Frugal Materialism and Risk Preferences

Robert Zeithammer

UCLA

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Abstract: Frugal materialism is a tendency of consumer demand to become more elastic in product durability in response to a tightening budget constraint. This paper proposes a model of frugal materialism, and establishes a theoretical link between frugal materialism and the slope of risk aversion: For both their absolute and relative versions, frugal materialism and increasing risk aversion are nearly equivalent to each other.

Contact: Robert Zeithammer, UCLA Anderson School of Management, rzeitham@ucla.edu

Introduction

It is well known that during recessions, consumer purchases of durables tend to fall more than their purchases of non-durable goods. Numerous explanations of this fact exist, for example the fact that durables tend to be bigger-ticket items, replacement purchases can be postponed, and resale markets soften due to lack of liquidity. However, the declining sales of durables should not be interpreted as evidence that the underlying consumer preferences shift away from durables during recessions. Instead, the opposite is likely true: this paper interprets recent results from the consumer decision-making literature as evidence of *frugal materialism* – the tendency of demand sensitivity to durability to increase in a downturn – and analytically links this tendency to the seemingly unrelated domain of risk preferences.

The main empirical inspiration of this paper is recent work by Tully, Hershfield, and Meyvis (2015, hereafter "THM"), who find that making people feel more financially constrained increases their "concern about the lasting utility of their purchases" (p. 59), and results in higher stated demand for durable material goods relative to perishable versions of the same goods.[1] The consumers that THM studied thus exhibit *frugal materialism*, whereby a reduction in disposable income (forcing one to become more "frugal") increases their demand for *more* durable material goods ("materialism" in the sense of demand's elasticity in durability[2]). Frugal materialism seems like an intuitive property of consumer preferences: the poorer you are, the more attractive is an

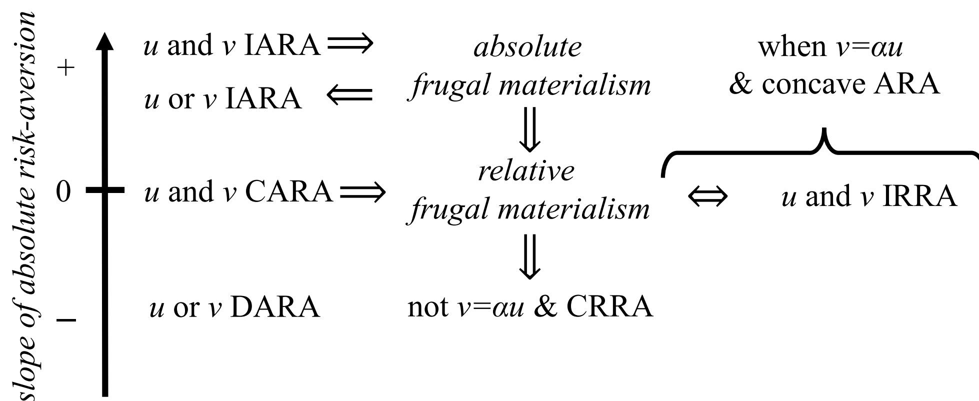
[1] THM's Study 6 provides a clear example of their finding: Subjects were to imagine they are walking around the city when it starts to rain, and they can either stop for a coffee in Starbucks or buy a poncho that is either described as "disposable" or "reusable" between subjects. Price variation is not an issue in the scenario, because the coffee costs the same as the poncho in all conditions. In a control group, the subjects expressed approximately the same strength of preference for both types of poncho over coffee. However, asking the subjects to "keep in mind their financial constraints" before making the decision dramatically increased their relative preference for the reusable poncho over coffee, while decreasing their relative preference for the disposable poncho.

[2] Note that throughout this paper, "materialism" means an individual-level increase in revealed preference for acquiring more durable material possessions, not a personal value or a belief system as in Richins (2011). In other words, materialism is just a label for the marginal effect of increased durability on demand.

increase in the durability of the goods you buy, ceteris paribus. This paper proposes a parsimonious model of frugal materialism, and shows analytically that it is not a generic property of standard preferences. Instead, it turns out that frugal materialism is nearly equivalent to increasing risk aversion. I now describe the model more formally, and preview the two main results of the paper.

Consider a consumer who faces a budget-constrained choice between two goods. One of the goods is a material good in that it can have various degrees of durability, and the other good is perishable (called "experience" throughout the paper). I analyze a canonical model of such a consumer's demand for different amounts of the two goods—an additively separable utility with one utility function u for the material good and a possibly different second utility function v for the experience. Let *absolute (relative) frugal materialism* be an increase in the absolute (relative) budget allocated to the material good in response to the joint event of (1) increasing the durability of the material good and (2) shrinking the overall budget. It is not clear whether THM found only relative or also absolute frugal materialism because their dependent variable is only a single choice between an experience and a material good, so I analyze both versions of the phenomenon. Figure 1 summarizes my findings.

Figure 1: Summary of results



The first major finding of this paper is that absolute frugal materialism implies at least one of the two good-specific utility functions exhibits increasing absolute risk aversion (IARA), and both utilities being IARA in turn implies absolute frugal materialism.[3] Therefore, when the two utility functions are affine transformations of each other, absolute frugal materialism is equivalent to IARA. Because most previous research has either found absolute risk aversion to be decreasing or argued a priori that it should be so (e.g. Bernoulli 1738, Pratt 1964, Arrow 1971, Rapoport, Zwick, and Funk 1988, Levy 1994, Gollier and Pratt 1996, and others) a finding of absolute frugal materialism would be surprising on its own. Additionally, a finding of absolute frugal materialism in consumers with CARA or DARA risk preferences in the same product domain and context would indicate an anomaly not captured by the simple model used here.

The second major finding of this paper is a somewhat restricted analogue of the above relationship that applies to the relative versions of the two constructs: I show that when the two utility functions are affine transformations of each other (denoted as $v=\alpha u$ throughout) and the absolute risk aversion is concave, relative frugal materialism is equivalent to increasing relative risk aversion (IRRA). When the two utility functions are distinct, CARA (which are IRRA) preferences imply relative frugal materialism, but CRRA preferences do not.

A finding of relative frugal materialism but not absolute frugal materialism in the context of two closely related goods thus zeroes in on non-IARA and IRRA preferences in accordance with Arrow's (1971) famous hypothesis. It is immediate that future studies of consumer demand for durable goods can be sharpened with a parallel analysis of risk preferences. The rest of the paper proceeds by first presenting the general results for the absolute and relative versions of frugal materialism / risk aversion, and then illustrating the results on several concrete examples.

[3] Note that researchers studying risk preferences often consider utility functions over different amounts of money, whereas the focus here is on the amount of a good as the argument of each utility function. The math is identical.

Model of frugal materialism and its relationship to risk preferences

Let there be two goods, one called an experience and one called a material product.[4] Both goods cost the same per unit, and a consumer has a budget B – the total units of both goods he can afford. The material product can be durable in that an expected number λ of future consumption opportunities exists during which a unit purchased today will still be available, with λ including any potential temporal discounting of future consumption. The utility of consuming E of experience and M of the material product with durability λ is additively separable, assuming away potential complementarities. In addition, the consumer experiences diminishing marginal utility (concavity of each univariate utility):

Assumption: $\textit{Utility}\left(E,M;\lambda\right)=\left(1+\lambda\right)u\left(M\right)+v\left(E\right)$ with u and v increasing and concave.

To determine his demand, the consumer selects the amount M^* of product and the amount E^* of the experience to purchase to maximize his utility such that the budget constraint $E+M \leq B$ holds:

$$\left\{M^*,E^*\right\}=\underset{M\geq 0,E\geq 0}{\arg\max}\ \left(1+\lambda\right)u\left(M\right)+v\left(E\right)\ \text{subject to}\ M+E\leq B \qquad (1)$$

In terms of the above notation, THM find tightening the budget constraint B increases the difference between demand for a durable version (high λ) and demand for the disposable version (low λ) of the material product. Considering a small change in durability, we can employ the tools of calculus to define local absolute (relative) frugal materialism in terms of the cross partial of (percentage) demand for the material product in budget and durability:

[4] Both the "experience" and the "product" are just generic goods in this paper; consumer framing of goods as either experiences or products is not modeled. I label the good with variable durability a "material product."

Definition: A consumer exhibits *absolute frugal materialism* when $\frac{\partial^2 M*}{\partial\lambda\,\partial B} < 0$, and exhibits *relative frugal materialism* when $\frac{\partial^2}{\partial\lambda\,\partial B}\left(\frac{M*}{B}\right) < 0$.

The goal of this paper is to explore what the sign of this cross partial teaches us about the shape of *u* and *v*. The first main result of this paper follows (see the Appendix for all proofs):

Proposition 1: *In terms of the absolute risk aversions of utilities u and v evaluated at the optimal consumption bundle* $A_u = \frac{-u''(M*)}{u'(M*)}$ *and* $A_v = \frac{-v''(E*)}{v'(E*)}$, *the demand cross partial driving absolute frugal materialism can be expressed as* $\frac{\partial^2 M^*}{\partial\lambda\,\partial B} = -\frac{A_v' A_u + A_u' A_v}{(1+\lambda)(A_u + A_v)^3}$.

The implications of Proposition 1 are straightforward: Because absolute risk aversions of concave functions are positive by construction, it follows that $\frac{\partial^2 M^*}{\partial\lambda\,\partial B} < 0 \Leftrightarrow A_v' A_u + A_u' A_v > 0$; that is, consumers exhibit absolute frugal materialism iff a weighted average of their absolute risk aversions of the two goods is increasing. Thus, either *u* or *v* of absolute frugal materialists must be IARA; the popular CARA and DARA specifications rule out frugal materialism. See Figure 1 for an illustration of these implications. The second main result of this paper is:

Proposition 2: *In terms of the absolute risk aversions* A_u *and* A_v *and the relative risk aversions* $R_u \equiv M^* A_u$ and $R_v \equiv E^* A_v$, *the percentage-demand cross partial driving relative frugal materialism can be expressed as* $\frac{\partial^2}{\partial\lambda\,\partial B}\left(\frac{M^*}{B}\right) = -\frac{(R_u' + R_v')(A_u + A_v) + (A_u' - A_v')(R_v - R_u)}{B^2(1+\lambda)(A_u + A_v)^3}$.

The implications of Proposition 2 are less stark than those of Proposition 1 because the expression in the numerator is more complicated. Nevertheless, it is immediate that CARA utilities imply $\frac{\partial^2}{\partial \lambda\, \partial B}\left(\frac{M^*}{B}\right) < 0$ because the second term in the numerator is zero and the first term is positive due to CARA implying IRRA.

When $v = \alpha u$, the sign of the slope of relative risk aversion is tightly connected to relative frugal materialism. It is immediate from Proposition 2 that CRRA implies $\frac{\partial^2}{\partial \lambda\, \partial B}\left(\frac{M^*}{B}\right) = 0$ because both terms are zero ($v = \alpha u$ implies $R_v = R_u$). It turns out CRRA is precisely the boundary case under the $R_v = R_u$ assumption as long as ARA is concave:

Corollary to Proposition 2: *When $v = \alpha u$ and ARA is concave, consumers exhibit relative frugal materialism iff the relative risk aversion of u is increasing.*

The requirement that ARA be concave is not necessary for frugal materialism to coincide with IRRA as evidenced by the quadratic utility function with a convex ARA, IRRA, and relative frugal materialism. When *u* and *v* are CRRA with $R_v \neq R_u$, the sign of the key cross partial for relative frugal materialism varies with λ: for example, when $u(x) = \sqrt{x}$ and $v(x) = \log(x)$, then

$$\left.\frac{\partial^2}{\partial \lambda\, \partial B}\left(\frac{M^*}{B}\right)\right|_{B=1} < 0 \Leftrightarrow \lambda > \sqrt{2\left(1+\sqrt{2}\right)} - 1 .$$

Concrete Examples of Utility Functions

This section illustrates the two main results on several concrete and popular examples of consumer-preference models. Table 1 at the end of the section collects all the formulae for easy reference, and includes additional functional forms not discussed in detail in the text.

Quadratic utility (example if IARA)

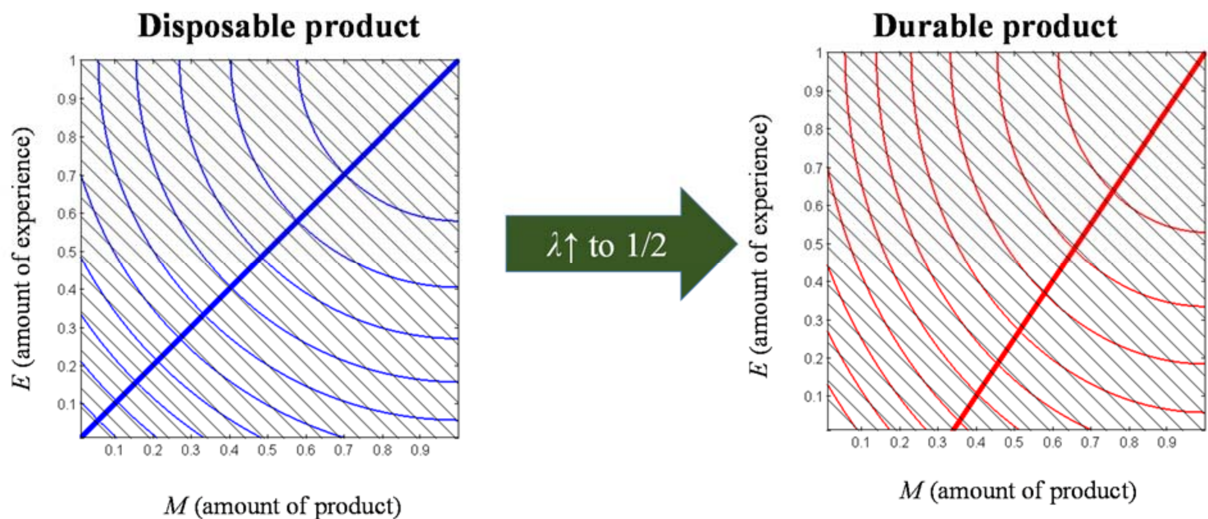
Consider the quadratic utility $U(M,E;\lambda)=(1+\lambda)\left(M-\frac{M^2}{2}\right)+\alpha\left(E-\frac{E^2}{2}\right)$ of Dixit (1979), where $\alpha>0$ is a constant that weighs the relative importance of the experience. Note these preferences involve $v=\alpha u$ in equation 1, and both u and v are IRRA and IARA. The consumer solves

$$\max_{M\geq 0,E\geq 0}(1+\lambda)\left(M-\frac{M^2}{2}\right)+\alpha\left(E-\frac{E^2}{2}\right) \text{ subject to } M+E=B \tag{2}$$

The solution is $M^*=\frac{1+\lambda+\alpha(B-1)}{1+\alpha+\lambda}$, which is less than B whenever $B>\frac{1+\lambda-\alpha}{1+\lambda}$. For smaller budgets, the consumer spends the whole budget on the material good. The consumer exhibits both absolute frugal materialism as predicted by IARA and Proposition 1: $\frac{\partial^2 M^*}{\partial\lambda\,\partial B}=\frac{-\alpha}{(1+\alpha+\lambda)^2}<0$, and also relative frugal materialism because $\frac{\partial^2}{\partial\lambda\,\partial B}\left(\frac{M^*}{B}\right)=-\frac{2\alpha}{B^2(1+\alpha+\lambda)^2}<0$. Since the absolute risk-aversion of a quadratic is the convex function $A(x)=\frac{1}{1-x}$, this example shows that the "ARA is concave" sufficient condition in the Corollary to Proposition 2 is not necessary.

To gain insight into quadratic preferences, consider the slope of relative demand in the budget: $\frac{\partial}{\partial B}\left(\frac{M*}{B}\right)=\frac{\alpha-(1+\lambda)}{B^2(1+\alpha+\lambda)}<0 \Leftrightarrow 1+\lambda>\alpha$. In words, given sufficient durability to make a unit of the material good preferable to a unit of the experience, an increase in the budget *decreases* the proportion of the budget spent on the material good. Figure 2 assumes the consumer values the non-durable versions of the two goods equally, and shows what happens when the budget increases and the product is durable: For small budgets, the consumer buys only the material good. As his budget increases, he adds some experience into the mix. In this sense, quadratic preferences capture the idea of perishable "experience" as a luxury, and the possible intuition that the THM result is obvious because poorer people should not waste their scarce money on coffee when they can get a durable poncho instead.

Figure 2: Quadratic preferences with *α*=1



Note to figure: The curves are indifference curves. The thin downward-sloping straight lines are budget constraints. The thick upward-sloping line is the locus of solutions to equation 2.

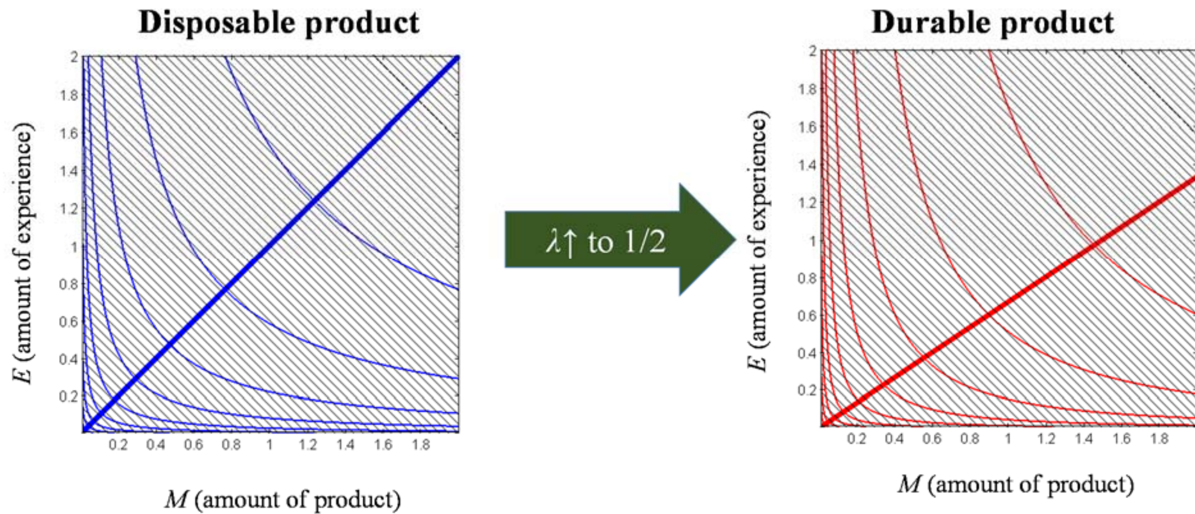
Cobb-Douglas utility (example of CRRA, and so DARA)

Another textbook example of preferences is the Cobb-Douglas utility function $U(M,E;\lambda)=(1+\lambda)\log(M)+\alpha\log(E)$, where $\alpha>0$ again represents the relative weight of the experience. Note that Cobb-Douglas preferences involve $v=\alpha u$ in equation 1, and both u and v are CRRA and DARA. The consumer solves

$$\max_{M,E}(1+\lambda)\log(M)+\alpha\log(E) \text{ subject to } M+E=B \tag{3}$$

The solution to this problem is $M^*=\frac{1+\lambda}{1+\alpha+\lambda}B$, so the consumer splits his budget according to the effective weight of each good in overall utility. Durability simply increases the effective weight of the material good. Clearly, these preferences support the potential intuition that relative frugal materialism is surprising because richer people should just buy more of everything proportionally instead of shifting their relative demand towards one particular good: Because the percentage demand does not depend on the budget, it is immediate that $\frac{\partial^2}{\partial\lambda\,\partial B}\left(\frac{M^*}{B}\right)=\frac{\partial}{\partial B}\left(\frac{M^*}{B}\right)=0$, so Cobb-Douglas preferences rule out relative frugal materialism as predicted by Proposition 2. Because $\frac{\partial^2 M^*}{\partial\lambda\,\partial B}=\frac{\alpha}{(1+\alpha+\lambda)^2}>0$, Cobb-Douglas preferences also rule out absolute frugal materialism as predicted by DARA and Proposition 1.

Figure 3: Cobb-Douglas preferences with α=1



Note to figure: See note to Figure 2, but replace equation 2 with equation 3.

Preferences that imply $\frac{M^*}{B}$ does not depend on B are called "homothetic.", and the previous paragraph shows that homothetic utility functions are inconsistent with relative frugal materialism. Graphically, homothetic preferences have indifference curves whose slopes are constant along rays beginning at the origin (see Fugure 3). Formally, a utility function is homothetic when a monotonic transformation of it (i.e., an alternative representation of the same underlying preferences) exists that is homogeneous of degree 1: $U(cM, cE) = cU(M, E)$. A well-known example of homothetic utility functions is the isoelastic function shown in Table 1.

Stone-Geary utility (DRRA, and so DARA):

So far, we have seen two examples with the crucial cross partials that are either negative or zero. Another example is needed to show the relative-demand cross partial can also be positive, and so its sign is thus not a priori even weakly constrained by standard consumer theory. Consider the

following generalization of the Cobb-Douglas preferences, due to Geary (1950) and used in empirical work by Iyengar et al. (2011): $U(M,E)=\log(M-m)+\alpha\log(E-e)$, where $m \geq 0$ and $e \geq 0$ represent minimum amounts of M and E that the consumer needs to purchase (Cobb-Douglas is the special case of $e=m=0$), with the utility only valid for $M>m$ and $E>e$. Note that Stone-Geary preferences involve u and v that are both DRRA and DARA. The solution to the consumer problem is $M^*=m+\frac{1+\lambda}{1+\alpha+\lambda}(B-e-m)$, and the key cross partial for relative frugal materialism is $\frac{\partial^2}{\partial\lambda\,\partial B}\left(\frac{M^*}{B}\right)=\frac{\alpha(m+e)}{B^2(1+\alpha+\lambda)^2}>0$. Therefore, Stone-Geary preferences cannot exhibit relative frugal materialism.

When we set $m=0<e$, we obtain a model of a consumer for whom increased durability makes him spend a greater part of his *discretionary* budget (B-e) on ponchos while very financially constrained consumers (i.e., $B \approx e$) spend all their money on coffee. Such a consumer's intuition may be that coffee is a necessity, so a budget reduction shifts their demand to coffee, and the shift is faster with durable ponchos because they obviously represent a bigger chunk of the discretionary budget.

Hyperbolic absolute risk-aversion utility (a general family)

A popular utility function in the study of risk preferences is the HARA function $U(x)=\frac{1-\gamma}{\gamma}\left(\frac{ax}{1-\gamma}+b\right)^{\gamma}$, known to allow all three possible combinations of increasing and decreasing absolute and relative risk aversions. For tractability, I consider the following three-parameter $u=v$ example (a, b, and γ are parameters):

$$\max_{M,E}(1+\lambda)\left(\frac{aM}{1-\gamma}+b\right)^{\gamma}+\left(\frac{aE}{1-\gamma}+b\right)^{\gamma} \text{ subject to } M+E=B\,. \tag{4}$$

It is well known that a HARA function is DARA if $\gamma<1$, IARA if $\gamma>1$, and CARA as $\gamma\to\infty$. As Proposition 1 predicts, the sign of the absolute-demand cross partial hinges only on γ because

$$\frac{\partial^2 M^*}{\partial\lambda\,\partial B}=\frac{1}{1-\gamma}F(\gamma,L), \text{ where } F(\gamma,L)=\frac{(1+L)^{\frac{2-\gamma}{\gamma-1}}}{\left(1+(1+L)^{\frac{1}{\gamma-1}}\right)^2}>0 \text{ for all } \gamma, \text{ and so } \frac{\partial^2 M^*}{\partial\lambda\,\partial B}<0\Leftrightarrow\gamma>1$$

It is also well known that a HARA function is IRRA iff $b>0$. Indeed, the sign of the relative-demand cross partial hinges only on b: $\frac{\partial^2}{\partial\lambda\,\partial B}\left(\frac{M^*}{B}\right)=-\frac{2b}{aB^2}F(\gamma,L)<0\Leftrightarrow b>0$.

Table 1: Summary of concrete examples under the $v=\alpha u$ assumption

Name of utility function	$u(x)$	$\frac{\partial^2}{\partial\lambda\,\partial B}\left(\frac{M^*}{B}\right)$	$\frac{\partial^2 M^*}{\partial\lambda\,\partial B}$
Stone-Geary (DARA, DRRA)	$\log(x-x_{\min})$	$\frac{\alpha(M_{\min}+E_{\min})}{B^2(1+\alpha+\lambda)^2}>0$	$\frac{\alpha}{(1+\alpha+\lambda)^2}>0$
Cobb-Douglas (DARA, CRRA 1)	$\log(x)$	0	$\frac{\alpha}{(1+\alpha+\lambda)^2}>0$
Isoelastic (DARA, CRRA r)	$\frac{x^{1-r}-1}{1-r}$	0	$\frac{\sqrt[r]{\alpha(1+\lambda)}}{r(1+\lambda)\left(\sqrt[r]{\alpha}+\sqrt[r]{1+\lambda}\right)^2}>0$
Exponential (CARA a, IRRA)	$\frac{1-e^{-ax}}{a}$	$\frac{-1}{2a(1+\lambda)B^2}<0$	0
Quadratic (IARA, IRRA)	$x-\frac{x^2}{2}$	$\frac{-2\alpha}{B^2(1+\alpha+\lambda)^2}<0$	$\frac{-\alpha}{(1+\alpha+\lambda)^2}<0$
Hyperbolic risk aversion (IARA iff $\gamma<1$, IRRA iff $b>0$)	$\left(\frac{ax}{1-\gamma}+b\right)^{\gamma}$	$-\frac{2b}{aB^2}\underbrace{F(\gamma,L)}_{>0}<0\Leftrightarrow b>0$	$\frac{1}{1-\gamma}\underbrace{F(\gamma,L)}_{>0}<0\Leftrightarrow\gamma>1$

Discussion

In an economic downturn, consumer demand for durables seems to be more elastic in the products' durability – a behavior recently documented in the behavior literature. Such "frugal materialism" can be rationalized in a canonical microeconomic model with additively separable utility, but it is not a generic property of standard preferences. This paper documents a close relationship between frugal materialism and the seemingly unrelated domain of decision-making under risk in a standard model of consumer demand. I show that under mild assumptions, consumers who exhibit absolute (relative) frugal materialism should exhibit *increasing* absolute (relative) risk aversion in the same context. This newly discovered relationship suggests further directions for empirical work at the intersection of risk and demand for durable goods.

The implications for further empirical work are at least threefold: First, we need to find whether and when consumers exhibit both forms of frugal materialism or only the relative version. Second, we need to conduct within-subject measurements of both the intensity of frugal materialism and the slope of risk aversion to empirically test the proposed link. Finally, we need to explore potential relationships between frugal materialism and other important behaviors under risk. For example, frugal materialism may be related to precautionary savings (Kimball 1990), because a durable good may serve as a useful hedge against a future income shock.

This paper also broadens the implications of the THM study which inspired it. The theoretically appropriate and empirically relevant slope of risk aversion has received much discussion since Pratt's (1964) definition of the concept. Regarding the slope of absolute risk aversion, most research to date has either found it to be negative (i.e., DARA, e.g., Rapoport, Zwick, and Funk 1988, Levy 1994, and others), or argued a priori that it should be so (Bernoulli 1738, Pratt 1964, Arrow 1971, Gollier and Pratt 1996, and others). Arrow (1971) advanced a DARA-IRRA hypothesis as the most plausible pair of slopes of absolute and relative risk aversion,

and recent work by Brocas et al. (2018) finds empirical evidence of Arrow's hypothesis. The relationship between frugal materialism and the slope of risk aversion thus extends the behavioral findings that inspired this paper as follows: On one hand, a finding of absolute frugal materialism would be quite surprising because subjects who exhibit it should have IARA preferences over at least one of the goods in question. On the other hand, a finding of relative but not absolute frugal materialism would be consistent with Arrow's hypothesis and the prevailing understanding of risk aversion in the literature. A finding of no frugal materialism would suggest DRRA preferences, found by a relative minority of work to date (for an example of a DRRA finding, see Ogaki and Masao 2001).

Beyond the above implications for risk preferences, frugal materialism of either kind is also incompatible with homothetic preferences commonly used in the empirical literature (e.g., the multinomial logit model of consumer demand). Future modelers need to develop non-homothetic models, especially when attempting to model demand for durable goods under varying financial constraints. Such models are rare in the literature; the seminal example is Allenby and Rossi (1991) extended in Allenby, Garratt, and Rossi (2010). Moreover, the sensitivity of THM's cross partial to the curvature of the utility function suggests specific functional forms of the non-homothetic models matter a lot for matching basic patterns of the data; for example, the popular Stone-Geary model is inconsistent with relative frugal materialism.

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Appendix: Proofs of Propositions

Proof of Proposition 1: Because both utilities are increasing in quantity consumed, the budget constraint binds and the consumer's problem in equation 1 is equivalent to

$\max_{M}(1+\lambda)u(M)+v(B-M)$, which has the first-order condition

$$(1+\lambda)u'(M^*)=v'(B-M^*). \qquad \text{(FOC)}$$

To derive the cross partial of interest, differentiate the FOC twice, starting with the budget, and and express in terms of the absolute risk aversions of u and v denoted $A_u=\frac{-u''}{u'}$ and $A_v=\frac{-v''}{v'}$ respectively:

$$(1+\lambda)u''\frac{\partial M^*}{\partial B}=v''\left(1-\frac{\partial M^*}{\partial B}\right)\Rightarrow\frac{\partial M^*}{\partial B}=\frac{v''}{(1+\lambda)u''+v''}=\frac{A_v}{A_u+A_v}, \qquad (2)$$

where the arguments of u, v, and their derivatives have been suppressed for clarity (from this point in, u, A_u, and their derivatives always have M^* as the argument, whereas v, A_v, and their derivatives always have $E^*\equiv B-M^*$). The formula is intuitive: When the budget increases, the consumer buys more of the material good when the utility of the experience is diminishing faster (larger v'') relative to the effective (durability-weighted) utility of the material good. The $(1+\lambda)$ weight drops out when $\frac{\partial M^*}{\partial B}$ is expressed in terms of the absolute risk aversions, because the implicit M^* and E^* arguments satisfy the FOC.

To finish the derivation of $\frac{\partial^2 M^*}{\partial B\partial\lambda}$, differentiate equation 2 with respect to λ, remembering the argument of A_v is $B-M^*$, and hence $\frac{\partial A_v}{\partial\lambda}=-\frac{\partial M^*}{\partial\lambda}A_v'$:

$$\frac{\partial^2 M^*}{\partial B \partial \lambda} = \frac{-\frac{\partial M^*}{\partial \lambda} A_v'\left(A_u + A_v\right) - A_v\left(A_u' - A_v'\right)\frac{\partial M^*}{\partial \lambda}}{\left(A_u + A_v\right)^2} = -\frac{\partial M^*}{\partial \lambda}\frac{A_v' A_u + A_u' A_v}{\left(A_u + A_v\right)^2}. \qquad (3)$$

Finally, differentiate the *FOC* with respect to *λ*, and again express the result in terms of the risk aversions:

$$u' + \left(1+\lambda\right)\frac{\partial M^*}{\partial \lambda}u'' = -\frac{\partial M^*}{\partial \lambda}v'' \Rightarrow \frac{\partial M^*}{\partial \lambda} = \frac{-u'}{\left(1+\lambda\right)u'' + v''} = \frac{1}{\left(1+\lambda\right)\left(A_u + A_v\right)}. \qquad (4)$$

Plugging equation 4 into equation 3 completes the proof.

QED Proposition 1

Proof of Proposition 2: To calculate the cross partial of percentage demand, first differentiate with respect to budget:

$$\frac{\partial}{\partial B}\left(\frac{M^*}{B}\right) = \frac{B\frac{\partial M^*}{\partial B} - M^*}{B^2} = \left(\frac{1}{B^2}\right)\left(B\frac{\partial M^*}{\partial B} - M^*\right).$$

Now differentiate by durability, and plug in the result of Proposition 1:

$$B^2\frac{\partial^2}{\partial \lambda\, \partial B}\left(\frac{M^*}{B}\right) = -\frac{\partial M^*}{\partial \lambda} + B\frac{\partial^2 M^*}{\partial \lambda\, \partial B} = -\frac{\left(A_u + A_v\right)^2 + B\left(A_v A_u' + A_u A_v'\right)}{\left(1+\lambda\right)\left(A_u + A_v\right)^3}.$$

When the relative risk aversions are denoted $R_u \equiv M^* A_u, R_v \equiv E^* A_v$, the denominator can be expressed in terms of $R_u' = M^* A_u' + A_u, R_v' \equiv E^* A_v' + A_v$ as follows to prove the result:

$$\begin{aligned} &A_v\left(MA_u' + A_u + EA_u' - EA_v' + EA_v' + A_v\right) + A_u\left(EA_v' + A_v + MA_v' - MA_u' + MA_u' + A_u\right) \\ &= A_v\left(R_u' + R_v' + E\left(A_u' - A_v'\right)\right) + A_u\left(R_u' + R_v' + M\left(A_v' - A_u'\right)\right) = \\ &= \left(R_u' + R_v'\right)\left(A_u + A_v\right) + \left(A_u' - A_v'\right)\left(R_v - R_u\right) \end{aligned}.$$

QED Proposition 2.

Proof of Corollary to Proposition 2: To show IRRA $\Rightarrow$ relative frugal materialism, it is enough to focus on the DARA case because we already know IARA and CARA are sufficient on their own. IRRA makes the first term in the numerator of $\frac{\partial^2}{\partial\lambda\,\partial B}\left(\frac{M^*}{B}\right)$ positive, so making the second term also positive, that is, $\left(A'_u - A'_v\right)\left(R_v - R_u\right) > 0$, is sufficient for relative frugal materialism. There are two cases:

1) When *M*>*E*, IRRA and $u = \alpha v$ means $R_v < R_u$, so we need $A'_u < A'_v$. From DARA, both slopes of ARA are negative. Because *M*>*E*, $A'_u < A'_v$ when ARA is steeper at the higher of the two consumption amounts, for which global concavity of ARA is sufficient.
2) When *M*<*E*, IRRA means $R_v > R_u$, and so we need $A'_u > A'_v$. From DARA, both slopes of ARA are negative. Because *M*<*E*, $A'_u > A'_v$ is steeper at the higher of the two consumption amounts, for which global concavity of ARA is sufficient.

To show relative frugal materialism $\Rightarrow$ not DRRA, note DRRA makes the first term in the numerator of $\frac{\partial^2}{\partial\lambda\,\partial B}\left(\frac{M^*}{B}\right)$ negative, so making the second term also negative, that is, $\left(A'_u - A'_v\right)\left(R_v - R_u\right) < 0$, is sufficient to rule out relative frugal materialism. There are two cases:

1) When *M*>*E*, DRRA and $u = \alpha v$ means $R_v > R_u$, so we need $A'_u < A'_v$. Because DRRA implies DARA, both slopes are negative, and the same argument as in the above case 1 shows global concavity of ARA is sufficient.
2) When *M*<*E*, DRRA and $u = \alpha v$ means $R_v < R_u$, so we need $A'_u > A'_v$. Because DRRA implies DARA, both slopes are negative, and the same argument as in the above case 2 shows global concavity of ARA is sufficient. *QED Corollary to Proposition* 2