLS) — 2^{nd} stage

	(1)	(2)	(3)	(4)
$Price^{gas}$	0.015	0.216***	-0.158**	-0.152**
	(0.065)	(0.066)	(0.067)	(0.074)
VMT	-0.134***	-0.150***	-0.205***	-0.410***
	(0.018)	(0.018)	(0.018)	(0.086)
Matching effect	**0.016*** **	**0.020** **	**0.023*** **	**0.022*** **
	(0.006)	**(0.006)**	**(0.006)**	**(0.007)**
Year FE		X	X	X
MSA FE			X	X
Demographic controls	Instr.	Instr.	Instr.	X
$Price^{gas} \times$Other controls	Instr.	Instr.	Instr.	Instr.
N =	287,463	287,463	287,463	287,463
F-statistics of excluded instruments				
VMT	1300.24	1287.19	1281.21	9.60
$Price^{gas} \times$VMT	1278.60	1276.77	1254.74	315.02

Measuring the matching effect: approach 3

3. Non-causal estimation
   - Issue with the 2nd approach: cannot include $Price_{ct}^{gas} \times \mathbf{X}_{\mathrm{ict}}$ in the 2nd stage
   - How the heterogeneous effects on MPG, due to changes in gasoline prices are correlated with predicted VMT?

Measuring the matching effect: approach 3

Consider the following two simultaneous equations:

$$MPG_{ijct} = \alpha + \mathbf{X}_{\text{ict}}\boldsymbol{\beta} + \delta Price_{ct}^{gas} + [Price_{ct}^{gas} \times \mathbf{X}_{\text{ict}}]\boldsymbol{\theta} + \eta_c + \lambda_t + \varepsilon_{ijct}$$
$$VMT_{ijct} = a + \mathbf{X}_{\text{ict}}\boldsymbol{b} + cPrice_{ct}^{gas} + [Price_{ct}^{gas} \times \mathbf{X}_{\text{ict}}]\boldsymbol{d} + \eta_c + \lambda_t + \mu_{ijct}$$

where $E[\varepsilon\mu] \neq 0$ and
$$E[\mathbf{X}\varepsilon] = E[Price^{gas}\varepsilon] = E[\mathbf{X}\mu] = E[Price^{gas}\mu] = 0.$$

How $\partial\widehat{MPG}/\partial Price^{gas}$, are correlated with predicted VMT?

This is equivalent to estimating the following model.

$$MPG_{ijct} = \alpha + \beta Price_{ct}^{gas} + \mathbf{X}_{\text{ict}}\boldsymbol{\gamma} + \theta\left[\widehat{VMT_{ijct}} \times Price_{ct}^{gas}\right] + \eta_c + \lambda_t + \xi_{ijct}$$

Measuring the matching effect: approach 3

Table : Non-causal estimation of the matching effect

	(1)	(2)	(3)	(4)
$Price^{gas}$	-0.079	0.021	0.223***	-0.069
	(0.083)	(0.061)	(0.064)	(0.085)
Matching effect	**0.016****	**0.015*****	**0.021*****	**0.015*****
	(0.008)	**(0.006)**	**(0.006)**	**(0.006)**
$\widehat{VMT}$		-0.130***	-0.150***	-0.179***
		(0.017)	(0.017)	(0.022)
Year FE	X		X	X
MSA FE	X			X
Demographic controls	X			
N =	290,601	293,496	293,496	290,601

Measuring the matching effect: approach 4

4. 2SLS: revisit approach 2
   - Using Bento et al. (2009) to create instruments.

$$VMT_{ij} = \exp\left(\alpha_{ij} + \beta_{ij}\frac{p_{ij}^{M}}{p_i^{x}} + \lambda_i\left(\frac{Y_i/T_i - r_{ij}}{p_i^{x}}\right)\right)$$

   - Use $\widehat{VMT}_{i\bar{j}}$ as an instrument

Measuring the matching effect: approach 4

Table : Difference-in-Difference-in-Differences w/ non-linear instruments (DDD - 2SLS) — 2^{nd} stage

	(1)	(2)	(3)	(4)	(5)
$Price^{gas}$	0.021	0.264*	-0.316**	-0.364**	-0.914*
	(0.158)	(0.153)	(0.161)	(0.170)	(0.507)
$V\widehat{MT}_{i\bar{j}}$	-0.108***	-0.115***	-0.250***	-0.212***	-0.006
	(0.043)	(0.043)	(0.046)	(0.081)	(0.185)
Matching effect	**0.014**	**0.016**	**0.038*** **	**0.045*** **	**0.127** **
	(0.014)	**(0.014)**	**(0.015)**	**(0.016)**	**(0.066)**
Year FE		X	X	X	X
MSA FE			X	X	X
Demographic controls				X	X
$Price^{gas} \times$Demographic controls					X
N =	247,850	247,850	247,850	247,850	247,850
F-statistics of excluded instruments					
$V\widehat{MT}_{i\bar{j}}$	1075.46	1096.83	1546.69	67.52	67.98
$V\widehat{MT}_{i\bar{j}} \times Price^{gas}$	1044.10	1058.39	1568.65	188.89	58.05

Conclusion

- First study to analyze the matching effect
  - Matching effect = In equilibrium, after an $\uparrow$ in the gasoline prices there should be a stronger matching from households, based on the amount of driving they are likely to do, to the fuel economy of the cars they own.
- Four different econometric methods employed to estimate the matching effect. The coefficient of interest is significant throughout.
- The estimates imply: for a $1 increase in gasoline price a household that drives 1000 more annual miles per vehicle, on average is driving a vehicle that gives 0.02 - 0.13 more miles per gallon.