

# New Goods and Asset Prices

Paul Scanlon\*

Trinity College, Dublin

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## Abstract

I propose an extension to the consumption capital asset pricing model to incorporate the introduction of new goods over time and states of nature. In the model, consumers have a love of variety, and consumption consists of different components: product groups and brands. Expected growth of product groups raises expected future marginal utility—thereby increasing the incentive to save and reducing the risk-free rate of interest. Meanwhile, cyclical variation in brand and quality growth makes marginal utility more volatile and countercyclical—thereby raising the expected equity premium.

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## Introduction

While the assumption of a single agent has received a lot of attention in the asset pricing literature, the assumption of a single *good* is largely overlooked. Yet this is surprising: by affecting consumers' expected marginal utility, changes in product variety should affect their valuation of future payoffs—and therefore asset prices. Moreover, new goods affect marginal utility in different ways; the release of a new drug, for instance, has a different effect on marginal utility to the release of a new brand of wine. To address these issues, this paper proposes an extension to the consumption capital asset pricing model (CCAPM) to incorporate changes in product variety over time and states of nature.

Because the standard CCAPM implicitly treats all goods—such as cars and wine—as perfect substitutes, variations in consumption expenditure fully determine variations in marginal utility. And essentially this is the source of the equity premium puzzle: expenditure growth is relatively smooth. As a result, there is little risk to holding equity, so only a high level of risk aversion can justify a large equity premium. Closely related to this is the risk-free rate puzzle: faced with higher expected consumption of the *same* good in the future, coupled with diminishing marginal utility to *that* good, why do consumers still save, thereby keeping the risk-free rate so low? Clearly the one-good assumption relates to both the stability of marginal utility growth and the expected decline in marginal utility over time—the very sources of the puzzles in the standard CCAPM.

Rather than consuming “more of the same,” people in my setting consume a variety of goods. By variety, I mean distinct product groups—such as cars—and relatively similar brands within each group—such as Volvos and Fords. Central to the model is variety growth: the number of goods, along with their quality, varies over time and states of nature. Throughout, I assume consumers have a love of variety, who, in turn, consume all existing goods. Yet I maintain the basic framework of time-separable, expected power utility, with complete, frictionless markets.

Because consumers now care about *what* they consume, both consumption expenditure and product variety determine marginal utility. For this reason, changes in product variety result in different “states of the world,” with states described by both the level of consumption expenditure *and* the variety of goods available. As we shall see, product group growth slows the decline in marginal utility

over time, while cyclical variation in brand and quality growth raises the level of consumption risk. Because financial assets are the means of smoothing marginal utility over time and states of nature, these dynamics affect asset prices.

To see the idea, consider the “tree economy” setting of Lucas (1978), where trees bear fruit—say, oranges—randomly, and consumers smooth marginal utility over time and states of nature. Faced with orange growth over time, consumers desire to borrow, which raises the risk-free rate. By contrast, in my setting the future heralds not only more oranges, but also fruit of a different nature: looking ahead, trees also bear apples, grapes, lemons, kiwis, pears, and so on. By raising the demand for future consumption, this increases savings and lowers asset returns—in particular, the risk-free rate.

Turning to the equity premium, in Lucas’s setting, the covariance of marginal utility with the number of oranges falling from a tree determines the price of the tree. Trees bearing more oranges when they are already plentiful provide poor consumption insurance, and therefore command a risk premium. But in my setting, trees not only bear a greater number, but also a greater variety of oranges in a boom; now there are Florida oranges, Spanish oranges, sweet ones, tender ones, organic ones, and so on. Because the consumption of a *given* number of oranges now provides more utility, consumer surplus or “real income” is relatively higher. As a result, consumption *services* now covary more with equity returns—so equities command a higher risk premium.

Although product variety clearly grows over time, is variety growth procyclical? A number of models make this prediction. Leading examples in this literature include Shleifer (1986), who models firms introducing new products at the same time, causing “implementation cycles”; Schmooller (1966), who maintains that firms innovate in booms in response to a greater market size; and, most famously, Schumpeter (1939), who describes the business cycle in terms of “waves of creative destruction.” More recently, several papers have emphasized the role of firm entry and expanding product variety as a transmission mechanism over the business cycle (see, e.g., Bilbiie, Ghironi, and Melitz, 2007; Corsetti and Bergin, 2005.) According to these models, procyclical profits induce firm entry, raising variety growth. And consistent with these predictions, procyclical variety growth is a feature of the data (see, e.g., Broda and Weinstein, 2007; Axerloglou, 2003.) For example, Broda and

Weinstein (2007) find that “net product creation is strongly procyclical”; while Bilbiie et al. report that “disproportionately more varieties are introduced during U.S. expansions.” Yet so far no one has studied the asset pricing implications of new goods.<sup>1</sup>

I proceed as follows. After describing the model in Section 1, I discuss its asset pricing implications in Section 2. Most importantly, the asset pricing kernel now depends on the variety of goods consumed. In particular, product group growth raises marginal utility, while brand and quality growth reduce it; intuitively, group growth creates more “needs,” while brand and quality growth act to satiate them. Overall, the model identifies four risk premia: one arising from consumption risk and three from composition risk—that is, risk arising from variation in each of brand, quality, and group growth. Meanwhile, the risk-free rate depends on the long-run trend in variety growth, together with precautionary savings arising from composition risk.

Having presented the theory, I survey empirical work on both long-run and short-run trends in variety growth and the associated welfare gains in Section 3. To approximate the expected risk-free rate, I use long-run trends in labor supply. According to standard theory, these trends relate to marginal utility growth over time; therefore, knowing wage and consumption growth, labor supply trends provide information on the net effect of variety growth on the long-run trend in marginal utility. Exploiting this relationship, I simplify the expression for the risk-free rate.

Depending on the magnitudes of group, brand, and quality growth, the model predicts marginal utility may either rise or fall relative to trend in booms. As a result, the model’s predictions for the equity premium are unclear. Nonetheless, I present both empirical evidence and theoretical arguments, suggesting procyclical variety growth largely represents quality improvements and new brand intro-

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<sup>1</sup>Some recent contributions analyze the CCAPM in a multi-good framework. Yet these studies examine variations in consumption over a *fixed* product space, so are qualitatively different to the analysis here. For example, Piazzesi, Schneider, and Tuzel (2007) incorporate a consumption bundle of non-housing consumption and housing services into the CCAPM. Assuming both components are nonseparable in utility, they show that cyclical variation in the housing share raises the expected equity premium, while long-run trends and volatility in the housing share reduce the risk-free rate. Pakoš (2004) and Yogo (2006) focus on a consumption bundle comprising nondurable and durable components, and show how the interaction of both components can increase aggregate consumption risk. Examining the role of consumption commitments, Chetty and Szeidl (2007) show that commitments increase the variability of discretionary consumption, and in turn raise the level of consumption risk. Closer to this paper, Parker, Yogo, and Ait-Sahalia (2004) introduce luxury goods into the CCAPM, and show how the covariance of luxury goods consumption with equity returns raises the equity premium. Finally, the classic contributions of Merton (1973) and Breeden (1979) consider variation in consumption opportunities, but in relation to changes in the relative prices of a fixed number of goods.

ductions. In addition, by making inferences from other observations—such as the procyclical nature of luxury good sales—I establish that marginal utility falls below trend in a boom. For these reasons, I infer that the effect of brand and quality growth on marginal utility dominates that of product group growth. Using all the empirical evidence, I then approximate—albeit roughly—cyclical variation in brand, quality, and group growth, along with the associated welfare gains. Together with data on asset returns and consumption growth, I then calibrate the expected equity premium and risk-free rate for a range of parameter values in Section 4. Compared to the standard CCAPM, the expected equity premium is higher, and the risk-free rate is lower, for reasonable parameter values. Finally, Section 5 concludes.

## 1 The Model

### 1.1 The Economic Environment

There is a representative consumer who lives for  $T$  periods. The consumer has preferences defined over a continuum of existing and potential goods, including leisure. There is latent demand for all potential goods, and no good is essential. The consumer receives income from investment returns and labor supply.

Consumption consists of different components, and there are two margins of differentiation: product groups and brands. Product groups represent broad categories of goods without close substitutes, for which demand is relatively inelastic; for example, new medicines, cars, microwave ovens, VCRs, printers, laptops, tvs, cell phones, and so on. There is a continuum of differentiated product groups indexed along the interval  $(0, \infty)$ , but at any time  $t$ , only a measure  $n_t < \infty$  of groups is available for purchase. There is a common elasticity of substitution between all product groups, and since groups are imperfect substitutes, I assume this is less than one. New goods on this margin represent “breakthrough” innovations.

Associated with each group is a continuum of brands, also indexed on  $(0, \infty)$ . Brands constitute different varieties or characteristics of goods within a given group—in terms of attributes like func-

tion, style, flavor, size, color, and so on. At time  $t$ , there is a measure  $m_t < \infty$  of brands available in each group.<sup>2</sup> Because brands are relatively good substitutes, demand on this margin is elastic, and the common elasticity of substitution between brands exceeds one. In addition to changes in the number of brands, there are also quality improvements to each existing brand over time; at time  $t$  all existing brands are of uniform quality  $A_t \in (0, \infty)$ . New goods on this margin represent incremental innovations.

Brand, quality, product group, and wage growth are random variables with means of  $g_m$ ,  $g_A$ ,  $g_n$ , and  $g_w$  respectively; the respective variances are  $\sigma_m^2$ ,  $\sigma_A^2$ ,  $\sigma_n^2$ , and  $\sigma_w^2$ . As for notation, groups are indexed by  $j \in [0, n_t]$  and brands by  $i \in [0, m_t]$ . Thus  $c_{jt}$  denotes the consumption service flow from group  $j$  at time  $t$ , while  $c_{jit} \geq 0$  denotes the consumption of brand  $i$  in group  $j$  at time  $t$ . All existing goods have a price of one, while non-existent goods have infinite prices.

The consumer has a love of variety for groups and brands. For groups, one can explain this by the welfare improvement associated with significant innovations: new groups satisfy previously unmet needs. Broadly, one can explain a love of variety for brands in two ways. First, with diminishing marginal utility to each good, there is a welfare gain to smoothing consumption over more goods. Faced with a variety of yoghurts, for example, the consumer might prefer to consume a little of each flavor; this is the Dixit-Stiglitz (1977) setup. Second, greater variety enables consumers to attain their ideal brand or bundle of characteristics; this is the Lancaster (1979) formulation. Either way, welfare of the representative consumer rises as the number of brands increases. Mostly for simplicity, I use the more tractable Dixit-Stiglitz formulation.

## 1.2 Consumer Preferences

Period utility is a function of consumption services from product groups,  $c_{jt}$ , and labor  $l_t \in [0, 1]$ . Both consumption services from individual groups and labor are separable in utility. Consumption services from a group  $c_{jt}$  are given by the constant elasticity of substitution index:

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<sup>2</sup>For convenience, I ignore indivisibilities and the non-integral nature of the variables  $n$  and  $m$ , and from now on refer to them loosely as numbers. More generally, it is convenient to view  $m$  and  $n$  as continuous indices of brand and group variety.

$$c_{jt} \equiv \mathbf{m}_t^{v+1-\frac{1}{\alpha}} \left( \int_0^{m_t} (A_t^\gamma c_{jit})^\alpha di \right)^{\frac{1}{\alpha}}, \quad (1)$$

where  $c_{jit} \geq 0$ ,  $\alpha \in (0, 1)$ , and  $\mathbf{m}_t > 0$  denotes the measure of brands actually consumed. A rise in quality  $A_t$  increases the utility derived from the consumption of each brand, and  $\gamma > 0$  mediates the taste for quality. Distinguishing between the number of brands available,  $m_t$ , and the number actually consumed,  $\mathbf{m}_t$ , ensures that only goods consumed affect welfare. For clarity, I set the upper integral limit to  $m_t$  and not to infinity, but technically utility is defined over the range  $[0, \infty)$ .<sup>3</sup> Since there is a continuum of brands, the elasticity of substitution between brands within a group is  $\frac{1}{1-\alpha} \in (1, \infty)$ .

Following Benassy (1996),  $v \in (0, \infty)$  mediates the taste for brand variety, and governs the elasticity of the marginal utility of consumption with respect to the number of brands consumed. The parameter  $v$  disentangles the concepts of and elasticity of demand and elasticity of substitution from the measure of love of variety.<sup>4</sup> Therefore, this formulation can handle situations where the consumer might be highly responsive to price changes, but still have a large taste for variety; or cases where the consumer has little taste for variety, but perceives goods as imperfect substitutes.

Now define:

$$u(c_{jt}) = \frac{(c_{jt} + \epsilon)^{1-\theta}}{1-\theta},$$

where  $\theta > 1$ ,  $\epsilon > 0$ , and  $c_{jt} \gg \epsilon \approx 0$ . For now, assume there is only a single product group. Then the utility from the consumption services of the group is given by

$$u(c_{jt}) - u(0) = \frac{(c_{jt} + \epsilon)^{1-\theta}}{1-\theta} - \frac{\epsilon^{1-\theta}}{1-\theta} \geq 0.$$

The constant  $\epsilon$  is arbitrarily small and governs the utility gain from consuming any positive quantity

<sup>3</sup>That is,  $c_{jt} \equiv \mathbf{m}_t^{v+1-\frac{1}{\alpha}} \left( \int_0^\infty (A_t^\gamma c_{jit})^\alpha di \right)^{\frac{1}{\alpha}}$ , where  $\mathbf{m}_t^{v+1-\frac{1}{\alpha}} \left( \int_{m_t}^\infty (A_t^\gamma c_{jit})^\alpha di \right)^{\frac{1}{\alpha}} = 0$ .

<sup>4</sup>To see why, suppose consumption expenditure on a group is  $C_t$ . Given symmetry and strict concavity, agents consume all available goods in equal quantities, so  $\mathbf{m}_t = m_t$ , and  $c_{jt} = m_t^{v+1-\frac{1}{\alpha}} m_t^{\frac{1}{\alpha}-1} A_t^\gamma C_t = m_t^v A_t^\gamma C_t$ . Clearly the parameter  $v > 0$  mediates the marginal utility gain to consuming additional brands. By comparison, the standard Dixit-Stiglitz function conflates the degree of love of variety with the elasticity of substitution (and elasticity of demand), and implies  $v = \frac{1}{\alpha} - 1 > 0$ .

of the group. It plays two roles. First, since  $\theta > 1$ , it ensures that the utility flow from consuming a group is positive and, second, it ensures period utility is well-defined when  $c_{jt} = 0$ . Otherwise, it plays no role in the results. Since  $\epsilon \approx 0$ , even a small amount of consumption on a new group raises utility significantly. As a result, there is a sizable welfare gain to consuming distinct new innovations, irrespective of the quantity consumed. Subsequently, utility increases at a diminishing rate, as consumption of the group rises.

Period utility from consumption services when  $n_t$  groups are available for purchase is

$$\mathbf{n}_t^\phi \int_0^{n_t} u(c_{jt}) - u(0) \, dj = \mathbf{n}_t^\phi \int_0^{n_t} \frac{(c_{jt} + \epsilon)^{1-\theta}}{1-\theta} - \frac{\epsilon^{1-\theta}}{1-\theta} \, dj, \quad (2)$$

where  $\phi > -1$ , and  $\mathbf{n}_t$  denotes the number of groups actually consumed. The constant  $\frac{1}{\theta} < 1$  is the elasticity of intertemporal substitution of consumption services from each group across time.<sup>5</sup> Because groups are separable in utility,  $\frac{1}{\theta}$  is also the elasticity of substitution between groups. As a result, consumption services in different periods and consumption services of different groups are equally substitutable. By assumption,  $\theta > 1$ , while empirical evidence strongly suggests that the intertemporal elasticity of substitution is also below one, so this is a reasonable simplification.<sup>6</sup>

Here,  $\phi$  plays a role similar to that of  $v$  in the discussion of brands: it disentangles the degree of love of variety for groups from the elasticity of substitution between groups. To see why, let  $\bar{c}_{jt}$  denote the equilibrium level of consumption services in each group at time  $t$ . If the consumer purchases  $\mathbf{n}_t$  product groups, then by symmetry the equilibrium level of utility in period  $t$  is given by  $\mathbf{n}_t^{\phi+1} (u(\bar{c}_{jt}) - u(0))$ . Holding the level of consumption services in each group constant,  $\phi > -1$  now mediates the marginal utility gain to group consumption; the restriction,  $\phi > -1$ , ensures that utility is rising in the number of groups consumed.

Keeping  $c_{jt}$  on other groups fixed, if  $-1 < \phi < 0$ , there is decreasing marginal utility to the number of groups consumed. When  $\phi = 0$ , groups are independent and additively separable in utility. In contrast, if  $\phi > 0$ , there is increasing marginal utility to the number of groups consumed: new

<sup>5</sup>Strictly speaking, this is an approximation that is only true as  $c_{jt} \rightarrow \infty$ . The elasticity of intertemporal substitution of  $c_{jt}$  is  $\frac{c_{jt} + \epsilon}{\theta c_{jt}}$ . But since  $\epsilon \approx 0$ ,  $\frac{c_{jt} + \epsilon}{\theta c_{jt}} \approx \frac{1}{\theta}$ .

<sup>6</sup>In equilibrium, the term  $\frac{1}{\theta}$  equals the elasticity of intertemporal substitution of real consumption expenditure  $C_t$ .

goods now enhance the usefulness of existing ones. As an example, suppose there are only two groups: food and recreation. Then a firm introduces a third group—say, cars. Keeping expenditure on all groups fixed, the introduction of cars now has two effects. Because the consumer can now travel to nice restaurants, the marginal utility of food rises. And since the consumer can now easily travel to airports for vacations, the marginal utility of recreation also rises. Thus the consumption of a new group can have a positive effect on the marginal utility of other groups.

### 1.2.1 Specification of Lifetime Utility

The consumer takes the distributions of  $m_t$ ,  $A_t$ ,  $n_t$ , and  $w_t$  as given. Expected lifetime utility is given by

$$\mathbb{U} \equiv \mathbb{E}_0 \sum_{t=0}^T \beta^t \left( \mathbf{n}_t^\phi \int_0^{n_t} u(c_{jt}) - u(0) dj - h(l_t) \right), \quad (3)$$

where  $\mathbb{E}_0\{\cdot\}$  is an expectations operator, conditional on information at time  $t = 0$ . The subjective rate of time preference is  $\rho > 0$ , and  $\beta \equiv \frac{1}{1+\rho} < 1$ . The function  $h(l_t)$  captures the disutility of supplying labor  $l_t$ .

## 1.3 The Solution to the Intra-temporal Problem

I solve the problem by two-stage budgeting. First I find the optimal allocation of goods within each period, subject to some given level of consumption expenditure  $C_t$ . Then I turn to the intertemporal problem and find the optimal time-path for  $C_t$ .

Given the form of the consumption index, it is optimal to consume equal amounts of each brand and group. Noting prices of unity for each existing good, the optimal quantity demanded of each existing good is then  $c_{jit} = \frac{C_t}{m_t n_t}$  for all  $j \in [0, n_t]$  and  $i \in [0, m_t]$ . Plugging these demands into Eq. (1) gives the optimal level of consumption services from group  $j$  at time  $t$ :

$$\max_{\{c_{jit} \geq 0\}} \left\{ c_{jt} : \int_0^{m_t} c_{jit} di = \frac{C_t}{n_t} \right\} = m_t^v A_t^\gamma \frac{C_t}{n_t}.$$

After substituting the optimal  $c_{jt}$  into Eq. (2), and noting that  $\epsilon \approx 0$ , the period indirect utility function for consumption reduces to:

$$V(C_t, m_t, n_t, A_t) = \frac{\mathbf{n}_t^{\phi+1} (m_t^v A_t^\gamma \frac{C_t}{\mathbf{n}_t} + \epsilon)^{1-\theta}}{1-\theta} + \frac{\mathbf{n}_t^{\phi+1}}{(\theta-1)\epsilon^{\theta-1}}.$$

If the parameter restriction,  $\epsilon < \left(\frac{\phi+\theta}{\phi+1}\right)^{\frac{1}{1-\theta}} \left(\frac{C_t m_t^v A_t^\gamma}{\mathbf{n}_t}\right)$ , holds, then indirect utility is increasing in the number of groups consumed, and hence  $\mathbf{n}_t = n_t$ . Because  $\epsilon$  is infinitesimally small by assumption, and that for all reasonable parameter values and trend growth rates, trend growth in  $n_t$  is almost surely smaller than trend growth in  $C_t m_t^v A_t^\gamma$ , I assume this condition is always satisfied. With this assumption,  $\mathbf{n}_t = n_t$ , and the consumer spends  $\frac{C_t}{n_t}$  on each existing group. For convenience, define  $\zeta \equiv \phi + \theta > 0$ . Then noting that  $\frac{m_t^v A_t^\gamma C_t}{n_t} \gg \epsilon \approx 0$ , I approximate to get

$$V(C_t, n_t, m_t, A_t) \approx \frac{n_t^\zeta m_t^{v(1-\theta)} A_t^{\gamma(1-\theta)} C_t^{1-\theta}}{1-\theta} + \frac{n_t^{\phi+1}}{(\theta-1)\epsilon^{\theta-1}}. \quad (4)$$

Finally, the reduced form expected life-time utility is

$$\mathbb{U} \equiv \mathbb{E}_0 \sum_{t=0}^T \beta^t \left( \frac{n_t^\zeta m_t^{v(1-\theta)} A_t^{\gamma(1-\theta)} C_t^{1-\theta}}{1-\theta} + \frac{n_t^{\phi+1}}{(\theta-1)\epsilon^{\theta-1}} - h(l_t) \right). \quad (5)$$

## 1.4 Discussion of Intertemporal Problem

Two important points follow from Eq. (4). First, in contrast to the standard model—where  $V(C_t) = \frac{C_t^{1-\theta}}{1-\theta}$ —the indirect utility function for consumption now depends on the variety of goods consumed. Moreover, by setting  $n_t = m_t = A_t = 1$ , or by keeping these variables constant, the resulting utility function represents the same preferences as in the standard one-good model. Thus the standard model is a special case of a multi-good setup, where the level of variety is constant or where all goods are perfect substitutes in the eyes of consumers.

Second, the intertemporal elasticity of substitution for real consumption *expenditure* is  $\frac{1}{\theta}$ . For a given level of variety, a high  $\theta$  implies sharp diminishing marginal utility to consumption expenditure at any given point in time. Yet because of product variety growth, marginal utility does not neces-

sarily fall this fast *over* time. Later on, variety growth plays an important role in reconciling low intertemporal elasticity of substitution at any given point in time with apparently high intertemporal substitution over time.

## 1.5 The Effect of Variety on Marginal Utility

From Eq. (4), marginal utility is

$$V'(C_t) = \frac{n_t^\zeta}{m_t^{v(\theta-1)} A_t^{\gamma(\theta-1)} C_t^\theta}. \quad (6)$$

Noting  $\theta > 1$ , marginal utility is increasing in the number of groups, but decreasing in the number of brands and level of quality. To see why, recall that the optimal value of  $c_{jt}$  is

$$c_{jt} = m_t^v A_t^\gamma \frac{C_t}{n_t}.$$

Expressed this way, one can view  $\frac{C_t}{n_t}$ ,  $A_t$ , and  $m_t$  as distinct inputs, all combining to produce consumption services  $c_{jt}$ . Because these inputs enter in Cobb-Douglas form, the intratemporal elasticity of substitution between them is unity. Now setting  $\epsilon = 0$  for simplicity,  $u(c_{jt})$  becomes

$$u(c_{jt}) = \frac{n_t^\phi (m_t^v A_t^\gamma \frac{C_t}{n_t})^{1-\theta}}{1-\theta}. \quad (7)$$

For expenditure allocation, the consumer has preferences defined over two margins. The first relates to the composition of each group; i.e., the allocation of inputs,  $m_t$ ,  $A_t$ , and  $\frac{C_t}{n_t}$ , to produce consumption services  $c_{jt}$  from each group. The second relates to the allocation of consumption services  $c_{jt}$  across time and groups.<sup>7</sup> Given that  $\theta > 1$ , the elasticity of substitution between  $m_t$ ,  $A_t$ , and  $\frac{C_t}{n_t}$ —i.e., 1—exceeds the elasticity of substitution of consumption services across time and groups,  $\frac{1}{\theta}$ .<sup>8</sup> Therefore, compared to the level of consumption services in each group each period,  $m_t$ ,  $A_t$ , and  $\frac{C_t}{n_t}$  are relatively

<sup>7</sup>Implicitly the standard one-good model assumes the consumer only cares about levels of consumption expenditure, and is risk-neutral over consumption composition. But there is no a priori reason to believe this is the case.

<sup>8</sup>From the standpoint of risk, the level of risk aversion over the level consumption services,  $\theta$ , in each group exceeds that over composition, 1.

good substitutes. As a result, consumers are more concerned about attaining similar levels of  $c_{jt}$  per group across time than with equating the level of each input within each group.<sup>9</sup>

Now, a rise in the number of groups  $n_t$  in a period has two effects on marginal utility. First, since consumers smooth expenditure  $C_t$  over groups, a rise in  $n_t$  reduces the consumption of each group. Because consumers have a relatively strong desire to smooth the level of consumption services across groups and time, this consumption “widening” raises the marginal utility of consumption for each group in period  $t$ . Second, there is a direct effect due to  $\phi$ , capturing the degree of complementarity between groups. Holding expenditure on all groups fixed, increasing the number of groups consumed affects the marginal utility of consuming each existing group.

By raising the level of consumption services derived from a given amount of expenditure on each existing group in a period, increases in  $m_t$  and  $A_t$  lead to consumption “deepening.” And since consumers prioritize the smoothing of  $c_{jt}$  across  $j$  and time, they quickly become satiated as consumption services from each group rise in a given period. Intuitively, since  $m_t$ ,  $A_t$ , and  $\frac{C_t}{n_t}$  are relatively good substitutes, increases in  $m_t$  or  $A_t$  act as substitutes for consumption expenditure  $C_t$ , and this tends to satiate the consumer.<sup>10</sup> Rather than wanting to consume more in a given period, consumers now desire to shift real consumption resources  $C_t$  to other periods. Thus a rise in  $m_t$  or  $A_t$  in a period reduces marginal utility in that period. To summarize, we have the following propositions:

**Proposition 1** : *A rise in the number of brands  $m_t$  or the level of quality  $A_t$  in a period reduces the marginal utility of consumption in that period; i.e.,  $\frac{\partial^2 V}{\partial m_t \partial C_t} < 0$ , and  $\frac{\partial^2 V}{\partial A_t \partial C_t} < 0$ .*

**Proposition 2** : *A rise in the number of groups  $n_t$  in a period raises the marginal utility of consumption in that period; i.e.,  $\frac{\partial^2 V}{\partial n_t \partial C_t} > 0$ .*

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<sup>9</sup>Because consumers always spread expenditure equally across all goods in each period, the relative magnitudes of the elasticities of substitution between brands, groups, and time have no bearing on the analysis. Instead, the chief tension is the difference between the elasticity of substitution between inputs of the Cobb Douglas index and the elasticity of substitution of product groups  $c_{jt}$  over time.

<sup>10</sup>Equivalently, increases in  $m$  and  $A$  in a period cause a fall in the price of consumption services that period; i.e., a fall in the “welfare-based” price index. Because  $\theta > 1$ , the income effect of this price fall dominates, inducing consumers to smooth the welfare gain and shift consumption expenditure to other periods. That is, the marginal utility of consumption falls that period.

## 2 Asset Pricing and Equilibrium Returns

In this section I turn to the asset pricing implications of the model. Regarding notation,  $\sigma_x$  denotes the standard deviation of the random variable  $x$ ,  $\rho_{xy}$  the correlation of random variables  $x$  and  $y$ , and  $\sigma_{xy} = \rho_{x,y}\sigma_x\sigma_y$  the covariance of  $x$  and  $y$ . As for returns,  $r_f$  denotes the return on the risk-free asset, while  $r$  denotes the return on the risky one. Finally,  $\frac{z_{t+1}}{z_t} = 1 + \tilde{g}_{z_t}$ , where  $\tilde{g}_{z_t}$  is the growth rate of  $z$ , and where  $\mathbb{E} \tilde{g}_z = g_z$ .

The standard Euler equation for holding an asset with a random return  $\tilde{r}_t$  is

$$V'(C_t) = \beta \mathbb{E}_t[(1 + \tilde{r}_t)V'(C_{t+1})] \quad (8)$$

for  $0 < t < T$ . Substituting the expression for marginal utility, Eq. (6), into (8), dividing across by  $V'(C_t)$ , dropping time subscripts, and taking unconditional expectations yields

$$1 = \beta \mathbb{E} [(1 + \tilde{r})(1 + \tilde{g}_c)^{-\theta}(1 + \tilde{g}_m)^{v(1-\theta)}(1 + \tilde{g}_A)^{\gamma(1-\theta)}(1 + \tilde{g}_n)^\zeta]. \quad (9)$$

### 2.1 Risk-Free Asset Return

To obtain an expression for the risk-free rate, set  $\tilde{r} = r_f$  in (9) above. After taking a second-order Taylor series approximation of  $(1 + r_f)(1 + \tilde{g}_c)^{-\theta}(1 + \tilde{g}_m)^{v(1-\theta)}(1 + \tilde{g}_A)^{\gamma(1-\theta)}(1 + \tilde{g}_n)^\zeta$  around the point  $r_f = \tilde{g}_c = \tilde{g}_m = \tilde{g}_n = \tilde{g}_A = 0$ , and dropping small terms, the expected risk-free rate reduces to

$$\begin{aligned} r_f = & \rho + \theta g_c - v(1 - \theta)g_m - \gamma(1 - \theta)g_A - \zeta g_n - \frac{1}{2} \left( \theta(\theta + 1)\sigma_{g_c}^2 + v(1 - \theta)(v(1 - \theta) - 1)\sigma_{g_m}^2 \right. \\ & \left. + \gamma(1 - \theta)(\gamma(1 - \theta) - 1)\sigma_{g_A}^2 + \zeta(\zeta - 1)\sigma_{g_n}^2 \right) + v\theta(1 - \theta)\sigma_{g_m}\sigma_{g_c}\rho_{g_m,g_c} \\ & + \gamma\theta(1 - \theta)\sigma_{g_A}\sigma_{g_c}\rho_{g_A,g_c} + \theta\zeta\sigma_{g_c}\sigma_{g_n}\rho_{g_c,g_n} - v\gamma(1 - \theta)^2\sigma_{g_A}\sigma_{g_m}\rho_{g_A,g_m} \\ & - v\zeta(1 - \theta)\sigma_{g_m}\sigma_{g_n}\rho_{g_m,g_n} - \gamma\zeta(1 - \theta)\sigma_{g_A}\sigma_{g_n}\rho_{g_A,g_n}. \end{aligned} \quad (10)$$

Several points are worth noting. By reducing expected future marginal utility, growth in brand, quality, and consumption growth lower the incentive to save and so raise the expected risk-free rate.

By raising expected future marginal utility, expected group growth promotes savings and lowers the risk-free rate. Variation in real consumption and variety growth raises precautionary savings, again reducing the risk-free rate. Because consumption, brand, and quality growth all have the same qualitative effect on marginal utility, positive covariance between them amplifies variations in marginal utility. This increases the need for precautionary savings and lowers the risk-free rate. In contrast, group and each of brand and quality growth have opposing effects on marginal utility. Thus positive covariance of these variables acts like a hedge against variation in marginal utility. By reducing the need for precautionary savings, this raises the risk-free rate. Finally, although the expected risk-free rate is stable at all horizons, changes in trend growth rates can cause changes in the expected risk-free rate over time.

## 2.2 Risky Asset Return

Taking differences and unconditional expectations of the linearized Euler equations for both the risk-free asset and the risky asset gives the expected equity premium:

$$\mathbb{E}(r - r_f) = \theta \sigma_r \sigma_{g_c} \rho_{r, g_c} + v(\theta - 1) \sigma_r \sigma_{g_m} \rho_{r, g_m} + \gamma(\theta - 1) \sigma_r \sigma_{g_A} \rho_{r, g_A} - \zeta \sigma_r \sigma_{g_n} \rho_{r, g_n}. \quad (11)$$

Because brand and quality growth tend to satiate the consumer, their positive covariance with returns makes equities a poor hedge against composition risk.<sup>11</sup> To compensate investors for this risk, there are two additional risk premia: one for quality variation and the other for brand variation. By contrast, because group growth raises marginal utility, positive covariance of the asset return with group growth provides consumption insurance. As a result, the asset commands a higher equilibrium price and a lower expected return. The taste parameters  $v$ ,  $\gamma$ , and  $\zeta$  mediate the magnitudes the risk premia.

Because of fluctuations in variety growth, there is still an equity premium even if consumption expenditure is stable. More important, since the variables  $C$ ,  $A$ ,  $m$ , and  $n$  are nonstationary, their covariance with returns generates an equity premium at both long and short horizons. Assuming i.i.d.

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<sup>11</sup>When  $\theta < 1$ , equities hedge against changes in the consumption opportunity set and therefore command a negative risk premium. Moreover, if the covariances were time-varying, this would lead to variation in the equity premium over time.

shocks to growth rates ensures the equity premium is constant.

### 2.3 Equilibrium Returns and Puzzles in a One-Good World

The model nests the standard CCAPM: assuming no love of variety or setting  $n = m = A = 1$  in Eq (10), the equation for the expected risk-free rate reduces to

$$r_f = \rho + \theta g_c - \frac{1}{2}\theta(\theta + 1)\sigma_{g_c}^2. \quad (12)$$

According to Eq. (12), with observed consumption growth of 2 percent and  $\theta = 25$ , the risk-free rate is  $r_f \approx 23$  percent. Yet empirically,  $r_f \approx 1 - 2$  percent. This inability of the standard one-good CCAPM to reconcile a steep consumption profile with a strong desire to smooth consumption is the risk-free rate puzzle. Even with generous values of  $\rho = 2$  percent,  $g_c = 2$  percent, and  $\theta = 2$ , the risk-free rate is around 6 percent—about four times the actual rate.<sup>12</sup> Although precautionary savings tend to depress the risk-free rate, they are small in this complete markets setup. Whether the risk-free rate in (10) ultimately rises or falls relative to the one-good model depends on the taste parameters and the magnitudes of the trend growth and variance terms.

Similarly, the unconditional expected equity premium becomes

$$\mathbb{E}(r - r_f) = \theta\sigma_{r,g_c} = \theta\sigma_r\sigma_{g_c}\rho_{r,g_c}. \quad (13)$$

The equity premium puzzle corresponds to the failure of Eq.(13) to hold. For example, in the United States from 1890 to 1979, the left-hand side is around 6 percent, while  $\sigma_{r,g_c} \approx .24$ .<sup>13</sup> Since the quantity of consumption risk, as conveyed by  $\sigma_{r,g_c}$  is relatively low, the level of risk aversion must be

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<sup>12</sup>Aside from the equity premium implications, actual empirical estimates of the intertemporal elasticity of substitution (IES) are low. For example, Campbell (2001) notes that “direct evidence on the elasticity of intertemporal substitution suggests that it is fairly low, certainly well below one [i.e.,  $\theta > 1$ ].” Hall (1988) estimates the inverse of the IES to be ten, implying a risk-free rate of around twenty percent. On recent evidence, Cochrane (2008) observes that “more recent macro literature has tended to side with Hall.” Carroll and Summers (1989) claim that a value below .25 is standard. Studies based on micro data find estimates somewhat higher, but not markedly so; for example, Attanasio and Weber (1995) report estimates in the range [.48, .67].

<sup>13</sup>Taking the United States as a benchmark, the risky asset refers to the market portfolio—here, the S & P index—while Treasury bills proxy for the risk-free asset. Consumption growth refers to the growth of consumption nondurables and services expenditure.

high to justify the high realized equity premium; here we need  $\theta = 25$ . Yet comparing expressions (13) and (11), it is unclear whether the premium in a multi-good setting rises or falls relative to the one-good model.

### 3 Empirical Evidence

To determine expected returns in this multi-good setup, it is important to address two questions. First, how does product variety change over time and over the business cycle? Second, how do consumers value increases in product variety? Although the welfare gains to product variety growth are widely cited and play a central role in economic theory (see, e.g., Brynjolfsson, Hu and Smith, 2003; Hausman, 1997; Nevo, 2002), the cyclical variation and long-run trends in the level of product variety are less well-known.<sup>14</sup> To address this, this section presents evidence on trends and cyclical variation in product creation. In addition, by examining luxury goods expenditure and long-run trends in labor supply, I infer variation in marginal utility over time and over the business cycle. Because brand, quality, and group growth affect marginal utility differently, this provides indirect evidence on variation in brand, quality, and product group growth. But considering data constraints, the goal of this section is to provide suggestive estimates of changes in variety growth.

#### 3.1 Empirical Evidence

A number of authors report large increases in product variety over time. Klenow (2003) documents that the number of products carried by an average supermarket rose from 10,425 in 1978 to 40,333 in 2000—yielding an annualized growth rate of 6.7 percent. Ebert and Griffin (2006) report that firms in the United States introduce more than 25,000 new household, grocery, and drugstore items annually. Another indicator of product creation is trademark growth, which has averaged 4 percent a year between 1920 and 2007. Bilal (2004) finds that quality growth for consumer durable goods has

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<sup>14</sup>For example, in a study of the welfare gains to new cereals, Hausman (1997) reports: “I also find that consumers highly value new goods, which provide significant consumer surplus despite the existence of other brands which compete closely with the new brand.”

averaged at least 5.8 percent a year—more than double the rate implied by CPI measurement. Most importantly, consumption patterns reflect this increase in variety growth. Using a database that covers around forty percent of all expenditure on goods in the CPI—concentrated in grocery, drugstore and mass-merchandise sectors—Broda and Weinstein (2007) find that the value of new goods represents around nine percent of annual consumption expenditure. According to them, “almost 80 percent of the products that existed in 2003 were not around in 1994; these new products comprised 64 percent of expenditures in 2003.” Together, this evidence suggests significant changes in consumption composition over time. In addition, they find that forty percent of household expenditure in a given year is on goods that were created in the last four years.

Especially relevant to this analysis is evidence of procyclical variety growth (see, e.g., Broda and Weinstein, 2007; Axerloglou, 2005; Divinney, 1990.) Using barcode data, Broda and Weinstein provide extensive evidence that net product creation is “strongly procyclical.” Figure 1 shows how the introduction of new food products slowed in the U.S. during the recession of the early nineties. More recently, Mintel report that new product launches from U.S food and beverage producers in the first quarter of 2009 are down fifty one per cent from a year earlier. Further evidence of procyclical variety growth is the increase in firm entry, imports, and new trademark registration in booms. Figure 2 shows that new trademark registration—which almost surely reflects brand growth—is also strongly procyclical. In the first four months of 2009, for example, new trademark applications in the U.S fell by twenty per cent. More importantly, in an analysis of new product introductions advertised in the Wall Street Journal between 1975 – 1993, Axerloglou (2003) reports that the correlation between the number of new products issued and new trademark registration is .84. This finding suggests that variation in new trademark registration reflects general trends in new product introduction. This would be true if the number of trademarked goods was roughly a constant fraction of all goods.<sup>15</sup> Because the data suggest that this assumption is approximately correct, I use trademark data to estimate the

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<sup>15</sup>To see this, suppose that the number of trademarked goods,  $T$ , is a constant fraction,  $\kappa$ , of the number of goods; i.e.,  $T = \kappa n$ . Then the growth of  $T$ ,  $g_T$ , equals the growth of the number of goods. The standard deviations are also equal. Because there is no clear reason to expect a trend in the fraction of goods trademarked, this approximation seems reasonable.

mean growth rate of the stock of goods, together with its standard deviation.<sup>16</sup> According to this crude estimation, the mean annual growth rate of the stock of goods is 3.6 percent, while its standard deviation is approximately 2.8 percent.

Does variation in the rate of product creation reflect changes in brand, quality, or group growth? Most of the existing evidence on procyclical variety growth comes from goods—such as new food products and trademarks—that almost certainly constitute brands. Yet the limited available evidence suggests that product group growth is largely acyclical: because demand for product groups is inelastic, their sales are less dependent on business cycle conditions. Oi (1997) surveys evidence indicating that the introduction of “major innovations” bears little relationship to the business cycle, while the introduction of “improvement innovations” does. Mensch (1975) and Kleinknecht (1981) provide evidence that firms introduce basic innovations during recessions; since demand is low for existing products, they are forced to innovate to generate new sources of revenue. By contrast, Kleinknecht finds an increase in the release of “improvement and process innovations” in booms. This evidence suggests that most cyclical variation in variety growth reflects changes in brand and quality growth.<sup>17</sup>

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<sup>16</sup>To estimate the stock of trademarks  $T$ , I use the perpetual inventory method. This implies that the stock is given by the formula  $T_t = (1 - \delta)T_{t-1} + i_t + r_t$ , where  $i_t$  denotes the flow of new trademarks in year  $t$ ,  $r_t$  the number of trademark renewals in year  $t$ , and  $\delta$  the annual depreciation rate (the fraction of the stock that is taken off the market each year.) Due to changes in trademark law, the growth rate of the stock is highly volatile over the period 1870–1919. Because of this, I omit these years, and assume the initial trademark stock in 1920 equals the number of goods available in 1920. I take the depreciation rate from Landes and Posner (2003), who estimate an average depreciation rate for trademarks between 1934 and 1999 of 6.6 percent—a figure in the same ballpark as the rate estimated by Broda and Weinstein (2007).

<sup>17</sup>As Kleinknecht (1981) points out, “the logical conclusion from this is that recessions are good times for quality-augmenting and cost reducing improvements, but they are bad times for radical innovation... Why should an enterprise deal with the uncertainty risks and costs of introducing completely new products into the market as long as established products can be easily sold?” As Divinney (1990) points out, “Over the long run, since unique products represent more extensive investment, it should be expected that they are less affected by short-term business cycle influences....” According to Alexander Field (2003), over the period 1929–1941, “there were also a remarkable number of dynamic sectors, generating new process and product innovations, with varying levels of commercial exploitation before the war.”

Number of New Food Products Introduced in United States, 1988-1994

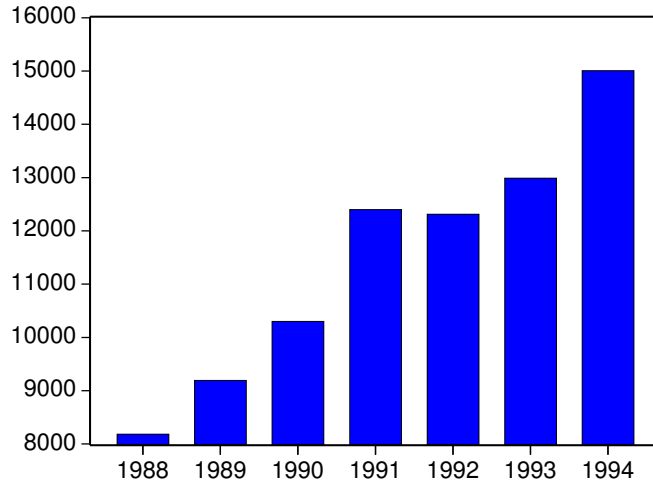


Figure 1: NUMBER OF NEW FOOD PRODUCTS INTRODUCED IN UNITED STATES, 1988-1994.  
SOURCE: NEW PRODUCT NEWS

Deviation From Trend of Consumption and New Trademark Registration: U.S., 1920-2007

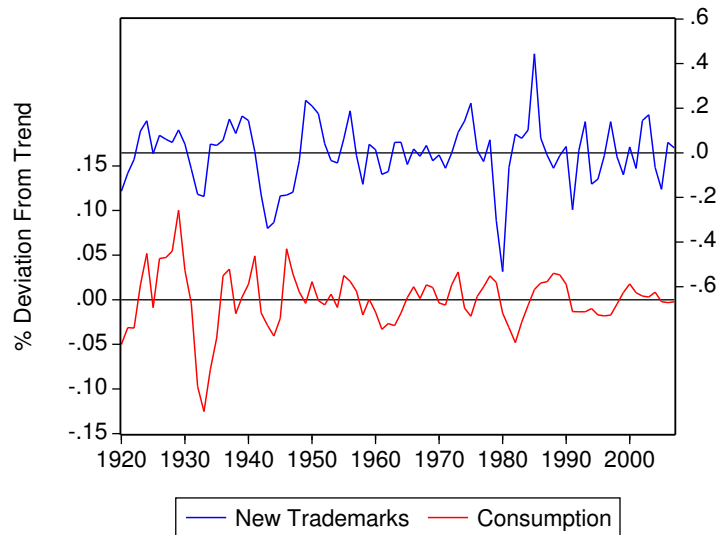


Figure 2: DEVIATION OF NEW TRADEMARK REGISTRATION AND CONSUMPTION FROM TREND: UNITED STATES, 1920-2007.  
SOURCE: HISTORICAL STATISTICS OF THE UNITED STATES.

## 3.2 Indirect Empirical Evidence

In addition to the direct evidence outlined above, other phenomena provide information on trends and variations in marginal utility. While labor supply trends provide information on the long-run trend in marginal utility, fluctuations in the consumption and price of rare goods shed light on the cyclical variation of marginal utility.

### 3.2.1 Empirical Evidence on Marginal Utility Growth

Dropping time subscripts and denoting the real wage at time  $t$  by  $w_t$ , the static neoclassical labor/leisure optimality condition is<sup>18</sup>

$$w_t V'(C_t) = h'(l_t). \quad (14)$$

Over long periods of time, labor hours per capita are approximately constant (see, e.g., Francis and Ramey, 2006.) To reconcile this observation with the model, the rate of increase of the wage  $w_t$  must equal the rate of decline in marginal utility  $V'(C_t)$ . Substituting the model's expression for marginal utility, Eq.(6), into Eq.(14), and then taking growth rates and means gives

$$-\theta g_c + \underbrace{v(1-\theta)g_m + \gamma(1-\theta)g_A + \zeta g_n}_{\approx(\theta-1)g_c > 0} = -g_w. \quad (15)$$

In the standard one-good setting where  $g_m = g_A = g_n = 0$ , marginal utility falls at a rate of  $\theta g_c$ . Reconciling this fact with stable labor hours therefore requires logarithmic utility—i.e.,  $\theta = 1$ . Yet this contradicts the empirical evidence on  $\theta$ .<sup>19</sup> By contrast, the variety-adjusted model introduces the extra terms in Eq.(15), which can reconcile the model with stable labor hours without restricting the value of  $\theta$ . Furthermore, noting that  $g_c \approx g_w$  in the data, these new terms imply that the rate of decline

<sup>18</sup>I assume consumption and leisure are separable in utility; see, e.g., Campbell and Ludvigston (1998) and Cochrane (2005).

<sup>19</sup>For standard parameter values, the standard model fails to explain long-run trends in labor supply. To see this, recall the standard labor/leisure condition,  $w_t V'(C_t) = h'(l_t)$ , and note that  $V'(C_t) = \frac{1}{C_t^\theta}$  in the standard model. For example, if  $\theta = 4$ , then to maintain stable hours,  $\frac{w_t}{C_t^4}$  must be constant. However, consumption per capita roughly doubled from 1960-2000, while wages increased at approximately the same rate.

in marginal utility over time is lower relative to the one-good model.

Manipulating Eq.(15) gives  $\zeta g_n = v(\theta - 1)g_m + \gamma(\theta - 1)g_A + (\theta - 1)g_c$ . Given the nature of product groups, the average rate of group growth,  $g_n$ , is almost surely lower than each of  $g_m$  and  $g_A$ . To ensure equality, therefore, it follows that the taste for groups,  $\zeta$ , must be high relative to  $\gamma$  and  $v$ . This is plausible: given their nature, new product groups likely affect marginal utility more so than new brands. Thus according to the model, product group growth is the main force sustaining a relatively stable labor supply over the long run.

### 3.2.2 New Expression for the Risk-Free Rate with Variety Growth

Notice now that the left-hand side of Eq. (15) also appears on the left of Eq. (10). Substituting (15) into (10) gives the equation for the expected risk-free rate, which I use to calibrate the model:

$$\begin{aligned}
 r_f = & \rho + g_w - \frac{1}{2} \left( \theta(\theta + 1)\sigma_{g_c}^2 + v(1 - \theta)(v(1 - \theta) - 1)\sigma_{g_m}^2 + \gamma(1 - \theta)(\gamma(1 - \theta) - 1)\sigma_{g_A}^2 \right. \\
 & \left. + \zeta(\zeta - 1)\sigma_{g_n}^2 \right) + v\theta(1 - \theta)\sigma_{g_m}\sigma_{g_c}\rho_{g_m,g_c} + \gamma\theta(1 - \theta)\sigma_{g_A}\sigma_{g_c}\rho_{g_A,g_c} + \theta\zeta\sigma_{g_c}\sigma_{g_n}\rho_{g_c,g_n} \\
 & - v\gamma(1 - \theta)^2\sigma_{g_A}\sigma_{g_m}\rho_{g_A,g_m} - v\zeta(1 - \theta)\sigma_{g_m}\sigma_{g_n}\rho_{g_m,g_n} - \gamma\zeta(1 - \theta)\sigma_{g_A}\sigma_{g_n}\rho_{g_A,g_n}. \quad (16)
 \end{aligned}$$

According to the labor evidence, variety growth slows down the rate of decline in marginal utility over time. In a deterministic setting, this causes savings to rise and the risk-free rate to fall. But whether the risk-free rate rises or falls relative to the one-good model, in the presence of uncertainty, is unclear.

### 3.3 Empirical Evidence on Cyclical Variation in Marginal Utility

One important piece of evidence suggesting that marginal utility falls below trend in booms is the procyclical nature of luxury goods expenditure. According to Ait-Sahalia, Parker, and Yogo (2004), luxury sales growth covaried strongly with the consumption growth of services and nondurables in the United States over the period 1961-2001. In addition, the authors find that charitable donations—which they consider a luxury good—are strongly procyclical. To see why procyclical luxury sales

indicates procyclical marginal utility, suppose there is a luxury brand of price  $p_t > 1$  in each group.<sup>20</sup> For simplicity, assume further that there is no expenditure on luxury goods during a recession. Denoting the marginal utility of income in period  $t$  by  $\lambda_t$  and the utility from luxury services  $l$  by  $z(l)$ —where  $z' > 0$ ,  $z'' < 0$ —in a recession we must have a corner solution; i.e.,  $\frac{z'(0)}{p_t} < \lambda_t$ . By contrast, in a boom,  $\frac{z'(C_l)}{p_t} = \lambda_t$ , where  $C_l > 0$  denotes the level of luxuries consumption, and  $z'(C_l) < z'(0)$ . Therefore, assuming no taste shifts or price shifts for luxury goods,  $\lambda_t$  must fall in a boom to ensure equality and yield an interior solution. Strengthening this reasoning, Bils and Klenow (2004) document that luxury good prices are procyclical.

In addition, Ait-Sahalia et al. find that the price changes of rare goods are strongly procyclical; for example, they find that the price of Manhattan pre-war coops rises in booms. Again, this is consistent with lower marginal utility in a boom. To see why, let the utility derived from rare goods be  $h(c_t)$ , and their price be  $p_t$ ; then optimality requires  $\frac{h'(c_t)}{p_t} = \lambda_t$ . Since rare goods are fixed in supply,  $c_t$  is constant over time, implying price increases of these goods indicate lower marginal utility of income. Further evidence of lower marginal utility in booms is the procyclical rise the savings rate and procyclical expenditure on of durable goods.

Summarizing, the evidence above indicates that marginal utility falls below trend in booms, suggesting that the negative effect of increasing brand and quality growth on marginal utility dominates that of product group growth. While this could be explained by procyclical consumption growth, this variation is realistically too small to explain the strong variation in marginal utility over the business cycle.

## 4 Calibration of Model

To obtain estimates of the model's predicted returns, and to determine whether variety changes have potentially important effects on asset prices, I now present a calibration. In cases where little data is available, I consider a range of parameter values.

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<sup>20</sup>With such non-homothetic preferences, it would be necessary to specify that the marginal utility of luxury goods is non-infinite at zero consumption.

Table 1: BASELINE PARAMETERS FOR CALIBRATION

PARAMETER	VALUE	PARAMETER	VALUE
$\theta$	5	$g_m$	2.4
$\rho$	3	$g_A$	0.8
$v$	0.3	$g_n$	1.2
$\gamma$	1	$g_w$	2
$\zeta$	12	$\rho_{r,g_c}$	.3
$\sigma_{g_c}$	3	$\rho_{r,g_A}, \rho_{r,g_m}$	.7
$\sigma_{g_m}$	3	$\rho_{r,g_n}$	.3
$\sigma_{g_A}$	2	$\rho_{g_m,g_c}, \rho_{g_A,g_c}$	.7
$\sigma_{g_n}$	0.5	$\rho_{g_n,g_c}$	.3
$\sigma_r$	20	$\rho_{g_m,g_A}$	.8
$g_c$	2	$\rho_{g_n,g_m}, \rho_{g_n,g_A}$	.3

Table 2: NOTE: Standard deviations and growth rates are in annualized percentage terms. Values of  $\zeta$  vary according to the parameter values chosen. This parameter derives from Eq. (15):  $\zeta = \frac{\theta g_c - g_w - v(1-\theta)g_m - \gamma(1-\theta)g_A}{g_n}$ .

#### 4.0.1 Data Sources and Calibration

Table 1 displays the baseline parameter values. All existing data are in annualized percentage terms and from the United States. For the period 1890 to 2004, Barro (2006) reports a 2 percent annual growth rate of real consumption expenditure per capita in the United States. Estimates of the standard deviation of equity returns and consumption, along with the correlation of returns and consumption, are from Mankiw (1986). I set wage growth equal to consumption growth, a stylized fact over long periods. For the baseline calibration, I set  $\theta = 5$ —a figure in line with standard measures of risk aversion, and also consistent with standard empirical estimates of the intertemporal elasticity of substitution,  $\frac{1}{\theta}$ . For annual data, a rate of time preference of 3 percent is standard. Given that product group growth, if anything, is probably mildly procyclical, I set  $\rho_{r,g_n} = .3$ . Correlations of .7 between equity returns and each of brand and quality growth reflect the strong procyclical nature of product creation noted earlier. A relatively small correlation of .3 between product group growth and each of brand and quality growth reflects the different cyclical properties of these categories.

According to the empirical estimates outlined earlier, the annual growth rate of the number of goods is 3.6 percent. Yet because it is relatively easy to introduce new brands, brand growth is almost

surely larger than group growth. To capture this, I set  $g_n = 1.2$  percent and  $g_m = 2.4$  percent; that is, brand growth is twice as large as product group growth.<sup>21</sup> Based on estimates from the Boskin Commission (1997) and Broda and Weinstein (2007), I set  $g_A = .8$ .<sup>22</sup> Although these estimates are crude, trend growth rates will have little bearing on the calibration.

The evidence cited earlier suggests significant cyclical variation in brand and quality growth. According to the estimation, the standard deviation of the growth rate of the stock of goods is approximately 2.8 percent a year. But because the calculation assumed a constant depreciation rate, this figure underestimates the volatility of the growth rate; Broda and Weinstein (2007), for example, estimate a countercyclical depreciation rate, albeit one of small magnitude. Based on this finding, I raise the standard deviation to 3.2 percent. Regarding the volatility of group growth, the nature of product groups suggests little high frequency variation in their introduction. Moreover, firms routinely publicize the development of new product groups—such as cell-phones—years in advance, suggesting that consumers expect their release. These points suggest that the variance of product group growth is relatively low.

Assuming small growth rates, the growth rate of the stock of goods approximately equals the sum of brand and group growth. It follows that the variance of the growth of the stock of goods—estimated to be 10.24—is  $\sigma_{g_T}^2 = \sigma_{g_n}^2 + \sigma_{g_m}^2 + 2Cov(g_n, g_m)$ .<sup>23</sup> Yet there is no available data on the components

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<sup>21</sup>The price index associated with each group is  $P_{jt} \equiv m_t^{-(v + \frac{\alpha-1}{\alpha})} \left( \int_0^{m_t} A_t^{-\gamma(1-\xi)} p_{it}^{1-\xi} di \right)^{\frac{1}{1-\xi}}$ , where  $\xi = \frac{1}{1-\alpha}$ , and  $p_{it}$  is the price of each brand (which is normalized to unity here.) In equilibrium, this reduces to  $P_t = m_t^{-v} A_t^{-\gamma}$ . Combining this estimate of brand growth with the estimate of  $v = .3$  implies the contribution of the inflation overstatement arising from brand growth is  $(.3)(2.4) = .72$  a year. One way to determine if this is reasonable is to compare it to other studies examining the effects of brand growth on the CPI bias. Diewert (1998) estimates a new goods bias of .51 percent a year. Using supermarket data, Melsar (2006) finds a new goods bias of between 1.2 and 2.4 percent a year. In an analysis of imports to the United States from 1972-2001, Broda and Weinstein (2006) estimate a four percent rate of import growth, and find that this is associated with an annual 1.2 percent understatement of the price index for imports.

<sup>22</sup>The Bureau of Labor Statistics (BLS) neglects the value of consumer surplus associated with new goods in the CPI; i.e., the welfare improvements due to brand and group growth. To the extent that the BLS has only recently started to incorporate quality change into the CPI, this figure represents what is unaccounted for. Recent research suggests this bias is large. For example, Hausman (2003) argues that current methods to incorporate welfare improvements due to quality change into the CPI are “severely inadequate”; Broda and Weinstein (2007) maintain that the net gains to product creation and destruction are largely unaccounted for and still contain “substantial bias,” especially at business cycle frequencies. The Boskin Commission estimated a CPI bias of between .8 and 1.6 in 1996, most of which accrues to unaccounted for quality change.

<sup>23</sup>To see this, suppose the number of trademarked goods  $T$  is a constant fraction  $\kappa$  of the number of existing goods; that is,  $T = \kappa nm$ . The growth rate of the stock of goods is then  $g_T \approx g_n + g_m$ . Taking variances then gives  $\sigma_{g_T}^2 = \sigma_{g_n}^2 + \sigma_{g_m}^2 + 2Cov(g_n, g_m)$ .

of this decomposition. But to ensure that this holds, and to capture the fact that the volatility of brand growth is almost surely markedly higher than that of group growth, while product group growth is relatively stable, I assume in the baseline calibration that the standard deviation of brand growth is 3 percent, while that of group growth is .5 percent. Since this breakdown is crude, I consider a range of values in the calibration.

Holding expenditure constant, quality growth captures factors relating to a good that increases a consumer's utility from it. This can occur in a number of ways. One way is through standard improvements in products. Another way is through an increase in the substitution and outlet bias arising from greater product and firm creation: a greater variety of products enables consumers to find the lowest quality-adjusted price. Also important is the role of product replacement: if consumers have a preference for blue shirts, for example, and a new product line replaces black shirts with blue ones, then this would constitute a quality increase.<sup>24</sup> Finally, by raising competition, new product and firm introduction also place downward pressure on markups and, in turn, quality-adjusted prices. Yet there is little precise information on the variation of quality growth. But considering the evidence of "strongly procyclical" variety growth provided by Broda and Weinstein (2007) and others, and the fact that the mean growth rate of quality is around 1 percent, a value of  $\sigma_{g_A} = 2$  seems a reasonable ball-park estimate. Because there is no concrete data on these parameters, and since these estimates have an important bearing on the analysis, I present calibration results for a range of values.

The parameter  $v$  mediates the welfare gains arising from greater choice. It answers the question: holding the level of quality fixed, if the number of brands in a group increases by one percent, what is the percentage increase in consumption services from a group? As is standard, I infer  $v$  from elasticities of demand.<sup>25</sup> Steinssen and Nakamura (2007) use an elasticity of demand of 4 to "roughly match estimates of the elasticity of demand from the industrial organization and trade literature." Rotemberg and Woodford (1995) favor markups from 20 to 40 percent, corresponding to elasticities of demand between 3.5 and 6.<sup>26</sup> Based on these findings, I use an elasticity of 5 as a baseline, implying

<sup>24</sup>This channel by which new products enable consumers to come closer to their ideal variety was stressed by Lancaster (1979).

<sup>25</sup>To see this, in the standard Dixit-Stiglitz model  $c_{jt} = m_t^{(\frac{1}{\alpha}-1)} A_t^\gamma C_t$ , corresponding to  $m_t^v A_t^\gamma C_t$  in my setup.

<sup>26</sup>Tellis (1988) surveys the marketing literature and reports an average price elasticity of 1.76. Broda and Weinstein

that  $\alpha = \frac{3}{4}$  and  $v \approx .3$ . Noting that  $c_{jt} = m_t^v A_t^\gamma C_t$  in equilibrium, the taste for quality,  $\gamma$ , answers the question: keeping the number of brands constant, if quality increases by one percent, what is the percentage increase in consumption services from a group? Following Hummels and Klenow (2005), I set  $\gamma = 1$ , making proportional quality increases equivalent to proportional price reductions. Finally, to calibrate the parameter  $\zeta$ , I use the stylized fact of stable labor hours over time, which from Eq. (15) implies that  $\zeta = \frac{\theta g_c - g_w - v(1-\theta)g_m - \gamma(1-\theta)g_A}{g_n}$ . For baseline parameters, this implies  $\zeta \approx 12$ , which I take as a baseline.

#### 4.0.2 Calibration of the Risk-Free Rate and Equity Premium

Table (3) presents the calibrations of the expected risk-free rate and the expected equity premium for the parameter values in each column.

Table 3: CALIBRATION OF EXPECTED RETURNS WITH RISK AVERSION,  $\theta = 5$ , AND TIME PREFERENCE,  $\rho = 3\%$

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
$\theta$	5	5	5	5	5	5	5	5	5	5	5	5	5	4	6
$v$	0	.3	.3	.3	.3	.3	.3	.3	.3	.3	.3	.6	.3	.3	.3
$\gamma$	0	1	1	1	1	1	1	1	1	1	1	1	1.5	1	1
$\sigma_{g_m}$	0	3	4	5	2	3	3	3	0	3	3	3	3	3	3
$\sigma_{g_A}$	0	2	3	4	1	2	2	2	2	0	2	2	2	2	2
$\sigma_{g_n}$	0	.5	.5	.5	.5	1	2	3	.5	.5	0	.5	.5	.5	.5
$r_f$	12.7	2.0	.7	-.9	2.9	2.0	1.0	-1.4	2.7	3.3	1.7	1.2	1.1	3.1	.6
$r - r_f$	.9	2.2	2.9	3.6	1.4	1.8	1.1	.4	1.7	1.0	2.5	2.6	2.7	1.7	2.7

NOTE: The table presents the expected rates of return for the parameter values in the cells. All statistics are in annualized percentage terms. The expected risk-free rate is from Eq. (16), and the expected equity premium is from Eq. (11). Standard deviations and rates of return are in percentage terms. In Column (1), the risk-free rate is from Eq. (12), and the equity premium is from Eq. (13).

Absent a love for variety, we get the well-known puzzles, highlighted in Column 1. This column corresponds to the standard one-good CCAPM, which prices only expenditure risk. Column 2 presents predictions for the multi-good model and the baseline set of parameters. Introducing product

(2007) cite evidence from marketing studies showing that the typical demand elasticity found between different products of the same brand lies in the range of 4 to 7. Broda and Weinstein (2006) report an average elasticity of demand of 4.2 for the United States. In a study of the welfare gains to variety growth, Feenstra (1994) finds elasticities between 3 and 8 for various goods; for example, he reports estimates of 6.23 for shoes, 4.21 for sheets, and 2.96 for typewriters.

variety causes the risk-free rate to fall from 12.7 to 2.0, and the equity premium to rise from .9 to 2.2. Columns 3 and 4 trace the effects of raising the volatilities of brand and quality growth. By raising precautionary savings, this causes the risk-free rate to fall; and because of greater consumption risk, the equity premium rises. Reducing volatilities in Column 5 has the opposite effects. Comparing Column 1 with Columns 2 – 5, it is apparent that risk to the level of consumption expenditure is a relatively small part of cyclical consumption risk. More important is the role of composition risk, which accounts for most of the predicted equity premium here.

Columns 6 – 8 display the effects of raising the volatility of product group growth. As noted earlier, this makes equities a good hedge against changes in marginal utility caused by variations in consumption, brand, and quality growth. As a result, the equity premium falls. Yet because group growth is only mildly procyclical, changing its volatility has relatively small effects on the results. Interestingly, a doubling of the volatility of group growth in Column 6 has no effect on the risk-free interest rate. There are two effects of this change. One effect of this change is to increase precautionary savings and reduce the risk-free rate. Another effect is to reduce variation in marginal utility and reduce precautionary savings; namely, group growth volatility acts as a hedge against unexpected variations in brand and quality growth. In Column 6, both effects just offset. But in the next two columns the former, standard effect predominates, causing the risk-free rate to fall.

Although not shown in the tables, raising the correlation between equity returns and each of brand, quality, and group growth has the same qualitative effects as raising the respective volatilities. Observing the expression for the equity premium in Equation (11), it is clear that raising the correlation between equity returns and brand growth by .1 raises the equity premium by .07% in the baseline case. In the case of quality growth, the premium rises by .2%; while for group growth the premium falls by .0012%. Asset returns, therefore, are relatively robust to these changes. Because the level of the risk-free rate is independent of equity returns, these changes have no effect on the risk-free rate.

Columns 12 and 13 show the effects of raising the taste for each of brands and quality. Because these changes make marginal utility more variable, they have the same qualitative effect as increasing the respective volatilities. In Column 6, doubling the taste for brands from .3 to .6 raises the equity

premium by .4. Raising the taste for quality from 1 to 1.5 increases the premium by .5 percent. Yet since consumers value proportional changes in quality more than brands, the results are more sensitive to changes on the quality margin. Due to a rise in precautionary savings, the risk-free rate falls in both cases, but more so in the case of quality.

Columns 14 and 15 show the effects of changing the level risk aversion. A comparison of all columns shows that increasing risk aversion has a similar effect on returns. As expected, reducing risk aversion from 5 to 4 reduces the equity premium and raises the risk-free rate. Raising risk aversion from 5 to 6 has the opposite effects. Overall, changing the degree of risk aversion by 1 leads to a moderate change in the equity premium of about .5 percent. In contrast, changing risk aversion has a relatively large effect on the risk-free rate, which changes by an average of 1.3%.

Although not shown in the tables, changes in growth rates have relatively small effects on the results. Growth rates affect predicted returns through their effect on the parameter  $\zeta$ , which is pinned down by the labor stability condition, Eq. (15). Increasing  $g_m$  by one, for example, raises  $\zeta$  by 1: by reducing marginal utility at each point, the taste for groups,  $\zeta$ , must rise to ensure stable labour hours. This, in turn, causes the equity premium to fall by .03 percent. Because a higher  $\zeta$  tends to reduce variation in marginal utility, it also reduces the need for precautionary savings, and causes the risk-free rate to rise by .0006 percent. Similarly, a rise in  $g_A$  by one raises  $\zeta$  by 2.67; this causes the premium to fall by .08% and the risk-free rate to fall by .0015%. Finally, a rise in  $g_n$  by one reduces  $\zeta$  by 6, causing the premium to rise by .18% and the risk-free rate to fall by .004%.

## 4.1 Discussion

Table 1 shows that the model can generate a wide range of asset returns. Incorporating changes in product variety into the CCAPM works against both the equity premium and risk-free rate puzzles. According to the calibration, the predicted equity premium lies in the range of 2 – 3 percent, while the risk-free rate is around 1.5 percent. By reducing marginal utility in booms, the volatility of brand and quality growth makes equities riskier, raising the equity premium. By attenuating the fall in marginal utility of consumption over time, product group growth raises savings, and reduces the risk-free rate.

Yet the predicted equity premium is lower than the historical value of around 6 percent. This could be explained in a number of ways. The model is simple, so other features—such as habit persistence in consumption services—would raise the premium further. Certain changes to the baseline calibration—such as raising the taste for quality—would also raise the equity premium. Most important, rationalizing a 6 percent equity premium is only meaningful if this was the actual expected return. Many economists have recently lowered their estimates of the equity premium; Cochrane (2008), for instance, notes that “many economists’ beliefs about the size of the equity premium are.....down to 2 or 3 percent or less.”<sup>27</sup> Reassuringly, the model matches figures for the risk-free rate reasonably well—the return most accurately measured.

In contrast to the standard one-good setup, the model is consistent with the stylized fact of relatively stable labor hours over time. Thus if predictions for the largest factor market were also added to the tables, the model would compare favorably. Further evidence in its favor is an empirical study by Normandin and St-Amour (1996), who find that taste shocks play a large role in explaining the equity premium. Although the source of the taste shocks remains unexplored in their analysis, the model here provides a natural interpretation of their finding.

Two more speculative pieces of evidence favor the model. The first is the historical pattern of asset returns. Examining United States asset returns back to the early nineteenth century, Siegel (1992) finds that the equity premium rose over time, while the risk-free rate fell. Clark (2007) also reports that the risk-free rate fell upon the onset of sustained economic growth. To the extent that the dynamics of the model become more relevant as a country develops, these observations are potentially reconcilable with the model. In particular, an increase in product group growth at the onset of the Industrial Revolution is consistent with a fall in the risk-free rate throughout that period.

Second, Savov (2008) shows that the growth rate of garbage is more procyclical than consumption expenditure. This greater volatility of garbage growth suggests a changing composition of con-

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<sup>27</sup>Blanchard (1993) estimates an equity premium of approximately 2 percent. He attributes a higher earlier premium to fears of a recurrence of an episode like Great Depression. Reviewing a number of recent studies on estimates of the equity premium, Jagannathan and McGrattan (2002) report that “all of these studies agree that the US equity premium is currently lower than it has been historically.” Goetzmann and Jorion (1998) contend that survival bias raises the equity premium by a factor of two, and estimate an expected premium of around 3.5 percent. Using international data, Dimson, Marsh and Staunton (2002) find lower equity returns in the early twentieth century than in the latter part.

sumption over the business cycle: by spreading consumption over more goods in booms, consumers generate more garbage.<sup>28</sup> By contrast, a constant consumption composition implies that consumption and garbage growth would be the same. Savov also shows that garbage growth performs better than expenditure growth in a test of the CCAPM—suggesting that garbage growth is a mimicking portfolio for variety growth.

Third, Divinney finds that firms introducing new products have higher average returns. In addition he finds that returns increase upon the announced release of a new product. This is consistent with the model's prediction for the cross-section of returns. Namely, firms regularly introducing new products have returns that are correlated with variety growth.

## 5 Conclusion

Recognizing that people care about what they consume, this paper presents an extension to the CCAPM, incorporating product variety growth over time and states of nature. In contrast to the baseline one-good model, marginal utility depends on both the level and composition of consumption. As a result, product variety growth affects consumers' incentives to save and the level of risk they face. This has implications for asset pricing.

According to the calibration, the model provides a better description of historical asset price data than the standard one-good CCAPM. Compared to the standard model, it predicts a lower risk-free rate and a higher equity premium at both long and short horizons. At higher frequencies, fluctuating brand and quality growth increases the level of consumption risk and raises the expected equity premium. For this reason, a premium arises even in the face of stable consumption growth and the low correlation of consumption with equity returns. At lower frequencies, product group growth raises the incentive to save and reduces the risk-free rate. As a result, the model can reconcile a strong desire to smooth consumption with steady consumption growth over time.

For convenience, the analysis has focussed on the equity premium and risk-free rate puzzles. Yet an interesting question is whether the framework can work against other asset-pricing puzzles. Along

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<sup>28</sup>This assumes...

the time-series dimension, time varying covariances between variety growth and asset returns could shed light on the equity volatility puzzle. In the cross section, meanwhile, the model predicts that firms whose returns are correlated with brand and quality growth command higher average returns. Determining the importance of these channels is an important path for future work. More generally, the model introduces product variety growth into a dynamic model of intertemporal choice, yielding a number of broader implications. For instance, the model casts doubt on the welfare cost of business cycles estimated by Lucas (1982) in a one-good world.

Although the calibrations suggest product variety growth is a potentially important determinant of asset prices, lack of precise data on variety growth and the associated welfare gains is a limitation of the analysis. Nonetheless, casual observation suggests that product development is a central concern of firms, while people care about what they buy. Moreover, the concept of “love of variety” has successfully explained economic phenomena in such fields as trade theory and industrial organization. Yet although the underlying mechanism seems robust, more rigorous empirical work to sharpen the calibrations presented here would be useful.

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