Abstract

- Garbage rather than consumption better explains a stock return
  - Relative risk aversion: 17 from garbage versus 81 from consumption
  - Evades the joint equity premium–risk-free rate puzzle
  - Explains size, value, industry portfolios and crowds out consumption
- European data

- EPA: The U.S. Environmental Protection Agency
- MSW: Municipal solid waste—i.e. garbage
- Equity premium puzzle
  - Why too high stock returns? (Mehra and Prescott (1985), Hansen and Jagannathan (1991))
  - Risk aversion versus intertemporal substitution (Epstein and Zin (1991))
  - Habit (Constantinides (1990), Campbell and Cochrane (1999))
  - Incomplete markets (Constantinides and Duffie (1996))
  - Disasters or long-run risks (Rietz (1988), Bansal and Yaron (2004), Parker and Julliard (2005), Jagannathan and Wang (2007))
  - Or oppositely, why too smooth consumption growth?
- As a proxy for consumption, garbage does better than NIPA expenditure
  - 2.5 times more volatile, 1.5 times more correlated with stock returns
  - More reasonable relative risk aversion estimates
  - Positive and significant risk premium estimates consistent with the RRA estimates above make NIPA expenditure insignificant
  - Consistent with the result from 19 European countries
- Garbage growth reveals consumption growth under a homothetic utility
  - If luxury goods are underweighted, then garbage growth will understate consumption growth ($\sigma \downarrow$)
  - Meanwhile, NIPA expenditure discounts nonmarket activity such as household production ($\sigma \downarrow$)
  - Furthermore, statistical techniques such as interpolation degrade the quality of NIPA expenditure

I. Data

- CRSP and Fama–French returns, NIPA expenditure, and the garbage data from EPA during 1960–2007
  - Includes recycling, commercial wastes, but excludes industrial, construction, automobiles, etc.
- Alternative *Biocycle* data (1989–), European data from Eurostat (1995–2005)

	Paper	Glass	Metals	Plastics	Food	Yard	Other	Total	Less Yard
Proportion	36	7	9	7	10	16	13	100	84
St. dev.	4.85	4.21	3.27	9.58	8.42	2.61	3.11	2.48	2.88
Corr. R^M	56	9	38	8	14	−6	16	54	58
Cov. R^M	44	6	20	12	19	−3	8	22	27

Table I. MSW component-wise—yard trimmings are excluded hereafter due to poor data quality

II. Results

A. Summary Statistics

Panel A: Sample Moments							
	Garbage	Durables	Nondurables	Services	Nondur. & Serv.	P–J	Q4–Q4
Mean	1.47	4.62	1.67	2.55	2.21	4.96	2.21
	(0.36)	(0.91)	(0.23)	(0.24)	(0.21)	(0.60)	(0.22)
St. dev.	2.88	5.56	1.45	1.18	1.14	2.99	1.29
	(0.39)	(0.60)	(0.19)	(0.09)	(0.11)	(0.33)	(0.14)
Autocorr.	−14.51	28.90	22.09	51.58	40.01	67.72	32.78
	(11.54)	(11.49)	(12.23)	(11.09)	(10.84)	(6.01)	(11.16)
Corr. R^M	57.94	46.33	47.35	21.89	37.83	13.79	26.42
	(11.25)	(12.00)	(11.58)	(12.11)	(11.64)	(10.53)	(11.47)
Cov. R^M	26.86	41.47	11.04	4.15	6.92	6.64	5.49
	(10.32)	(14.32)	(4.27)	(2.48)	(2.70)	(4.84)	(2.71)
Garbage		42	51	45	53	13	36
Durables			78	57	74	61	65
Nondurables				57	85	54	72
Services					92	42	82
Nondur. & Serv.						53	87
P–J							61

Panel B: $(Garbage)_t = a + b\,(Durables)_t + c\,(Nondurables)_t + d\,(Services)_t + e_t$				
Constant	Durables	Nondurables	Services	R^2
0.79	0.22			18%
(0.07)	(0.07)			
−0.01		1.01		26%
(0.25)		(0.24)		
−0.11			1.10	20%
(0.29)			(0.29)	
−0.33	−0.00	0.74	0.58	29%
(0.38)	(0.10)	(0.37)	(0.35)	

Table II. Garbage and competitors—higher volatility, higher R^M–correlation, closer to nondurables

- Garbage exhibits
  - ×2.5 standard deviation, ×1.5 correlation compared to nondurables and services expenditure
  - Parker–Julliard 3-year consumption growth is more volatile, but less correlated (more autocorrelated)
  - Jagannathan–Wang Q4-Q4 consumption growth is inferior to garbage
  - Less autocorrelated—consistent with permanent income hypothesis (Hall (1978)), martingale
  - Explained mostly by nondurables, marginally by durables and services
- Consumption growth, according to other papers
  - Postwar: 1%–1.2% (Cochrane (2005))
  - Since 1926: 1.7% (Campbell, Lo, and MacKinlay (1996))
  - Back in 1890s: 3.6% (Mehra (2003))
  - Limited participation studies: 3.6% (Malloy, Moskowitz, and Vissing-Jørgensen (2009))
  - Luxury goods are more volatile (Aït-Sahalia, Parker, and Yogo (2004))

- Note that NIPA expenditure is subject to
  - Interpolation by benchmarking
  - Selection bias caused by non-reporting
  - Residually computed after government and business
  - Lack of nonmarket consumption

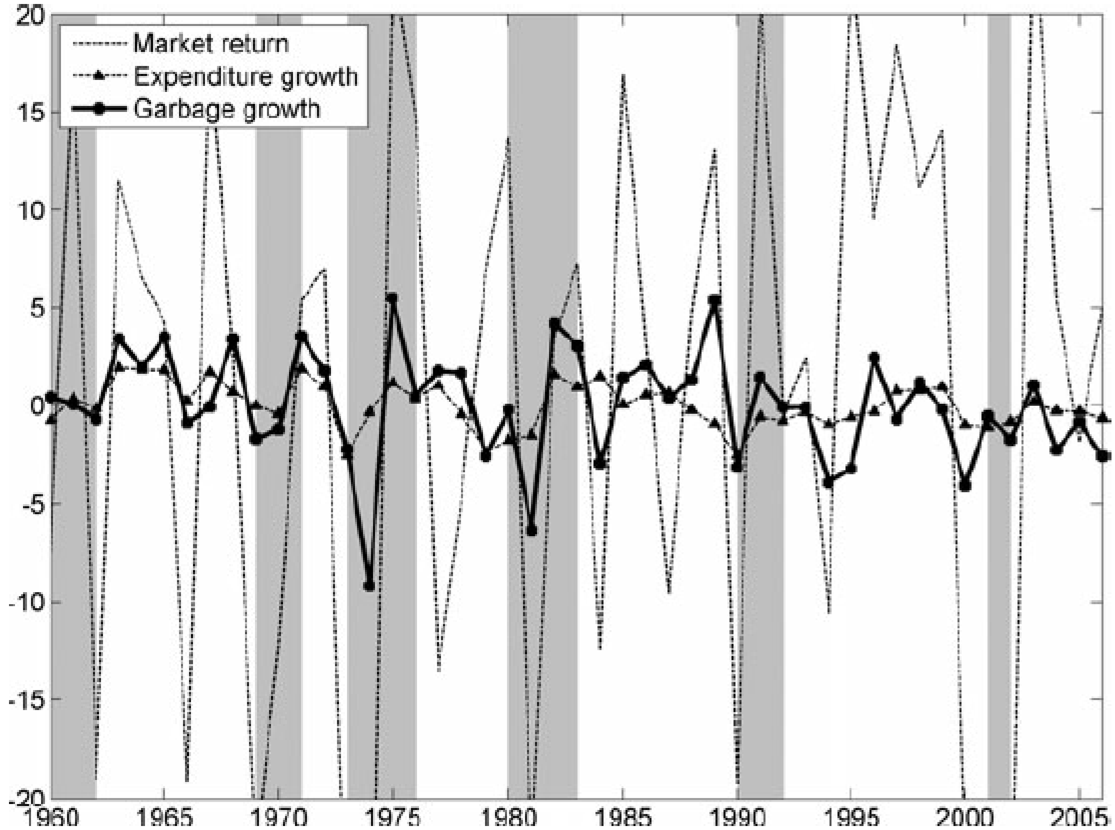

Figure 1. Garbage growth detects the stock shocks ignored by NIPA expenditure (1974, 1981, 2000)

B. The Equity Premium and Risk-Free Rate

- Using GMM, estimates the following RRA coefficients
- Following Breeden, Gibbons, and Litzenberger (1989), adjusted coefficients account for time aggregation

$$E\left[\beta\left(\frac{c_{t+1}}{c_t}\right)^{-\gamma}R^e_{t+1}\right]=0,\qquad \beta=0.95,\qquad R^f=1/E\left[\beta\left(\frac{c_{t+1}}{c_t}\right)^{-\gamma}\right]$$

	Garbage	Expenditure	P–J	Q4–Q4
RRA (γ)	17	81	66	85
(s.e.)	(9)	(49)		(71)
Adjusted γ	9	40	33	
Implied R^f	17	303	417	300
Pricing error	(0.00)	(0.00)	(4.30)	(0.00)

Table III. The RRA coefficient by garbage is admissible, while those by competitors are unreasonable

- To be more precise, Table IV introduces other instrumental variables and moment conditions
    - IVs include lagged garbage growth, expenditure growth, the market price–dividend ratio, and cay
    - Two assets (left panel), many IVs (mid), Fama–French 25 portfolios (right)
    - Identity matrix weighting (Panel A), Hansen–Jagannathan (B), Efficient weighting (C)
    - P-values for J-tests, r.m.s. for the root-mean-squared pricing error
- The RRA coefficients by garbage range from 5 to 31, while those by competitors range from 48 to 1,159

$$\mathrm{E}\left[\beta\left(\frac{c_{t+1}}{c_t}\right)^{-\gamma} R^e_{i,t+1} \otimes z_t\right] = 0, \qquad \mathrm{E}\left[\beta\left(\frac{c_{t+1}}{c_t}\right)^{-\gamma} R^f_{t+1}\right] = 1.$$

	Equity Premium & R^f				Equity Premium & Instruments				Fama–French 25			
	Garbage	Expenditure	P–J	Q4–Q4	Garbage	Expenditure	P–J	Q4–Q4	Garbage	Expenditure	P–J	Q4–Q4
Panel A: One-Stage GMM												
RRA (γ)	26	1,030	305	955	15	71	60	74	22	103	66	136
(s.e.)	(231)	(84)	(250)	(8)	(50)	(309)	(70)	(9)	(56)	(43)	(128)	
Adj. γ	13	515	153		7	36	30		11	51	33	
R^f					18	258	367	250	14	405	418	459
r.m.s.	3.58	11.58	10.36	18.69	0.59	1.25	3.58	0.99	3.80	2.49	4.28	2.39
(p)	(0.11)	(0.00)	(0.00)	(0.00)	(0.01)	(0.47)	(0.25)	(0.24)	(0.00)	(1.00)	(0.99)	(1.00)
Panel B: Hansen–Jagannathan Weighting Matrix												
RRA (γ)	19	814	257	672	5	160	53	122	11	126	48	127
(s.e.)	(10)	(237)	(88)	(259)	(10)	(18)	(47)	(45)	(10)	(25)	(60)	(61)
Adj. γ	10	407	128		3	80	27		5	63	24	
R^f					13	560	342	398	17	502	340	436
r.m.s.	7.40	67.12	49.97	110.75	2.98	4.94	3.43	2.80	6.63	3.83	4.46	2.37
H-J error	1.10	7.01	9.18	8.50	0.07	0.05	0.09	0.08	1.95	2.52	3.05	2.90
(p)	(0.16)	(0.00)	(0.00)	(0.00)	(0.05)	(0.36)	(0.22)	(0.41)	(0.00)	(0.92)	(0.00)	(0.95)
Panel C: Two-Stage GMM												
RRA (γ)	10	1,072	357	1,159	17	199	96	187	31	259	127	284
(s.e.)	(10)	(231)	(79)	(238)	(7)	(14)	(18)	(24)	(5)	(5)	(2)	(7)
Adj. γ	5	536	179		8	99	48		16	130	63	
R^f					18	604	394	488	−2	666	384	517
r.m.s.	7.64	13.38	33.20	39.28	1.00	6.19	4.63	5.12	6.33	12.91	7.15	6.83
(p)	(0.63)	(0.00)	(0.00)	(0.00)	(0.01)	(0.28)	(0.06)	(0.17)	(0.00)	(0.99)	(0.92)	(0.98)

Table IV. Garbage outperforms the competitors—the left panel displays the critical difference

C. *The Cross-section of Returns*

- Following Breeden, Gibbons, and Litzenberger (1989) and Jagannathan and Wang (2007), the linearized version is

$$\mathrm{E}[R^e_{t+1}] \approx \gamma\beta R^f \mathrm{Cov}\left[\frac{c_{t+1}}{c_t}, R^e_{t+1}\right].$$

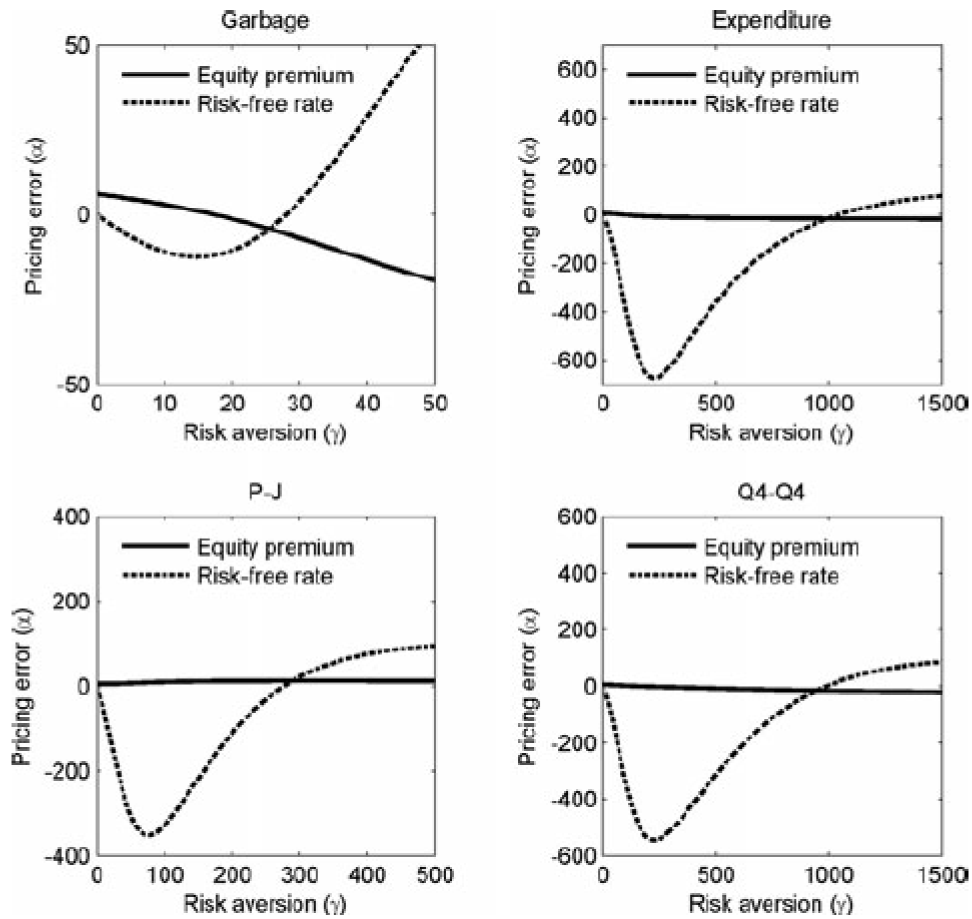

Figure 2. Only garbage minimizes the pricing error with an admissible RRA coefficient (about 20–30)

C.1. *Fama–MacBeth Regressions*

- Using 25 size and book-to-market portfolios and 10 industry portfolios, full sample consumption betas, annual cross-sectional regressions, and the pricing errors and the risk premia are estimated respectively by

$$\begin{aligned} R^e_{i,t} &= a_i + \beta_{i,\Delta c}\left(\frac{c_{t+1}}{c_t}\right) + \epsilon_{i,t} \\ R^e_{i,t} &= \lambda_{c,t}\beta_{i,\Delta c} + \alpha_{i,t} \\ \lambda_c &= \frac{1}{T}\sum_{t=0}^{T}\lambda_{c,t}\,, \qquad \alpha_i = \frac{1}{T}\sum_{t=0}^{T}\alpha_{i,t}. \end{aligned}$$

- Cross-sectional regressions exclude intercepts
- According to Table V
  - Overall, garbage outperforms expenditure (coefficients, multiple regressions, and r.m.s.)
  - With garbage, cay plays a marginal role
  - The implied RRA coefficient from garbage is about 29, which is consistent with the former result
  - Those from expenditure, P–J, and Q4-Q4 are 97, 63, and 125, respectively

$$\lambda_c \approx 2.44, \qquad \gamma \approx \frac{\lambda_c}{\beta R^f \mathrm{Var}\left[\frac{c_{t+1}}{c_t}\right]} \approx 29.$$

Garbage	Garbage × *cay*	Expenditure	Expenditure × *cay*	P–J	Q4–Q4	MRF	SMB	HML	r.m.s. (*p*)
2.44									3.42
(3.59)									(0.00)
2.06	0.34								3.21
(2.32)	(0.74)								(0.00)
		1.25							3.74
		(3.56)							(0.00)
		0.56	0.84						3.24
		(1.50)	(1.85)						(0.00)
2.38		0.57							3.42
(3.53)		(1.69)							(0.00)
				5.61					3.08
				(3.91)					(0.00)
					2.08				2.33
					(3.85)				(0.00)
						8.18			3.46
						(3.57)			(0.00)
1.92						8.01			3.41
(2.15)						(3.50)			(0.00)
		0.48				7.89			3.42
		(1.43)				(3.54)			(0.00)
						6.48	2.73	4.90	1.96
						(2.98)	(1.22)	(2.65)	(0.00)
−0.03						6.52	2.69	5.03	1.93
(0.04)						(2.99)	(1.21)	(2.74)	(0.00)
		0.10				6.51	2.72	4.82	1.95
		(0.34)				(2.99)	(1.22)	(2.59)	(0.00)

Table V. Garbage wins expenditure, matches P–J and Q4-Q4, and survives after all but Fama–French

C.2. GMM Cross-sectional Test

- Fama–MacBeth regressions are subject to the measurement errors in the estimated betas
- Estimate simultaneous GMMs after restricting first-stage betas as OLS coefficients
  - These moment conditions are not linearly independent
  - Instead, among N+NK+N moments, only N+NK+K moments are independent
  - This issue can be addressed by (i) a one-stage GMM, (ii) a pseudoinverse, and (iii) imposing a selection matrix—the third one is adopted not to sacrifice efficiency
  - The internet appendix introduces the selection matrix L

$$\mathrm{E}\left[\begin{pmatrix} \mathrm{R^e - a - \beta f} \\ (\mathrm{R^e - a - \beta f}) \otimes \mathrm{f} \\ \mathrm{R^e - \beta\lambda} \end{pmatrix}\right] = \begin{pmatrix} 0 \\ 0 \\ 0 \end{pmatrix}$$

$$\begin{pmatrix} \mathrm{I_N} & 0 & 0 \\ 0 & \mathrm{I_{NK}} & 0 \\ 0 & 0 & \mathrm{L} \end{pmatrix} \mathrm{E}\left[\begin{pmatrix} \mathrm{R^e - a - \beta f} \\ (\mathrm{R^e - a - \beta f}) \otimes \mathrm{f} \\ \mathrm{R^e - \beta\lambda} \end{pmatrix}\right] = \mathrm{E}\left[\begin{pmatrix} \mathrm{R^e - a - \beta f} \\ (\mathrm{R^e - a - \beta f}) \otimes \mathrm{f} \\ \mathrm{L(R^e - \beta\lambda)} \end{pmatrix}\right]$$

$$\text{where } \mathrm{L} = \beta^\top(\lambda^\top \mathrm{Var[f]}^{-1}\lambda \otimes \mathrm{I_N} + \mathrm{Var[R^e - \beta\lambda]})^{-1}.$$

- The cross-section only contains 6 size and book-to-market portfolios and 5 industry portfolios
  - This smaller cross-section is chosen to estimate the full covariance matrix

Garbage	Garbage × *cay*	Expenditure	Expenditure × *cay*	P–J	Q4–Q4	MRF	SMB	HML	r.m.s. (*p*)
2.30									2.88
(2.62)									(0.00)
2.91	−0.39								2.73
(2.29)	(0.41)								(0.00)
		1.25							3.05
		(2.12)							(0.00)
		0.66	0.67						2.76
		(1.55)	(0.92)						(0.00)
2.18		0.66							2.87
(2.16)		(1.64)							(0.00)
				5.50					3.24
				(1.36)					(0.00)
					1.99				2.17
					(1.67)				(0.00)
						7.59			2.93
						(3.47)			(0.00)
2.01						7.52			2.88
(1.54)						(3.44)			(0.00)
		0.59				7.37			2.87
		(1.57)				(3.35)			(0.00)
						6.89	1.80	4.68	1.64
						(3.09)	(0.83)	(2.25)	(0.00)
−0.22						6.96	1.77	4.82	1.60
(0.18)						(3.11)	(0.82)	(2.34)	(0.00)
		0.42				6.83	1.86	4.90	1.62
		(1.16)				(3.06)	(0.86)	(2.48)	(0.00)

Table VI. Estimates λs with the smaller cross-section and simultaneous GMMs—consistent with Table V

- The result is consistent with Table V—garbage outperforms expenditure
- Parker–Julliard consumption is insignificant and underperforms garbage
- Q4-Q4 outperforms garbage in terms of r.m.s., but is insignificant

D. *European Data*

- Table VII estimates the RRA coefficients using GMM based on entire European data with the assumption that the countries share the same RRA coefficient—the annual time-series data are too short (1995–2005)
  - European data also display higher volatility (4 v. 2) and higher correlation (30 v. 28)
  - The estimates are about 7 for garbage, while 22 for expenditure

E. *Controlling for Durability*

- The inference may be distorted by the durability issue—consumption doesn't coincide with expenditure (Yogo (2006), Gomes, Kogan, and Yogo (2009))
- To crowd out the durability effect, Table VIII excludes the durable components from garbage (1960–1990)
  - 3-year garbage growth (Parker and Julliard (2005))
  - Remove durable goods explicitly
  - Orthogonalize garbage with respect to durables and a time trend using a regression

	Market	Garbage			Expenditure		
	St. Dev.	Corr.	Cov.	St. Dev.	Corr.	Cov.	St. Dev.
Belgium	29	56	38	2	36	11	1
Czech Rep.	31	51	124	8	7	5	3
Denmark	33	0	0	4	31	18	2
Germany	38	15	28	5	28	13	1
Greece	46	41	64	3	−33	−16	1
Spain	32	5	8	5	62	21	1
France	35	42	14	1	41	15	1
Italy	39	12	7	2	57	32	1
Luxembourg	33	−7	−4	2	21	9	1
Hungary	52	26	44	3	−75	−156	4
Netherlands	36	81	55	2	73	52	2
Austria	19	6	2	1	11	12	5
Poland	37	75	131	5	76	73	3
Portugal	41	31	51	4	65	56	2
Finland	68	63	200	5	−23	−13	1
Sweden	42	4	5	3	67	36	1
United Kingdom	25	47	28	2	9	3	1
Norway	30	12	15	4	33	14	1
Switzerland	32	4	2	2	58	20	1
Average	37	30	43	4	28	10	2
Pos. corr.		32	46	4	42	24	2

	All	Pos. Corr.	All	Pos. Corr.
RRA (γ)	7	7	22	44
(St. err.)	(12)	(11)	(36)	(28)
Adj. RRA	3	3	11	22
R_f	16	16	71	120
(p-value)	(0.01)	(0.00)	(0.01)	(0.00)

Table VII. With European data as well, garbage produces lower RRA coefficients compared with expenditure

	Garbage		Expenditure		3-Year Garbage	Excluding Durables	Orthogonal to Durables
	1960–2007	1960–1990	1960–2007	1960–1990	1960–2005	1960–1990	1960–1990
St. dev.	3	3	1	1	4	4	5
Corr. R^M	58	70	38	35	22	67	53
Cov. R^M	27	35	7	7	16	37	43
RRA (γ)	17	12	81	77	21	10	8
St. err.	(9)	(8)	(49)	(93)		(7)	(6)
Adj. RRA	9	6	40	38	10	5	4
R^f	17	23	303	328	70	18	6

Table VIII. The main result is not affected by the durability issue—the coefficients are consistent after durables

III. Conclusion

- Garbage provides more reasonable estimates compared to expenditure candidates
  - This improvement may be because of the poor quality of NIPA expenditure suffering from benchmarking, selection bias, the peculiar residual method
  - Or, garbage may not overlook general nonmarket consumption that NIPA expenditure understates
- CCAPM may have been failed not because the model is bad, but because the data is bad