Online Appendix for "Estimating Household Consumption Insurance"

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A State-Space Forms

In this appendix, we present state-space forms for unobserved components representations of the Blundell, Pistaferri, and Preston (2008) (BPP hereafter) model in levels and first differences.

Suppressing household-specific subscripts for simplicity and letting z denote the accumulation of a shock, the observation equation for the BPP model in levels is

$$\mathbf{y_t} = \mathbf{HX_t},$$

where

$$\mathbf{y_t} = \begin{bmatrix} y_t \\ c_t \end{bmatrix}, \; \mathbf{H} = \begin{bmatrix} 1 & \theta & 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & \gamma_\eta & \gamma_\varepsilon & 1 \end{bmatrix}, \text{ and } \mathbf{X_t} = \begin{bmatrix} \varepsilon_t \\ \varepsilon_{t-1} \\ \upsilon_t \\ \tau_t \\ z_{\varepsilon t} \\ z_{ut} \end{bmatrix}.$$

The state equation is

$$\mathbf{X_t} = \mathbf{FX_{t-1}} + \mathbf{v_t},$$

where

$$\mathbf{F} = \begin{bmatrix} 0 & 0 & 0 & 0 & 0 & 0 \\ 1 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 1 \end{bmatrix}, \; \mathbf{v_t} = \begin{bmatrix} \varepsilon_t \\ 0 \\ \upsilon_t \\ \eta_t \\ \varepsilon_t \\ u_t \end{bmatrix},$$

and the covariance matrix of $\mathbf{v}_t$, $\mathbf{Q}$, is given by

$$\mathbf{Q} = \begin{pmatrix} \sigma^2_{\varepsilon,t} & 0 & 0 & 0 & \sigma^2_{\varepsilon,t} & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & \sigma^2_{\upsilon,t} & 0 & 0 & 0 \\ 0 & 0 & 0 & \sigma^2_{\eta,t} & 0 & 0 \\ \sigma^2_{\varepsilon,t} & 0 & 0 & 0 & \sigma^2_{\varepsilon,t} & 0 \\ 0 & 0 & 0 & 0 & 0 & \sigma^2_{u,t} \end{pmatrix}.$$

For the state-space form of the BPP model in first differences, first note that (again suppressing household-specific subscripts) equations (1)-(4) in the main paper imply the following for the first differences of income and consumption:

$$\Delta y_t = \eta_t + \varepsilon_t + (\theta - 1)\varepsilon_{t-1} - \theta \varepsilon_{t-2}$$

$$\Delta c_t = \gamma_\eta \eta_t + \gamma_\varepsilon \varepsilon_t + u_t + \upsilon_t - \upsilon_{t-1}.$$

Thus, the vectors and matrices of the state-space form are

$$\mathbf{y_t} = \begin{bmatrix} \Delta y_t \\ \Delta c_t \end{bmatrix}, \mathbf{H} = \begin{bmatrix} 1 & \theta - 1 & -\theta & 0 & 0 & 1 & 0 \\ \gamma_\varepsilon & 0 & 0 & 1 & -1 & \gamma_\eta & 1 \end{bmatrix}, \mathbf{X_t} = \begin{bmatrix} \varepsilon_t \\ \varepsilon_{t-1} \\ \varepsilon_{t-2} \\ \upsilon_t \\ \upsilon_{t-1} \\ \eta_t \\ u_t \end{bmatrix},$$

$$\mathbf{F} = \begin{bmatrix} 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 1 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 \end{bmatrix}, \mathbf{v_t} = \begin{bmatrix} \varepsilon_t \\ 0 \\ 0 \\ \upsilon_t \\ 0 \\ \eta_t \\ u_t \end{bmatrix}, \text{ and } \mathbf{Q} = \begin{pmatrix} \sigma^2_{\varepsilon,t} & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & \sigma^2_{\upsilon,t} & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & \sigma^2_{\eta,t} & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & \sigma^2_{u,t} \end{pmatrix}.$$

Given a state-space form and an assumption of Normality, the Kalman filter can then be used to calculate the likelihood based on the prediction error decomposition and an assumption of independence of idiosyncratic income and consumption across households. We adapt the Kalman filter equations to handle missing observations, which are prevalent in the BPP dataset.

For the BPP model in levels, the likelihood is evaluated from the second time period of the data in levels using highly diffuse priors on initial values of unobserved stochastic trends centered at $\tau_{0|0} = y_1$,

$z_{\varepsilon 0|0} = 0$, and $z_{u0|0} = c_1 - \gamma_\eta y_1$ (or first available values given missing observations) with variances of 100 along with $\varepsilon_{0|0} = \varepsilon_{-1|0} = \upsilon_{0|0} = 0$ and variances of these shocks to initialize the Kalman filter. We have verified that, in the absence of missing values, this diffuse-prior approach is equivalent to estimating the BPP model in first differences from the second time period of the data in levels using $\mathbf{X_{1|1}} = \mathbf{0}$ and variances of the various shocks to initialize the Kalman filter.[1] However, if there is a missing observation in levels for a households in one of two consecutive time periods, as is often the case in the BPP dataset, the estimates can differ in practice because estimation with first differences will have more missing observations.

We note that our approach of casting an unobserved components model of household income and consumption into state-space form is somewhat related to Primiceri and van Rens (2009), who employ likelihood-based Bayesian estimation with flat and uninformative priors for an unobserved components model of household income and consumption inequality in order to examine changes in inequality over time. We also note that, related to our Monte Carlo analysis, Nakata and Tonetti (2015) conduct Monte Carlo analysis to evaluate the root mean squared error of likelihood-based Bayesian estimators of income risk in a univariate setting and find that they perform better than GMM.

B Additional Results

In this appendix, we provide various additional results beyond those reported in the main paper. First, we report tables with initial estimates of all parameters for the BPP model. As referred to in the main paper, these tables reveal which variances are set to be the same across certain years, following BPP. Second, we report a table with bias-corrected estimates of consumption response parameters for QMLE based on the BPP model in first differences. As noted in the main paper, the estimates are reasonably similar to those based on the BPP model in levels, but are less precise due to more missing observations. Third, we report tables with Monte Carlo results for the initial estimators and for bias-corrected estimators allowing for a structural break in γ_η and γ_ε in 1984 (new estimated parameters apply from 1985 on), also both as referred to in the main paper.

[1] As can be seen by comparing Tables 2 and 4 in Morley, Nelson, and Zivot (2003), this diffuse-prior approach to constructing the likelihood for a univariate unobserved components model with a stochastic trend is also equivalent to considering the likelihood for the reduced-form ARIMA representation of the model in first differences. In the multivariate case of the BPP model, the reduced-form will have a VARIMA representation with implicit restrictions on the VARIMA parameters (see Trenkler and Weber, 2016, on the relationship between multivariate unobserved components models and their reduced-form VARIMA representations). It is not clear how to impose these restrictions when directly estimating VARMA parameters by maximum likelihood. Thus, we only estimate the unobserved components representations of the model, which in any event provides us with direct estimates of our parameters of interest and, in the case of the BPP model in levels, could allow us to make filtered and smoothed inferences about the permanent and transitory components for each household, if desired.

Table B1: Initial Estimates of All Parameters for Full Dataset

Parameter		QMLE	DWMD	OMD
σ_η	1979-81	0.13 (0.01)	0.10 (0.02)	0.12 (0.01)
.	1982	0.12 (0.02)	0.14 (0.01)	0.13 (0.01)
.	1983	0.14 (0.02)	0.17 (0.02)	0.13 (0.01)
.	1984	0.13 (0.01)	0.17 (0.01)	0.08 (0.01)
.	1985	0.15 (0.03)	0.17 (0.03)	0.14 (0.02)
.	1986	0.11 (0.02)	0.15 (0.02)	0.12 (0.01)
.	1987	0.15 (0.02)	0.17 (0.02)	0.12 (0.02)
.	1988	0.07 (0.03)	0.13 (0.03)	0.14 (0.02)
.	1989	0.13 (0.02)	0.13 (0.02)	0.12 (0.01)
.	1990-92	0.13 (0.01)	0.12 (0.02)	0.10 (0.01)
σ_ε	1979	0.20 (0.01)	0.19 (0.02)	0.14 (0.01)
.	1980	0.18 (0.01)	0.17 (0.01)	0.12 (0.01)
.	1981	0.18 (0.01)	0.17 (0.01)	0.14 (0.01)
.	1982	0.19 (0.01)	0.17 (0.01)	0.16 (0.01)
.	1983	0.18 (0.01)	0.16 (0.01)	0.14 (0.01)
.	1984	0.19 (0.01)	0.19 (0.01)	0.16 (0.01)
.	1985	0.24 (0.02)	0.21 (0.02)	0.17 (0.01)
.	1986	0.23 (0.01)	0.21 (0.01)	0.18 (0.01)
.	1987	0.23 (0.01)	0.21 (0.01)	0.18 (0.01)
.	1988	0.21 (0.01)	0.20 (0.01)	0.16 (0.01)
.	1989	0.20 (0.01)	0.20 (0.02)	0.17 (0.01)
.	1990-92	0.22 (0.01)	0.21 (0.01)	0.16 (0.01)
σ_u		0.09 (0.01)	0.10 (0.02)	0.09 (0.01)
σ_v	1979	0.27 (0.02)	0.25 (0.02)	0.23 (0.01)
.	1980	0.23 (0.01)	0.23 (0.02)	0.20 (0.01)
.	1981	0.23 (0.01)	0.23 (0.02)	0.20 (0.01)
.	1982	0.27 (0.01)	0.25 (0.02)	0.21 (0.01)
.	1983	0.26 (0.01)	0.26 (0.02)	0.20 (0.01)
.	1984	0.33 (0.02)	0.31 (0.02)	0.25 (0.02)
.	1985	0.30 (0.02)	0.28 (0.03)	0.25 (0.02)
.	1986	0.26 (0.02)	0.26 (0.01)	0.23 (0.01)
.	1989	0.31 (0.02)	-	-
.	1990-92	0.27 (0.01)	0.26 (0.01)	0.21 (0.01)
θ		0.16 (0.02)	0.11 (0.02)	0.12 (0.02)
γ_η		0.46 (0.04)	0.67 (0.09)	0.33 (0.03)
γ_ε		0.03 (0.02)	0.03 (0.04)	0.07 (0.03)

Note: Point estimates are reported, with standard errors in parentheses. The standard errors for QMLE are based on the Huber-White sandwich formula using numerical derivatives and the standard errors for GMM are calculated as in BPP. There are a total of 1,765 households and 15 years of data in levels, but with many missing observations. GMM cannot estimate the standard deviation for the transitory consumption shock in 1989 given missing consumption data in 1988.

Table B2: Initial Estimates of All Parameters for Younger Households

Parameter		QMLE	DWMD	OMD
σ_η	1979-81	0.11 (0.01)	0.10 (0.02)	0.09 (0.01)
.	1982	0.12 (0.02)	0.15 (0.02)	0.13 (0.01)
.	1983	0.14 (0.02)	0.16 (0.02)	0.14 (0.01)
.	1984	0.13 (0.02)	0.16 (0.02)	0.09 (0.01)
.	1985	0.09 (0.02)	0.13 (0.02)	0.08 (0.01)
.	1986	0.13 (0.02)	0.17 (0.02)	0.13 (0.01)
.	1987	0.15 (0.02)	0.17 (0.02)	0.12 (0.01)
.	1988	0.10 (0.03)	0.13 (0.03)	0.14 (0.02)
.	1989	0.11 (0.02)	0.14 (0.02)	0.09 (0.02)
.	1990-92	0.12 (0.01)	0.13 (0.02)	0.09 (0.01)
σ_ε	1979	0.18 (0.01)	0.18 (0.01)	0.15 (0.01)
.	1980	0.17 (0.01)	0.16 (0.01)	0.13 (0.01)
.	1981	0.17 (0.01)	0.16 (0.01)	0.12 (0.01)
.	1982	0.18 (0.01)	0.16 (0.01)	0.14 (0.01)
.	1983	0.17 (0.01)	0.16 (0.01)	0.14 (0.01)
.	1984	0.17 (0.01)	0.15 (0.01)	0.13 (0.01)
.	1985	0.19 (0.01)	0.18 (0.02)	0.15 (0.01)
.	1986	0.20 (0.01)	0.17 (0.02)	0.15 (0.01)
.	1987	0.22 (0.01)	0.21 (0.02)	0.17 (0.01)
.	1988	0.19 (0.01)	0.18 (0.01)	0.15 (0.01)
.	1989	0.18 (0.01)	0.16 (0.01)	0.14 (0.01)
.	1990-92	0.19 (0.01)	0.18 (0.01)	0.14 (0.01)
σ_u		0.09 (0.01)	0.10 (0.02)	0.09 (0.01)
σ_v	1979	0.29 (0.03)	0.27 (0.02)	0.20 (0.01)
.	1980	0.23 (0.02)	0.23 (0.02)	0.18 (0.01)
.	1981	0.24 (0.02)	0.24 (0.02)	0.19 (0.01)
.	1982	0.27 (0.02)	0.25 (0.02)	0.21 (0.01)
.	1983	0.25 (0.02)	0.25 (0.02)	0.20 (0.01)
.	1984	0.35 (0.03)	0.33 (0.03)	0.23 (0.02)
.	1985	0.33 (0.03)	0.32 (0.04)	0.26 (0.02)
.	1986	0.26 (0.02)	0.24 (0.01)	0.21 (0.01)
.	1989	0.34 (0.03)	-	-
.	1990-92	0.26 (0.01)	0.25 (0.02)	0.21 (0.01)
θ		0.15 (0.03)	0.11 (0.04)	0.17 (0.02)
γ_η		0.57 (0.06)	0.73 (0.11)	0.52 (0.05)
γ_ε		-0.01 (0.00)	-0.02 (0.07)	0.02 (0.04)

Note: Point estimates are reported, with standard errors in parentheses. The standard errors for QMLE are based on the Huber-White sandwich formula using numerical derivatives and the standard errors for GMM are calculated as in BPP. There are a total of 1,413 'Younger' (ages 30-47) households and 15 years of data in levels, but with many missing observations. GMM cannot estimate the standard deviation for the transitory consumption shock in 1989 given missing consumption data in 1988.

Table B3: Initial Estimates of All Parameters for Older Households

Parameter		QMLE	DWMD	OMD
σ_η	1979-81	0.14 (0.03)	0.08 (0.03)	0.13 (0.01)
.	1982	0.10 (0.04)	0.12 (0.03)	0.10 (0.01)
.	1983	0.14 (0.03)	0.18 (0.02)	0.12 (0.01)
.	1984	0.13 (0.03)	0.17 (0.02)	0.12 (0.01)
.	1985	0.23 (0.05)	0.16 (0.04)	0.16 (0.03)
.	1986	0.06 (0.10)	0.09 (0.04)	0.00 (∞)
.	1987	0.14 (0.04)	0.17 (0.04)	0.12 (0.02)
.	1988	0.00 (0.00)	0.11 (0.05)	0.04 (0.03)
.	1989	0.13 (0.04)	0.13 (0.05)	0.16 (0.02)
.	1990-92	0.16 (0.03)	0.08 (0.04)	0.15 (0.01)
σ_ε	1979	0.22 (0.03)	0.22 (0.03)	0.09 (0.02)
.	1980	0.22 (0.02)	0.20 (0.02)	0.10 (0.01)
.	1981	0.19 (0.03)	0.19 (0.02)	0.15 (0.01)
.	1982	0.21 (0.02)	0.19 (0.02)	0.15 (0.01)
.	1983	0.21 (0.02)	0.17 (0.02)	0.11 (0.01)
.	1984	0.23 (0.02)	0.23 (0.02)	0.18 (0.01)
.	1985	0.30 (0.04)	0.27 (0.03)	0.18 (0.01)
.	1986	0.27 (0.02)	0.27 (0.02)	0.21 (0.01)
.	1987	0.25 (0.02)	0.22 (0.02)	0.18 (0.01)
.	1988	0.25 (0.02)	0.23 (0.02)	0.18 (0.01)
.	1989	0.25 (0.02)	0.25 (0.04)	0.18 (0.01)
.	1990-92	0.26 (0.02)	0.26 (0.02)	0.19 (0.01)
σ_u		0.10 (0.01)	0.06 (0.05)	0.10 (0.01)
σ_v	1979	0.24 (0.02)	0.22 (0.02)	0.16 (0.01)
.	1980	0.22 (0.01)	0.23 (0.02)	0.16 (0.01)
.	1981	0.22 (0.01)	0.22 (0.02)	0.18 (0.01)
.	1982	0.26 (0.02)	0.25 (0.03)	0.13 (0.01)
.	1983	0.27 (0.03)	0.27 (0.03)	0.21 (0.01)
.	1984	0.30 (0.02)	0.27 (0.03)	0.21 (0.01)
.	1985	0.24 (0.02)	0.23 (0.02)	0.21 (0.01)
.	1986	0.25 (0.02)	0.25 (0.02)	0.22 (0.01)
.	1989	0.26 (0.02)	-	-
.	1990-92	0.29 (0.02)	0.29 (0.02)	0.20 (0.01)
θ		0.16 (0.03)	0.11 (0.03)	0.17 (0.02)
γ_η		0.26 (0.06)	0.85 (0.22)	0.20 (0.03)
γ_ε		0.09 (0.02)	0.06 (0.05)	0.15 (0.03)

Notes: Point estimates are reported, with standard errors in parentheses. The standard errors for QMLE are based on the Huber-White sandwich formula using numerical derivatives and the standard errors for GMM are calculated as in BPP. There are a total of 708 'Older' (ages 48-65) households and 15 years of data in levels, but with many missing observations. GMM cannot estimate the standard deviation for the transitory consumption shock in 1989 given missing consumption data in 1988. The OMD estimate for the standard deviation of the permanent income shock in 1986 is zero to six decimals with a very large standard error.

Table B4: Initial Estimates of All Parameters for Households without College Education

Parameter		QMLE	DWMD	OMD
σ_η	1979-81	0.11 (0.02)	0.08 (0.02)	0.12 (0.01)
.	1982	0.10 (0.02)	0.12 (0.02)	0.11 (0.01)
.	1983	0.15 (0.02)	0.18 (0.02)	0.12 (0.01)
.	1984	0.14 (0.02)	0.18 (0.02)	0.10 (0.01)
.	1985	0.12 (0.03)	0.17 (0.02)	0.08 (0.02)
.	1986	0.12 (0.03)	0.13 (0.02)	0.14 (0.01)
.	1987	0.13 (0.03)	0.14 (0.03)	0.12 (0.01)
.	1988	0.06 (0.05)	0.11 (0.04)	0.09 (0.02)
.	1989	0.11 (0.03)	0.10 (0.05)	0.10 (0.02)
.	1990-92	0.11 (0.02)	0.10 (0.03)	0.06 (0.02)
σ_ε	1979	0.22 (0.02)	0.21 (0.02)	0.13 (0.01)
.	1980	0.20 (0.02)	0.18 (0.01)	0.15 (0.01)
.	1981	0.20 (0.02)	0.19 (0.01)	0.15 (0.01)
.	1982	0.21 (0.01)	0.20 (0.02)	0.15 (0.01)
.	1983	0.21 (0.01)	0.19 (0.02)	0.17 (0.01)
.	1984	0.22 (0.01)	0.20 (0.01)	0.18 (0.01)
.	1985	0.21 (0.01)	0.19 (0.01)	0.19 (0.01)
.	1986	0.23 (0.01)	0.22 (0.02)	0.17 (0.01)
.	1987	0.24 (0.02)	0.23 (0.02)	0.19 (0.01)
.	1988	0.22 (0.01)	0.22 (0.02)	0.15 (0.01)
.	1989	0.23 (0.02)	0.23 (0.03)	0.19 (0.01)
.	1990-92	0.24 (0.01)	0.23 (0.01)	0.18 (0.01)
σ_u		0.10 (0.01)	0.08 (0.04)	0.09 (0.01)
σ_v	1979	0.31 (0.03)	0.28 (0.02)	0.20 (0.01)
.	1980	0.26 (0.02)	0.27 (0.03)	0.24 (0.01)
.	1981	0.25 (0.02)	0.25 (0.03)	0.20 (0.01)
.	1982	0.30 (0.02)	0.28 (0.02)	0.22 (0.01)
.	1983	0.28 (0.02)	0.28 (0.03)	0.21 (0.01)
.	1984	0.38 (0.04)	0.35 (0.04)	0.23 (0.02)
.	1985	0.34 (0.03)	0.33 (0.05)	0.23 (0.02)
.	1986	0.28 (0.03)	0.29 (0.02)	0.24 (0.01)
.	1989	0.35 (0.04)	-	-
.	1990-92	0.31 (0.02)	0.29 (0.02)	0.22 (0.01)
θ		0.17 (0.03)	0.13 (0.03)	0.19 (0.02)
γ_η		0.65 (0.08)	0.95 (0.17)	0.25 (0.04)
γ_ε		0.02 (0.01)	0.07 (0.06)	0.18 (0.03)

Note: Point estimates are reported, with standard errors in parentheses. The standard errors for QMLE are based on the Huber-White sandwich formula using numerical derivatives and the standard errors for GMM are calculated as in BPP. There are a total of 883 households without college education and 15 years of data in levels, but with many missing observations. GMM cannot estimate the standard deviation for the transitory consumption shock in 1989 given missing consumption data in 1988.

Table B5: Initial Estimates of All Parameters for Households with College Education

Parameter		QMLE	DWMD	OMD
σ_η	1979-81	0.14 (0.02)	0.10 (0.02)	0.09 (0.01)
.	1982	0.14 (0.02)	0.16 (0.02)	0.16 (0.01)
.	1983	0.12 (0.02)	0.15 (0.03)	0.11 (0.01)
.	1984	0.12 (0.02)	0.13 (0.02)	0.06 (0.02)
.	1985	0.17 (0.04)	0.15 (0.05)	0.00 (∞)
.	1986	0.10 (0.05)	0.18 (0.03)	0.14 (0.01)
.	1987	0.18 (0.02)	0.19 (0.03)	0.12 (0.02)
.	1988	0.09 (0.03)	0.14 (0.04)	0.18 (0.02)
.	1989	0.15 (0.02)	0.17 (0.02)	0.11 (0.01)
.	1990-92	0.15 (0.02)	0.15 (0.02)	0.09 (0.01)
σ_ε	1979	0.16 (0.02)	0.17 (0.02)	0.13 (0.01)
.	1980	0.16 (0.02)	0.17 (0.02)	0.12 (0.01)
.	1981	0.16 (0.03)	0.16 (0.01)	0.09 (0.01)
.	1982	0.17 (0.02)	0.15 (0.01)	0.10 (0.01)
.	1983	0.16 (0.02)	0.14 (0.01)	0.12 (0.01)
.	1984	0.17 (0.01)	0.17 (0.01)	0.15 (0.01)
.	1985	0.27 (0.04)	0.22 (0.03)	0.13 (0.01)
.	1986	0.23 (0.02)	0.21 (0.02)	0.11 (0.01)
.	1987	0.22 (0.02)	0.21 (0.02)	0.12 (0.01)
.	1988	0.20 (0.02)	0.19 (0.02)	0.15 (0.01)
.	1989	0.17 (0.02)	0.15 (0.02)	0.15 (0.01)
.	1990-92	0.20 (0.01)	0.19 (0.01)	0.15 (0.01)
σ_u		0.09 (0.01)	0.11 (0.02)	0.09 (0.01)
σ_v	1979	0.23 (0.01)	0.21 (0.01)	0.19 (0.01)
.	1980	0.20 (0.01)	0.18 (0.01)	0.16 (0.01)
.	1981	0.22 (0.02)	0.22 (0.02)	0.17 (0.01)
.	1982	0.23 (0.02)	0.21 (0.02)	0.19 (0.01)
.	1983	0.23 (0.01)	0.24 (0.02)	0.18 (0.01)
.	1984	0.28 (0.02)	0.27 (0.03)	0.23 (0.01)
.	1985	0.25 (0.01)	0.23 (0.02)	0.22 (0.01)
.	1986	0.23 (0.01)	0.22 (0.01)	0.19 (0.01)
.	1989	0.27 (0.02)	-	-
.	1990-92	0.24 (0.01)	0.24 (0.02)	0.20 (0.01)
θ		0.14 (0.04)	0.11 (0.03)	0.13 (0.03)
γ_η		0.31 (0.04)	0.47 (0.09)	0.47 (0.04)
γ_ε		0.04 (0.02)	-0.01 (0.05)	-0.13 (0.04)

Notes: Point estimates are reported, with standard errors in parentheses. The standard errors for QMLE are based on the Huber-White sandwich formula using numerical derivatives and the standard errors for GMM are calculated as in BPP. There are a total of 882 households with college education and 15 years of data in levels, but with many missing observations. GMM cannot estimate the standard deviation for the transitory consumption shock in 1989 given missing consumption data in 1988. The OMD estimate for the standard deviation of the permanent income shock in 1985 is zero to six decimals with a very large standard error.

Table B6: Bias-Corrected Estimates of Consumption Responses for QMLE with First Differences

Parameter	Households				
	ALL	YOUNGER	OLDER	NO COLLEGE	COLLEGE
γ_η	0.49	0.67	0.29	0.60	0.39
	(0.06)	(0.09)	(0.08)	(0.10)	(0.07)
γ_ε	0.05	-0.02	0.10	0.05	0.04
	(0.03)	(0.02)	(0.03)	(0.04)	(0.04)

Notes: Point estimates are reported, with standard errors in parentheses. The point estimates are corrected for bias using semi-parametric bootstrap replications based on initial parameter estimates and smoothed estimates of shocks until bias estimates remain stable up to three decimals. The standard errors are based on the Huber-White sandwich formula using numerical derivatives. There are a total of 1,765 households. For the sub-groups based on education, there are 883 households classified as 'No College' and 882 households as 'College'. For age, there are 1,413 households classified as 'Younger' (ages 30-47) and 708 households classified as 'Older' (ages 48-65). There are 14 years of data in first differences, but with many missing observations and changes in classification by age.

Table B7: Properties of Initial Estimators

Parameter	Estimator Property	QMLE	DWMD	OMD	QMLE	DWMD	OMD
		LARGE SAMPLE			SMALL SAMPLE		
$\gamma_\eta = 0.50$	RMSE	0.04	0.20	0.09	0.07	0.44	0.37
	Bias	0.02	0.10	0.04	0.03	0.23	0.07
	Standard Deviation	0.04	0.17	0.08	0.07	0.38	0.36
$\gamma_\varepsilon = 0.10$	RMSE	0.02	0.03	0.03	0.04	0.05	0.07
	Bias	-0.02	-0.01	0.01	-0.03	-0.01	0.00
	Standard Deviation	0.01	0.03	0.03	0.02	0.05	0.07

Note: RMSE, bias, and standard deviation for estimators are calculated across 500 simulations. The large sample has 32,547 observations and the same missing observations as the full BPP dataset. The small sample has 11,437 observations and the same missing observations as the sub-group of older households in the BPP dataset.

Table B8: Properties of Bias-Corrected Estimators Allowing for a Structural Break

Parameter	Estimator Property	QMLE	DWMD	OMD	QMLE	DWMD	OMD
		LARGE SAMPLE			SMALL SAMPLE		
$\gamma_\eta = 0.50$	RMSE	0.07	0.34	0.24	0.10	0.77	0.89
	Bias	0.04	0.08	0.09	0.05	0.16	0.18
	Standard Deviation	0.06	0.33	0.22	0.09	0.75	0.87
$\gamma_\varepsilon = 0.10$	RMSE	0.02	0.04	0.04	0.03	0.08	0.11
	Bias	-0.01	0.00	0.01	-0.01	0.00	0.00
	Standard Deviation	0.01	0.04	0.04	0.02	0.08	0.11

Notes: RMSE, bias, standard deviation, and (root mean squared) differences for estimators are calculated across 500 simulations. Parameter estimates were corrected for bias using 100 semi-parametric bootstrap replications based on initial average parameter estimates and smoothed estimates of shocks given the average large-sample QMLE estimates. The large sample has 32,547 observations and the same missing observations as the full BPP dataset. The small sample has 11,437 observations and the same missing observations as the sub-group of older households in the BPP dataset. Estimation allows for a structural break in γ_η and γ_ε in 1984, although no break occurs in the DGP.

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