Econometrica Supplementary Material

SUPPLEMENT TO "(S)CARS AND THE GREAT RECESSION"

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ORAZIO ATTANASIO
Department of Economics, Yale University, Institute for Fiscal Studies, FAIR at NHH, and NBER

KIERAN LARKIN
Institute for International Economic Studies, Stockholm University

MORTEN O. RAVN
Department of Economics, University College London and Centre for Economic Policy Research

MARIO PADULA
Commissione di Vigilanza sui Fondi Pensione (COVIP) and Department of Economics, Università Ca' Foscari di Venezia

This Appendix contains (i) data documentation; (ii) details of the numerical solution method; (iii) details on the measurement of shocks; (iv) an analysis of uncertainty shocks; (v) details of the Clash for Clunkers analysis; (vi) additional tables; (vii) additional figures.

S1. DATA DESCRIPTION

S1.1. *Data Construction, Definition, and Sources*

OUR CORE CEX extract covers the sample period 1981–2012. For the aggregate level series, we use quarterly expenditure by a household (summing across monthly reported expenditures) to calculate the average expenditure in each quarter. For aggregate moments, we use all households in the survey and apply a seasonal adjustment. For life-cycle cohorts, we take an average across households quarterly spending in a given cohort-year cell and multiply by four to get an annualized measure. We assign the cohort the median age of the group. For household level micromoments, we aggregate expenditure to the household level and assign the relevant year. For model targets, we use the sample of households aged 25–84, consistent with our model calibration.

Except for the value of car purchases, we adjust for households with missing quarters by a simple four divided by the number of quarterly observations present weighting. For the value of car purchases, we use the unadjusted measure to avoid inflating infrequent purchases. We summarize sources and definitions of variables in Table A.1.

S1.2. *Cohort Data Used and Time Period Definitions*

We use CEX data at the household-year observation level and construct aged based cohorts. Our baseline is the average recession value of a cohort in 2008–2010, relative to the level in 2007. We use the same recession period in the data, but a longer baseline (2006–2007) to ensure the results are not overly affected by a small number of observations in a

Orazio Attanasio: orazio.attanasio@yale.edu
Kieran Larkin: kieran.larkin@iies.su.se
Morten O. Ravn: m.ravn@ucl.ac.uk
Mario Padula: mpadula@unive.it

TABLE A.1

DATA DEFINITIONS.

Variable	Source	Period	Description
Car purchase	CEX	1981–2018	Dummy variable equal to one if household reports a positive car purchase value.
Value|purchase	CEX	1981–2018	Summation of the value of new and used car purchases. In aggregate statistics, we include the value of trade in credit. When comparing the model to the data, this is excluded to match definition. Deflated by New Car CPI and Used Car CPI. In Sections 2.1–2.3, we deflate with the all item CPI.
Stock of cars	CEX	1981–2012	From an average of CEX imputed values using dummies for the car model.
Nondurables	CEX	1981–2012	Includes: food in and out, alcohol and tobacco, fuel, education, clothing, insurance payments, transport costs, child care, medical and hospital bills, entertainment, and donations. Deflated by CPI.
Consump. growth	CEX	1981–2012	The log. difference between consumption reported by households in the 1st quarter interviewed in the survey and 4th quarter in the survey. Three quarter growth rate is multiplied by 4/3 to recover an annualized value.
Life-cycle income	CEX	1981–2012	*To estimate the deterministic life-cycle profile*. Log of the sum of head and spouse/partner labor earnings. Drop observations earning less the $10,000 or where the household head works less than an average of 20 hours a week.
Income	NIPA	1950–2019	*Used for predicted consumption regressions and income shocks pre-1964* wages and salary, compensation of employees (Tb:2.1,Ln:3) deflated by the PCE deflator (Tb:1.1.4,Ln:2) and divided by the mid-year population (Tb 2.1,Ln: 40).
Nondurables	NIPA	1970–2019	Nondurable goods (Tb:2.3.5,Ln:8) and Services (Tb:2.3.5,Ln:13) divided by PCE deflator and mid-year population.
Car expenditure	NIPA	1970–2019	Motor vehicles and parts (Tb:2.3.5,Ln:4) divided by PCE deflator and mid-year population.
Savings rate	NIPA	1980–2015	Personal saving (Tb:2.1,Ln:34) divided by disposable personal income (Tb:2.1,Ln:27).
Income	CPS	1964–2015	*Income measure from 1964 onwards.* Income from wages for all household members. Income to zero if households report no income and report being unemployed. Wage reported in March for previous year. The wage is deflated by the PCE deflator.
Rate spread	FRB G19	1971–2015	Average of New Car Average Finance Rate at Auto Finance Companies and the Finance Rate on Consumer Installment Loans at Commercial Banks, New Autos 48-Month Loan. We subtract inflation. Series weighted according to Attanasio, Goldberg, and Kyriazidou (2008).
Car loans	FRB G19	1980–2015	Motor Vehicle Loans Owned and Securitized.
House price index	FHFA	1975–2015	All-Transactions House Price Index. Deflated by the CPI.
Stock price index	Yahoo	1960–2015	S&P 500 Adjusted Close Price. Deflated by the CPI.

(*Continues*)

TABLE A.1
Continued.

Variable	Source	Period	Description
Fuel price	BLS	1967–2015	*Estimate AR(1) process of the detrended log.* Price index for Gasoline (all types). Deflated by CPI.
Portfolio shares	SCF	2004	*Estimate the housing and stock share of net wealth.* Housing is primary residence and other real estate. Stock holdings includes corporate stock, mutual funds, and other business equity.

Note: CEX: Consumer Expenditure Survey, NIPA: National Income and Product Account, BEA: Bureau of Economic Affairs. CPS: Current Population Survey Annual Social and Economic Supplement, FRB: Federal Reserve Board, FHFA: US Federal Housing Finance Agency, BLS: Bureau of Labor Statistics. SCF: Survey of Consumer Finance. PCE: Personal Consumption Expenditures. CPI: Consumer Price Index Tb: Table, Ln: Line.

given year. For a few variables, we make an adjustment to reflect features of the data and model. In particular, for the share of households with net saving, we move the effect one period onwards in the model to capture the full effect of the growth shock.

- **Consumption growth:** data: log change in household consumption between first quarter and last quarter of interview. Multiplied by (4/3) to give an annual value (CEX). pre: 2007, recession period: 2008–2010.
- **Car expenditure:** data: expediture on new and used cars (CEX). pre: 2007, recession period: 2008–10.
- **% purchase:** data: dummy variable for if a household purchased a car (CEX). pre: 2007, recession period: 2008–2010.
- **Car value:** data: expenditure on new and used cars. No value if no car purchased (CEX) pre: 2007, recession period: 2008–2010.
- **share net saving** data: Dummy variable set to 1 if household reports financial income after tax that is greater than expenditure on nondurables and cars (CEX).
  - *data:-* pre: 2006–2007, recession period: 2008–2010;
  - *model:-* pre: 2008, recession period: 2009–2011.
- **Car loans:** data: stock of loans reported by household. No value if no car loan reported (CEX). pre: 2007, recession period: 2008–2010.

S2. MODEL: VALUE FUNCTIONS AND COMPUTATION

S2.1. *Household Dynamic Programming Problems*

Consider the dynamic programming problem for a household of age a. The household chooses the vector $h^j_{a,s} = (c^j_{a,s}, d^j_{a,s+1}, i^j_{a,s}, \vartheta^j_{a,s}, b^j_{a,s+1}, k^j_{a,s+1}, f_{a,s})$ given the relevant state variables $s^j_a = (d^j_{a-1,s} b^j_{a-1,s}, k^j_{a-1,s}, \delta^j_{a,s}, a, p^j_{a,s}, u^j_{a,s}, m^j_{a,s}, x_s)$ where the exogenous aggregate variables are collected in the vector $x_s = (g_{a,s}, \sigma^2_{\upsilon,s}, \sigma^2_{\varepsilon,s}, r^c_s, q_{a,s}, q_{F,s})$.

We remove time, age, and individual indicators. The household choices will be determined by the outer envelope of two value functions:

$$\mathbb{W}(s) = \max\bigl(\mathbb{W}^p(s), \mathbb{W}^{np}(s)\bigr), \tag{S1}$$

where $\mathbb{W}^p(s)$ is the value of actively adjusting the household car stock (i.e., purchasing or selling) and $\mathbb{W}^{np}(s)$ is the value of nonadjusting (maintenance). Bellman's equation for an adjusting household is given as

$$\mathbb{W}^p(s) = \max_h u_a\big(c, \mathbf{D}'(d')\big) + \beta\pi(a)\mathbb{E}\big(\mathbb{W}(s')\big) \tag{S2}$$

subject to the constraints for the car law of motion, budget constraint, borrowing constraint and income specification, and imposing $\delta' = \delta^N$ such that households who adjust their car stock avoid breakdown risk in the first period thereafter.

The value of nonadjusting is

$$\mathbb{W}^{np}(s) = \max_{h^{np}} u_a\big(c, \mathbf{D}'(d')\big) + \beta\pi(a)\mathbb{E}\big(\mathbb{W}(s')\big) \tag{S3}$$

subject to the car law of motion, budget constraint, borrowing constraint, and income specification imposing that car investment equals maintenance, $d' = (1 - \delta\varphi)d$.

Having solved the household choice problems, we define aggregate variables as

$$z_s = \frac{\sum_{a=a_0}^{a_{\max}} \lambda_a \int_{s_a} z_a^j(s_a)\, d\mu_a(s_a)}{\sum_{a=a_0}^{a_{\max}} \lambda_a}, \tag{S4}$$

where $\mu_a(s_a)$ denotes the distribution of cohort a agents over the states.

S2.2. *Solving the Dynamic Programming Problems*

For ease of exposition and with no loss of generalization, we condense the decision whether to adjust or not into the choice of d' and, therefore, we ignore the max operator in equation (S1) above. Further, given the positive interest rate spread $r_k > 0$, no household will find it optimal to hold both savings and a car loan. Therefore, we can consider a single asset k, with a kink in the interest rate schedule, and shocks to the return that are only present when $k > 0$.

To solve the dynamic programme problem for a household of age a, we first redefine variables in terms of permanent assets and income

$$V_a(k, d, r_k, q, P, U, G_{a,j}) = \max_{c,d',k'} u\big(c, d'\big) + \beta\mathbf{E}V_{a+1}\big(k', d', r_k', q', P', U', G_{a+1,j'}\big)$$

subject to

$$\begin{aligned}
c + qk' \cdot \mathbb{1}\big[k' \geq 0\big] + k' \cdot \mathbb{1}\big[k' < 0\big] + d' = {} & (1+r)qk \cdot \mathbb{1}[k \geq 0] \\
& + \big(1 + r + r^k\big)k \cdot \mathbb{1}[k < 0] \\
& + (1-\delta)d - \Psi d \cdot \mathbb{1}[\text{adj}] + Y, \\
k' \geq {} & -\eta d', \\
Y = {} & PU, \\
P = {} & G_{a,j}P_{-1}V, \\
q = {} & q_{-1}W.
\end{aligned}$$

Given the restriction $q > 0$, we can define

$$\mathbf{k}' = \begin{cases} qk' & \text{if } k' \geq 0, \\ k' & \text{if } k' < 0. \end{cases}$$

It therefore follows that if $k' > 0$,

$$\begin{aligned} qk &= \frac{q}{q_{-1}}\mathbf{k} \\ &= W\mathbf{k}. \end{aligned}$$

We can rewrite the problem, removing the asset price q as a state variable:

$$V_a(\mathbf{k}, d, r_k, P, U, G_{a,j}) = \max_{c,d',\mathbf{k}'} u\big(c, d'\big) + \beta \mathbf{E} V_{a+1}\big(\mathbf{k}', d', r_k', P', U', G_{a+1,j'}\big)$$

subject to

$$\begin{aligned} c + \mathbf{k}' + d' &= (1+r)W\mathbf{k} \cdot \mathbb{1}[\mathbf{k} \geq 0] + \big(1 + r + r^k\big)\mathbf{k} \cdot \mathbb{1}[\mathbf{k} < 0] \\ &\quad + (1-\delta)d - \Psi d \cdot \mathbb{1}[\text{adj}] + Y, \\ \mathbf{k}' &\geq -\eta d', \\ Y &= PU, \\ P &= G_{a,j} P_{-1} V. \end{aligned}$$

Now redefine assets in terms of the maximum collateral constraint, $b' = \mathbf{k'} + \eta d'$ so that we can express the dynamic programming problem as

$$V_a(b, d, r_k, P, U, G_{a,j}) = \max_{c,d',b'} u\big(c, d'\big) + \beta \mathbf{E} V_{a+1}\big(b', d', r_k', P', U', G_{a+1,j'}\big)$$

subject to

$$\begin{aligned} c + b' + (1-\eta)d' &= (1+r)W(b - \eta d) \cdot \mathbb{1}\big[(b \geq \eta d)\big] \\ &\quad + \big(1 + r + r^k\big)(b - \eta d) \cdot \mathbb{1}\big[(b < \eta d)\big] \\ &\quad + (1-\delta)d - \Psi d \cdot \mathbb{1}[\text{adj}] + Y, \\ b' &\geq 0, \\ Y &= PU, \\ P &= G_{a,j} P_{-1} V. \end{aligned}$$

Next, we scale consumption and assets by permanent income by defining: $\tilde{c} = c/P$, $\hat{b}' = b'/P$ and $\hat{d}' = d'/P$. Using these normalizations, the above program can be rewritten as

$$\left(\frac{1}{P}\right)^{1-\rho} V_a(\tilde{b}, \tilde{d}, r_k, U, G_{a,j}) = \max_{\tilde{c},\hat{d}',\hat{b}'} u\big(\tilde{c}, \hat{d}'\big) + \beta \mathbf{E}\left(\frac{1}{P}\right)^{1-\rho} V_{a+1}\big(\tilde{b}', \tilde{d}', r_k', U', G_{a+1,j'}\big)$$

subject to

$$\begin{aligned}\tilde{c}+\hat{b}'+(1-\eta)\hat{d}' &= (1+r)W(\tilde{b}-\eta\tilde{d})\cdot\mathbb{1}\big[(\tilde{b}\geq\eta\tilde{d})\big]\\ &\quad+\big(1+r+r^k\big)(\tilde{b}-\eta\tilde{d})\cdot\mathbb{1}\big[(\tilde{b}<\eta\tilde{d})\big]\\ &\quad+(1-\delta)\tilde{d}-\Psi\tilde{d}\cdot\mathbb{1}[\text{adj}]+U,\\ \tilde{b}' &\geq 0,\\ \tilde{b}' &= \frac{P}{P'}\hat{b}',\qquad \tilde{d}'=\frac{P}{P'}\hat{d}'.\end{aligned}$$

Now let $\tilde{V}_a(\cdot)=(\frac{1}{P})^{1-\rho}V_a(\cdot)$. Then as $P/P'=G_{a+1,j'}V'$, it follows that we can rewrite the previous problem as

$$\tilde{V}_a(\tilde{b},\tilde{d},r_k,U,G_{a,j}))=\max_{\tilde{c},\hat{d}',\hat{b}'}u\big(\tilde{c},\hat{d}'\big)+\beta\mathbf{E}\big(G_{a+1,j'}V'\big)^{1-\rho}\tilde{V}_{a+1}\big(\tilde{b}',\tilde{d}',r_k',U',G_{a+1,j'}\big)$$

subject to

$$\begin{aligned}\tilde{c}+\hat{b}'+(1-\eta)\hat{d}' &= (1+r)W(\tilde{b}-\eta\tilde{d})\cdot\mathbb{1}\big[(\tilde{b}\geq\eta\tilde{d})\big]\\ &\quad+\big(1+r+r^k\big)(\tilde{b}-\eta\tilde{d})\cdot\mathbb{1}\big[(\tilde{b}<\eta\tilde{d})\big]\\ &\quad+(1-\delta)\tilde{d}-\Psi\tilde{d}\cdot\mathbb{1}[\text{adj}]+U,\\ \tilde{b}' &\geq 0,\\ \tilde{b}' &= \frac{\hat{b}'}{G_{a+1,j'}V'},\qquad \tilde{d}'=\frac{\hat{d}'}{G_{a+1,j'}V'}.\end{aligned}$$

Finally, as the last step, we rewrite the problem in terms of cash in hand, $\tilde{x}$:

$$\tilde{V}_a(\tilde{x},\tilde{d},r_k,G_{a,j})=\max_{\tilde{c},\hat{d}',\hat{b}'}u\big(\tilde{c},\hat{d}'\big)+\beta\mathbf{E}\big(G_{a+1,j'}V'\big)^{1-\rho}\tilde{V}_{a+1}\big(\tilde{x}',\tilde{d}',r_k',U',G_{a+1,j'}\big)$$

subject to

$$\begin{aligned}\tilde{c}+\hat{b}'+(1-\eta)\hat{d}' &= x-\Psi\tilde{d}\cdot\mathbb{1}[\text{adj}],\\ \tilde{b}' &\geq 0,\\ \tilde{d}' &= \frac{\hat{d}'}{G_{a+1,j'}V'},\\ \tilde{x}' &= \begin{cases}(1+r)W\big(\hat{b}'-\eta\hat{d}'\big)/\big(G_{a+1,j'}V'\big)+(1-\delta)\hat{d}'/\big(G_{a+1,j'}V'\big)+U\\ \quad\text{if }\hat{b}'\geq\eta\hat{d}',\\ \big(1+r+r^k\big)\big(\hat{b}'-\eta\hat{d}'\big)/\big(G_{a+1,j'}V'\big)+(1-\delta)\hat{d}'/\big(G_{a+1,j'}V'\big)+U\\ \quad\text{if }\hat{b}'<\eta\hat{d}'.\end{cases}\end{aligned}$$

S2.3. *Computation*

The model is solved by discrete value function iterations. We use 200 grid points for cash in hand, x, 200 grid points for assets a', 150 grid points for cars, d' and 5 grid points for the interest rate spread, r_k. Expectations are taken over future shocks, using 7 grid points for permanent income, V, 5 grid points for transitory shocks U and 5 grid points for the asset price shock, W.

We then simulate a panel of households with 2000 households, born age 25 each period, for 4000 periods to calculate the aggregate properties of the economy. We also simulate the life cycle of a panel of households without aggregate shocks to uncover the life-cycle properties.

Finally, we feed in a series of shocks estimated from the data to income $\{Y_t\}_{t=1946}^{2015}$, the interest rate spread $\{r^c\}_{t=1972}^{2015}$, the asset price $\{q_t\}_{t=1976}^{2015}$, and deterministic growth rate of economy to replicate the behavior of the economy in the period 1980–2015.

S3. MEASUREMENTS OF SHOCKS

S3.1. *Wealth Shocks*

In this section, we provide more detail than provided in the main text on the wealth shock specification we use. We introduce wealth shocks through stochastic capital gains and losses on financial assets, $q_{a,s}$, which impact on households with positive net financial assets. $q_{a,s}$ is assumed to follow a random walk:

$$\log q_{a,s} = \log q_{a,s-1} + \varepsilon^q_{a,s}, \tag{S5}$$

where $\varepsilon^q_{a,s} \sim N(0, \sigma^2_{q,a})$. The cohort weights allow for differences across cohorts in the portfolio composition of savings between the shares of housing and equity. When computing these weights, we allow households to be leveraged in housing.

Our calibration matches financial assets to a portfolio of equity and housing assuming age specific portfolio weights for housing, ω^H_a, and equity, ω^E_a. Prices in the housing and stock market follow a random walk in logarithms:

$$\begin{aligned}
\log q^H_s &= \log q^H_{s-1} + \varepsilon^H_{q,s}, \\
\log q^E_s &= \log q^E_{s-1} + \varepsilon^E_{q,s}, \\
\begin{pmatrix} \varepsilon^H_{q,s} \\ \varepsilon^E_{q,s} \end{pmatrix} &\sim N \begin{pmatrix} \mu^H_q & \sigma^2_{q,H} & \sigma_{q,HE} \\ \mu^E_q & \sigma_{q,HE} & \sigma^2_{q,E} \end{pmatrix},
\end{aligned}$$

We set the means to $\mu^H_q = -0.5\sigma^2_{q,H}$ and $\mu^E_q = -0.5\sigma^2_{q,E}$ such that the price indices do not have a drift. It follows that

$$\begin{aligned}
\varepsilon^q_{a,s} &= \omega^H_a \varepsilon^H_{q,s} + \omega^E_a \varepsilon^E_{q,s}, \\
\sigma^2_{q,a} &= \left(\omega^H_a\right)^2 \sigma^2_{q,H} + \left(\omega^E_a\right)^2 \sigma^2_{q,E} + 2\omega^H_a \omega^E_a \sigma_{q,HE}.
\end{aligned}$$

We estimate the mean share of household's asset in housing, ω^H_a, and stocks, ω^S_a, in the Survey of Consumer Finance. For the simulation exercise, we estimate the sequence of shocks as the innovations to the log of the house price index produced by the Federal

Housing Finance Association and innovations to the log of the stock price using the S&P 500 index for the period 1960–2007 assuming both follow random walks.[1]

S3.2. *Estimating Cohort Income Shocks*

Our income measure of choice is household income from wages. We use a sample in the CPS of households aged 25–64, for the years 1963–2015. We generate shocks for 10 year cohorts. A household is a member of cohort s if born in the 10-year period 19s3 to 19$(s+1)$2, such that cohorts are balanced starting in 2007.

We use two measures to uncover aggregate permanent income shocks and aggregate "transitory" shocks.[2] Let $y_{it} = \log(Y_{it})$ be the log of household income and $p_{it} = \mathbf{1}[Y_{it} \leq 0]$ and indicator variable for household income being zero (or below).

S3.2.1. *Permanent Shocks*

We first remove a trend from log income, using the sample period 1975–2007. To find the permanent income component, we regress the detrended income data, $\hat{y}_{it}$, on a life-cycle age polynomial, cohort (s) dummies, and demographic controls using pre-2008 data:

$$\hat{y}_{it} = \alpha + f(age_{it}) + \sum_s \gamma^s + \beta X_{it} + \xi_{it}.$$

We then construct a "year of birth" synthetic cohort, j, such that year of birth earnings is given as

$$\bar{y}_{jt} = \gamma^s + \frac{1}{N_t^j} \sum_{i \in j} \xi_{it}.$$

The initial income of each household during the simulation is then

$$\hat{\bar{y}}_{j,t=j+25} = \bar{y}_{j,t=j+25} - \frac{1}{N^{J^{25}}} \sum_{j \in J^{25}} \bar{y}_{j,t=j+25},$$

where we normalize the average initial income to zero. We then use $\bar{y}_{jt}$ as the year of birth permanent income. Given the random walk in permanent income, a shock for a year of birth cohort then follows as

$$\eta_{jt} = \bar{y}_{jt} - \bar{y}_{jt-1} \quad \forall t.$$

Finally, we the average over these year of birth cohort shocks to find the cohort shocks that are fed into the model:

$$\hat{\eta}_{st} = \frac{1}{N_t^s} \sum_{j \in s} \eta_{jt}.$$

[1]We remove linear trends from the log house price index and from the log stock price index.

[2]For the measurement of transitory shocks, we are seeking to capture the share of households with zero income, which increased during the Great Recession. These observations would typically be excluded from standard wage estimation.

S3.2.2. *Transitory Shocks*

The transitory shocks for a "year of birth synthetic cohorts," is defined as the share of a year of birth cohort with zero income:

$$\bar{p}_{jt} = \frac{1}{N_t^j} \sum_{i \in j} p_{it}.$$

We regress share of cohorts with zero income, $\bar{p}_{jt}$, on a life-cycle age polynomial, and cohort (s) dummies using data for ≤ 2007:

$$\bar{p}_{jt} = \alpha + f(age_{jt}) + \sum_s \gamma^s + \nu_{it}.$$

The aggregate transitory shock for the year of birth cohort is ν_{jt}. To derive the cohort shocks that are fed into the model, we the average ν_{it} over year of birth cohort shocks:

$$\hat{\nu}_{st} = \frac{1}{N_t^s} \sum_{j \in s} \nu_{jt}.$$

S3.3. *Estimating Cohort Responses*

To estimate the deviations in the consumption response of households during the Great Recession, we regress the log of a consumption variable, x_{it}, on a life-cycle age polynomial, cohort (s) dummies, and linear trend, using data prior to 2007:

$$x_{it} = \alpha + f(age_{it}) + \sum_s \gamma^s + \phi t + \epsilon_{it}.$$

For each household, we then predict consumption in each year during the Great Recession, that would counterfactually have occurred in the absence of the crisis as

$$\hat{x}_{it} = \hat{\alpha} + \hat{f}(age_{it}) + \sum_s \hat{\gamma}^s + \hat{\phi} t.$$

We divide the sample up into three cohorts $j = 1, 2, 3$ (young, middle aged, older) based on the household head age in 2007. The young generation, $j = 1$, refers to those householder for which $25 \leq age_{2007} < 34$, the middle aged, $j = 2$, if $35 \leq age_{2007} < 44$, and the older cohort, $j = 3$, if $45 \leq age_{2007} < 54$. We measure average consumption for a cohort in year t as

$$X_{jt} = \frac{1}{N_t^j} \sum_{i \in j} x_{it}.$$

Actual consumption growth for year t in the recession is, growth relative to the 2007 baseline year:

$$\Delta X_{jt} = \frac{X_{jt}}{X_{j,2007}} - 1.$$

For variables already in percentage terms (nondurables consumption growth, % purchasing car, share net saving), we use

$$\Delta X_{jt} = X_{jt} - X_{j,2007}.$$

Predicted consumption growth, $\hat{X}_{jt}$, is the analogue using the expected values for the estimates of $(\alpha, f, \gamma, \phi)$ (and equivalently so for other other variables).

To minimize concerns about measurement error, we focus on the average value of (actual and predicted) consumption during the recession relative to the average value of consumption in the baseline period, that is,

$$\Delta X_{j,08:10} = \frac{1}{2010 - 2008 + 1} \sum_{t=2008}^{2010} X_{jt} - \frac{1}{2007 - 2006 + 1} \sum_{t=2006}^{2007} X_{j,t},$$

$$\Delta \hat{X}_{j,08:10} = \frac{1}{2010 - 2008 + 1} \sum_{t=2008}^{2010} \hat{X}_{jt} - \frac{1}{2007 - 2006 + 1} \sum_{t=2006}^{2007} \hat{X}_{j,t}.$$

The reported consumption deviation is then measured as

$$\Omega_x^j = \Delta X_{j,08:10} - \Delta \hat{X}_{j,08:10}.$$

We calculate model generated equivalents the same way and similarly for the other outcome variables.

S3.4. *Growth Rate Shock Calibration*

For the estimation of the growth rate shock, annual household income is aggregated to year, t. age, a cell: Y_t^a. Then for each year age income growth is calculated:

$$dY_t^a = Y_t^a - Y_{t-1}^{a-1}.$$

For each age, the average of these growth rates across years was calculated for the pre-recession (1990–2005) and post-recession (2010–2012) period:

$$d\hat{Y}^{a,\mathbf{pre}} = \frac{1}{T^{\text{pre}}} \sum_{t=1990}^{2005} dY_t^a,$$

$$d\hat{Y}^{a,\mathbf{post}} = \frac{1}{T^{\text{post}}} \sum_{t=2010}^{2012} dY_t^a.$$

Having calculated the average growth rate at each age in the pre- and post-recession period, we fit a moving average or polynomial $f(a)$ across all ages to smooth the pattern:

$$d\hat{Y}^{a,\mathbf{x}} = g^{\mathbf{x}}(a) + \epsilon_a. \tag{S6}$$

The implied life cycle can be calculated by cumulating the estimated smoothed growth rate function $\hat{g}^{\mathbf{pre}}(a)$ and $\hat{g}^{\mathbf{post}}(a)$. Given model specification $G^{\text{post}} = \min\{(G^{\text{pre}})^{\gamma}, G\}$, and the growth rate functions, we estimate $\hat{\gamma}$ to find model that provides a fit to the change in the life-cycle profile from $\hat{g}^{\mathbf{pre}}(a)$ to $\hat{g}^{\mathbf{post}}(a)$. We estimate $\hat{\gamma}$ using four measures of income: financial income before tax, financial income after tax, family earnings, and income from wages in the CPS. We take the average $\hat{\gamma}$ from across these four specifications. The data, estimated moving average, polynomial and implied life-cycle profiles are presented in Figure A.13. Figure A.14 shows the effect on the expected income path of households in the model at various ages.

S4. FURTHER EVIDENCE FROM THE UNIVERSITY OF MICHIGAN'S SURVEY OF CONSUMERS

In this section, we present further data from the University of Michigan's Survey of Consumers. Figure A.15, panel (a) plots the long run index for the sentiment of households toward purchasing a vehicle. Car purchasing sentiment usually declines during recessions. However, it is clear the Great Recession hit car purchasing sentiment particularly hard. The only time the index fell as low was during the 1980s double recession, when our model also predicts a large decline in car investment.

The survey also provides information on why households perceive it to be a bad time to purchase a vehicle. Panels (b)–(d) in Figure A.15 illustrate the main factors that explain why households believe it is a "bad time to purchase a vehicle." As the Great Recession hit the U.S. economy, the main factor that drives this sentiment is declining income expectations deriving either from "can't afford" or "future is uncertain." This factor never recovers its pre-recession level during the period we focus upon. Gasoline prices matter only for a short period during 2008. Credit market concerns (high interest rates or tight credit) matters for a short period during the Great Recession and mainly for the youngest cohort. These patterns in the data appear entirely consistent with our analysis.

S5. UNCERTAINTY

S5.1. *Income and Asset Price Uncertainty*

In the paper, we show an increase in income uncertainty might be an important factor to take into account but, in itself, is not sufficient to match the consumption, saving and car expenditure adjustments observed in the U.S. during the Great Recession. However, given the turmoil in the housing and financial markets during the Great Recession it is reasonable to assume other dimensions of uncertainty may also play a role. To capture this, we here examine the case where asset price uncertainty increases on top of income uncertainty. We assume σ^2_{house} and σ^2_{stock} follow the same two-state Markov process as income variance.

We calibrate the shocks by examining the average increase in the volatility of the growth rate of asset prices during NBER recession periods prior to 2007. For house prices, we use the Federal Housing Finance Agency's state level House Price Index and calculate the real annual growth rate in state level house prices at a quarterly frequency. State level house prices are used to provide a more accurate estimate. For the period 1975–2007, the average standard deviation in house price growth in booms was 0.055 while the average standard deviation in recessions was 0.081. This gives us an increase in uncertainty during recessions of 46%. For stock prices, we compare annual returns at a monthly frequency. For the period 1960–2007, the standard deviation during booms was 0.13 while in recessions it was 0.15 giving a 13% increase in uncertainty. We multiply these scaling factors by the values we use in the baseline model to find the implied variance during recessions. These values are shown in Table A.10

We simulate the model using the parameters from the baseline specification. The results are shown in Figure A.19. The model delivers a larger decline in car expenditure, predominantly driven by a big fall in the extensive margin (see panel (d)). This may suggest broader uncertainty was an important feature of the Great Recession particularly in the period after the largest income declines. However, for similar reasons to the income uncertainty shock, the intensive margin is muted; see panel (e).

S5.2. *Negative Skewness*

An alternative formulation involving higher order moments that has been discussed in the literature is negative skewness. Guvenen, Ozkan, and Song (2014) argue that countercyclical left skewness of income shocks better captures the U.S. data than countercyclical variance.[3] We now explore the potential impact of such changes in skewness and follow Guvenen, Ozkan, and Song (2014) by specifying the income shock process with a mixture of normals with state varying parameters. Each period idiosyncratic permanent shocks can be drawn from either a high variance or (a close to degenerate) low variance distribution:

$$\varepsilon^j_{t,a,S} \sim \begin{cases} N\left(\mu^S_{\varepsilon,1}, \sigma^2_{\varepsilon,1}\right) & \text{with probability } p_\varepsilon, \\ N\left(\mu^S_{\varepsilon,2}, \sigma^2_{\varepsilon,2}\right) & \text{with probability } 1 - p_\varepsilon. \end{cases}$$

The state S is a Markov process, which moves between boom and recession with probability $P_N(S, S')$. The means of the two normals differ in boom and recession. The differing means of these distributions generate the skewness of the shocks. We use the parameter values from Guvenen, Ozkan, and Song (2014), and estimate an annual transition matrix for NBER recession years. To estimate the structural parameters, we add an additional moment such that the skewness model deliver that same standard deviation of income as in the baseline model. The structural parameter estimates are reported in Table A.11. These are mostly unaffected apart from the variance of the aggregate income shock. The reason for this is that as idiosyncratic shocks now effectively contain an aggregate component, the model requires a much smaller variance of aggregate income shocks, $\sigma^2_v = 0.009^2$. As in Guvenen, Ozkan, and Song (2014), skewness falls by around 15 points on Kelly's measure of skewness during a recession.

We simulate the Great Recession experiment using the same income shocks, but with the economy moving to the recessionary negative skewness regime at NBER recession dates so that skewness of income returns to normal in 2010. The effects of the negative skewness shock are perhaps counterintuitive: These shocks *stimulate* the extensive margin and *contract* the intensive margin, effects that are the reverse of what we observe for the uncertainty shock. The reason for this is that, since the skewness shock increases the downside risk in recessions, many poorer agents are pushed out of the no-adjustment zone forcing them to engage in a car transaction and reduce their car size; see Figure A.20, panel (b). However, given the temporary nature of the shock, the intensive margin counterfactually rebounds strongly once the recession passes. Moreover, the skewness shock makes it harder to explain the strong contraction of the extensive margin. It is interesting to contrast the skewness shock with the life-cycle income profile shock. The latter

[3]There is an obvious relation between negative skewness shocks and the growth shock we investigated in the baseline model. However, as negative skewness shocks affect all ages they have a less clear life-cycle dimension.

shock also increases downside risk during the Great Recession. However, while the skewness shock impacts on agents across all cohorts, the life-cycle income profile shock affects mainly the younger generation and mainly though expected future income growth. Therefore, while the negative skewness shock stimulates the extensive margin, the income profile leads to a reduction in this adjustment channel.

S6. CASH FOR CLUNKERS ALTERNATIVE POLICY EXPERIMENT DETAILS

Here, we provide additional details on the Cash for Clunkers extension to the baseline life-cycle model. We simulate (and reparametrize) the model at the bimonthly frequency due to the short duration of the program, which lasted from July 1, 2009, to August 24, 2009. The policy is modeled as a two-state Markov process, where switching to the policy is a zero probability event, but once implemented, the households understand that the policy is a time limited state.

Congestion effects are modeled by assuming only a fraction of households, π, are transitioned to the policy state. During the Cash for Clunkers regime, households that adjust their car stocks and who receive the subsidy, experience a larger change in their car stock than their out of pocket expenditure. In particular, adjusting the car stock to $d^j_{a,t+1} - (1-\delta^j_{a,t})d^j_{a-1,t}$ costs the household: $(1-\varpi)d^j_{a,t+1} - (1-\delta^j_{a,t})d^j_{a-1,t}$ with $\varpi \in (0,1)$. To capture the policy incentive to purchase a lower value vehicle, the household is assumed only to be eligible for the subsidy if $d^j_{a,t+1}/p^j_{a,t} < \overline{D}$.

As the model is solved in terms of permanent income, we impose the restriction on access to the subsidy on car investment relative to household income rather than an absolute value. Similarly, as current car stock is not a state variable in the value function of adjusters, we apply the discount to the whole of next period's car stock $(1-\varpi)d^j_{a,t+1}$. We take this into account in the calibration. We compute and simulate the model both with no aggregate shocks and with the same aggregate shocks in the data, divided equally over the course of the year.

Figure A.21 presents additional aggregate series from the Cash for Clunkers policy experiment. Panel (a) shows total car expenditure. These dynamics largely follow share of households purchasing a car. It can be seen that the total boost to expenditure is modest. Panel (b) shows the effect on the total household car stock. The policy increases the size of households stock of cars but by 2011 this effect has disappeared. By comparing the no shocks and monthly shocks panels, we also see that as the policy took place during a recession the effectiveness of the policy was slightly increased. This result is the opposite to Berger and Vavra (2015), and is of interest because it more closely resembles the actual policy setting. The Cash for Clunkers discount, ϖ, provides a much stronger incentive to bring forward adjustment than a fiscal boost.

Finally, we consider how variations in the policy design might have impacted the effectiveness of the policy as measured by total car expenditure. These results are presented in Table A.12. Not imposing a maximum size of vehicle, $\overline{D}$, would have slightly increased the impact of the policy (in terms of total car expenditure) had the same total cost had been imposed. Interestingly, there is less evidence of reversion in the longer run due to the better allocation. If instead the same share of recipients has been targeted, the policy would have had a much larger impact on total additional car expenditure (157% increase compared to 70%), but at almost double the fiscal cost.

S7. ONLINE APPENDIX: ADDITIONAL TABLES

TABLE A.2

CONSUMER EXPENDITURE SURVEY SUMMARY STATISTICS.

	1981–2007		2008–2012	
	25–64	65–84	25–64	65–84
Nondurables	33,693.0	27,479.8	33,749.6	30,838.3
Car expenditure	4861.0	2480.2	3416.1	2086.2
Car purchase | adj	16,707.6	18,659.3	16,113.6	18,145.5
New car purchases | adj	27,283.1	26,837.8	27,382.7	25,922.0
Old car purchases | adj	10,805.4	11,822.2	10,896.1	11,556.3
% car purchase	0.208	0.102	0.155	0.095
% new car purchase	0.067	0.044	0.045	0.042
% old car purchase	0.149	0.059	0.114	0.055
Car loan	6649.2	2391.6	5664.2	2396.5
Car stock	16,005.6	12,591.1	15,510.6	13,701.7
Number of cars	1.159	1.012	0.886	0.881
Age of cars	7.946	8.424	8.688	9.328
Employed	0.898	0.233	0.879	0.278
Hours worked	39.1	7.2	37.6	9.1
Family income (before tax)	71,878.7	39,889.5	75,801.4	46,735.1
Family income (after tax)	66,301.4	37,803.2	72,695.2	45,449.8
Family labor earnings	60,223.5	6635.4	63,030.6	10,304.5
Head labor earning	48,800.0	5453.7	50,252.2	8343.6
Age	41.9	72.6	44.1	72.3

Note: All variables are in 2014 prices and deflated by the CPI.

TABLE A.3

CAR PURCHASING BEHAVIOR IN RECESSIONS.

	% purchase			Value|purchase ($)		
Variable	All	New	Old	All	New	Old
GDP growth	0.020	0.020	0.002	48.9	114.9	−24.0
	(0.013)	(0.007)	(0.011)	(23.4)	(39.3)	(20.0)
Great Recession	−0.501	−0.037	−0.469	−913.0	−2226.6	−687.1
	(0.156)	(0.087)	(0.133)	(321.6)	(534.2)	(275.6)
R^2	0.002	0.001	0.001	0.022	0.058	0.031
N	600,012	600,012	600,012	42,447	12,595	30,299

Note: Standard errors in parentheses. Data is at quarterly frequency. Variable is regressed on annualized quarterly GDP growth and dummy for Great Recession. Additional controls are quarter dummies and a quadratic series for the time period.

TABLE A.4

CAR PURCHASING BEHAVIOR IN NBER RECESSION PERIODS (LOG. TRANSFORMATION).

	% purchase			log. value|purchase		
Variable	All	New	Old	All	New	Old
Recession	−0.37	−0.21	−0.18	−0.02	−0.07	0.03
	(0.11)	(0.06)	(0.09)	(0.02)	(0.02)	(0.02)
Great Recession	−0.010	0.09	−0.10	−0.10	−0.09	−0.12
	(0.18)	(0.10)	(0.15)	(0.03)	(0.03)	(0.04)
R^2	0.001	0.001	0.001	0.015	0.037	0.025
N	600,012	600,012	600,012	39,748	12,552	27,604

Note: Standard errors in parentheses. Data is at quarterly frequency. Variable is regressed on dummy for NBER recession dates and dummy for Great Recession. Additional controls are quarter dummies and a quadratic series for the time period. Minimum car price of $750 dollars imposed to remove small car purchases.

TABLE A.5

DURABLES PURCHASING BEHAVIOR IN RECESSIONS.

	% purchase		Value|purchase ($)	
Variable	(1)	(2)	(3)	(4)
Recession	−1.08		−43.1	
	(0.20)		(13.4)	
GDP growth		0.07		4.2
		(0.02)		(1.5)
Great Recession	1.69	0.94	48.6	24.8
	(0.32)	(0.28)	(20.6)	(17.3)
R^2	0.019	0.019	0.000	0.000
N	600,012	600,012	420,912	420,912

Note: Standard errors in parentheses. Data is at quarterly frequency. Variable is regressed on annualized quarterly GDP growth and dummy for Great Recession. Additional controls are quarter dummies and a quadratic series for the time period.

TABLE A.6

PROBABILITY OF PURCHASING A CAR (AVG. MARGINAL EFFECTS).

Variable	(1)	(2)	(3)	(4)
Stock ($10,000)	−0.012	−0.008		
	(0.0003)	(0.0014)		
Stock:ndur			−0.010	−0.0068
			(0.0002)	(0.0009)
Black	−0.028	−0.028	−0.029	−0.029
	(0.0015)	(0.0015)	(0.0015)	(0.0015)
Education	−0.005	−0.0054	−0.007	−0.007
	(0.0004)	(0.0004)	(0.0004)	(0.0004)
Sex	−0.027	−0.027	−0.026	−0.026
	(0.0011)	(0.0011)	(0.0011)	(0.0011)
Family size	0.013	0.0126	0.011	0.011
	(0.0003)	(0.0003)	(0.0003)	(0.0003)
Full time	0.004	0.004	0.005	0.005
	(0.0011)	(0.0011)	(0.0011)	(0.0010)
Weeksp.	0.0002	0.0002	0.0002	0.0002
	(0.0000)	(0.0000)	(0.0000)	(0.0000)
Age	−0.018	−0.018	−0.013	−0.013
	(0.0024)	(0.0024)	(0.002)	(0.002)
Log. Income	0.014	0.014	0.011	0.011
	(0.0005)	(0.0005)	(0.0005)	(0.0005)
year F.E	✓		✓	
stock x year		✓		✓
age polynomial	✓	✓	✓	✓
R^2	0.0304	0.0307	0.0369	0.0372
N	458,234	458,234	458,210	458,210

Note: Probit estimation of probability of adjustment. Standard errors in parentheses. Stock:ndur is the ratio of the car stock to nondurables consumption. Age polynomial specification is quartic, only first term is shown.

TABLE A.7

PROBABILITY OF PURCHASING A CAR (AVG. MARGINAL EFFECTS).

Variable	(1)	(2)	(3)	(4)
Stock ($10,000)	−0.010	−0.008		
	(0.0003)	(0.0014)		
Stock:ndur			−0.0093	−0.0068
			(0.0002)	(0.0009)
Black	−0.031	−0.031	−0.031	−0.031
	(0.0014)	(0.0014)	(0.0014)	(0.0014)
Education	−0.002	−0.0025	−0.004	−0.004
	(0.0004)	(0.0004)	(0.0004)	(0.0004)
Sex	−0.031	−0.031	−0.030	−0.030
	(0.0011)	(0.0011)	(0.0010)	(0.0011)
Family size	0.014	0.014	0.012	0.012
	(0.0003)	(0.0003)	(0.0003)	(0.0003)
Full time	0.009	0.009	0.009	0.009
	(0.0010)	(0.0010)	(0.0010)	(0.0010)
Weeksp.	0.0003	0.0003	0.0003	0.0003
	(0.0000)	(0.0000)	(0.0000)	(0.0000)
Age				
Log. Income				
year F.E	✓		✓	
stock x year		✓		✓
age polynomial				
R^2	0.0256	0.0258	0.0331	0.0334
N	500,018	500,018	499,984	499,984

Note: Probit estimation of probability of adjustment. Standard errors in parentheses. Stock:ndur is the ratio of the car stock to nondurables consumption.

TABLE A.8

PROBABILITY OF PURCHASING A CAR (AVG. MARGINAL EFFECTS).

Variable	(1)	(2)	(3)	(4)
Stock ($10,000)	−0.010	−0.007		
	(0.0003)	(0.0013)		
Stock:ndur			−0.009	−0.0065
			(0.0002)	(0.0009)
Black	−0.031	−0.030	−0.031	−0.031
	(0.0014)	(0.0014)	(0.0014)	(0.0014)
Education	−0.003	−0.0025	−0.004	−0.004
	(0.0004)	(0.0004)	(0.0004)	(0.0004)
Sex	−0.032	−0.032	−0.031	−0.031
	(0.0011)	(0.0010)	(0.0012)	(0.0011)
Family size	0.014	0.0138	0.012	0.012
	(0.0003)	(0.0003)	(0.0003)	(0.0003)
Full time	0.009	0.009	0.009	0.009
	(0.0010)	(0.0010)	(0.0010)	(0.0010)
Weeksp.	0.0003	0.0003	0.0003	0.0003
	(0.0000)	(0.0000)	(0.0000)	(0.0000)
Age	−0.012	−0.012	−0.008	−0.008
	(0.0023)	(0.0027)	(0.002)	(0.002)
Log. Income				
year F.E	✓		✓	
stock x year		✓		✓
age polynomial	✓	✓	✓	✓
R^2	0.0266	0.0269	0.0343	0.0345
N	500,018	500,018	499,984	499,984

Note: Probit estimation of probability of adjustment. Standard errors in parentheses. Stock:ndur is the ratio of the car stock to nondurables consumption. Age polynomial specification is quartic, only first term is shown.

TABLE A.9

MODEL PERFORMANCE (CUMULATIVE DECLINE).

	Share of Cumulative Decline						
	Δc_i	I^d	% buy	val|buy	Saving	Loans	MEAN
a. Aggregates							
uniform income	0.566	0.582	0.331	0.657	−0.091	0.194	0.373
cohort income	0.324	0.420	0.168	0.506	−0.249	0.220	0.232
+ wealth	0.661	0.765	0.432	0.835	0.379	0.090	0.527
+ loan premium	0.699	0.908	0.663	0.855	0.517	0.193	0.639
+ profile	0.683	0.909	0.626	0.888	0.607	0.510	0.704

Note: Panel (a) reports the share of cumulative decline accounted for in the aggregate series for the period 2007–2015 as shown in Section 4 (value closer to 1 preferred). The data and model series and normalized in 2006. For Δc_i, only data up until 2014 is used, due to data set. For value|buy, we realign model forward 1 year. Saving is the aggregate savings rate. Loans is total loan holdings.

TABLE A.10

INCOME PARAMETERS FOR HIGHER ORDER MOMENT MODELS.

Parameter	Value	Source
Income uncertainty		
Variance of aggregate shock in high uncertainty state	0.032^2	Bloom, Floetotto, Jaimovich, Saporta-Eksten, and Terry (2018)
Variance of idio. shock in high uncertainty state	0.202^2	Bayer, Luetticke, Pham-Dao, and Tjaden Bayer et al. (2019)
Probability of transition to high uncertainty state	0.10	Bloom et al. (2018)
Persistence of high uncertainty state	0.79	Bloom et al. (2018)
Asset price uncertainty		
Variance of aggregate house price shock in high uncertainty state	0.045^2	estimated
Variance of aggregate stock price shock in high uncertainty state	0.15^2	estimated
Skewness		
Variance of transitory idio. income shock (σ_u^2)	0.186^2	Guvenen, Ozkan, and Song (2014)
Variance of persistent idio. income shock (1) ($\sigma_{\varepsilon,1}^2$)	0.325^2	Guvenen, Ozkan, and Song (2014)
Variance of persistent idio. income shock (2) ($\sigma_{\varepsilon,2}^2$)	0.001^2	Guvenen, Ozkan, and Song (2014)
Mean of persistent idio. income shock (1,boom) ($\mu_{\varepsilon,1}^B$)	0.119	Guvenen, Ozkan, and Song (2014)
Mean of persistent idio. income shock (2,boom) ($\mu_{\varepsilon,2}^B$)	−0.026	Guvenen, Ozkan, and Song (2014)
Mean of persistent idio. income shock (1,recess) ($\mu_{\varepsilon,1}^R$)	−0.102	Guvenen, Ozkan, and Song (2014)
Mean of persistent idio. income shock (2,recess) ($\mu_{\varepsilon,2}^R$)	0.094	Guvenen, Ozkan, and Song (2014)
Probability of persistent idio. state 1	0.49	Guvenen, Ozkan, and Song (2014)
Probability of transition to recession state	0.17	NBER
Persistence of recession state	0.33	NBER

TABLE A.11

ESTIMATED PARAMETERS FOR SKEW INCOME MODEL.

	Parameter	Skew
α	weight on nondurables in utility function	0.814
μ	elasticity of substitution	1.404
ξ	service flow from durables	0.728
ψ	car adjustment cost parameter	0.122
ς	car maintenance cost parameter	0.777
δ^N	normal car depreciation rate	0.165
δ^B	break down car depreciation rate	0.213
σ_v^2	variance of aggregate permanent income shock	0.009^2
β	subjective discount factor	0.921

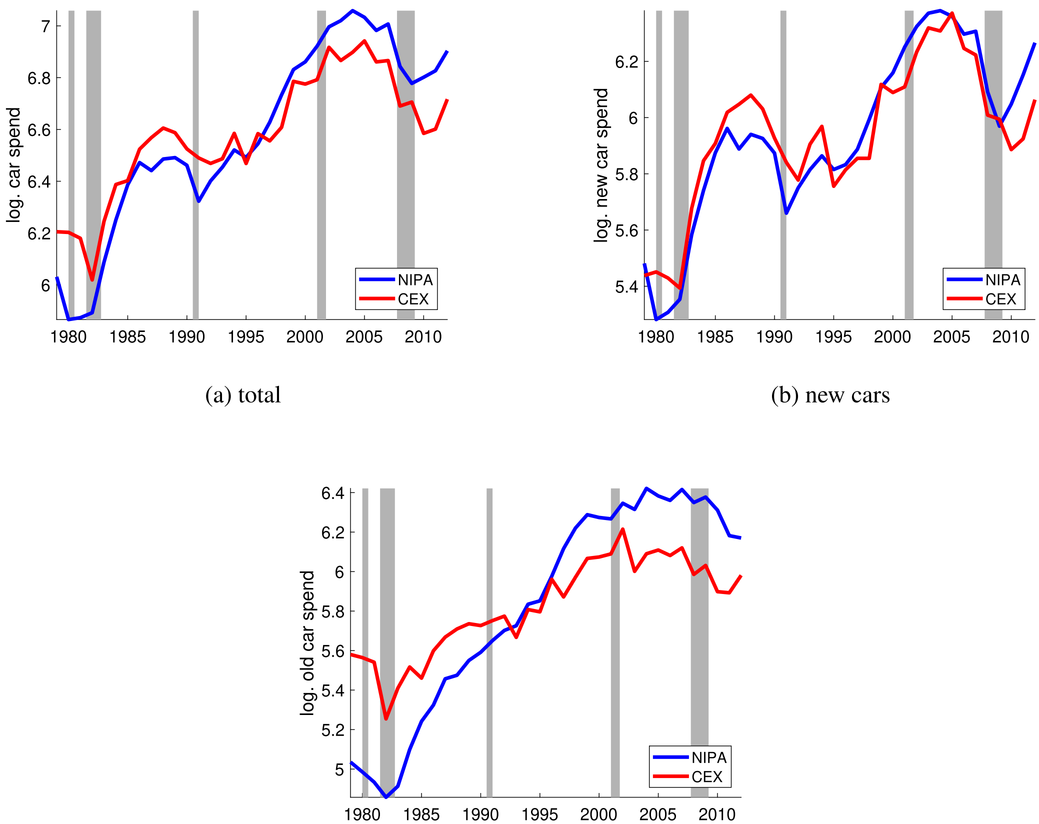
TABLE A.12

CASH FOR CLUNKER POLICY EXPERIMENT.

Variable	% Additional car expenditure			Cost
	July 09–Aug 09	July 09–June 10	July 09–Dec 11	(% Inv. 2008)
Cash for Clunkers	70.3	4.6	−0.2	1.0
No car threshold, same cost	72.6	6.6	0.7	1.0
No car threshold, same share	157.1	14.0	1.4	2.1

Note: Variable of interest is total car expenditure relative to counterfactual with no Cash for Clunkers policy. No threshold, removes the maximum stock size threshold from eligibility for the discount. Same cost rescales the share of eligibile households to deliver the same program cost, same share retains the same eligibility share as in the calibrated policy.

S8. ONLINE APPENDIX: ADDITIONAL FIGURES

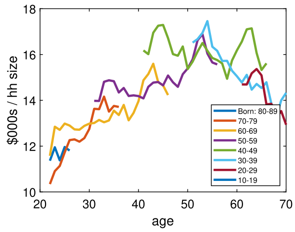


(a) total

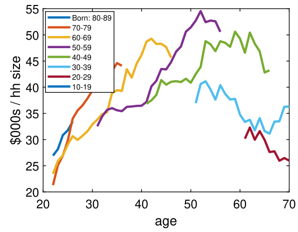
(b) new cars

(c) old cars

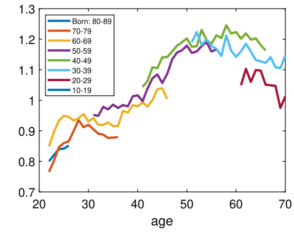
FIGURE A.1.—Comparing NIPA to CEX: New and Old Cars.



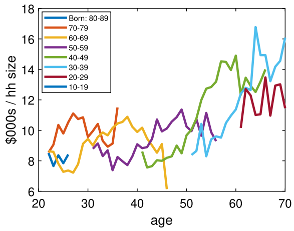
(a) non-durable consumption



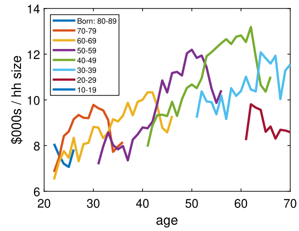
(b) income



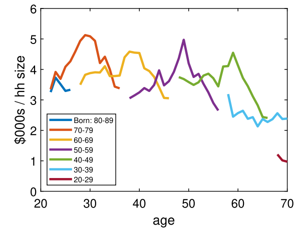
(c) number of cars



(d) value of purchase

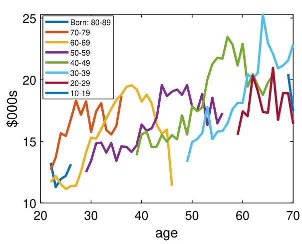


(e) stock

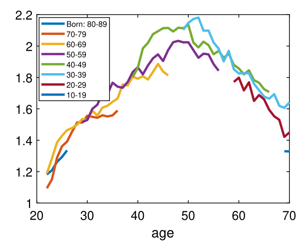


(f) car loans

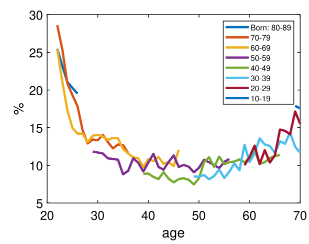
FIGURE A.2.—CEX Cohorts: Household Equivalent Measures. Notes: Each variable is divided by the OECD equivalent scale, which assigns 1 to the first adult, 0.5 to each additional adult, and 0.3 to children aged 18 and under.



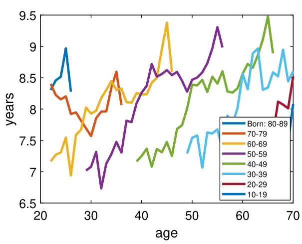
(a) value of purchase



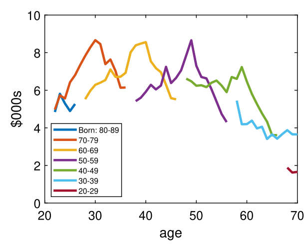
(b) Number of cars



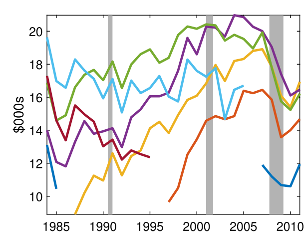
(c) % no car



(d) average car age

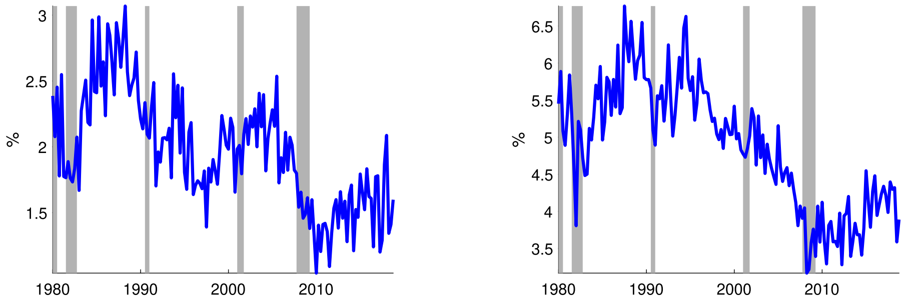


(e) car loans



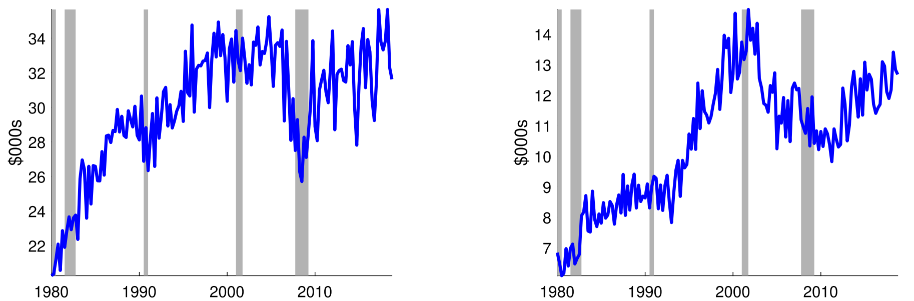
(f) Value of car stock

FIGURE A.3.—CEX Cohorts: Additional Car Measures. Notes: Car loans is 1 month ago stock. Available from 1993.



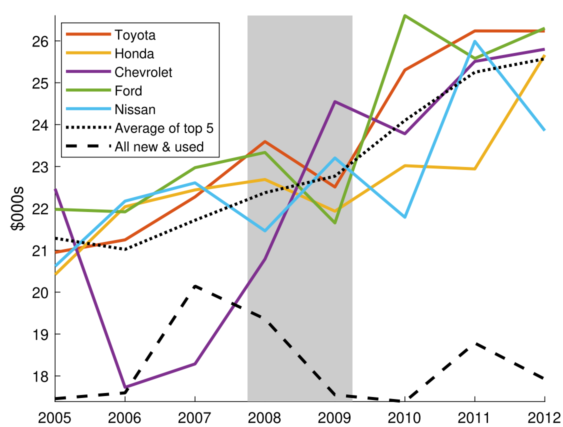
(a) new (b) used

FIGURE A.4.—Extensive Margin Time Series: % hh Purchasing, New and Used.



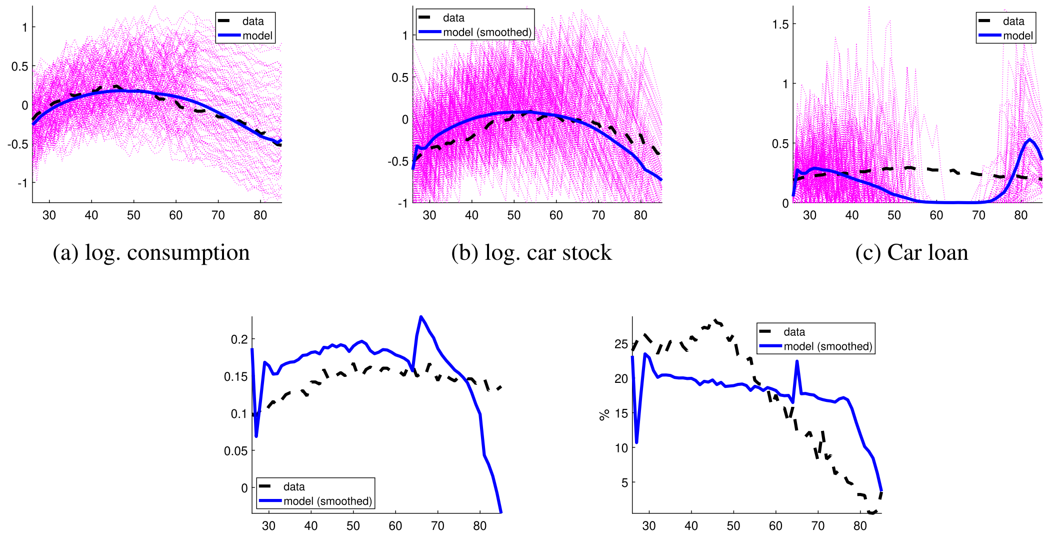
(a) new (b) used

FIGURE A.5.—Intensive Margin Time Series: Value of Purchase, New and Used.



(a) new

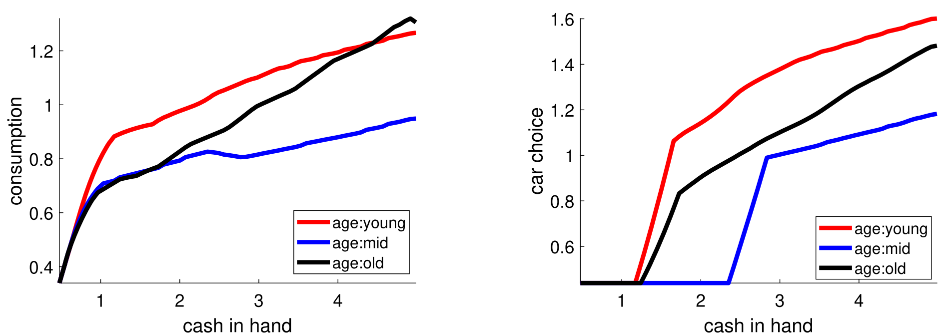
FIGURE A.6.—Average Purchase Price by Brand. Notes: Consumer Expenditure Survey: Owned Vehicles file. Plots show average nominal price of a new car (excluding trucks and SUVs) by each of top five brands in U.S. Currently owned vehicles purchased between $t-2$ and t are included in measure. "All new and used" is comparator of average purchase price of all automobiles.



(a) log. consumption (b) log. car stock (c) Car loan

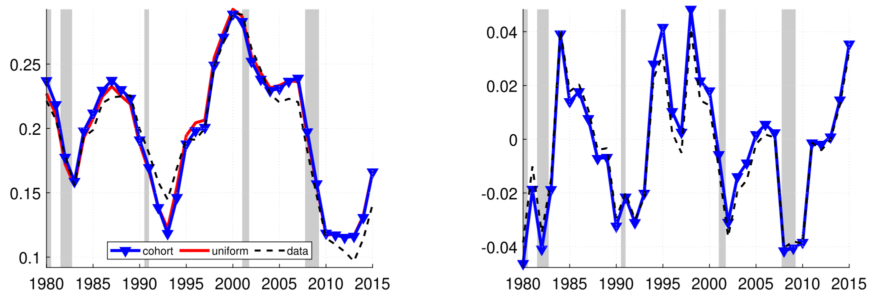
(d) Car investment (e) % purchasing car

FIGURE A.7.—Model Life-Cycle Fit. Notes: Plots show average life-cycle profile in data and model. Also shown are example paths for 10–90th percentile of model households conditional on income realization to indicate heterogeneity. Data series rescaled to match model mean. Car loans rescaled by car investment.



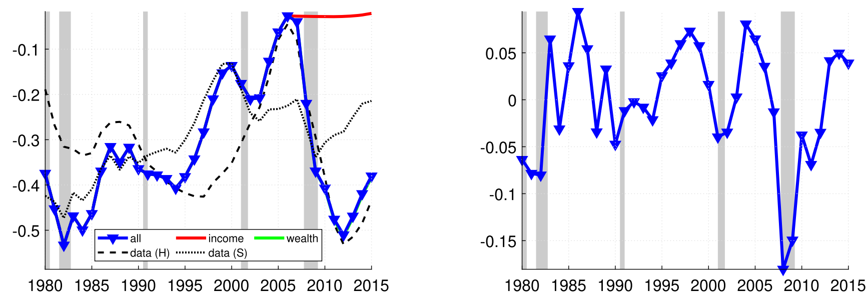
(a) Consumption (b) Car choice

FIGURE A.8.—Additional Policy Functions. Notes: The figures are the policy functions generated by the parameters for the baseline model.



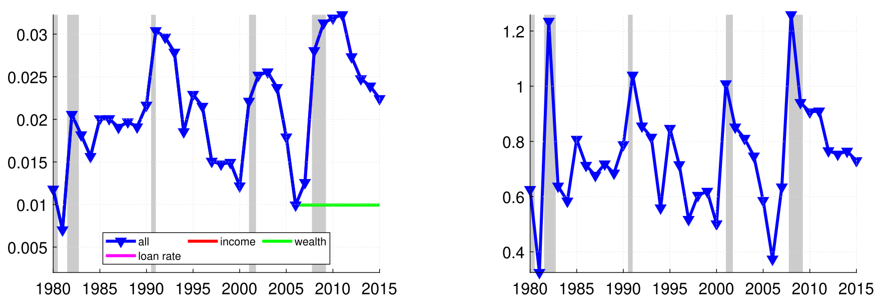
(a) log. income (b) Δ log. income

FIGURE A.9.—Income Shocks. Notes: Estimated from Current Population Survey. Panel (a) shows the de-trended level of cross-sectionally aggregate income measure. Panel (b) shows the income innovations.



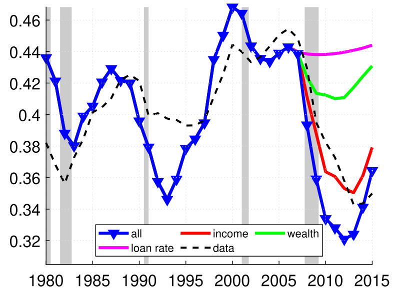
(a) asset price (b) asset price shocks

FIGURE A.10.—Asset Price Shock. Notes: Data (H): House price data series [FHFA All-Transactions House Price Index], Data (S): Stock price data series [S&P 500].

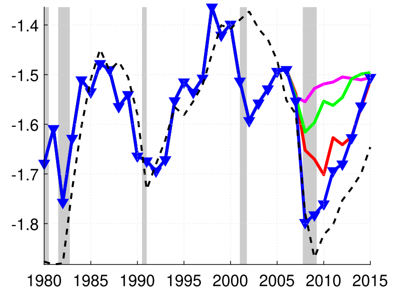


(a) car loan premium (b) car loan premium shocks

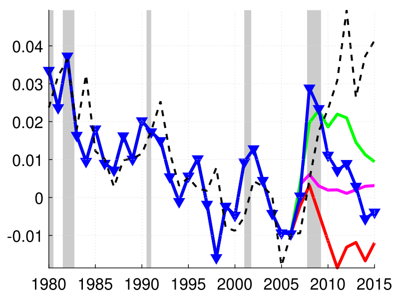
FIGURE A.11.—Interest Rate Spread Shock. Notes: Estimated from FRB G19 Consumer Credit.



(a) log. consumption

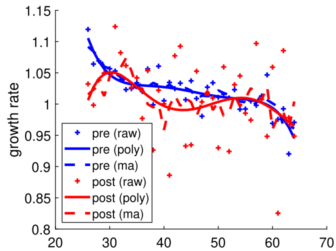


(b) log. car investment

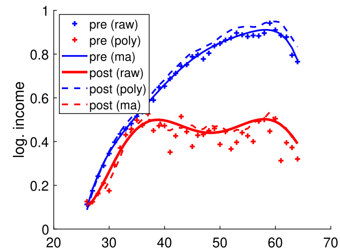


(c) saving ratio

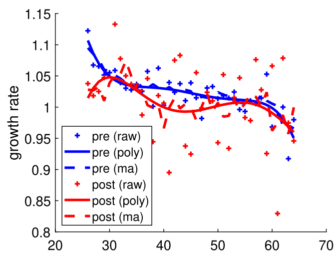
FIGURE A.12.—Interest Rate Spread Shock: Additional Series. Notes: Data for consumption, car investment, and saving from NIPA. Data for intensive and extensive car margin from CEX. Data for car loans from FRB G19 Consumer Credit.



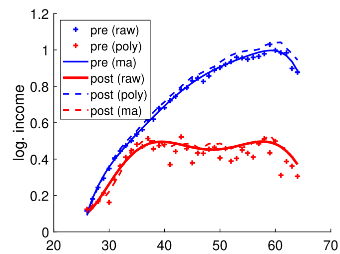
(a) Fall in growth rate
(CEX:fincbtax)



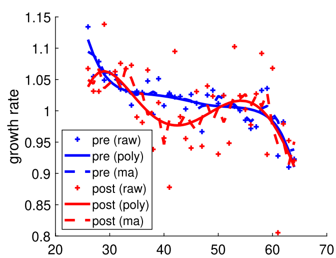
(b) Implied life-cycle
(CEX:fincbtax)



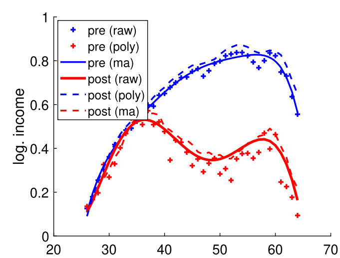
(c) Fall in growth rate
(CEX:fincatax)



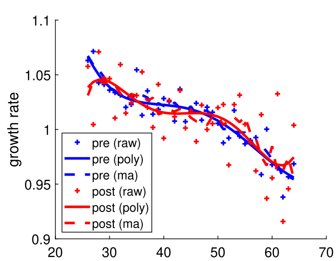
(d) Implied life-cycle
(CEX:fincatax)



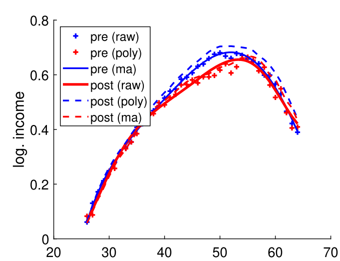
(e) Fall in growth rate
(CEX:fearn)



(f) Implied life-cycle
(CEX:fearn)



(g) Fall in growth rate
(CPS:incwage)



(h) Implied life-cycle
(CPS:incwage)

FIGURE A.13.—Evidence Supporting Decline in Life-Cycle Growth Rate. Notes: CEX: Consumer Expenditure Survey. CPS: Current Population Survey. fincbtax: Financial income before tax, fincatax: Financial income after tax, fincbtax: fearn: family earnings. incwage: income from wages.

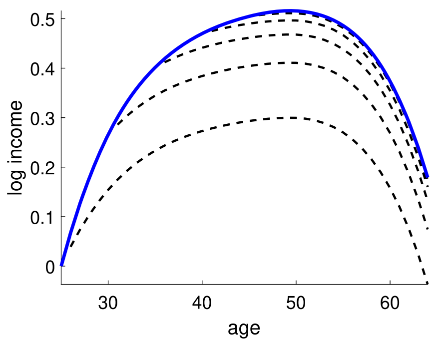
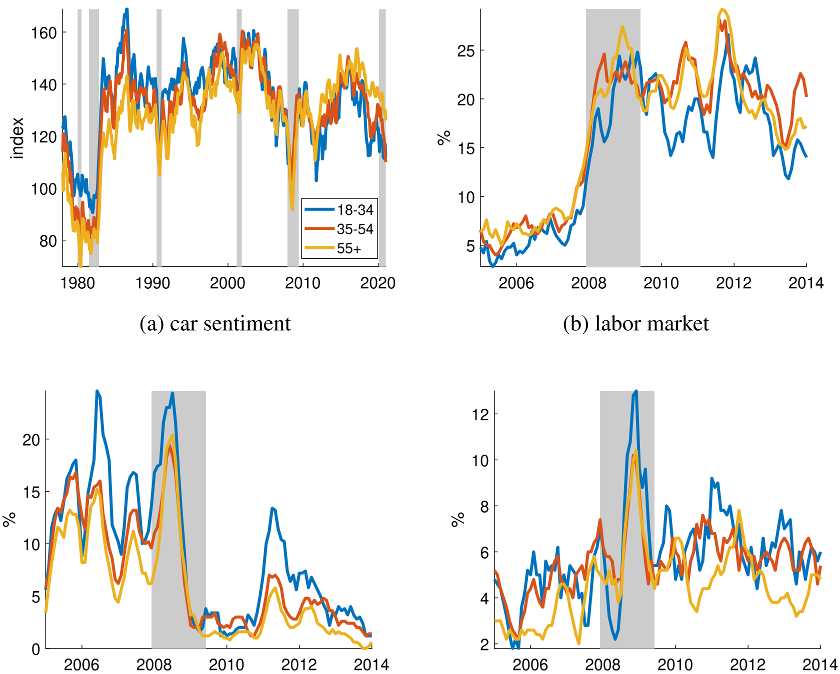


FIGURE A.14.—Growth Rate Shock: Example Paths.



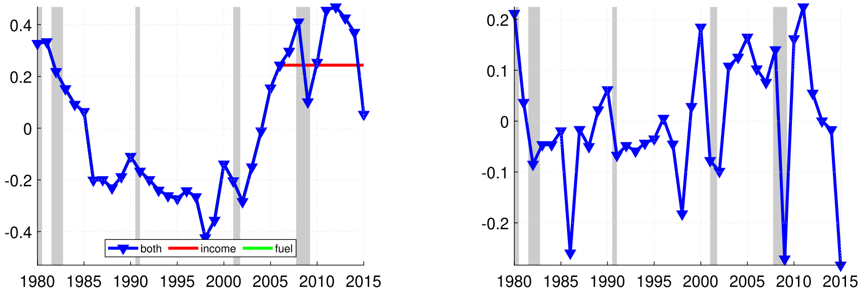
(a) car sentiment

(b) labor market

(c) gas price

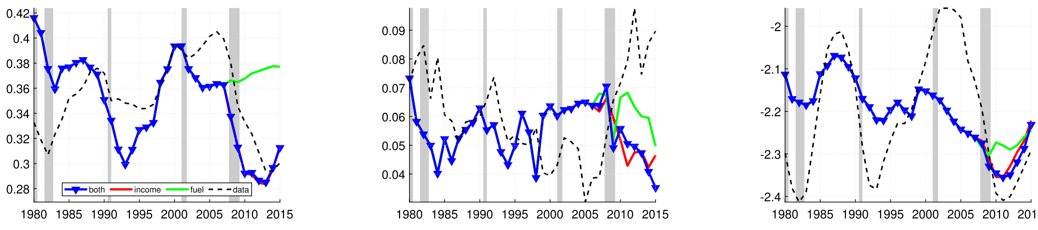
(d) credit

FIGURE A.15.—Household Expectations and Consumer Confidence. Notes: All data from the University of Michigan's Survey of Consumers. Panel (a) shows the long run index of households sentiment toward purchasing a car. Panels (b)–(d) show the reason households think it is a bad time to purchase a vehicle: (b) cannot afford or the future is uncertain, (c) the price of gasoline is high, (d) interest rate is high or credit is tight.



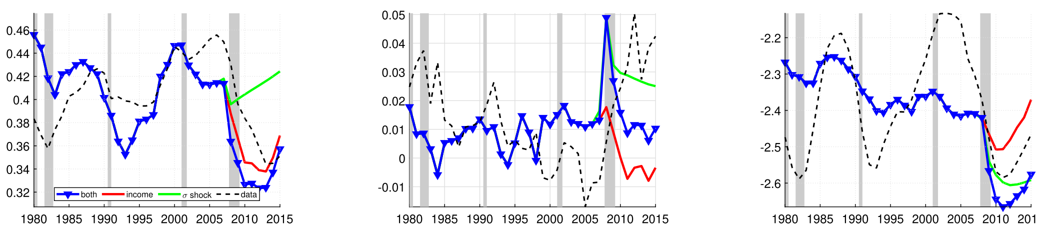
(a) fuel price (b) fuel price shocks

FIGURE A.16.—Fuel Price. Notes: Estimated from BLS Consumer Price Indicies, gasoline price index.



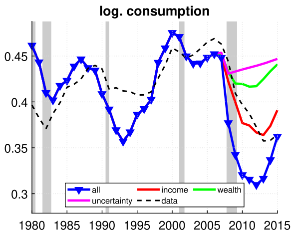
(a) log. consumption (b) saving ratio (c) car loans

FIGURE A.17.—Fuel Price Shock: Additional Series. Notes: Data for consumption, car investment, and saving from NIPA. Data for intensive and extensive car margin from CEX. Data for car loans from FRB G19 Consumer Credit.

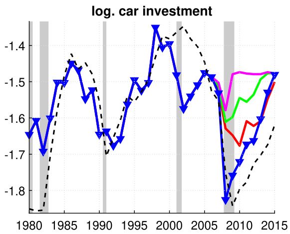


(a) log. consumption (b) saving ratio (c) car loans

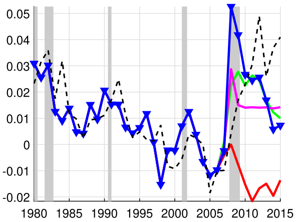
FIGURE A.18.—Uncertainty Shock: Additional Series. Notes: Data for consumption, car investment and saving from NIPA. Data for intensive and extensive car margin from CEX. Data for car loans from FRB G19 Consumer Credit.



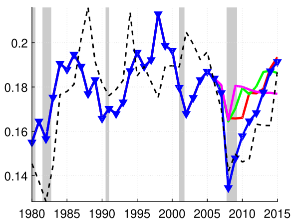
(a) log. consumption



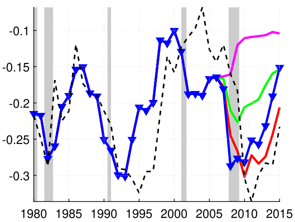
(b) log. car investment



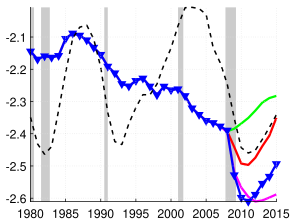
(c) saving ratio



(d) share of hh purchasing car

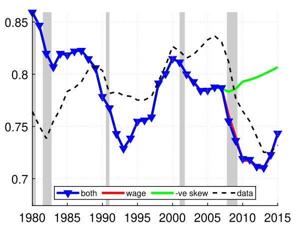


(e) log. value|purchase

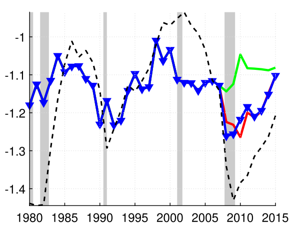


(f) log. car loans

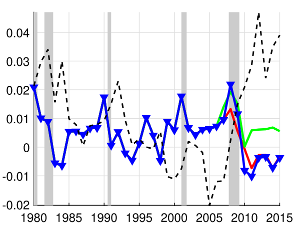
FIGURE A.19.—Asset Price and Income Uncertainty. Notes: Data for consumption, car investment, and saving from NIPA. Data for intensive and extensive car margin from CEX. Data for car loans from FRB G19 Consumer Credit.



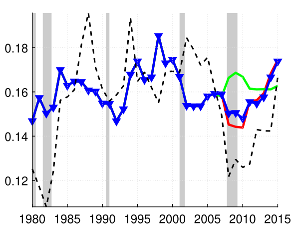
(a) log. consumption



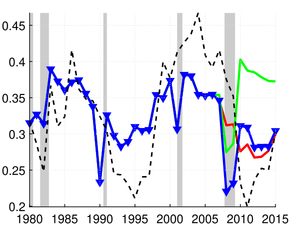
(b) log. car investment



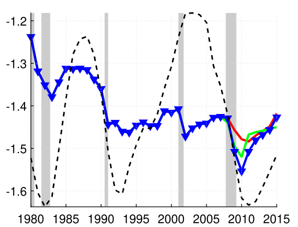
(c) saving ratio



(d) share of hh purchasing car

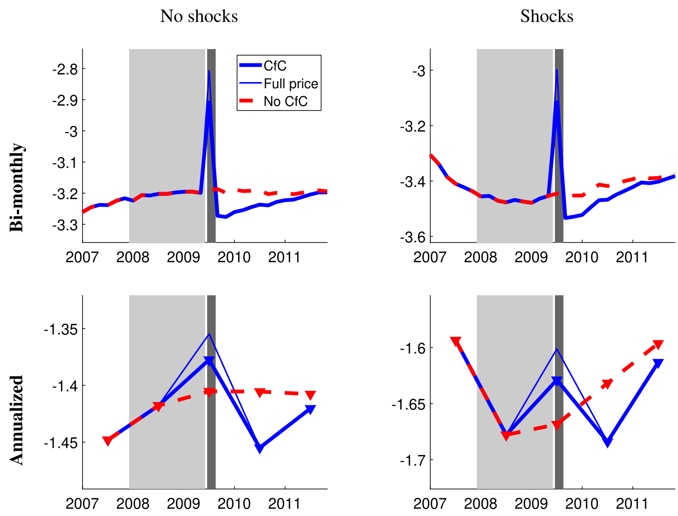


(e) log. value|purchase

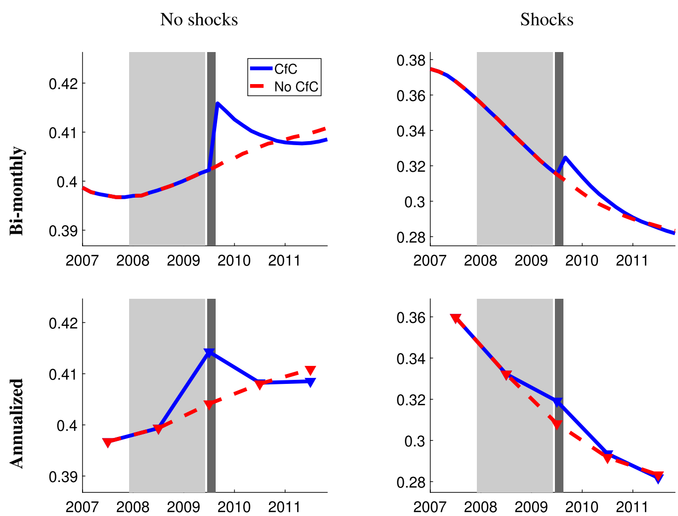


(f) log. car loans

FIGURE A.20.—Skewness Shocks. Notes: Data for consumption, car investment, and saving from NIPA. Data for intensive and extensive car margin from CEX. Data for car loans from FRB G19 Consumer Credit.



(a) log. car expenditure



(b) log. car stock

FIGURE A.21.—Cash for Clunkers: Car Expenditure and Stock. Notes: Top row shows the results of the monthly model, the bottom row is the results of the monthly model aggregated on a household basis to yearly averages. *No shocks* is a model without aggregate shocks, *Shocks* is the aggregate shocks from the data averaged across the year. The dashed red line is without the policy intervention. The solid thick blue line is with the policy, calculated on a post subsidy household expenditure basis. The thin blue line is with the policy and includes the value of the subsidy. The light shaded area is the Great Recession, the dark shaded area is the duration of the Cash for Clunkers policy.

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