Formative Experiences and the Price of Gasoline

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Motivation

Some people drive, some people do not. Why?

- Standard controls typically do not fully explain behavior.
- Where do idiosyncratic differences in behavior come from?

Literature has focused on:

- Recent experiences influence behavior (Malmendier & Nagel 2011; Simonsohn 2006)
- Extreme episodes/changes have long-lasting effects, but decay (Malmendier, Nagel, Shen 2018; Callen et al. 2012; Bronnenberg et al. 2012)
- Mental plasticity during youth (Alesina & Giuliano 2011; Giuliano & Spilimbergo 2013)

Here: **Formative** experiences during **narrow window** explain later-life behavior

- High weights on experience during first few years of driving

Results relevant for other literatures:

- Enviro/Energy/Urban: Why do people drive (so much)?
- Behavior/Exp: Price levels vs. price shocks.
- Macro: Long-run demand effects of energy shocks.

This Paper

Link early-life (teen) gasoline prices to adult ($\geq$25) driving behavior

- Ex ante knowledge of when **formative window** might "turn on"
- Consider extensive and intensive margins

Multiple identification strategies

- 1979 Oil Crisis, space-time variation in gas prices, min. driving age
- Mediation analysis explores confounding channels; little effect

New evidence that experiences during formative windows have long-lasting effects

- Considerably narrower than other hypotheses
  e.g. impressionable years, recency bias, cumulative experience
- 'Path dependence' in behavior $\rightarrow$ preference heterogeneity
- Shocks matter more in some settings than levels (Haushofer and Fehr 2019)
- Experience with relatively mundane goods matter, too

Key Findings

Cohorts starting driving during 1979/80 Oil Crisis different than older cohorts

- Up to 0.5pp less likely to drive in 2000, 1.2pp in city

A doubling of gas prices during formative years:

- Decreases auto commuting by 0.4pp, and VMT|driving by 7%
- Perhaps 2pp less likely to purchase truck/SUV

Effect lies within narrow formative window ($\sim$ 15-18yo)

- No need for (monotonic) cumulative exposure func. (ex. Malmendier & Nagel '11)
- Even if follow M&N '11, recent experiences economically insignificant:
  - Formative-year shock 25.3x shock last year on 1[drive]
  - Intensive margin flatter, but still 2.7x weight on earlier years

Rule out confounding factors and other stories ($+$ much robustness):

- Age-18 unemp/adult income explain only a small portion ($<$20%) of effect
- Unlikely to be caused by frictions in skill acquisition

Literature

1. Experiences accumulate to shape later-life behavior
   - Risk, equity, consumption, labor outcomes ← recessions (Malmendier & Nagel 2011, & Shen 2018; Oreopoulus et al. 2012; Giuliano & Spilimbergo 2013; Stuart 2019)
   - Inflation expectations ← recent, lived inflation (Malmendier & Nagel 2015)
   - Risk ← violence (Callen et al. 2012)

2. Determinants of driving
   - Are driving behaviors changing?
     - No, though demographics are (Leard et al. 2019)
     - Millennials aren't really different (Knittel & Murphy 2019)
   - Effect of gas prices on VMT and fuel economy (Hughes et al. 2008; Knittel & Tanaka 2019; Li et al. 2009; Busse et al. 2013; Gillingham et al. 2015)

3. Path-dependent effects of transportation
   - Mostly studying supply (e.g. Bleakley & Lin 2012; Brooks & Lutz 2016)
   - A few study demand (Anderson et al. 2015; Larcom et al. 2017; Simonsohn 2006; Yang & Lim 2017)

Roadmap

1. Data
2. The 1979/80 Oil Crisis
3. Long run effects of gasoline price movements
4. Mediation and robustness
5. Formative window and cumulative experience (placebo tests)
6. Mechanisms and interpretation

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Data

Census 'Journey to Work' data for **extensive margin** results (IPUMS)

- Use 1980, 1990, 2000 Census, 2006-17 ACSs. Outcomes:
  - For all at work: commuted by a car/truck/van, commuted by transit
  - For all people: car in household
- Limit sample to non-farm, native born, age 25-54
- 10 to 15 millions observations

NHTS (and predecessors) for **intensive margin** results

- Use 1990, 1995, 2001, 2009, and 2017. Outcomes:
  - Vehicle miles traveled by car
  - Vehicle make/model

Gasoline prices, state-X-year post tax average price (1966-2017) (Small & Van Dender 2007; Li, Linn, & Muehlegger 2014)

More challenging data components:

- Construct a panel of driving license regulations back to 1966
  - DL-101 in *Highway Statistics* (FHWA), IIHS, DMV histories, ...
- Map coarse vehicle info to fuel economy data

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Event Study: The 1979/80 Oil Crisis

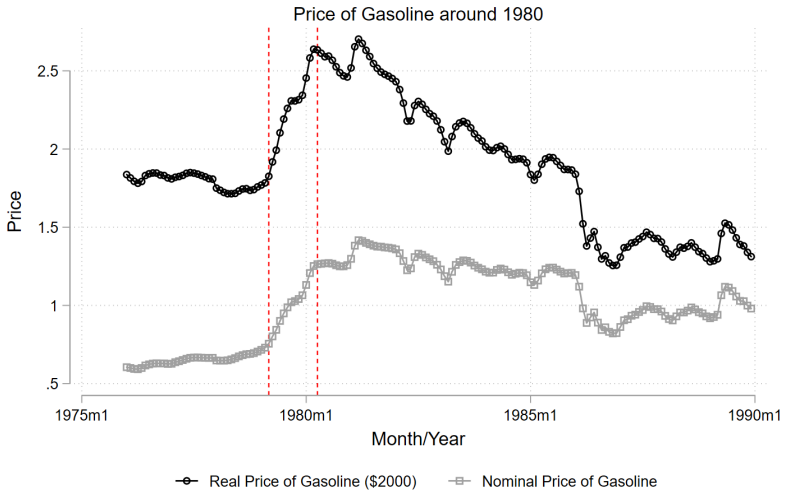
Gas price shock: Unexpected, large increase in gasoline prices

- Queuing added substantial non-monetary costs (Deacon & Sonstelie 1985)
- Exogenous for teen drivers

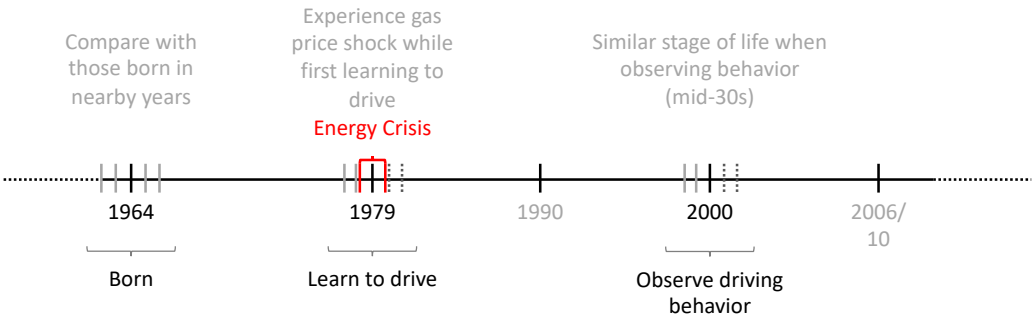
Sample: Driving/commuting behavior in 2000 Census

- Outcomes:
  - 1[Drove in a car/truck/van to work]
  - 1[Car in household]
  - 1[Transit to work]
- All aged in mid-30s by 2000
- All face *same contemporaneous gas price* in 2000
- Age $\leftrightarrow$ Birth-year require specific interpretation in (pre-ACS) census
  - *Ex*: born 5/1964, age 35 in 4/2000 $\rightarrow$ appears born 1965 (=15 in 1980)
  - People are slightly older than they appear

The 1979/80 Oil Crisis and Gasoline Prices

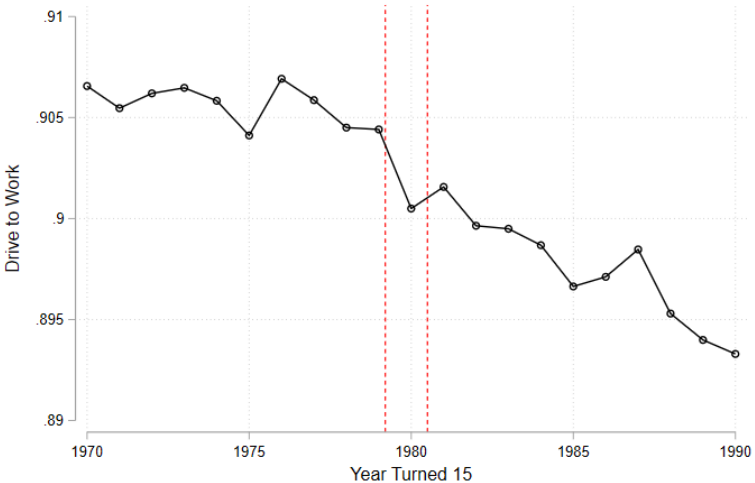


Timing


Compare with those born in nearby years
Experience gas price shock while first learning to drive
Energy Crisis
Similar stage of life when observing behavior (mid-30s)
1964
1979
1990
2000
2006/ 10
Born
Learn to drive
Observe driving behavior

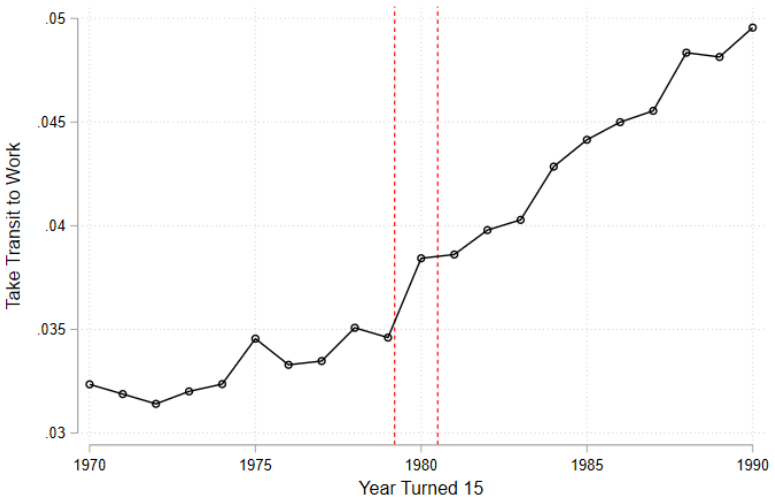
Drive to Work in 2000

Employed and at work



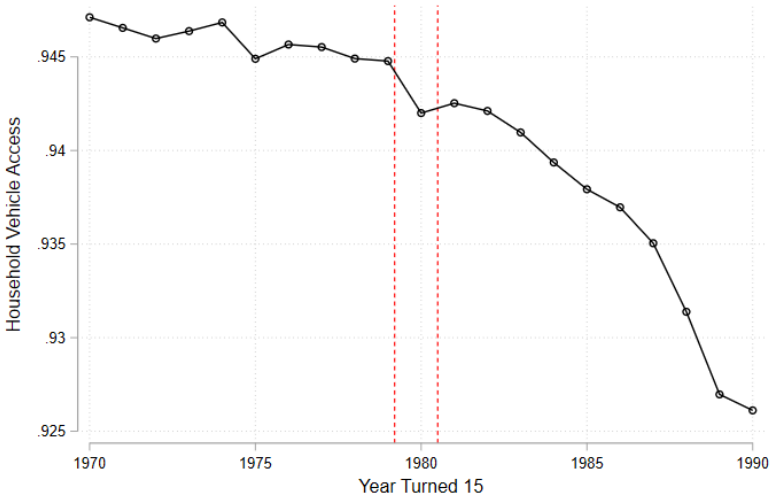
Transit in 2000

Employed and at work



No Car Access in 2000

All people



- Large declines in 15-in-late-80s group; in their mid-late 20s

Event Study: The 1979/80 Oil Crisis

Event study/RD-in-time:

$$Y_i = \alpha + \tau \cdot 1[S_i \geq 1980] + g_1(S_i) + g_2(S_i)1[S_i \geq 1980] + \varepsilon_i$$

- S_i = year turned 15
  - "Turn 15 in 1980 or later" means after April 2, 1979

Identification: Covariates cannot jump at $S_i = 0$

- Observable covariates do not show discontinuity Details

Turning 15 in 1980 or later $\rightarrow$ **(-0.21, -0.50)pp** drive in 2000

- Robust to different bandwidth, quadratic running variable Details

Event Study Results: The 1979/80 Oil Crisis

$\sim$50-100% substitution to **mass transit** (bus or rail) Details

Results robust to covariates

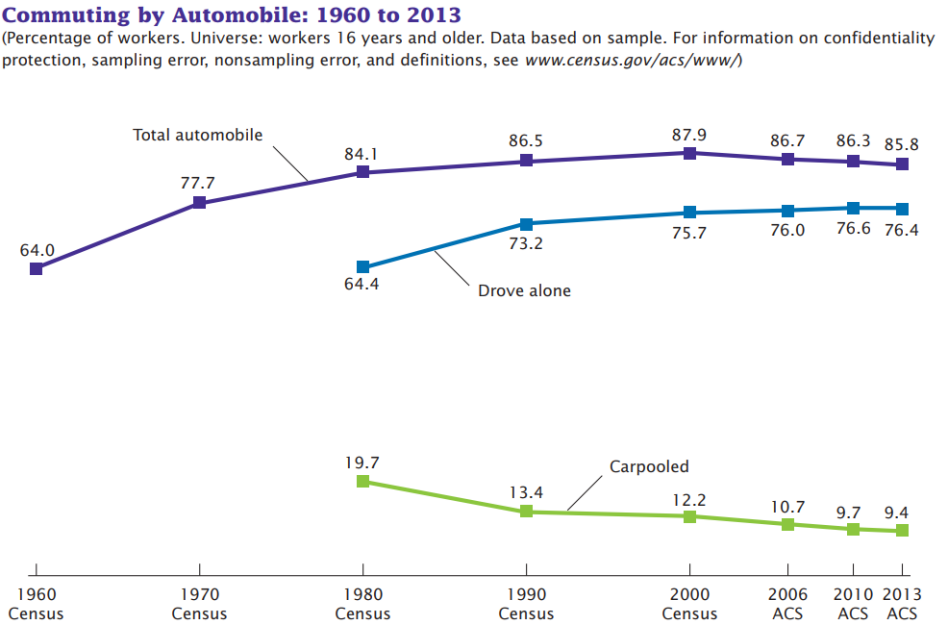
- Covariates here are tricky – many potential bad controls
- But help control for wealth, geography, etc.

Heterogeneity — effects strongest for

- Principal city (**urban core**) residents: (-0.9,-1.9)pp
- African Americans: (-0.7,-1.8)pp Details
- Lowest decile of income: -1.3pp Details

Why is this notable?

Stable distribution of driving in U.S. since 1980 . . .



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Panel Analysis

Directly estimate effect of **teen gas price shocks** on later-life driving

- Pool all census/ACS data from 1980–2017
- State-by-year gasoline prices since 1966

Match to gas price in state of birth (Census), state of residence (Census/NHTS)

- Primary sample uses **stayers**: state of birth = state of residence (64%)
- Some specifications use everyone

Merge to formative ages in two ways:

i) by year turned $X = \{\dots, 15, 16, 17, \dots\}$ years old

ii) by $\pm 0, 1, 2, \dots$ years from minimum (full privilege) driving age

- introduces variation in formative window across states
- ... and over time (as regs change) ▸ DL ages over time

Empirical design

$$Y_{icst} = \theta T_{cs} + \kappa_s + \delta_t + \eta_a + X'_{it}\lambda + \varepsilon_{icst}$$

Person i, of cohort c, in state s, sampled in (census/ACS) year t:

- Treatment T_{cs} varies by cohort and state
- Fixed effects regime:
  - State FEs κ_s – control for time-invariant differences across states
  - Sample year FEs δ_t – control for current gas prices, business cycles, etc.
  - Age FEs η_a – capture life-cycle trends in transportation behavior
  - State-X-sample year FEs – capture local, contemporaneous shocks
- Covariates are still tricky ...

Identification: No latent differences between cohorts correlated with outcomes

- Add *quadratic birth year trends* for continuous changes across cohorts
- Further variation induced by minimum DL age
- Robustness + placebo tests + mediation analysis support causal statements
- Can relax with cohort FEs (some loss of power) ▸ Gas Price (random walk)

Defining treatment

Treatment: levels or changes in the price of gas during formative years

P_{cs}^{a}: real price of gas at age a

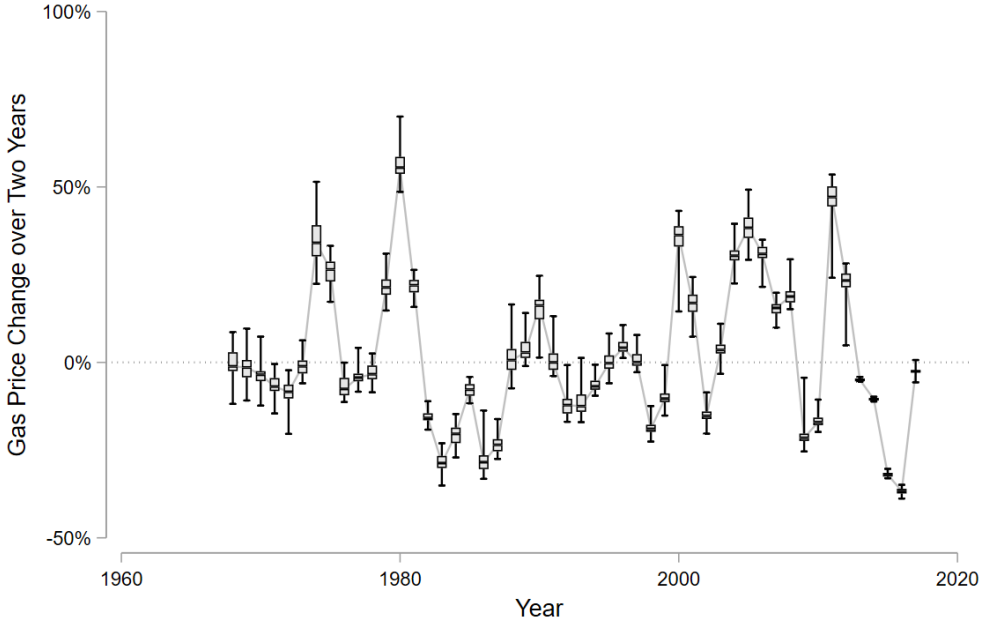
$$P_{cs}^{\Delta(a+j,a-k)} = \frac{P_{cs}^{a+j} - P_{cs}^{a-k}}{P_{cs}^{a}}$$

$P_{cs}^{m_{cs}}$: price at minimum driving age m_{cs}

$$P_{cs}^{\Delta(m_{cs}+j,m_{cs}-k)} = \frac{P_{cs}^{m_{cs}+j} - P_{cs}^{m_{cs}-k}}{P_{cs}^{m_{cs}}}$$

- Use 2-year window after able to drive (roughly 15-17)
  - Similar (but smaller) effects with 1-year window
- Look at levels, but changes wind up more important
- Use other ages as placebo

Gasoline Price Fluctuations, 2-Year: $P_{cs}^{\Delta(year,year-2)}$



Panel Results – Extensive Margin (Drive to Work)

	1[drive] (1)	1[drive] (2)	1[drive] (3)	1[drive] (4)	1[drive] (5)	1[drive] (6)	1[drive] (7)
$P_{cs}^{\Delta 17,15}$	-0.0038***	-0.0028**	-0.0031***	-0.0037***	-0.0039***	-0.0039***	-0.0043***
	(0.0010)	(0.0008)	(0.0009)	(0.0010)	(0.0010)	(0.0010)	(0.0009)
P_{cs}^{16}	-0.0007	0.0012+	-0.0029***	-0.0009	-0.0011	-0.0011	-0.0011
	(0.0010)	(0.0006)	(0.0007)	(0.0008)	(0.0009)	(0.0008)	(0.0008)
$P_{cs}^{\Delta(m_{cs}+1,m_{cs}-1)}$	-0.0041***	-0.0038***	-0.0040***	-0.0040***	-0.0040***	-0.0042***	-0.0045***
	(0.0010)	(0.0008)	(0.0008)	(0.0011)	(0.0010)	(0.0011)	(0.0010)
$P_{cs}^{m_{cs}}$	-0.0012	0.0006	-0.0012	-0.0013	-0.0015	-0.0015+	-0.0015+
	(0.0010)	(0.0006)	(0.0010)	(0.0009)	(0.0009)	(0.0008)	(0.0008)
Census year FEs	Y	Y	Y	Y	Y	-	-
State of birth FEs	Y	Y	Y	Y	Y	-	-
Age FEs	Y	Y	Y	Y	Y	Y	Y
Demographics	-	-	-	Y	Y	Y	Y
ln HH income	-	-	-	-	Y	Y	Y
State-X-Year FEs	-	-	-	-	-	Y	Y
Quad. birth year	-	-	-	-	-	-	Y
Price in state of	Birth	Birth	Res	Birth	Birth	Birth	Birth
Sample	Stay	All	All	Stay	Stay	Stay	Stay

- Variation in formative window (DL age) increases strength
- ∼50-75% shift to transit Details

Panel Results

Estimates slightly larger in magnitude than event-study

- **-0.4pp** versus **-0.5pp** $\times$ **60%**
- Robust to many different definitions of treatment
  - So long as between ages 15 and 18 ...
- Robust to dropping to 1979/80 cohorts

Similar effects when using cohort FEs

- Only when using DL-age merge (some loss of power) Details

Changes matter more than levels

- Frictions to skill acquisition
- Learning that driving expenses are volatile
- Negative shocks | levels increase present bias (Haushofer and Fehr 2019)

Panel Results – Intensive Margin (VMT)

$P_{cs}^{\Delta 17,15}$	-0.0786**	-0.0822**	-0.0771**	-0.0773**	-0.0624*
	(0.0264)	(0.0260)	(0.0261)	(0.0259)	(0.0255)
P_{cs}^{16}	0.0213+	0.0202+	0.0190+	0.0198+	0.0032
	(0.0109)	(0.0110)	(0.0109)	(0.0111)	(0.0096)
$P_{cs}^{\Delta(m_{cs}+1,m_{cs}-1)}$	-0.0502*	-0.0567**	-0.0470*	-0.0478*	-0.0344+
	(0.0193)	(0.0197)	(0.0201)	(0.0204)	(0.0196)
$P_{cs}^{m_{cs}}$	0.0147	0.0127	0.0108	0.0108	-0.0027
	(0.0120)	(0.0120)	(0.0117)	(0.0118)	(0.0107)
NHTS year FEs	Y	Y	Y	-	-
State FEs	Y	Y	Y	-	-
Age FEs	Y	Y	Y	Y	Y
Controls	-	Y	Y	Y	Y
Income-by-Yr Bin FEs	-	-	Y	Y	Y
State-X-Yr FEs	-	-	-	Y	Y
Quad. birth year	-	-	-	-	Y

- Again, changes matter more than levels
- Change in vehicle choice? Details
  - Gallons-per-mile: no effect, but noisily measured
  - 1[light-duty truck]: modest suggestive evidence for negative effect

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Interpreting the Results

Extensive margin

Negative, long-run wage effects of coming of age during recession (Oreopoulus et al. 2012; Stuart 2019)

- Recessions often associated with large gas price movements

Are results due to an indirect effect of 'unlucky' timing into adulthood?

1. Controlling for contemporaneous income barely changes $\hat{\theta}$
2. Dropping those coming of age around 1979 barely changes $\hat{\theta}$
   - 1979/80 recession more about oil prices than others
3. Mediation: *Do unemployment at age 18 or current wage explain effect?*
   - Unemployment rate at age 18 explains 0% of effect
   - Income channel explains 2-24% of effect

Most of the effect is **not** due to income (or correlates)

- Points to a preference channel

Mediation Analysis

Jointly model both

- Joint effect of gas price shock T and mediator M on driving Y
- Effect of gas price shock T on mediator M

$$\begin{pmatrix} Y \\ M \end{pmatrix} = \begin{pmatrix} \theta^Y \\ \theta^M \end{pmatrix} T + \begin{pmatrix} \gamma \\ 0 \end{pmatrix} M + \begin{pmatrix} \delta^Y \\ \delta^M \end{pmatrix} X + \begin{pmatrix} \epsilon^Y \\ \epsilon^M \end{pmatrix}$$

- θ^Y – *Direct effect* of T on Y
- θ^M – Strength of confounding channel
- $\gamma\theta^M$ – *Indirect effect* of T on Y through M
- $\theta^Y + \gamma\theta^M$ – *Total effect* of T on Y from all channels

Two different mediators meant to capture potential scarring:

- Unemployment rate in state of treatment at age 18 (likely exogeneous)
- Contemporaneous income (less exogenous)

Interpret as providing data-consistent bounds on alternative stories

Mediation Analysis

Mediator (M):	Unempl. Rate at 18		Household income		Wage income		Personal income	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Effects of M and T on Y	1[drive]	1[drive]	1[drive]	1[drive]	1[drive]	1[drive]	1[drive]	1[drive]
θ^Y	-0.0042***	-0.0044***	-0.0038***	-0.0041***	-0.0032**	-0.0037**	-0.0031**	-0.0037**
	(0.0011)	(0.0010)	(0.0010)	(0.0011)	(0.0009)	(0.0010)	(0.0011)	(0.0012)
γ	0.0001	0.0000	0.0223***	0.0223***	0.0170***	0.0170***	0.0216***	0.0216***
	(0.0002)	(0.0002)	(0.0024)	(0.0024)	(0.0045)	(0.0045)	(0.0044)	(0.0045)
Effect of T on M	M	M	$\ln(M)$	$\ln(M)$	$\ln(M)$	$\ln(M)$	$\ln(M)$	$\ln(M)$
θ^M	1.0286***	0.0451	-0.0053	-0.0062+	-0.0488***	-0.0371***	-0.0460***	-0.0335***
	(0.2875)	(0.3481)	(0.0034)	(0.0036)	(0.0034)	(0.0034)	(0.0035)	(0.0033)
Direct effect (θ^Y)	-0.0042***	-0.0044***	-0.0038***	-0.0041***	-0.0032**	-0.0037**	-0.0031**	-0.0037**
	(0.0011)	(0.0010)	(0.0010)	(0.0011)	(0.0009)	(0.0010)	(0.0011)	(0.0012)
Indirect effect ($\gamma\theta^M$)	0.0001	0.0000	-0.0001	-0.0001	-0.0008**	-0.0006**	-0.0010***	-0.0007***
	(0.0002)	(0.0000)	(0.0001)	(0.0001)	(0.0002)	(0.0002)	(0.0002)	(0.0002)
Total effect ($\theta^Y + \gamma\theta^M$)	-0.0041***	-0.0044***	-0.0040***	-0.0042***	-0.0040***	-0.0043***	-0.0041***	-0.0044***
	(0.0010)	(0.0010)	(0.0010)	(0.0010)	(0.0008)	(0.0043)	(0.0010)	(0.0010)
Treatment definition (T)	$P_{cs}^{\Delta 17,15}$	$P_{cs}^{\Delta(m_{cs}\pm 1)}$	$P_{cs}^{\Delta 17,15}$	$P_{cs}^{\Delta(m_{cs}\pm 1)}$	$P_{cs}^{\Delta 17,15}$	$P_{cs}^{\Delta(m_{cs}\pm 1)}$	$P_{cs}^{\Delta 17,15}$	$P_{cs}^{\Delta(m_{cs}\pm 1)}$

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Placebo Tests – the Formative Window

Test for effect of gasoline price shocks at different ages

- Ages 13 through 29
- From 3 years before minimum DL age to 6 years after

Significant effects concentrate between ages 15 and 18

- No significant effects at younger ages
- Smaller, mostly insignificant effects at older ages
- Similar pattern across extensive and intensive margin!

Placebo Tests – the Formative Window

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
$a =$	13	14	15	16	17	18	19	20	21	22
$\tau =$	-3	-2	-1	0	1	2	3	4	5	6
Extensive (1[drive])										
$P_{cs}^{\Delta(a,a-1)}$	-0.0005	0.0012	-0.0001	-0.0054**	-0.0036**	-0.0023	-0.0009	0.0001	0.0005	0.0022*
	(0.0016)	(0.0012)	(0.0015)	(0.0016)	(0.0014)	(0.0016)	(0.0014)	(0.0017)	(0.0013)	(0.0011)
$P_{cs}^{\Delta(m_{cs}+\tau,m_{cs}+\tau-1)}$	0.0009	-0.0015	-0.0029	-0.0048***	-0.0044*	-0.0036*	0.0004	0.0012	0.0002	-0.0011
	(0.0012)	(0.0013)	(0.0019)	(0.0013)	(0.0018)	(0.0017)	(0.0020)	(0.0013)	(0.0014)	(0.0019)
Intensive (ln(person VMT))										
$P_{cs}^{\Delta(a,a-1)}$	-0.0567	0.0263	0.0211	-0.0949*	-0.1125**	-0.0954*	-0.0395	0.0080	-0.0253	-0.0169
	(0.0498)	(0.0374)	(0.0403)	(0.0428)	(0.0401)	(0.0374)	(0.0422)	(0.0378)	(0.0412)	(0.0366)
$P_{cs}^{\Delta(m_{cs}+\tau,m_{cs}+\tau-1)}$	-0.0571	-0.0120	-0.0204	-0.0606+	-0.0618+	-0.0678+	-0.0583	-0.0077	-0.0213	0.0198
	(0.0379)	(0.0428)	(0.0445)	(0.0350)	(0.0343)	(0.0346)	(0.0399)	(0.0376)	(0.0379)	(0.0406)

- Nothing significant from 22-29
- Effects persist for decades Details
  - Similar-sized effects at 45-54 as at 25-34
- Looks similar if use 2-year shocks

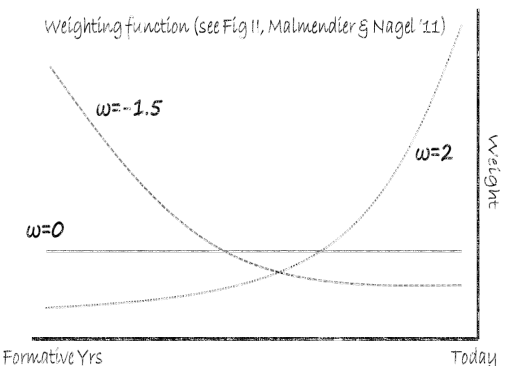
Cumulative Exposure Function

Malmendier & Nagel (2011) propose a cumulative exposure function

- Weights a vector of experiences (monotonically)
- Parameter determines whether weights are increasing/decreasing/flat
- We adapt to our setting (we exploit **state-level** variation in T)
  - Using prior results, exposure 'turns on' at age 15

$$Y_{icst} = \beta A_{cst}(\omega, \mathbf{T}_{st}) + \kappa_s + \delta_t + \eta_a + X'_{it}\lambda + \varepsilon_{icst}$$

$$A_{cst}(\omega, \mathbf{T}_{st}) = \sum_{k=15}^{\text{age}_{ct}-1} \frac{(k-14)^{\omega} \times T_{s,t-(\text{age}_{ct}-k)}}{\sum_{k=15}^{\text{age}_{ct}-1}(k-14)^{\omega}}$$



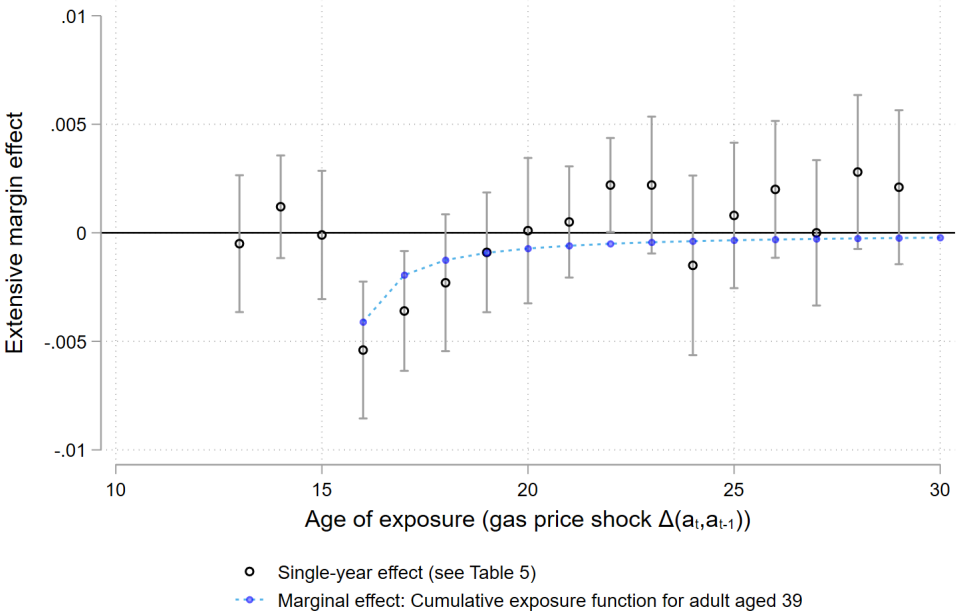
Cumulative Exposure Function – Results

	Extensive margin	Intensive margin
	1[drive]	ln(VMT)
	(1)	(2)
β $(A_{cst}(\omega, \mathbf{P}_s^{\Delta 1yr}))$	-0.0140**	-0.6796***
	(0.0045)	(0.1809)
ω (shape)	-1.0786***	-0.3294*
	(0.2796)	(0.1617)
Sample year FEs	Y	Y
State FEs	Y	Y
Age FEs	Y	Y

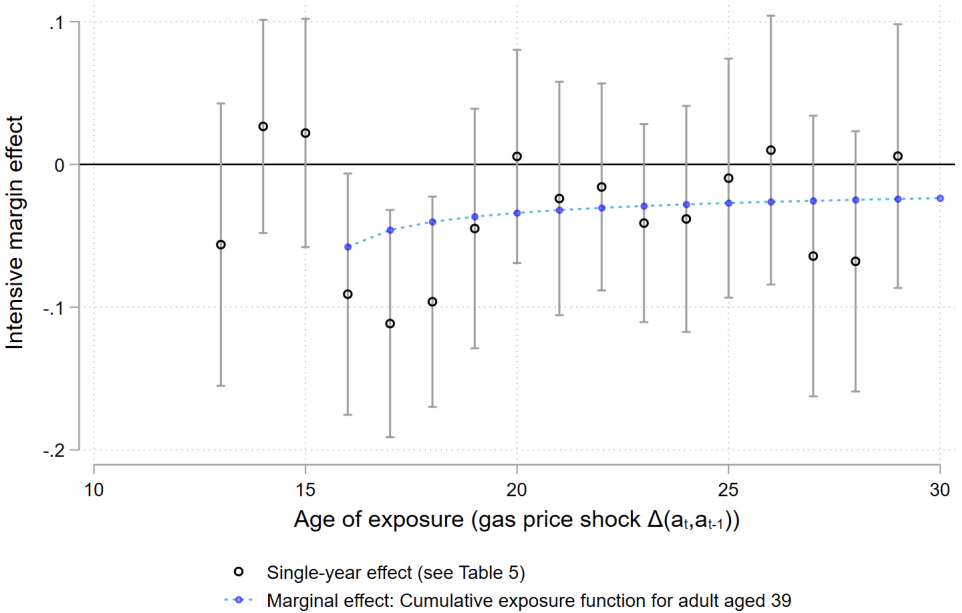
- Estimation via NLLS with grid-search for starting values
- Magnitude is specific to current age (ave. is 39) and age-at-exposure k
- To translate:

$$\frac{\partial Y_{icst}}{\partial T_{s,t-(\text{age}_{ct}-k)}} = \theta_{[k]} = \beta \times \frac{(k-14)^{\omega}}{\sum_{k=15}^{\text{age}_{ct}-1}(k-14)^{\omega}}$$

Placebo Tests & Cumulative Exposure Function (Extensive)



Placebo Tests & Cumulative Exposure Function(Intensive)



1. Data
2. The 1979/80 Oil Crisis
3. Long run effects of gasoline price movements
4. Mediation and robustness
5. Formative window and cumulative experience (placebo tests)
6. Mechanisms and interpretation

Mechanism – Did Fewer People Learn How to Drive?

Learning to drive is costly (time, vehicles, and fuel)

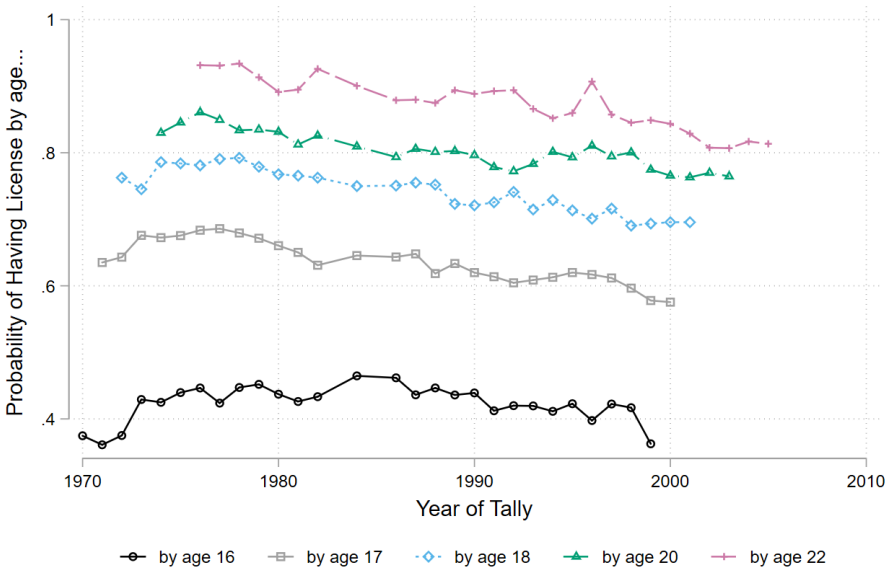
- Especially in U.S., driver learning takes placed during teen years
- Parental/family inputs important

Do higher learning costs (due to gasoline price shocks) keep people from learning to drive in the long run?

Probably not (if so, not quantitatively large)

1. No straightforward explanation for intensive margin effect
2. No strong evidence teens reduce take up of licenses around '79 crisis
3. Explicit minimum driver licensing age requirements do not have negative effect on later-life driving rates

Driver License Uptake



Data: FHWA DL-220 (2016) "Licensed Drivers, by Sex and Age Group" (data from 1963 to 2016; 1983 and 1985 imputed). SEER data on population by age

Effects of Driver Licensing Restrictions

If increasing costs delay licensing, and fewer people learn to drive, **explicit minimum age requirements** likely do the same

We test for the effect of the full-privilege and intermediate minimum driving age on later-life driving and VMT

- Misc. changes in the 70s and 80s
- Widespread GDL adoption starting in the mid-90s

Legal restrictions **more extreme** than gas price hikes

- Youngsters caught driving without a license can be disallowed a license until the age of 18 in most states
- If legal minimum driving age has no effect, unlikely that gas prices affect driving through reduced license takeup

Effects of Driver Licensing Restrictions

	(1)	(2)	(3)	(4)	(5)	(6)
Extensive (1[drive])						
Minimum Full Privilege Age	0.0078	0.0048	0.0071	0.0072	0.0082+	0.0092
	(0.0052)	(0.0040)	(0.0047)	(0.0048)	(0.0048)	(0.0056)
Minimum Intermediate License Age	-0.0107	-0.0088	-0.0091	-0.0097	-0.0137	-0.0124
	(0.0147)	(0.0122)	(0.0136)	(0.0138)	(0.0127)	(0.0121)
Sample	Stay	All	Stay	Stay	Stay	Stay
Intensive (ln(person VMT))						
Minimum Full Privilege Age	0.0012		0.0010	-0.0030	-0.0108	0.0196
	(0.0129)		(0.0132)	(0.0159)	(0.0182)	(0.0143)
Minimum Intermediate License Age	-0.0269		-0.0239	-0.0270	-0.0007	0.0239
	(0.0651)		(0.0565)	(0.0592)	(0.0699)	(0.0588)
Sample year FEs	Y	Y	Y	Y	-	-
State FEs	Y	Y	Y	Y	-	-
Age (FEs)	Y	Y	Y	Y	Y	Y
Dem. Controls	-	-	Y	Y	Y	Y
Income controls	-	-	-	Y	Y	Y
State-X-Yr FEs	-	-	-	-	Y	Y
Quad. birth year	-	-	-	-	-	Y

- Combined effect on 1[drive] of raising age by one year is small-ish
- Combined VMT coefficients small relative to doubling of gas prices
- Therefore, our earlier effects most likely reflect a shift in preferences

1. Data
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6. Mechanisms and interpretation
7. Conclusion

Summary and Conclusion

Panel estimates: Doubling of gas prices during early driving years $\rightarrow$

- (-0.2,-0.5)pp drive to work later in life
- (-3.4,-8.2)% VMT later in life
- Compensating substitution toward transit

Formative experiences important to understand behavior

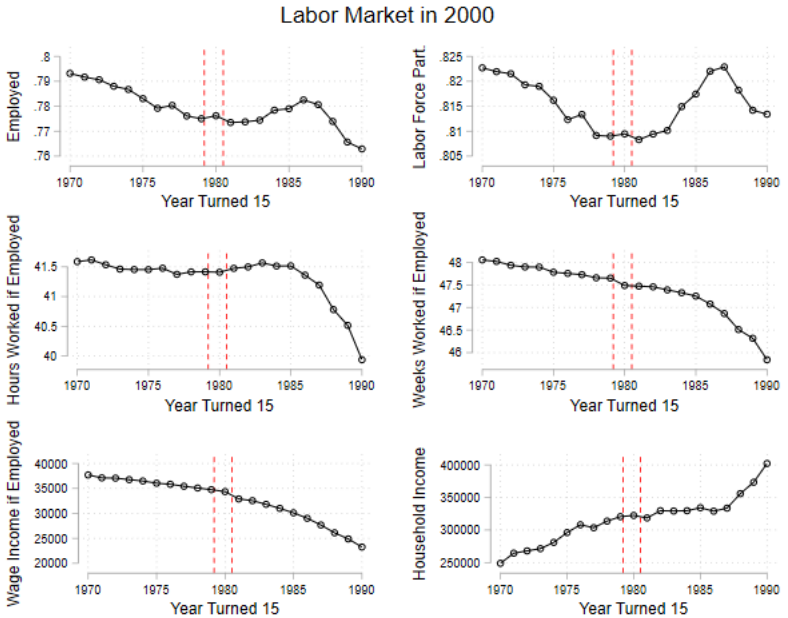
- Consumption behavior 'imprinted' from initial interactions
- Appears more important than cumulative experience in this setting
  - At very least, behavior is complicated function of prior experience
- Alternative channels cannot explain results

Some (speculative) consequences for policy

- Early experiences matter, but in particular ways
- A large carbon tax could have an imprintation effect
- Positive environmental and public safety consequences

Thank you!

The 1979/80 Oil Crisis – Covariate Smoothness



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The 1979/80 Oil Crisis – with Covariates

Event study estimates without covariates: -0.21 to -0.50pp

Model	Poly. order	Bandwidth (years) 2	3	4	5	6	7	8	9	10
Panel A: Effect on driving, no controls										
	1	-0.0050*	-0.0029+	-0.0026+	-0.0032**	-0.0026*	-0.0027**	-0.0032**	-0.0032**	-0.0029**
		(0.0022)	(0.0016)	(0.0014)	(0.0012)	(0.0011)	(0.0010)	(0.0009)	(0.0009)	(0.0008)
	2				-0.0033	-0.0039*	-0.0032+	-0.0021	-0.0027+	-0.0032*
					(0.0022)	(0.0019)	(0.0016)	(0.0015)	(0.0014)	(0.0013)
Panel B: Effect on driving, controls:										
+ demographics	1	-0.0046*	-0.0025	-0.0023+	-0.0029*	-0.0025*	-0.0024*	-0.0028**	-0.0026**	-0.0021*
		(0.0022)	(0.0016)	(0.0014)	(0.0012)	(0.0011)	(0.0010)	(0.0009)	(0.0009)	(0.0008)
	2				-0.0028	-0.0035+	-0.0030+	-0.0020	-0.0026+	-0.0034**
					(0.0022)	(0.0018)	(0.0016)	(0.0015)	(0.0014)	(0.0013)
Panel C: Effect on driving, controls:										
+ demographics, state of birth FEs	1	-0.0046*	-0.0023	-0.0019	-0.0025*	-0.0020+	-0.0019+	-0.0022*	-0.0020*	-0.0014+
		(0.0022)	(0.0016)	(0.0013)	(0.0012)	(0.0011)	(0.0010)	(0.0009)	(0.0009)	(0.0008)
	2				-0.0027	-0.0031+	-0.0027+	-0.0019	-0.0024+	-0.0030*
					(0.0021)	(0.0018)	(0.0016)	(0.0015)	(0.0014)	(0.0013)
Panel D: Effect on driving, controls:										
+ demographics, state of birth FEs	1	-0.0046*	-0.0022	-0.0018	-0.0024*	-0.0019+	-0.0017+	-0.0021*	-0.0019*	-0.0013
+ ln(income)		(0.0022)	(0.0016)	(0.0013)	(0.0012)	(0.0011)	(0.0010)	(0.0009)	(0.0009)	(0.0008)
	2				-0.0027	-0.0030+	-0.0026	-0.0018	-0.0023	-0.0029*
					(0.0021)	(0.0018)	(0.0016)	(0.0015)	(0.0014)	(0.0013)
N		545k	811k	1075k	1343k	1614k	1888k	2148k	2398k	2642k

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The 1979/80 Oil Crisis – Other Outcomes

Poly. order	Bandwidth (years) 2	3	4	5	6	7	8	9	10
Panel A: Transit usage									
1	0.0036*	0.0027*	0.0027**	0.0023**	0.0017*	0.0016*	0.0016**	0.0015**	0.0018**
	(0.0015)	(0.0011)	(0.0009)	(0.0008)	(0.0007)	(0.0007)	(0.0006)	(0.0006)	(0.0005)
2				0.0038**	0.0037**	0.0030**	0.0023*	0.0024**	0.0018*
				(0.0014)	(0.0012)	(0.0011)	(0.0010)	(0.0009)	(0.0009)
N	545k	811k	1075k	1343k	1614k	1888k	2148k	2398k	2642k
Panel B: No vehicle access									
1	0.0033*	0.0026*	0.0020*	0.0016+	0.0009	0.0007	0.0005	-0.0002	-0.0012*
	(0.0016)	(0.0011)	(0.0010)	(0.0008)	(0.0008)	(0.0007)	(0.0007)	(0.0006)	(0.0006)
2				0.0037*	0.0034**	0.0027*	0.0023*	0.0028**	0.0034**
				(0.0015)	(0.0013)	(0.0012)	(0.0011)	(0.0010)	(0.0009)
N	698k	1038k	1376k	1717k	2061k	2409k	2739k	3058k	3370k

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The 1979/80 Oil Crisis – Subgroup Analysis

Model	Poly. order	Bandwidth (years) 2	3	4	5	6	7	8	9	10
Panel A: Effect on driving										
Sample: Principal city	1	-0.0185*	-0.0120+	-0.0108*	-0.0124**	-0.0092*	-0.0061	-0.0090*	-0.0096**	-0.0094**
		(0.0089)	(0.0065)	(0.0054)	(0.0047)	(0.0043)	(0.0039)	(0.0037)	(0.0035)	(0.0033)
	2				-0.0157+	-0.0167*	-0.0163*	-0.0087	-0.0085	-0.0096+
					(0.0085)	(0.0073)	(0.0065)	(0.0059)	(0.0055)	(0.0051)
	N	62k	92k	122k	154k	187k	220k	252k	283k	313k
Panel B: Effect on driving										
Sample: Not in metro	1	-0.0030	0.0004	0.0000	0.0013	0.0008	0.0014	0.0002	0.0003	0.0006
		(0.0042)	(0.0030)	(0.0025)	(0.0022)	(0.0020)	(0.0019)	(0.0017)	(0.0017)	(0.0016)
	2				-0.0016	0.0003	-0.0002	0.0022	0.0013	0.0006
					(0.0041)	(0.0035)	(0.0031)	(0.0028)	(0.0026)	(0.0024)
	N	114k	170k	225k	280k	336k	393k	447k	500k	552k
Panel C: Effect on driving										
Sample: Black	1	-0.0168*	-0.0099	-0.0107*	-0.0107*	-0.0067+	-0.0052	-0.0048	-0.0019	0.0002
		(0.0083)	(0.0061)	(0.0050)	(0.0045)	(0.0040)	(0.0037)	(0.0035)	(0.0033)	(0.0031)
	2				-0.0145+	-0.0176*	-0.0144*	-0.0118*	-0.0135**	-0.0136**
					(0.0080)	(0.0068)	(0.0061)	(0.0056)	(0.0052)	(0.0048)
	N	57k	84k	111k	139k	166k	193k	220k	245k	270k
Panel D: Effect on driving										
Sample: No college	1	-0.0037	-0.0017	-0.0022	-0.0027*	-0.0020+	-0.0023*	-0.0028**	-0.0023*	-0.0016+
		(0.0025)	(0.0018)	(0.0015)	(0.0014)	(0.0012)	(0.0011)	(0.0011)	(0.0010)	(0.0009)
	2				-0.0021	-0.0033	-0.0022	-0.0016	-0.0027+	-0.0036*
					(0.0025)	(0.0021)	(0.0019)	(0.0017)	(0.0016)	(0.0015)
	N	394k	585k	774k	965k	1157k	1350k	1534k	1711k	1883k

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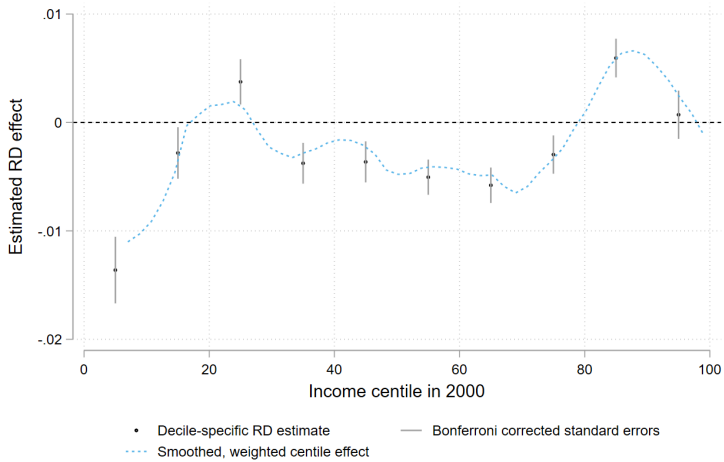
The 1979/80 Oil Crisis – Subgroup Analysis by Income



Estimated with a 5 year window and linear trends in time.

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Minimum Driver Licensing Ages

Year	[14,14.5)	[14.5,15.5)	[15.5,16.5)	[16.5,17.5)	[17.5,18]
Minimum Full Privilege License Age					
1970	1	5	38	4	3
1980	0	5	39	5	2
1990	0	5	39	5	2
2000	0	2	24	18	7
2010	0	0	4	32	15
Minimum Provisional License Age					
1970	2	7	39	3	0
1980	2	7	40	2	0
1990	1	7	41	2	0
2000	1	4	41	5	0
2010	1	2	39	9	0
Learner's Permit Minimum Age					
1972	8	18	24	1	0
1980	8	21	22	0	0
1988	7	22	22	0	0
1994	6	24	21	0	0
2010	6	25	20	0	0

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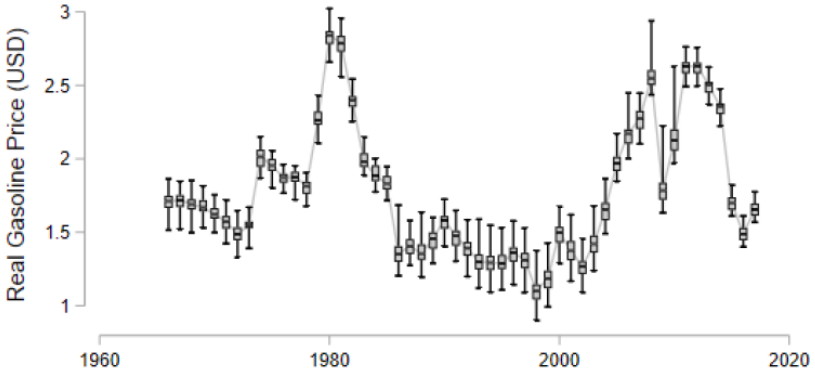
Gasoline Prices in Levels



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Panel Results – Extensive Margin (Other Outcomes)

	Transit Usage		Vehicle Available			
	1[transit] (1)	1[transit] (2)	1[vehicle] (3)	1[vehicle] (4)	1[vehicle] (5)	1[vehicle] (6)
$P_{cs}^{\Delta 17,15}$	0.0029***	0.0024**	-0.0014	-0.0009	-0.0019*	-0.0018**
	(0.0007)	(0.0009)	(0.0008)	(0.0006)	(0.0009)	(0.0006)
P_{cs}^{16}	0.0001	0.0004	0.0004	0.0007	-0.0007	-0.0001
	(0.0007)	(0.0005)	(0.0007)	(0.0005)	(0.0009)	(0.0007)
$P_{cs}^{\Delta(m_{cs}+1,m_{cs})}$	0.0028*	0.0021	-0.0025	-0.0023+	-0.0019	-0.0022
	(0.0012)	(0.0013)	(0.0016)	(0.0013)	(0.0016)	(0.0013)
$P_{cs}^{m_{cs}}$	0.0006	0.0008	0.0001	0.0003	-0.0008	-0.0005
	(0.0007)	(0.0005)	(0.0007)	(0.0005)	(0.0008)	(0.0006)
Census year FEs	Y	-	Y	-	Y	-
State of birth FEs	Y	-	Y	-	Y	-
Age FEs	Y	Y	Y	Y	Y	Y
Demographics	-	Y	-	Y	-	Y
ln HH income	-	Y	-	Y	-	Y
State-X-Year FEs	-	Y	-	Y	-	Y
Quad. birth year	-	Y	-	Y	-	Y
Sample	Empl	Empl	Empl	Empl	All	All

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Panel Results – Cohort FEs

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	1[drive] (1)	1[drive] (2)	1[drive] (3)	1[drive] (4)
2-year price change				
$P_{cs}^{\Delta(m_{cs}+2,m_{cs})}$	-0.0041+	-0.0039+	-0.0038+	-0.0037+
	(0.0023)	(0.0021)	(0.0021)	(0.0020)
$P_{cs}^{\Delta(m_{cs}+1,m_{cs}-1)}$	-0.0016	-0.0016	-0.0012	-0.0017
	(0.0019)	(0.0019)	(0.0019)	(0.0019)
1-year price change				
$P_{cs}^{\Delta(m_{cs}+2,m_{cs}+1)}$	-0.0057*	-0.0053*	-0.0054*	-0.0048*
	(0.0024)	(0.0022)	(0.0021)	(0.0021)
$P_{cs}^{\Delta(m_{cs}+1,m_{cs})}$	-0.0019	-0.0018	-0.0016	-0.0019
	(0.0025)	(0.0025)	(0.0025)	(0.0025)
$P_{cs}^{\Delta(m_{cs},m_{cs}-1)}$	-0.0009	-0.0009	-0.0004	-0.0008
	(0.0024)	(0.0023)	(0.0024)	(0.0024)
Levels				
$P_{cs}^{m_{cs}}$	-0.0013	-0.0015	-0.0020	-0.0022
	(0.0026)	(0.0024)	(0.0024)	(0.0019)
Census year FEs	Y	Y	Y	Y
State of birth FEs	Y	Y	Y	Y
Age FEs	Y	Y	Y	Y
Birth year FEs	Y	Y	Y	Y
Demographics	-	Y	Y	Y
ln HH income	-	-	Y	Y
State-X-year FEs	-	-	-	Y

Effect on Vehicle Efficiency and Type

	Gallons per mile				Truck, SUV, etc.			
	Ave GPM (1)	Ave GPM (2)	GPM (3)	GPM (4)	Any Big (5)	Any Big (6)	1[Big] (7)	1[Big] (8)
$P_{cs}^{\Delta(18,16)}$	-0.0000	-0.0001	-0.0001	-0.0001	-0.0265**	-0.0245*	-0.0193*	-0.0194+
	(0.0003)	(0.0003)	(0.0003)	(0.0003)	(0.0095)	(0.0101)	(0.0092)	(0.0097)
$P_{cs}^{\Delta(17,15)}$	0.0000	-0.0002	-0.0002	-0.0003	-0.0213+	-0.0173	-0.0155	-0.0141
	(0.0003)	(0.0003)	(0.0002)	(0.0002)	(0.0111)	(0.0112)	(0.0106)	(0.0104)
$P_{cs}^{\Delta(m_{cs}+2,m_{cs})}$	0.0001	0.0001	-0.0001	-0.0000	-0.0203*	-0.0169+	-0.0141	-0.0110
	(0.0003)	(0.0003)	(0.0003)	(0.0003)	(0.0090)	(0.0085)	(0.0094)	(0.0085)
$P_{cs}^{\Delta(m_{cs}+1,m_{cs}-1)}$	-0.0002	-0.0003	-0.0003	-0.0004	-0.0238+	-0.0209	-0.0193	-0.0179
	(0.0003)	(0.0003)	(0.0003)	(0.0003)	(0.0126)	(0.0125)	(0.0117)	(0.0116)
NHTS year FEs	Y	-	Y	-	Y	-	Y	-
State FEs	Y	-	Y	-	Y	-	Y	-
Age FEs	Y	Y	Y	Y	Y	Y	Y	Y
Demographic Controls	-	Y	-	Y	-	Y	-	Y
Income-by-Yr Bin FEs	-	Y	-	Y	-	Y	-	Y
State-X-Yr FEs	-	Y	-	Y	-	Y	-	Y
Vehicle Age	-	-	Y	Y	-	-	Y	Y
Quad. Vehicle year	-	-	Y	Y	-	-	Y	Y
Sample	Person	Person	Vehicle	Vehicle	Person	Person	Vehicle	Vehicle

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Persistence

	Extensive		Intensive	
	1[drive] (1)	1[drive] (2)	ln(VMT) (3)	ln(VMT) (4)
$P_{cs}^{\Delta 17,15} \times$				
1[25-34]	-0.0050**	-0.0054***	-0.0890*	-0.0552
	(0.0018)	(0.0013)	(0.0433)	(0.0425)
1[35-44]	-0.0001	0.0006	-0.0529	-0.0328
	(0.0014)	(0.0014)	(0.0578)	(0.0524)
1[45-54]	-0.0050***	-0.0054***	-0.0925+	-0.1111*
	(0.0014)	(0.0013)	(0.0516)	(0.0497)
$P_{cs}^{\Delta(m_{cs}+1,m_{cs}-1)} \times$				
1[25-34]	-0.0031*	-0.0039*	-0.0464	-0.0279
	(0.0015)	(0.0015)	(0.0341)	(0.0323)
1[35-44]	-0.0038*	-0.0019	-0.0595	-0.0581
	(0.0019)	(0.0014)	(0.0479)	(0.0474)
1[45-54]	-0.0056**	-0.0069**	-0.0445	-0.0406
	(0.0019)	(0.0020)	(0.0427)	(0.0425)
Sample year FEs	Y	Y	Y	Y
State FEs	Y	Y	Y	Y
Age FEs	Y	Y	Y	Y
Demographics	-	Y	-	Y
Income	-	Y	-	Y
State-X-Year FEs	-	Y	-	Y
Quad. birth year	-	Y	-	Y

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Habit Formation

Is this just habit formation at work? Consider simple model (d, driving)

$$\max_{c,d} U(c_t, d_t, d_{t-1}) \text{ s.t. } c_t + p_t^d d_t \leq I$$

Model predictions

1. $d_{t-1} \to d_t$
2. $p_{t-1}^d \to d_{t-1} \to d_t$
3. $p_{t-1}^d | d_{t-1} \not\to d_t$

We see:

- Past prices matter, even conditional on past use ~~(3)~~
- Price shocks matter more than price levels
- Intensive and extensive margins effects
- Don't see past consumption effect ~~(2)~~
- Shock only matters in a narrow window