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Asset Pricing with Garbage

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ABSTRACT

A new measure of consumption, garbage, is more volatile and more correlated with stocks than the canonical measure, National Income and Product Accounts (NIPA) consumption expenditure. A garbage-based consumption capital asset pricing model matches the U.S. equity premium with relative risk aversion of 17 versus 81 and evades the joint equity premium-risk-free rate puzzle. These results carry through to European data. In a cross-section of size, value, and industry portfolios, garbage growth is priced and drives out NIPA expenditure growth.

THE TEXTBOOK STATEMENT of the equity premium puzzle is that under standard assumptions, given the observed low volatility of consumption, the average excess return of stocks over bonds is too high (Mehra and Prescott (1985)). The textbook response is to introduce new preferences (e.g., Epstein and Zin (1991) and Constantinides (1990)), posit incomplete markets (e.g., Constantinides and Duffie (1996)), or conjure rare disasters (e.g., Rietz (1988)). Similarly, the long-run risk literature (e.g., Bansal and Yaron (2004)) relies on both nonstandard preferences and hard-to-detect low-frequency consumption volatility. But a simple restatement of the puzzle hints at a more parsimonious solution: under standard assumptions, given the observed high equity premium, measured consumption is too smooth. A new and distinct measure of consumption could shed light on the puzzle by addressing the key question: is the problem with the model or with the data?

In this paper, I use municipal solid waste (MSW), or simply garbage, as a new measure of consumption. Virtually all forms of consumption produce waste, and they do so at the time of consumption. Rates of garbage generation should be informative about rates of consumption.

The main sample consists of 47 years of annual data from the U.S. Environmental Protection Agency (EPA). Per capita garbage growth, the ratio of next year's garbage (in tons) to this year's garbage, is two and a half times more volatile and one and a half times more highly correlated with stock returns than the standard measure of consumption, personal expenditure on nondurable goods and services from the National Income and Product

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Accounts (NIPA). Alternative expenditure-based proxies such as the ultimate consumption risk measure of Parker and Julliard (2005), the fourth-quarter year-over-year expenditure growth measure of Jagannathan and Wang (2007), and nondurables-only expenditure all covary with stocks only weakly.

As a direct consequence, the consumption capital asset pricing model (CCAPM) of Lucas (1978) and Breeden (1979) using garbage as a measure of consumption matches the observed equity premium with an estimated relative risk-aversion coefficient of 17 versus 81 for NIPA expenditure. The other expenditure-related proxies require risk aversion between 67 and 85. Adding instruments or more test assets, like the 25 Fama and French (1993) portfolios, widens the performance gap between garbage and the expenditure-based measures. The full range of risk-aversion estimates for the garbage-based model is between 5 and 31, whereas that for expenditure is between 71 and over 1,000. The garbage-based model also implies a risk-free rate that, while still high, is an order of magnitude lower than that under any other consumption measure. In a joint pricing test using garbage, a risk-aversion coefficient of 26 prices both the equity premium and the risk-free rate, whereas all expenditure-based measures are strongly rejected. Garbage is the only measure able to formally resolve the joint equity premium-risk-free rate puzzle of Weil (1989).

In the cross-section of assets, I run Fama and MacBeth (1973) regressions on the 25 size and book-to-market Fama–French portfolios and 10 industry portfolios as well as a linear generalized method of moments (GMM) test using an efficient weighting matrix. Both tests show a positive and significant premium for garbage growth used as a risk factor. Garbage growth drives out NIPA expenditure growth in joint specifications. The ultimate consumption risk measure of Parker and Julliard (2005) performs similarly to the garbage measure, while the fourth-quarter year-over-year expenditure growth measure of Jagannathan and Wang (2007) and the Fama and French (1993) three-factor model perform somewhat better. Including the consumption-to-wealth ratio proxy *cay* of Lettau and Ludvigson (2001) as a scaling variable has little effect. Using the estimated cross-sectional premia, I back out risk-aversion estimates similar to those from the nonlinear equity premium test.

To check out-of-sample performance, I test the garbage-based model on 10 years of data from 19 European countries. As in the United States, garbage growth leads to much lower risk-aversion estimates and implied interest rates than expenditure.

Removing discarded durable goods from the garbage series does not affect the estimated risk-aversion coefficient. Garbage is more highly correlated with nondurable goods and services expenditure than with durable goods expenditure. In a multivariate regression that includes nondurable goods and services expenditure, durable goods expenditure is conditionally uncorrelated with garbage.

Overall, my results suggest that when it comes to explaining the equity premium, the risk-free rate, and the cross-section of returns, garbage does better than NIPA expenditure as a proxy for consumption. This finding could be due to either conceptual or methodological factors. On the conceptual side, the timing of garbage is tightly linked to consumption because there is no benefit to keeping a good past its consumption usefulness.

A sufficient condition for garbage growth to reveal consumption growth perfectly is that preferences are homothetic over a relevant range. In this case, the weight of goods consumed scales one-for-one with consumption itself. But, if luxury goods weigh less than normal goods, then garbage growth understates the true volatility of consumption, making the results in this paper conservative.

Fundamentally, garbage and expenditure represent different weightings of the aggregate consumption bundle. Expenditure discounts nonmarket activity such as household production (Becker (1965)). For example, expenditure assigns higher value to a restaurant meal than a home-cooked meal because it considers the wages of the restaurant cook but not the implicit wages of the home cook. The same reasoning applies to the informal sector as a whole, and more broadly to any part of the economy that is undersampled by NIPA. If these sectors tend to be more volatile than average, then expenditure understates the true volatility of consumption.

The two measures also treat services differently. Expenditure attempts to account for services directly, whereas garbage does so indirectly through the waste they produce. However, NIPA services expenditure appears to be poorly measured due to imputation and interpolation. As discussed below, excluding services from expenditure does not close the gap between the two measures.

On the methodological side, the construction of the NIPA series creates biases that lead to understatement of the true covariance between stocks and consumption. These biases stem from the use of 5-year benchmarking, interpolation and forecasting, the incidence of nonreporting, and the residual method for estimating personal expenditure as total expenditure net of government and business purchases. These factors are not relevant in the case of the garbage series, however. Consistent with this intuition, NIPA expenditure, especially the services component, is highly autocorrelated, whereas garbage is not.

The paper is organized as follows. I discuss the garbage data in more detail in Section I. In Section II, I turn to the main results. Finally, Section III concludes.

I. Data

I draw on three sets of data: garbage data, expenditure data, and stock return data. The stock index comes from the Center for Research in Security Prices. The stock portfolios come from the Fama–French (1993) size, book-to-market, and industry sorts, readily available on Kenneth French's website.[1] I take excess returns over the 30-day T-bill return. I deflate all returns using the NIPA price index for nondurable goods and services. I use the same return deflator across all measures of consumption for consistency between them and with previous studies. In the case of excess returns, the choice of deflator is not important so long as realized inflation is anticipated at a 1-year horizon. The

[1] See http://mba.tuck.dartmouth.edu/pages/faculty/ken.french/.

errors for pricing the risk-free rate are too large to be affected by the choice of deflator.

Expenditure data come from NIPA. I calculate real per capita personal consumption expenditure on nondurable goods and services (henceforth, expenditure),[2] where I deflate using the corresponding NIPA price index and take the data at the annual frequency to coincide with the available garbage data. Following Campbell (1999), I use the beginning-of-period timing convention as it gives expenditure its best chance with stocks.[3] This is arguably the most widely used measure of consumption.

To compare my results against other models, I also construct 3-year nondurables growth, a measure of long-run consumption used in Parker and Julliard (2005), as well as the year-over-year growth in fourth-quarter expenditure as suggested by Jagannathan and Wang (2007). In each case, I follow the timing convention favored by the author, which also turns out to give each model its best results. In some cross-sectional tests, I include as a conditioning variable *cay*, a proxy for the consumption-to-wealth ratio used in Lettau and Ludvigson (2001) and available through Martin Lettau's website.[4]

The novel data in this paper are the garbage data from the EPA, which cover the period from 1960 through 2007 at an annual frequency. These data are collected by the consulting firm Franklin Associates[5] on behalf of the EPA for its annual report on waste generation.[6] The variable of key interest is the generation of MSW, which the EPA (U.S. Environmental Protection Agency (2008)) defines as follows:

> MSW—otherwise known as trash or garbage—consists of everyday items such as product packaging, grass clippings, furniture, clothing, bottles, food scraps, newspapers, appliances, and batteries. Not included are materials that also may be disposed in landfills but are not generally considered MSW, such as construction and demolition materials, municipal wastewater treatment sludges, and nonhazardous industrial wastes.

Importantly, these data include materials that are destined for recycling. They also include office and other commercial wastes in addition to household waste and thus measure consumption outside the home as well. For example, a restaurant meal is counted through the waste produced by the restaurant in preparing that meal. Residential sources account for the majority of the total waste generated (U.S. Environmental Protection Agency (2008)). The data do not include industrial process wastes, or wastes related to construction and other fixed investment. Automobiles are also excluded.

[2] Omitting services from expenditure produces slightly better results (risk aversion drops by about a third). I choose to include services for three reasons: there are some durable goods in the nondurables category; services are more than twice as large as nondurables, forming the single largest component of expenditure; and the difference in performance is not large.

[3] Using end-of-period timing causes the correlation between expenditure and the excess stock return to fall from 38% to 2%, increasing risk aversion by a factor of 19.

[4] See http://faculty.haas.berkeley.edu/lettau/.

[5] See http://www.fal.com/.

[6] See http://www.epa.gov/epawaste/nonhaz/municipal/msw99.htm.

Table I

The Components of MSW (Garbage)

The sample covers 1960 through 2007. Data are from the EPA and include recycled materials. Proportion is in percent of the total based on weight. Standard deviation is the sample standard deviation of the annual per capita growth in each component (c_{t+1}/c_t). Correlations and covariances are between the growth in the respective garbage component and the excess real return on the market portfolio, R^M. Less yard is the total less the yard trimmings component.

	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

To collect these data, the EPA uses what it calls a "materials flow methodology."[7] Its numbers are based on both industry production estimates and waste site sampling. For example, to get a number for the amount of plastics waste generated in a given year, the EPA collects data on the volume of various types of plastic products produced that year and then estimates how much of that volume ended up discarded based on a complex calibration using data from landfills, recycling plants, and other sources. For some waste categories like food, waste site sampling is the sole data source. The methodology is reviewed annually using direct state-level data and the numbers are backfilled.

The journal *Biocycle* provides an alternative data source, one based entirely on waste site sampling.[8] Going back to 1989, the *Biocycle* series is 50% more volatile than the EPA series and the two are equally correlated with the return on the stock market. This leads to a benchmark risk-aversion estimate of 11 using *Biocycle* data versus 17 for the EPA data. I focus on the EPA sample because it goes back to 1960. The European data in the paper are also based on waste sampling and not materials flow, providing an additional check.

Table I summarizes the garbage data by material. At 36% of the total, the largest component is paper, which consists mostly of the ubiquitous paper packaging (48% of all paper in 2007), newspapers (13%), and office paper (7%), among others (U.S. Environmental Protection Agency (2008)). At 56%, paper is also the component most highly correlated with stock returns, although overall, total waste less yard trimmings exhibits a correlation of 58%. Plastics are the most volatile but also the smallest component.

In the remainder of the paper, I exclude yard trimmings because they appear to be poorly measured: their numbers round off to the million tons and remain constant for extended periods. In addition, at 17% of total garbage, yard trimmings command a share that is out of line with the consumption value of trimmed lawns. The results in this paper are robust to the inclusion of yard trimmings however, with the benchmark risk-aversion estimate increasing slightly from 17 to 20.

[7] See http://www.epa.gov/epawaste/nonhaz/municipal/pubs/06numbers.pdf.

[8] See http://www.jgpress.com/archives/2008_12.html.

The final data set in this paper comprises European garbage data from Eurostat, the EU's statistics portal.[9] These data cover the period from 1995 through 2005. As in the United States, the European data focus on MSW, but the European definition is narrower: it includes "household and similar waste." In addition, the European data are collected by sampling waste sites. I keep all countries with uninterrupted garbage data over the length of the sample, which leaves 19 countries. European consumption expenditure data also come from Eurostat and the stock indices come from Datastream.

II. Results

The standout feature of the data is that garbage growth is significantly more volatile and more highly correlated with stocks than NIPA expenditure growth or any of the other measures considered. This property allows garbage growth to fit the equity premium with a more plausible and robust coefficient of relative risk aversion of 17 versus 81, which helps keep the implied risk-free rate down and statistically resolves the joint equity premium-risk-free rate puzzle.

Turning to the cross-section of returns, garbage growth obtains a robust positive premium, driving out expenditure growth in joint specifications and leading to smaller pricing errors. The performance of the garbage-based model is comparable to that of the long-run consumption growth model of Parker and Julliard (2005) but somewhat worse than the fourth-quarter year-over-year expenditure growth measure of Jagannathan and Wang (2007) and the Fama and French (1993) three-factor model. The cross-sectional tests yield risk-aversion estimates in line with the nonlinear equity premium test results.

I conclude the results section with an out-of-sample test on European data that corroborates the results from the United States and a robustness check showing that durability in the garbage flow is unlikely to explain the results of the paper.

A. Summary Statistics

Panel A of Table II compares the distributions of various measures of consumption growth. A key observation is that with a standard deviation of 2.88%, garbage growth is two and a half times more volatile than NIPA nondurables and services expenditure growth, whose standard deviation is 1.14%. Moreover, at 58% garbage growth is also one and a half times more correlated with the stock market return than expenditure growth at 38%. As the standard errors suggest, the differences in these moments are highly significant. Durables expenditure is highly volatile, but at 41% it is one-third less correlated with stocks than garbage. Nondurables covary with stocks more than services. The ultimate consumption risk measure of Parker and Julliard (2005) and the fourth-quarter year-over-year (Q4–Q4) expenditure growth measure from Jagannathan and Wang (2007) are rather volatile, but they are only weakly

[9] See http://ec.europa.eu/eurostat/waste/.

Table II

Alternative Measures of Consumption

Garbage excludes yard trimmings (see Table I). Durables, nondurables, and services are real per capita from NIPA. P–J is the 3-year future consumption expenditure growth as in Parker and Julliard (2005). Q4–Q4 is the fourth-quarter year-over-year consumption expenditure growth as in Jagannathan and Wang (2007). Panel A: R^M is the excess market return. Bootstrapped standard errors are from 10^6 simulations using blocks of size three. The last rows report pairwise correlations. Panel B: Standard errors are Newey–West with three lags.

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)	

correlated with stocks. Combining high volatility and a high correlation with the stock market return, garbage has the highest covariance with stocks of any consumption flow measure (this excludes durables), making stocks appear significantly riskier. This is the key empirical fact behind the equity premium results in this paper and it also bears out in European data.

In comparison, other papers in the equity premium literature like Campbell and Cochrane (1999) and Cochrane (2005, p.457) report 1% to 1.2%

consumption growth volatility in the postwar sample. Campbell, Lo, and MacKinlay (1996) report 1.7% volatility since 1926. Going back as far as 1890 gives a higher 3.6% (Mehra (2003) and Campbell and Cochrane (1999)), but there is no way of knowing what the volatility of garbage growth was over this extended period. Limited participation studies such as Malloy, Moskowitz, and Vissing-Jørgensen (2009) report up to 3.6% worth of consumption growth volatility for stockholders. Aït-Sahalia, Parker, and Yogo (2004) find that growth in expenditures on various luxury goods is more volatile and more closely linked to the stock market.

Garbage and expenditure growth also differ in their persistence. Table II shows that the sample autocorrelation of garbage growth is actually negative if indistinguishable from zero, whereas nondurables and services expenditure has a statistically significant autocorrelation of 40%. The other expenditure-based measures are also highly autocorrelated. Hall (1978) shows that a strict interpretation of the permanent income hypothesis implies that the consumption process is a martingale. Following Working (1960), Breeden, Gibbons, and Litzenberger (1989) show that time aggregation leads to a measured autocorrelation of 25% if the underlying consumption process is a martingale in continuous time. Jagannathan and Wang (2007) deal with time aggregation by using data from nonconsecutive quarters, moving closer to a spot rather than an interval measure of consumption. However, as Table II shows, even their Q4–Q4 measure is 33% autocorrelated. To account for potential time aggregation, I present corrected risk-aversion estimates alongside the base estimates in the main tests of the paper.

That NIPA expenditure growth is persistent and garbage growth is not may be a consequence of the NIPA methodology. As discussed in the Internet Appendix,[10] the NIPA expenditure series is in part the product of interpolation. This is especially true of the services component, and indeed services appear highly autocorrelated. Interpolation is particularly harmful for asset pricing tests as it tends to reduce both volatility and stock market correlation, making stocks appear less risky.

Table II is also useful for understanding the link between garbage and consumption expenditure. The pairwise correlations in Panel A show that garbage is most highly correlated with nondurables expenditure, followed by services, and then durables. The differences are not large because all four series have a strong common component. Panel B addresses this issue in a multivariate setting. In a regression on durables, nondurables, and services, garbage growth appears conditionally correlated with nondurables and uncorrelated with durables.

Figure 1 gives a graphical sense of the data by plotting the full time series of garbage growth and expenditure growth. Expenditure growth appears much flatter than garbage growth, and this pattern is consistent throughout the 47-year sample. Like the stock market, garbage growth tends to fall sharply at

[10] An Internet Appendix for this article is available online in the "Supplements and Datasets" section at http://www.afajof.org/supplements.asp.

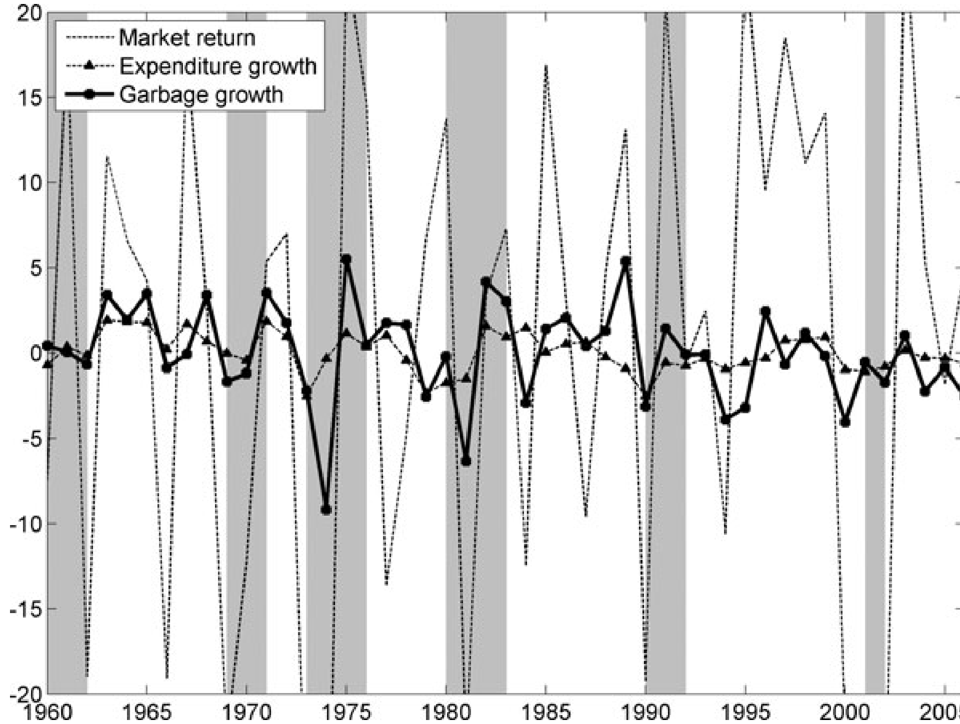

Figure 1. The time series of garbage growth and expenditure growth. This figure shows the time series of realized annual garbage growth and NIPA nondurables and services expenditure growth over the sample 1960 through 2007 against the contemporaneous excess return on the CRSP value-weighted portfolio. Gray bands indicate NBER recessions. All three series are demeaned for ease of comparison. The growth of consumption measure c is c_{t+1}/c_t, using the beginning-of-period convention.

the onset of a recession and to spike up near its end. Garbage growth picks up a few stock market spikes undetected by NIPA expenditure, the most pronounced of which are in 1974, 1981, and 2000.

B. The Equity Premium and Risk-Free Rate

The strong positive comovement between garbage growth and the market return suggests that stocks present significant consumption risk, helping to justify their high average returns. I test this conjecture formally in a plain-vanilla complete markets power utility setup to focus exclusively on the differences between the various measures of consumption. This classic model is due to Breeden (1979) and Lucas (1978) and its principal testable implication is the Euler equation of consumption,

$$E_t\left[\beta\left(\frac{c_{t+1}}{c_t}\right)^{-\gamma} R^e_{t+1}\right] = 0, \tag{1}$$

at every date t, where β is the subjective discount factor, c is consumption, γ is the coefficient of relative risk aversion, and R^e is the excess return on any portfolio over the T-bill return. All inputs into this equation are observable except β and γ. Following Hansen, Heaton, and Li (2008) among others, I fix $\beta = 0.95$ to focus exclusively on risk aversion.[11] Classic results (Hansen and Singleton (1982) and Mehra and Prescott (1985)) show that estimates of the risk-aversion coefficient γ obtained from this equation are orders of magnitude too high from an economic perspective. Furthermore, high risk aversion drives the implied unconditional risk-free rate above plausible levels (Weil (1989)).[12] With only one curvature parameter γ, power utility consumers substitute across states of nature in the same way they substitute over time. High risk aversion goes hand in hand with a high smoothing motive, causing interest rates to rise.

The high estimates of γ are a direct consequence of the fact that consumption appears too smooth. High γ magnifies whatever small volatility exists in consumption growth in order to increase its covariance with the stock return and satisfy the Euler equation. Put differently, because the observed quantity of risk is low, the unobserved price of risk must be high to match the data. It is in this sense that the equity premium or high risk prices puzzle is equivalently a consumption smoothness or low risk quantities puzzle. A new measure of consumption addresses this puzzle directly.

Table III shows the results of a GMM test of the Euler equation for the excess market return. As in previous studies, NIPA expenditure produces an unpalatable risk-aversion estimate of 81, which in turn leads to an implied risk-free rate of 303%. In contrast, garbage growth produces a relative risk-aversion coefficient of 17, which is almost five times smaller, and an implied risk-free rate of 17%, by all means high but nonetheless many times smaller. The ultimate consumption risk measure of Parker and Julliard (2005) requires a risk-aversion coefficient of 66, which is an improvement over the standard expenditure model, but the implied risk-free rate is way out of line. The Q4–Q4 proxy of Jagannathan and Wang (2007) gives virtually the same results as standard expenditure. Following Aït-Sahalia, Parker, and Yogo (2004) and Breeden, Gibbons, and Litzenberger (1989), the third row reports a risk-aversion coefficient corrected for possible time aggregation. The adjustment leads to estimates half the size of the unadjusted ones with the relative differences unaffected.

Table IV takes a closer look at these results by adding instruments and test assets to increase power and precision. It also shows results using three

[11] Alternative values of β do not impact the relative performance of the models. Higher values decrease the implied risk-free rate.

[12] The implied unconditional risk-free rate is $R^f = E[\beta(\frac{c_{t+1}}{c_t})^{-\gamma}]^{-1}$. A lognormal approximation yields $\log(R^f) = -\log(\beta) + \gamma E[\log \frac{c_{t+1}}{c_t}] - \frac{1}{2}\gamma^2 \mathrm{Var}(\log \frac{c_{t+1}}{c_t})$. The volatility of consumption growth is on the order of $(0.01)^2 = 0.0001$ and its mean is around 1.01, so the linear term dominates for low γ, causing interest rates to rise with γ, a result of the smoothing motive. The quadratic term can be interpreted as a precautionary savings motive.

Table III

The Equity Premium: GMM Test and Estimates of Relative Risk Aversion

The column labeled Garbage uses garbage growth as a measure of consumption growth; Expenditure uses NIPA expenditure on nondurable goods and services; P–J uses 3-year consumption growth as suggested by Parker and Julliard (2005); and Q4–Q4 uses the fourth-quarter year-over-year growth in expenditure as in Jagannathan and Wang (2007). The moment restriction is

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

I fix $\beta = 0.95$. The excess market return (relative to the T-bill return) is the sole test asset. RRA (γ) is the estimated relative risk-aversion coefficient with a GMM standard error directly below. Adjusted RRA accounts for time aggregation as in Breeden, Gibbons, and Litzenberger (1989). The implied R^f is based on estimated risk aversion. The pricing error is nonzero in the P–J column because the model does not price the test asset for any risk aversion.

	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)

different weighting matrices: equal-weighting in Panel A, Hansen and Jagannathan (1997) weighting in Panel B, and two-stage efficient GMM in Panel C. Each of these has a distinct advantage, namely, the equal-weighted results focus on the original test assets, the Hansen–Jagannathan estimates weigh portfolios inversely to their variability but assign common weights across models, and the efficient weighting leads to the most precise parameter estimates.

The four center columns of Table IV add instruments to the specification in Table III. The instruments include the lags of garbage growth, expenditure growth, the market price–dividend ratio, and *cay*, a proxy for the consumption–wealth ratio from Lettau and Ludvigson (2001). Overall, garbage retains its relatively low risk-aversion coefficient under all weighting schemes whereas the expenditure-related measures see theirs increase in the Hansen–Jagannathan and efficient GMM panels. This is due to the apparent predictability of these measures. Finally, interpreting the instrumented returns as actively managed portfolios, garbage growth generally gives the lowest pricing errors under any of the weighting methods.

The last four columns of Table IV take up a wider cross-section of returns with the 25 Fama and French (1993) size and book-to-market portfolios. The risk-aversion estimates in Panels A (one-stage GMM) and B (Hansen–Jagannathan weights) are similar to the ones in Table III, but the more precise two-stage GMM estimates in Panel C are much higher for the expenditure-related measures and slightly higher for garbage. Garbage leads to higher pricing errors in Panel A but a lower Hansen–Jagannathan weighted error in Panel B

Table IV

Risk-Aversion Estimates

The columns labeled Garbage use garbage growth as a measure of consumption growth; Expenditure uses NIPA expenditure on nondurable goods and services; P–J uses 3-year consumption growth as suggested by Parker and Julliard (2005); and Q4–Q4 uses the fourth-quarter year-over-year growth in expenditure as in Jagannathan and Wang (2007). The main moment restrictions are

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

I fix $\beta = 0.95$. The left panel uses the excess market return and T-bill return as test assets, with no instruments. The center panel uses the excess market return as a test asset and lagged garbage growth, lagged expenditure growth, lagged *cay* from Lettau and Ludvigson (2001), and the lagged and demeaned log price–dividend ratio as instruments z_t. The right panel uses the excess returns on the 25 Fama–French (1993) size and book-to-market portfolios and no instruments. Panel A uses an identity weighting matrix. Panel B uses the Hansen and Jagannathan (1997) weighting matrix. Panel C uses efficient two-stage GMM. RRA (γ) is the estimated relative risk aversion coefficient with a GMM standard error directly below. Adjusted RRA accounts for time aggregation as suggested by Breeden, Gibbons, and Litzenberger (1989). R^f is the implied risk-free rate. R.m.s. is the root-mean-squared pricing error of the test assets. H-J error is the average pricing error weighted by the Hansen–Jagannathan weigthing matrix. The p-values correspond to J-tests of the overidentified restrictions.

	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)

(*continued*)

Table IV—*Continued*

	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 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)

and lower pricing errors in Panel C. I explore this cross-section further in the linear Fama–MacBeth (1973) and GMM cross-sectional tests.

The most striking numbers in Table IV are in the first four columns, which report results from a joint test that includes both the excess market return and the T-bill return as a proxy for the risk-free rate. This double restriction puts a severe strain on the expenditure-based models. For example, NIPA expenditure gives estimated risk aversion between 800 and over 1,000, a stratospheric number that, given such low volatility, is needed for the precautionary savings motive to take over and bring the interest rate down. The long-run measure of Parker and Julliard (2005) fares somewhat better with risk aversion between 250 and 350. By contrast, the risk-aversion estimate of the garbage model increases to 26 in the one-stage weighting method in Panel A but decreases to 10 in Panel C. In addition, the garbage specification is the only one not formally rejected; its p-value is 11% in Panel A and higher in the other two panels.

Figure 2 presents this result graphically by showing the pricing errors of the market premium and the risk-free rate as a function of the risk-aversion coefficient. The most prominent feature of the four plots is the dramatic difference in the scale of their vertical axes. In the top left plot, garbage growth roughly prices both assets with risk aversion between 20 and 30. In the other plots, low stock covariances require high risk aversion to price the market premium but this introduces extreme volatility in marginal utility, leading to wild swings in the interest rate.

Overall, the results in Tables III and IV show that when garbage measures consumption, equity returns are more in line with risk. In addition, both the equity premium and the risk-free asset can be priced jointly without the extra degree of freedom afforded by the subjective discount factor. In this sense, garbage is the only consumption proxy able to formally resolve the joint equity premium-risk-free rate puzzle.

C. The Cross-section of Returns

In this section, I check whether garbage growth can help us understand the observed cross-sectional variation in average returns. Specifically, I use a linear factor model because it allows for head-to-head comparison between many risk factors via cross-sectional regressions. I linearize the Euler equation (1) similarly to Jagannathan and Wang (2007) and Breeden, Gibbons, and Litzenberger (1989):

$$E\left[R^e_{t+1}\right] \approx \gamma\beta R^f \mathrm{Cov}\left(\frac{c_{t+1}}{c_t}, R^e_{t+1}\right). \tag{2}$$

Expected excess returns should be linear in consumption growth betas (or covariances). In addition, implicit in the estimated reduced-form consumption growth premium is a new estimate of the structural risk-aversion parameter,

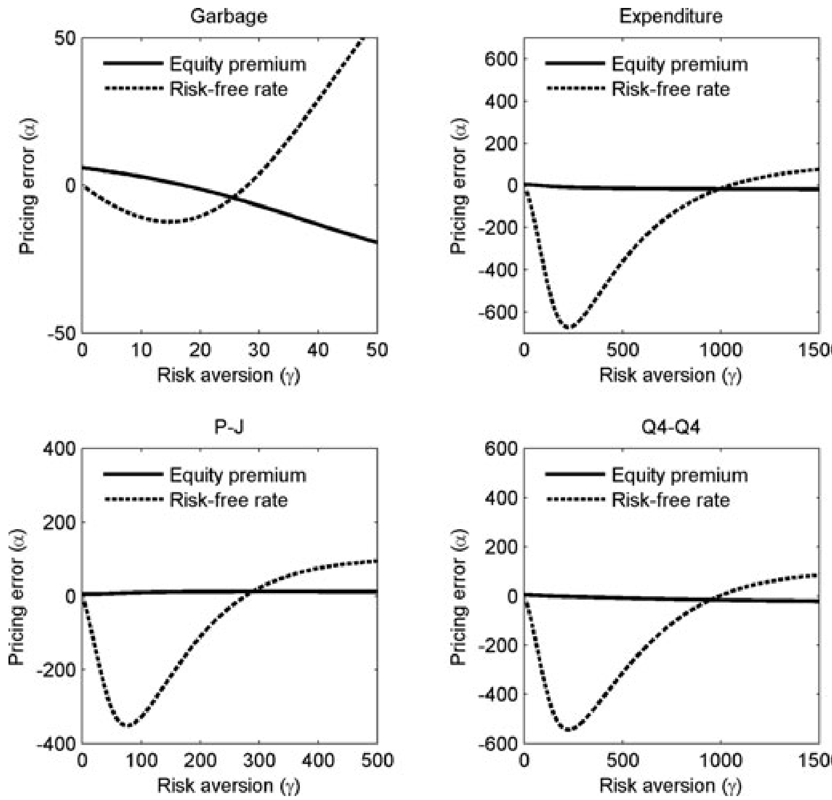

Figure 2. The time series of garbage growth and expenditure growth. The pricing errors of the excess market return (equity premium) and risk-free rate as a function of the relative risk-aversion coefficient γ. The top left plot uses garbage as a measure of consumption, the top right plot uses NIPA expenditure, the bottom left plot uses the measure of Parker and Julliard (2005), and the bottom right plot uses the fourth-quarter year-over-year expenditure growth measure of Jagannathan and Wang (2007). Note the different axis scales, all in percent.

which should be in line with the results of the nonlinear tests in Tables III and IV.

C.1. Fama–MacBeth Regressions

Following Fama and MacBeth (1973), I estimate consumption growth betas in a time-series regression using the full sample of each asset's returns:

$$R^e_{i,t} \;=\; a_i + \beta_{i,\Delta c}\left(\frac{c_t}{c_{t-1}}\right) + \epsilon_{i,t}. \tag{3}$$

Next, at every date t I run cross-sectional regressions of the form

$$R^e_{i,t} \;=\; \lambda_{c,t}\beta_{i,c} + \alpha_{i,t}. \tag{4}$$

Other studies (e.g., Lettau and Ludvigson (2001) and Jagannathan and Wang (2007)) include a free constant in the cross-sectional regression. This gives the model more freedom but it can lead to poorly estimated factor premia when there is little variation in betas, which is a common occurrence.[13] It also implies a paradoxical risk-free rate that has a nonzero excess return relative to itself. Because the garbage series is short, omitting an intercept and thus imposing a restriction of the model delivers more power. Finally, I average the estimated premia and pricing errors over time:

$$\lambda_c = \frac{1}{T}\sum_{t=0}^{T}\lambda_{c,t}, \quad \alpha_i = \frac{1}{T}\sum_{t=0}^{T}\alpha_{i,t}. \tag{5}$$

The consumption model (see equation (2)) predicts $\lambda_c > 0$ and $\alpha_i = 0$ for every asset i. Together with Newey–West standard errors, the Fama–MacBeth (1973) methodology is robust to both time-series and cross-sectional correlation in the errors but it does not account for the fact that the second-stage regressors are themselves estimated. I address this issue below with the GMM linear test.

In selecting test assets, I follow custom by including the 25 Fama–French (1993) size and book-to-market portfolios, both because they present an economically interesting cross-section and because they provide a common proving ground for the asset pricing models in this and other studies. To enrich the dimensionality of this cross-section and following the critique of Lewellen, Nagel, and Shanken (2010), I also incorporate 10 industry portfolios. The Internet Appendix contains results for alternative sets of test assets.

Table V shows the results from the Fama–MacBeth (1973) regressions. All models are rejected. The pricing errors are large, ranging from 2% for the Fama–French model to 3.74% for the NIPA expenditure model. At 3.42%, the pricing errors for the garbage model are slightly smaller than those for the NIPA expenditure model and the CAPM. Adding *cay* as in Lettau and Ludvigson (2001) leads to somewhat lower pricing errors of around 3.20%. The ultimate consumption risk measure of Parker and Julliard (2005), labeled “P–J,” has an average pricing error of 3.08%, but this relative success does not extend to the GMM tests that follow. The fourth-quarter year-over-year measure of Jagannathan and Wang (2007), labeled “Q4–Q4,” performs well with a low average pricing error of 2.33%, a robust result.

In terms of the slopes, garbage growth obtains a stable positive and significant premium, except when matched up against the Fama–French size and book-to-market factors SMB and HML. (The premium is also robust to the inclusion of the Parker and Julliard (2005) and Q4–Q4 measures.) The benchmark premium estimate is $\lambda_c = 2.44\%$. To assess this number, invert equation (2):

[13] For example, a free constant leads to a negative market premium among the 25 Fama–French (1993) portfolios, as noted by Jagannathan and Wang (2007).

Table V

Fama–MacBeth Regressions

The test assets are the 25 Fama–French (1993) size and book-to-market portfolios and 10 industry portfolios. There is no cross-sectional intercept. The estimates follow the Fama–MacBeth (1973) cross-sectional procedure. R.m.s is the root-mean-squared pricing error with an associated p-value for the hypothesis that all pricing errors are zero in parentheses. Three-lag Newey–West t-statistics are also in parentheses. P–J is 3-year expenditure growth as in Parker and Julliard (2005); Q4–Q4 is the fourth-quarter year-over-year growth in expenditure as in Jagannathan and Wang (2007); and *cay* is the consumption-to-wealth ratio proxy from Lettau and Ludvigson (2001).

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)

$$\gamma \approx \frac{\lambda_c}{\beta R^f \mathrm{Var}\left(\dfrac{c_{t+1}}{c_t}\right)}. \tag{6}$$

This gives $\gamma \approx 29$, which is just below the efficient estimate from Panel C in Table IV, which also includes the 25 Fama–French (1993) portfolios. Thus, the estimated cross-sectional premium is consistent with the nonlinear time series test.

The premium on NIPA expenditure growth is not as robust. When used as the sole factor, expenditure growth obtains a positive and significant premium of 1.25%, but this premium is lost both in magnitude and significance in the presence of garbage growth or any other factor for that matter. The observed premium corresponds to an implied risk-aversion coefficient of 97, roughly in line with the earlier numbers but a lot lower than the efficient estimates in Table IV.

The measure of Parker and Julliard (2005) obtains a strong positive premium with an implied risk-aversion coefficient of 63, which is in line with the benchmark estimate of Table III. The Q4–Q4 measure of Jagannathan and Wang (2007) implies risk aversion of 125, which is too high for Table III.

C.2. GMM Cross-sectional Test

The Fama–MacBeth (1973) methodology does not account for the fact that the inputs to the second-stage cross-sectional regression are themselves estimates. In addition, the test is not efficient. Shanken (1992) derives a correction for the generated regressors problem and Cochrane (2005, p. 241) shows an easy way to deal with both issues in a GMM framework in which all moments are estimated simultaneously and their cross-correlations are taken into account. I use a slightly modified version of Cochrane's approach to see if the results from the Fama–MacBeth regressions carry through.

Specifically, I consider the set of moments

$$E\begin{bmatrix} R^e - a - \beta f \\ (R^e - a - \beta f) \otimes f \\ R^e - \beta\lambda \end{bmatrix} = \begin{bmatrix} 0 \\ 0 \\ 0 \end{bmatrix}, \tag{7}$$

where R_t^e is a vector of asset returns, f_t is a vector of factors, β is a matrix of factor betas, and λ is a vector of factor premia. The first two restrictions correspond to the time-series estimates of the betas and the last restriction corresponds to the cross-sectional test. A closer look at the criterion (7) shows that the first and third restrictions are linearly dependent.[14] This makes standard efficient GMM impossible as the moment covariance matrix is analytically singular. To deal with this issue, I use a weighting matrix that imposes OLS estimates on the betas but selects the third set of restrictions efficiently to produce the most precise premium estimates. Fixing the betas to their OLS estimates is important because doing so does not allow the unwanted flexibility of manipulating betas to obtain a better cross-sectional fit. The Internet Appendix shows the derivation of this weighting as well as results using alternative matrices.

I use a smaller cross-section than in Table V in order to be able to estimate the full covariance matrix well. Specifically, I restrict attention to the six Fama–French (1993) size and book-to-market portfolios in addition to five industry portfolios. The results are in Table VI.

[14] To see why, subtract the first set from the third, leaving $a + \beta(f - \lambda)$. If there are N assets and K factors with $N > K$, then β selects N linear combinations of K random variables, so at most K of the moments are linearly independent. This shows that in fact only $N + NK + K$ of the full set of $N + NK + N$ moments are linearly independent.

Table VI

GMM with an Efficient Selection Matrix

The test assets are the six Fama–French (1993) size and book-to-market portfolios and five industry portfolios. Returns are in excess of the T-bill return. The moment restrictions are

$$E\begin{bmatrix} R^e - a - \beta f \\ (R^e - a - \beta f)\otimes f \\ R^e - \beta\lambda \end{bmatrix} = 0.$$

The betas are set to their OLS estimates and the factor premia are computed efficiently. The table shows factor premia with three-lag GMM t-statistics in parentheses. The last column shows root-mean-squared pricing errors and associated p-values in parentheses.

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)

Overall, the estimates are very similar to the Fama–MacBeth (1973) results in Table V. Garbage growth still does somewhat better than the standard expenditure measure and prevails when the two factors are matched head-to-head. Garbage also does better than the ultimate consumption risk measure of Parker and Julliard (2005), reversing the result from Table V. In terms of pricing errors, the Q4–Q4 measure of Jagannathan and Wang (2007) is still the best performer among the consumption-related factors, although its premium is actually not statistically significant.

Table VII

European Data

Descriptive statistics and GMM test. Correlations and covariances are with the excess market return in each country. The risk-free rate is set to be the following investment: convert one unit of local currency into dollars, buy 30-day U.S. T-bills, roll over for 12 months, and convert back at the end of the year. Pos. corr. is among all countries with positive correlation.

	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)

Together, the cross-sectional results in Tables V and VI suggest that garbage growth is priced cross-sectionally and that it drives out expenditure growth. The linear cross-sectional tests confirm the earlier results showing that garbage growth requires a much lower coefficient of relative risk aversion than the expenditure-based measures.

D. European Data

To check out-of-sample robustness, I re-run the equity premium tests on a panel of European countries. Table VII reports summary statistics and GMM asset pricing test results. Expenditure and garbage exhibit similar stock market correlations of 28% and 30% respectively.[15] Restricting attention to only those countries for which the correlation is positive, these numbers increase to 42% and 32%. On the other hand, as in the United States, garbage growth tends to be more volatile; its standard deviation is on average two times that of expenditure growth. Also, as in the United States, this allows garbage growth to match the equity premia in these countries with lower risk aversion than expenditure.

In the GMM asset pricing test, I impose the restriction that the representative agent in all European countries has the same risk-aversion coefficient or equivalently that markets are integrated so that the set of country indices can be thought of as a cross-section of assets in the same market. Without this restriction, the test would have no power, as there are only 10 observations per country. To get a consistent proxy for the risk-free rate across all countries, I use the U.S. 30-day T-bill rate and use exchange rates from Datastream to convert to local rates.[16]

I report risk-aversion estimates for both the full set of countries and for the subset with positive correlations between each consumption measure and stocks. I make this split because the negative correlations are likely the product of mismeasurement. In both groupings, garbage growth delivers a lower estimate of the coefficient of relative risk aversion. When all countries are included, the estimate is 7 for garbage versus 22 for expenditure. Among the countries with positive consumption-return correlation, the difference is larger as the expenditure-based risk-aversion estimate doubles to 44 whereas the garbage-based estimate remains unchanged. Given these differences, garbage also generates a much lower implied risk-free rate of 16%, which of course is still very high. Overall, Table VII is consistent with the U.S. results: garbage delivers a lower risk-aversion coefficient while dramatically lowering the implied risk-free rate.

E. Controlling for Durability

Other studies (e.g., Gomes, Kogan, and Yogo (2009)) find that durable goods purchases are particularly volatile and procyclical. Because durable goods are consumed over a prolonged period, they should not be counted only at the time of purchase. Yogo (2006) deals with this issue explicitly by modeling the stock of durables and the utility flow derived from that stock. The more common approach is to remove durable goods from the measure of consumption. I do

[15] A few correlations are negative, but most of these can be corrected with a different timing convention. For consistency, I maintain the same timing convention across all countries as in the United States. Finally, the small sample size might also cause some correlations to be imprecisely estimated. In Japan, where there are strict limits on waste generation, the correlation between garbage growth and stocks is 90%.

[16] To the extent that this asset might not be risk-free from another country's perspective, the reported risk aversion coefficients may be understated, although this should not impact the relative performance of the garbage and expenditure models.

Table VIII

Controlling for Durability

As in earlier tables, Garbage is growth in total garbage, and Expenditure is growth in NIPA nondurable goods and services. Three-year garbage uses the 3-year growth in garbage as suggested by Parker and Julliard (2005). Excluding Durables removes durable goods from the garbage series. Orthogonal to Durables excludes the fitted value from a regression of total garbage on durable goods garbage net of a time trend. Durable goods in the garbage series are major appliances, small appliances, furniture, carpets, tires, batteries, electronics, and miscellaneous other durables. The last two measures cover the years 1960 through 1990. The table shows descriptive statistics and GMM estimates of relative risk aversion. The sole test asset is the excess market return. RRA (γ) is the GMM estimate of the relative risk-aversion coefficient. Adjusted RRA adjusts for time aggregation as in Breeden, Gibbons, and Litzenberger (1989). Standard errors are Newey–West with three lags. R^f is the implied risk-free rate. The last two measures use data only available for the period 1960 through 1990.

	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

the same because the garbage series is too short to estimate a durable goods model.

Note that garbage treats durable goods in a more subtle way than expenditure, counting their packaging at the point of purchase but not counting the goods themselves until later. Because packaging represents only a fraction of the weight of a durable good, investment in the stock of durable goods increases the volatility of expenditure but not necessarily that of garbage. It is possible, however, that old durables of equal weight are discarded at the time of purchase of new durables, in which case garbage and expenditure would suffer from the same problem.

To exclude durable goods, I use a shorter but more detailed sample from the EPA, which covers the years from 1960 through 1990. The short sample is identical to the full sample in terms of totals, but it breaks down the waste stream into 50 product categories, which allows for selective removal of durable products. I use three specifications: (1) one in which I remove durable goods, (2) one in which I remove the part of garbage that is perfectly correlated with discarded durables, net of a time trend, to control for packaging, and (3) one in which I use the 3-year growth in total garbage. The third approach is based on the observation in Parker and Julliard (2005) that the stock of durables should be cointegrated with durables expenditure, which implies that long-run movements in durables flow should capture changes in the stock of durables.

Table VIII presents summary statistics and the results of a GMM equity premium test. The table includes matched time subsamples for the different measures. It shows that removing durable goods from the garbage series actually increases volatility a bit. The component of garbage that is orthogonal to durables is also more volatile but slightly less correlated with stocks. As a result, both alternative measures lead to lower risk aversion of 10 and 8, respectively. Three-year garbage growth is only half as correlated with stocks as single-year growth but tends to be a bit more volatile, leading to a risk-aversion coefficient of 21. Overall, the evidence in Table VIII suggests that durability does not account for the main results of the paper. This conclusion is further corroborated by the result in Table II, Panel B, that garbage is uncorrelated with durables expenditure conditional on nondurables expenditure.

III. Conclusion

Archaeologists unearth the trash deposits of earlier humans to discern their tastes and habits. In this paper, I use garbage to illuminate consumption in the contemporary world. I find that the CCAPM with garbage as a measure of consumption matches the equity premium with a relative risk-aversion coefficient of around 17, which is several times lower than when any other expenditure-based measure is used. Similarly low estimates also emerge from cross-sectional tests. As a consequence, the implied risk-free rate is an order of magnitude lower, leading to a formal resolution of the joint equity premium-risk-free rate puzzle.

As a possible explanation, statistical issues related to benchmarking, survey bias, and the residual method may cause NIPA expenditure to be a poor proxy for consumption growth. Moreover, garbage may be picking up important unobserved sectors of the economy such as household production in particular and nonmarket consumption in general. The relative success of garbage as an alternative measure of consumption raises the possibility that the failure of the standard consumption-based model is due to a failure to measure consumption properly.

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