# Deep habits and the cross-section of expected returns*

**Jules H. van Binsbergen**
Fuqua School of Business
Duke University†

This version: December 2007

**Abstract**

I study the cross-section of expected returns in a general equilibrium framework in which agents form habits over individual varieties of goods as opposed to over a composite consumption good. Goods are produced by monopolistically competitive firms whose income and price elasticities of demand depend on the habit formation of the consumers. Firms who produce goods with a low consumption surplus ratio earn low expected returns because their income and price elasticities of demand are low. Under the assumption that firms face adjustment costs to their input factors, such firms also temporarily charge higher prices for their products. As such, the model generates a negative relationship between the expected return on a firm's stock and (changes in) the selling price of its product. I analyze this relationship empirically by sorting firms into portfolios based on recent price changes, as measured by the industry level producer price index. This sorting generates a statistically significant annual return spread of 6 percent that cannot be explained by the unconditional CAPM nor by the four-factor model.

*First version: November 2007. I thank Hengjie Ai, Ravi Bansal, Michael Brandt, Alon Brav, Craig Burnside, Jesus Fernandez-Villaverde, Simon Gervais, John Graham, Cam Harvey, Ralph Koijen, Rich Matthews, Juan Rubio Ramirez, David Robinson, Tano Santos, Stephanie Schmitt-Grohe, Martin Uribe, Vish Viswanathan, seminar participants at Barclays, Carnegie Mellon, Chicago, Columbia, Duke, the Federal Reserve Board, Harvard, MIT, Northwestern, NYU, Princeton, Stanford, UCLA, USC, Wharton, Yale and in particular Anamaría Pieschacón for helpful discussions and comments. All remaining errors are my own.

†Durham, NC 27708. Phone: (919) 660-7636. Email: jules.vanbinsbergen@duke.edu.

# 1 Introduction

Explaining the cross-section of expected returns lies at the core of asset pricing. Even though habit formation models have proven successful in explaining some of the key properties of the time series of expected returns,[1] explaining the cross-section of expected returns has proven to be more challenging.[2] So far, in the asset pricing literature, it is common to assume that households derive utility and form their habits from the consumption of a single aggregate good.[3] In this paper, I study asset prices in an economy where households form their habits not over a single aggregate good, but over individual varieties of goods that are produced by monopolistically competitive firms as first explored in the macro literature by Ravn, Schmitt-Grohe and Uribe (2006). Both the income elasticity and the price elasticity of demand of each monopolist is time-varying and dependent on the households' habit stock for the monopolist's good. When the factor inputs to production exhibit short term frictions, these time-varying elasticities generate a negative relationship between the expected return on a firm's stock and the price it charges for its product. Firms that produce goods with a low consumption surplus ratio, that is, a consumption level that is close to the habit level, temporarily charge high prices for their products and earn low expected returns. These low expected returns are driven by the low income and price elasticities of demand for such firms, making their profits less susceptible to real aggregate supply (productivity) and demand (habit) shocks. Furthermore, the low price-elasticity of demand in combination with short-term frictions to the input factors of production will temporarily lead to high product prices. I confirm this prediction using data from the industry level Producer Price Index (PPI) program. The PPI measures the average change over time in the selling prices received by domestic producers for their output. By sorting firms into quintile portfolios based on their recent percentage price changes, I find that firms that recently increased their prices earn lower expected returns than firms that recently decreased their prices, generating an annual expected return spread of 6 percent that can neither be explained by the unconditional Capital Asset Pricing Model (CAPM) nor by size, book-to-market and momentum effects.

The main mechanism generating the difference in expected returns is straightforward. Consumers are highly averse to scaling back on goods for which the consumption level is close

[1]See Abel (1990), Constantinides (1990), Heaton (1995), Jermann (1998), Campbell and Cochrane (1999) and Campbell and Cochrane (2000)

[2]See for example Lettau and Wachter (2007) and Santos and Veronesi (2006)

[3]Notable exceptions are Ait-Sahalia, Parker, and Yogo (2004), Yogo (2006), Gomes, Kogan, and Yogo (2006). For the case of investment goods, see Papanikolaou (2007).

to the habit level, which implies that both the income elasticity and price-elasticity of demand for such goods is low. In response to negative aggregate income shocks, the demand for goods with a low consumption surplus ratio will remain relatively strong, due to the low income elasticity of demand. Furthermore, if the factor inputs to production exhibit short-term frictions, the relative prices of goods with a low consumption surplus ratio are temporarily high, and most importantly increase in response to a negative productivity (supply) shock.[4] These price increases lower the exposure of the producers to such systematic shocks resulting in a lower risk premium. In contrast, the producers of goods with a high consumption surplus ratio, that is, a consumption level that is far way from the habit level, are faced with a negative relative price change in addition to the negative aggregate productivity shock. A similar reasoning holds for preference (demand) shocks. I model preference shocks as a shock to the habit levels of all goods. As such, a positive preference shock makes consumers worse off. In response to a positive preference shock, firms with a low consumption surplus ratio face a relative price increase whereas producers of goods with a high consumption surplus ratio face a relative price decrease.

In the model each good is produced by a single monopolistically competitive firm. Ex ante all firms are identical but as productivity or preference shocks realize, firms differ with respect to the habit stock for the goods they produce. In this setup, the unconditional CAPM beta of each firm, that is, the beta with respect to the market portfolio, equals one and the unconditional risk premia of all firms are equal. However, each firm's risk premium is time-varying and dependent on the habit stock for its good relative to the habit stocks of all other goods in the economy.[5] Because the relative price that each monopolist charges for its product is also driven by the relative habit stock, the econometrician can use the observable cross-section of product prices to learn about the cross-section of expected returns. In other words, when sorting firms into quintiles based on their recent pricing behavior a large premium can be generated. The raw (unadjusted) average return difference between quintile 1 (firms with the largest price decreases) and quintile 5 (firms with the largest price increases) equals 0.54 percent per month. Part of this premium can be explained by the CAPM and the loading of the DMI portfolio (Deflationary-minus-Inflationary), on the market portfolio is positive. The pricing error relative to the unconditional CAPM is however still significant. When including the other Fama-French factors and momentum, the pricing

[4]In my model, relative product prices are defined as product prices relative to the aggregate producer price index.

[5]The aggregate risk premium is time-varying as well and dependent on the cross-sectional distribution of consumption surplus ratios.

error further increases, as firms with recent price decreases earn high expected returns, but load negatively and significantly on the book-to-market factor.

My approach stands in contrast to several recent papers that employ cross-sectional variation on the production side of the economy to explain characteristics of the cross-section of expected returns.[6] In the deep habits model the cross section of expected returns is purely driven by the demand side of the economy and I assume that all firms have access to the same production technology to produce their good. However, it is important to stress that I view the deep habits model not as a competing explanation for the cross-section of expected returns but rather as the demand-side complement to the existing literature that employs cross-sectional differences in the production technologies of firms to explain the cross-section of expected returns.

Apart from the cross-sectional implications, I also study the aggregate time series properties of the model. I show that the model performs equally well as the one-sector habit formation model with production as in Jermann (1998). The model matches the aggregate risk premium, the level of the riskfree rate and the volatility of output growth, investment growth and consumption growth. Furthermore, by imposing persistence for the evolution of the habit stock, the model also matches the low volatility of the riskfree rate, whereas in the one-sector habit formation model with production this volatility seems several factors too high. Further, the volatility of dividend growth in Jermann's model seems too low, whereas the deep habits model generates volatile dividend growth rates close to those of firms' net payout, as opposed to per share dividends.[7] However, both models seem to perform poorly with respect to the conditional moments of the financial variables. In particular, the variation in the price dividend ratio seems mainly driven by variation in expected dividend growth rates and not by variation in expected returns, as, in the model, the latter only has limited variation. This variation in expected returns can be substantially increased by allowing for preference shocks, that is, direct shocks to the habit level of consumers. I conclude that the model maintains most of the time series characteristics of the standard habit formation model with production, but generates additional testable predictions for the cross-section of expected returns.

The main feature of the model is that households have preferences and form habits over individual goods as opposed to over a single aggregate consumption bundle. There are two

[6] See Zhang (2005), Whited, Xiaolei, and Zhang (2007) and Gala (2006).

[7] See Yogo and Larrain (2007) and Bansal and Yaron (2006)

special cases when the stochastic discount factor simplifies to the standard habit formation model with a single aggregate good: (i) when goods are perfect substitutes and (ii) when there is perfect symmetry between goods (and firms). When goods are perfect substitutes consumers only care about the size of the aggregate consumption bundle and not about its composition. This seems an unlikely characteristic of household preferences. With perfect symmetry between goods and firms, I mean that all firms face the same productivity shocks resulting in the same habit level for all goods.[8] In this case, the model implies that all relative prices are constant over time. However, empirically we do observe time variation in relative prices. Good-specific habits endogenously generate such time variation in prices. Given that habit formation models have proven successful in explaining the level and time variation of aggregate risk premia, it seems natural to study the interaction between relative prices and the cross-section of expected returns in a good-specific habits framework.

The implications of multiple goods for asset prices has also been explored by Ait-Sahalia, Parker, and Yogo (2004), Yogo (2006) and Gomes, Kogan, and Yogo (2006). Ait-Sahalia, Parker, and Yogo (2004) argue for the distinction between luxury goods and basic goods. Households are more risk averse with respect to the consumption of basic goods due to the presence of a subsistence point for such goods. Using data on the consumption of luxury goods, they find that the risk aversion implied by luxury good consumption is more than an order of magnitude less than that implied by national accounts data which mostly reflects basic consumption. Yogo (2006) and Gomes, Kogan, and Yogo (2006) argue for the distinction between durable goods and non-durable goods and find that the producers of durable goods earn higher expected returns, as the demand for durable goods is more pro-cyclical. The stocks of producers of durable goods therefore carry more systematic risk. None of these papers, however, consider good-dependent habit formation and the interaction between the price-setting behavior of producers and the expected returns on their stock.

My model also relates to the recent literature on the cross-section of expected returns and product market competition. Hou and Robinson (2006) show that US firms in the quintile of the most competitive industries earn annual returns that are nearly 4% higher than those of similar firms in the quintile of the most concentrated industries. The market power that Hou and Robinson (2006) consider is related to the price setting behavior that

[8]Even though the stochastic discount factor simplifies to the standard habit formation discount factor with a single aggregate good, the firm's optimization problem still takes the habit formation of the consumers into account, resulting in different cash flow dynamics. I further explore the perfect symmetry case when assessing the time series properties of the model.

I study in this paper. That being said, in my model, the elasticity of substitution between all goods is equal, and therefore the competition between all firms is equal. Furthermore, in my model, low expected returns are not a unconditional characteristic of an industry or firm but are a consequence of the current low income and price elasticities of demand faced by a particular firm or industry, which is time-varying. When I construct the quintile portfolios, I indeed find that firms (and industries) frequently rotate across quintiles.[9] In contrast, firm sorts based on each industry's Herfindahl-Hirschman Index (HHI), as in Hou and Robinson (2006), can be used to generate a spread in expected returns up to several decades into the future. By including the return spread on the HHI portfolios as a factor, I find that the DMI portfolio that I construct does not significantly load on the HHI factor, both in the economic and the statistical sense.[10]

To my knowledge this is the first paper that explores the implications of good-dependent habits and producer prices on asset prices. One obvious question that comes to mind is how coarse the classification of varieties should be. With varieties of goods, I have in mind an environment in which consumers form habits over narrowly defined categories of goods, such as clothing, vacation destinations, music and cars. The advantage of defining habits over categories of goods as opposed to over specific goods within categories, is that household expenditure on categories of goods general goes up as income increases, that is, they behave as normal goods. Individual goods within categories, on the other hand, may be inferior.

The idea that households form their habits over individual varieties of goods has recently been introduced in the macroeconomic literature by Ravn, Schmitt-Grohe, and Uribe (2006) who propose to call this type of habit formation "deep" habits. These authors show that the deep habits model can help to explain several interesting macroeconomic empirical facts. In particular, they show that expansions in output driven by preference shocks, government-spending shocks, or productivity shocks are accompanied by declines in mark-ups. This implication of the deep habits model is in line with the extant empirical literature, which finds mark-ups to be counter-cyclical (Rotemberg and Woodford (1999)). Product-specific habit formation also has a long tradition in the marketing literature, starting with Guadagni and Little (1983). This literature uses the term "loyalty variable". This loyalty variable measures how hooked consumers are on a given firm's product and it is measured as a weighted average of past sales. It therefore closely resembles the notion of habits in the

[9]This also indicates that the return spread I generate is not driven by fixed industry characteristics such as durables vs non-durables and luxury goods vs necessities.

[10]I thank David Robinson and Kewei Hou for providing me with their data

economics and finance literature. This literature also widely discusses the importance of brand and product loyalty for firm valuation. In this paper, I argue that product loyalty does not only increase firm value due to higher cash flows, but also due to a lower discount factor.

I start with a parsimonious two-period setup to convey the main intuition underlying the model. This model can easily be solved by quadrature and is therefore numerically straightforward. Secondly, I present the full-fledged dynamic model. I solve this model using perturbation methods, as further explained in appendix A. The paper proceeds as follows. In section 2 I present the two-period model which I then extend to the full-fledged model in section 3. Section 4 introduces capital stock variation and compares the deep habits model to the standard habit formation model with production. Section 5 contains the empirical results followed by several robustness checks in section 6. Section 7 contains a discussion with possible extensions of the model, in particular to explain the existing documented return spreads such as the value premium. Section 8 concludes.

# 2 The two-period model

To convey the main intuition and mechanism underlying the model, I first present a parsimonious two-period setup.

## 2.1 The representative household

Following Ravn, Schmitt-Grohe, and Uribe (2006), the economy consists of a representative household and a continuum of goods, also called varieties, with an aggregate mass of one. Goods are produced by monopolistically competitive firms. As such, each good is produced by a single monopolist and there exists a one-to-one mapping between varieties and firms. I assume that the representative household's preferences are described by the utility function:

$$U = U\left(X_0\right) + E_0\left[U\left(X_1\right)\right] = \frac{X_0^{1-\gamma}}{1-\gamma} + \beta E_0\left[\frac{X_1^{1-\gamma}}{1-\gamma}\right] \tag{1}$$

where $X_t$ is the aggregate level of habit-adjusted consumption for $t \in \{0, 1\}$. The level of aggregate habit-adjusted consumption, $X_t$ is defined as:[11]

$$X_t = \left[ \int_0^1 (C_{it} - \theta S_{it})^{1-\frac{1}{\eta}} \, di \right]^{\frac{1}{1-\frac{1}{\eta}}} \tag{2}$$

where $C_{it}$ is the level of consumption of variety $i$, and $S_{it}$ is the habit of variety $i$, which is known at time $t-1$ apart from a preference shock. The parameter $\eta$ is the elasticity of substitution between the varieties of goods as in Dixit and Stiglitz (1977) and the parameter $\theta$ determines the time non-separability of the preferences. Assume that the habit for good $i$ in period 1 is given by:

$$S_{i1} = \rho S_{i0} + (1-\rho) \, C_{i0} + \varepsilon_{i1} \tag{3}$$

where $\varepsilon_{i1} \sim N(0, \sigma_{si}^2)$ represents the preference or demand shock. Let $P_{it}$ denote the price charged by the producer of good $i$ for one unit of good $i$ at time $t$. For a given level of aggregate habit-adjusted consumption $X_t$, the household chooses its consumption bundle to minimize total expenditure

$$\min \int_0^1 P_{it} C_{it} di \tag{4}$$

subject to:

$$\left[ \int_0^1 (C_{it} - \theta S_{it})^{1-\frac{1}{\eta}} \, di \right]^{\frac{1}{1-\frac{1}{\eta}}} = X_t \tag{5}$$

This optimization results in the following demand function:

$$C_{it} = \left( \frac{P_{it}}{P_t} \right)^{-\eta} X_t + \theta S_{it} \tag{6}$$

where $P_t$ is an aggregate price index given by:

$$P_t = \left[ \int_0^1 P_{it}^{1-\eta} di \right]^{\frac{1}{1-\eta}} \tag{7}$$

[11]In the exposition that follows, I assume that there is a continuum of goods, but similar expressions can be derived for a discrete number of goods.

From equation 6, it is easy to see that the consumption of variety $i$ is decreasing in its relative price $p_{it} \equiv \frac{P_{it}}{P_t}$, increasing in the level of aggregate habit-adjusted consumption $X_t$, and, for $\theta > 0$, increasing in the habit stock for consumption of variety $i$.

The household then maximizes utility $U$ subject to the budget constraint:

$$\int_0^1 p_{it} C_{it} di + E_t \left[ M_{t,t+1} d_{t+1} \right] = d_t + \int_0^1 \Phi_{it} di \tag{8}$$

where $d_t$ is a set of Arrow Debreu securities and $\Phi_{it}$ are the profits of firm $i$. Using equation 6, it is straightforward to derive that the budget constraint can be rewritten as:

$$X_t + \int_0^1 \theta p_{it} S_{it} di + E_t \left[ M_{t,t+1} d_{t+1} \right] = d_t + \Phi_t \tag{9}$$

Let $\Lambda_t$ denote the scaled Lagrange multiplier on the budget constraint. Taking first order conditions with respect to $X_t$ leads to:

$$\Lambda_t = X_t^{-\gamma} \tag{10}$$

## 2.2 Price, income and habit elasticities

The price (P) elasticity of demand (C) for good $i$ at time $t$ measures the percentage change of the demand for good $i$ when changing the price of good $i$ by one percent while holding the habit level and the aggregate price level constant:

$$\epsilon_{it}^{C,P} = \frac{\partial \ln C_{it}}{\partial \ln P_{it}} = \frac{\partial \ln \left[ \left( \frac{P_{it}}{P_t} \right)^{-\eta} X_t + \theta S_{it} \right]}{\partial \ln P_{it}} = -\eta \left( \frac{C_{it} - \theta S_{it}}{C_{it}} \right). \tag{11}$$

Note that this elasticity is time-varying and proportional to the consumption surplus ratio for good $i$.

Furthermore, the elasticity of demand (C) for firm $i$ with respect to the aggregate habit-adjusted consumption (X), which ceteris paribus (c.p.) measures the percentage change of demand in response to a one percent change in $X_t$, is given by:

$$\epsilon_{it}^{C,X} = \frac{\partial \ln C_{it}}{\partial \ln X_t} = \frac{\partial \ln \left[ \left( \frac{P_{it}}{P_t} \right)^{-\eta} X_t + \theta S_{it} \right]}{\partial \ln X_t} = \frac{C_{it} - \theta S_{it}}{C_{it}}. \tag{12}$$

I will refer to this elasticity as the income elasticity of demand even though strictly speaking it is not the elasticity with respect to income but the elasticity with respect to aggregate habit-adjusted consumption. This income elasticity is equal to the consumption surplus ratio and it provides a parsimonious (partial equilibrium) explanation for why firms with a low consumption surplus ratio earn low expected returns. The profits of firm $i$ can be written as $\Phi_{it} = C_{it}\left(P_{it} - MC_{it}\right)$. Where $MC_{it}$ is the appropriate cost measure. Log changes of profits can therefore be written as:

$$\Delta \ln \Phi_{it+1} = \Delta \ln C_{it+1} + \Delta \ln \left(P_{it+1} - MC_{it+1}\right) \tag{13}$$

First consider the case where prices and costs are constant. In this case, profits only vary over time due to changes in the quantity sold $C_{it}$. With a slight abuse of notation, the covariation between the log stochastic discount factor and log changes in profits can then be written as:

$$-\gamma \mathrm{cov}\left(\Delta \ln \Phi_{it+1}, \Delta \ln X_{it+1}\right) \approx -\gamma \mathrm{cov}\left( \frac{C_{it+1} - \theta S_{it+1}}{C_{it+1}} \Delta \ln X_{it+1}, \Delta \ln X_{it+1} \right) \tag{14}$$

When the consumption surplus ratio of each good moves slowly over time, which implies that the current consumption surplus ratio can be used as a proxy for the next period's surplus ratio, the one-period risk premium is roughly proportional to the current consumption surplus ratio.

$$-\gamma \mathrm{cov}\left(\Delta \ln \Phi_{it+1}, \Delta \ln X_{it+1}\right) \approx -\gamma \frac{C_{it} - \theta S_{it}}{C_{it}} \mathrm{var}\left(\Delta \ln X_{it+1}\right) \tag{15}$$

The equation above shows that firms with a low consumption surplus ratio have a demand for their product with a low income elasticity. Hence, such firms have a lower exposure to aggregate shocks, that is, shocks to aggregate habit-adjusted consumption $X_t$. Because shocks to aggregate habit adjusted consumption drive shocks to the stochastic discount factor, such firms have a lower risk premium.

In the derivation above I have assumed that quantities are free to adjust and that prices remain constant. Now consider the other extreme when quantities are not free to adjust. In this case, product prices will have to adjust in equilibrium.[12] Suppose that all firms face an equally large percentage productivity shock. Suppose further that firms can not unwind this negative productivity shock by employing more input factors to production, which implies an equally large negative output shock. In this case, firms with a low consumption surplus ratio are less risky due to their smaller price elasticity of demand. Recall that the price elasticity of demand of each firm is proportional to the consumption surplus ratio. As a consequence, if the percentage change of the quantities is the same for all goods, the goods with the smallest consumption surplus ratio will have the largest product price change. In other words, because the price elasticity of demand is so small, small quantity changes imply large price changes. As a consequence, in response to a negative (aggregate) productivity shock, the product prices of goods with a low consumption surplus ratio will increase, which serve as a hedge against these negative productivity shocks. Because the aggregate price index is normalized to one, firms with a high consumption surplus ratio will face a real price decrease in addition to the negative productivity shock.

The latter result can also be understood in terms of markups. Note that the deep habits model endogenously generates countercyclical markups. For all firms, these countercyclical markups serve as a hedge against aggregate income shocks. Even though aggregate demand goes down, the markup increase will compensate for this loss in demand. However, the argument presented in the previous paragraph indicates that markups go up more for firms with a low consumption surplus ratio thereby creating cross-sectional differences in expected returns. As such, the differences in expected returns are driven by both income- and price-elasticity effects.

I will also study the impact of shocks to the habit level of firms, which I call demand shocks. To study these type of shocks, it is useful to derive the habit elasticity of demand and the habit elasticity of price. The habit elasticity of price is given by:

$$\epsilon_{it}^{P,S} = \frac{\partial \ln P_{it}}{\partial \ln S_{it}} = \frac{\theta}{\eta} \frac{S_{it}}{C_{it} - \theta S_{it}}. \tag{16}$$

Suppose that all firms face an equal percentage positive shock to their habit level. Such a positive habit shock makes consumers worse off. Ceteris paribus, this will lead to a price

[12] One particular example when quantities are not free to adjust is the presence of adjustment costs to the input factors to production which I will further discuss in the next section, which addresses the fully fledged model.

increase which will be the largest for those firms whose consumption level is close to the habit level. As before, these price increases will serve as a hedge against such habit shocks. Because the aggregate price index is normalized to one, firms whose consumption level is far away from the habit level will face a relative price decrease, making such firms riskier.

Finally, the habit elasticity of demand is given by:

$$\epsilon_{it}^{C,S} = \frac{\partial \ln C_{it}}{\partial \ln S_{it}} = \frac{\theta}{\eta}\frac{S_{it}}{C_{it}}. \tag{17}$$

As before, for firms whose consumption level is close to the habit level, the percentage increase in demand in response to an increase in the habit level will be the largest.

In the next subsection I will calibrate the two-period model assuming that the factor inputs to production are fixed. In this case the difference in expected returns is purely driven by the cross-sectional differences in the price-elasticity of demand and the habit elasticities of price. In the next section, I present the full-fledged model. I then allow the input factors to production to vary, but I assume that there are adjustment costs to changing these input factors. In this case the differences in expected returns between firms are driven by a combination of all the above-mentioned cross-sectional differences in elasticities.

## 2.3 The supply side

Recall that each good is produced by a monopolist. I assume, for now, that the factor inputs to production as well as their prices, are fixed. In other words, in the short run adjustment costs to the input factors are infinitely large. The production function is given by:

$$Y_{it} = A_{it} \tag{18}$$

where:

$$\ln A_{i0} = 0 \tag{19}$$

$$\ln A_{i1} \sim N(0, \sigma_i) \tag{20}$$

The stochastic nature of $A_{i1}$ represents a productivity or supply shock. Firms are price-setters who satisfy demand at the announced prices. As such, prices in period $t$ are set after the level of productivity $A_{it}$ is observed:

$$Y_{it} \geq C_{it} \tag{21}$$

The demand function that monopolist $i$ faces is given in equation 6. In period 1, firm $i$ then solves a static optimization problem, with the Lagrangian given by:

$$L_1 = p_{i1}C_{i1} + \kappa_{i1}\left(Y_{i1} - C_{i1}\right) + \nu_{i1}\left(p_{i1}^{-\eta}X + \theta S_{i1} - C_{i1}\right) \tag{22}$$

Taking first order conditions with respect to $p_{i1}$, $C_{i1}$ and $\nu_{i1}$ results in the following three equations:

$$\eta\nu_{i1}p_{i1}^{-\eta-1}X_1 - C_{i1} = 0 \tag{23a}$$

$$p_{i1} - \kappa_{i1} - \nu_{i1} = 0 \tag{23b}$$

$$p_{i1}^{-\eta}X + \theta S_{i1} - C_{i1} = 0 \tag{23c}$$

The first equation balances the marginal cost and benefits to the monopolist of decreasing its price by one unit. If the demand curve was completely price-inelastic, such a unit price decrease would lead to a decrease in revenue equal to $C_{i1}$. However, because the demand curve is price-elastic, decreasing the price will lead to an increase in demand equal to $\eta p_{i1}^{-\eta-1}X_1$. This increase in demand leads to a higher revenue equal to $\eta\nu_{i1}p_{i1}^{-\eta-1}X_1$. The value of an additional unit of demand is given by the Lagrange multiplier $\nu_{it}$. If the monopolist could increase its production at zero cost, $\nu_{it}$ will equal $p_{it}$. However, because production can not be increased at zero cost, there is a wedge between $p_{it}$ and $\nu_{it}$ equal to the Lagrange multiplier $\kappa_{i1}$. In fact, in this setup, because the factor inputs to production are fixed, production can not be increased. As such, demand pressure will only drive up to the price paid for the existing demand.[13]

At period 0, the firm maximizes profits subject to the resource constraint, the demand

[13] Given that the production factors are fixed in this example, I could have substituted out $C_{it}$ and put $A_{it}$ instead. However, this would ignore the Kuhn-Tucker condition that $C_{it}$ needs to be smaller or equal than $A_{it}$. The monopolist could potentially sell less than it produces thereby increasing its selling price. In that case, the Lagrange multiplier $\kappa_{i1}$ is equal to zero. In the calibration that follows I ensure that $\kappa_{i1}$ is strictly positive.

curve and the evolution of the habit:

$$L_0 = E_0 \sum_{t=0}^{1} \beta^t \frac{\Lambda_t}{\Lambda_0} \left[ \begin{array}{c} p_{it} C_{it} + \kappa_{it} \left( Y_{i1} - C_{it} \right) + \nu_{it} \left( p_{it}^{-\eta} X_t + \theta S_{it} - C_{it} \right) \\ + \zeta_{it} \left( \left( 1 - \rho \right) C_{it} + \rho S_{it} + \varepsilon_{it+1} - S_{it+1} \right) \end{array} \right] \tag{24}$$

where

$$\zeta_{i1} = 0 \tag{25}$$

The first order conditions for $p_{i0}$ and $\nu_{i0}$ are the same as in period 1. However the first order condition with respect to consumption includes an additional term. A one unit increase in consumption in period 0 will lead to a higher level of habit equal to $(1 - \rho)$ in period 1. This increase of the habit stock in period 1 has a present value of $\zeta_{i0}$ which, in turn, equals the discounted value of $\theta \nu_{i1}$. The first order condition with respect to consumption is therefore given by:

$$p_{i0} - \kappa_{i0} - \nu_{i0} + \theta \left( 1 - \rho \right) E_t \left[ \beta \frac{\Lambda_1}{\Lambda_0} \nu_{i1} \right] = 0 \tag{26}$$

## 2.4 Asset pricing equations

The real profits of firm $i$ at time t, $\Phi_{it}$, are equal to:

$$\Phi_{it} = p_{it} C_{it} \tag{27}$$

The stock price of firm $i$ at time 0, $V_{i0}$, is equal to the discounted profits:

$$V_{i0} = E_0 \left[ \beta \frac{\Lambda_1}{\Lambda_0} \Phi_{i1} \right] \tag{28}$$

The return on stock $i$ is then given by:

$$R_{i1} = \frac{\Phi_{i1}}{V_{i0}} \tag{29}$$

The difference in expected returns between two firms $i$ and $j$ can then be measured as:

$$\frac{E_0 \left[ R_{i1} \right]}{E_0 \left[ R_{j1} \right]} = \frac{E_0 \left[ \Phi_{i1} \right]}{E_0 \left[ \Phi_{j0} \right]} \frac{V_{j0}}{V_{i0}} = \frac{E_0 \left[ \Phi_{i1} \right]}{E_0 \left[ \Phi_{j0} \right]} \frac{E_0 \left[ \Lambda_1 \Phi_{j1} \right]}{E_0 \left[ \Lambda_1 \Phi_{i1} \right]} \tag{30}$$

which is independent of $\beta$ and $\Lambda_0$.

## 2.5 Calibration

In the quarterly calibration I assume that there are two groups of firms each with aggregate mass 0.5. Within each group there is perfect symmetry, implying that each firm within a group faces the same habit stock and the same realization of the productivity shock. For the time non-separability parameter $\theta$, I choose a value of 0.72 which is in the range of values commonly applied in the habit formation literature (see Constantinides (1990), Cochrane and Hansen (1992) and Jermann (1998)). For the risk aversion parameter $\gamma$ I choose a value of 9. There is considerable debate about what are reasonable magnitudes for the risk aversion parameter. Mehra and Prescott (1985) argue that a risk aversion of 10 and below seems reasonable. I set the persistence of the habit formation process $\rho$ equal to 0.85 and the elasticity of substitution $\eta$ equal to 5.3 following **?**. I set the volatility of the productivity shocks $\sigma_1$ and $\sigma_2$ equal to 1 per cent per quarter and assume they are perfectly correlated. Further, I allow for a trend growth of 0.4 percent per quarter and calibrate $\beta$ such that the risk free rate equals 0.3 percent per quarter. The table below summarizes the calibrated parameters.

| Variable | Symbol | Value |
|---|---|---|
| Risk aversion | $\gamma$ | 9 |
| Elasticity of substitution | $\eta$ | 5.3 |
| Time non-separability parameter | $\theta$ | 0.72 |
| Persistence of the habit stock | $\rho$ | 0.85 |
| Output volatility | $\sigma_1, \sigma_2$ | 0.01 |
| Preference shock volatility | $\sigma_{s1}, \sigma_{s2}$ | 0.01 |

## 2.6 Productivity shocks

I first consider a setting with only productivity (supply) shocks and will consider the influence of preference (demand) shocks in the next subsection. As such, I set the volatility of the preference shocks $\varepsilon_{i1}$ equal to 0. I then compute the equilibrium of this economy for values of $S_{0i}$ between 0.92 and 1.08 with increments of 0.01 for $i = 1, 2$. When $S_{0i} = 1$ for both sectors, the equity risk premium equals 0.4 percent per quarter. This equity risk premium is relatively low, which is due to the low level of the time non-separability parameter $\theta$.

The right bottom panel of Figure 1 shows the scatter plot of the expected return difference $E_t(R_{1,t+1}) - E_t(R_{2,t+1})$ against the product price difference $p_{1t} - p_{2t}$ where each point in the scatter plot represents a combination of $S_{01}$ and $S_{02}$. The graph shows a negative relationship between the price difference between the sectors and the expected return difference. That is, when the habit stock of one sector is low and the habit stock of the other is high, the product price of the sector with a high habit stock is high and earns a low expected return. This low expected return is driven by the relative price increase in response to an aggregate negative productivity shock. Consumers are highly averse to scaling back on goods with a high habit level. Therefore, the prices of these goods will increase the most in response to a negative (aggregate) productivity shock. For the producers of high habit goods, these price increases serve as a hedge against this type of systematic risk. As the aggregate price level, which is a weighted average of the price level in the two sectors, is normalized to 1, a relative price increase in one sector will lead to a relative price decrease in the other sector. This implies that the sector with the low habit level is faced with a lower relative price in addition to suffering a negative productivity shock.

For this simple example with only two sectors, the quarterly expected return difference can be as high as 0.1 percent, which, compounded, is close to half a percent per year. This number should be compared to the risk premium in the economy which equals 0.4 percent when the state variables are at their steady state level. Obviously, when more sectors are involved, sorting on the extremes will generate a larger expected return difference. A higher spread can also be achieved by choosing a higher value of the time non-separability parameter $\theta$, which will result in both a higher expected return and a higher spread. However, in the parsimonious setup presented here, a relatively low level of $\theta$ is required to ensure that the monopolist is willing to sell all its output, that is, $\kappa_{it}$ is positive. If $\theta$ is too high, the price elasticity of demand will be so low that the monopolist has an incentive to not sell part of its output.

The remaining three panels in Figure 1 portray the product price of sector 1, the expected return of sector 1's equity and the riskfree rate, each as a function of the initial habit stock of both sectors. Both the riskfree rate and the expected return on sector 1's equity are increasing in both the habit stock of sector 1 and the habit stock of sector 2. The riskfree rate is highly sensitive to the variation in the habit level, leading to a volatile riskfree rate (see Jermann (1998)). The risk premium on sector 1's equity is sensitive to the habit level in sector 2. A high level of habit in sector 2 and a low level of habit in sector 1, will imply that in response to a negative productivity shock, the price of sector 2 will increase. As the aggregate price index is normalized to 1, this implies that the relative price of sector 1 will decrease. Finally, the product price of sector 1 is increasing in the habit of sector 1 and decreasing in the habit of sector 2.

## 2.7 Preference shocks

I now consider the case of preference (demand) shocks. I set the volatility of the productivity shocks equal to zero and set the volatility of the preference shocks equal to 1 percent and assume that these shocks are perfectly correlated. I then compute the equilibrium of this economy for values of $S_{0i}$ between 0.92 and 1.08 with increments of 0.01 for $i = 1, 2$. The right bottom panel of Figure 2 shows the scatter plot of the expected return difference $E_t(R_{1,t+1}) - E_t(R_{2,t+1})$ against the product price difference $p_{1t} - p_{2t}$ where each point in the scatter plot represents a combination of $S_{01}$ and $S_{02}$. As before there is a strong negative relationship between the expected return difference and the product price difference.

A positive aggregate preference shock will lower the level of aggregate habit-adjusted consumption, making consumers worse off. In response to a positive preference shock, firms will want to increase their prices. This absolute price increase will be the largest for those firms who already have a high habit stock relative to the consumption level. As such, firms with a high habit stock have a relative price increase in response to such a systematic positive preference shock and firms with a low habit stock have a relative price decrease. Similar to the case of productivity shocks, the relative price increases of firms with a high habit stock serve as a hedge against this form of systematic risk.

The remaining three panels in Figure 2 portray the product price of sector 1, the expected return of sector 1's equity and the riskfree rate, each as a function of the initial habit stock of both sectors. Interestingly, if the habit stock of sector 1 is high and the habit stock of sector 2 is not, the risk premium on sector 1's equity is negative. In other words, in this case, sector 1's equity serves as a hedge against a negative aggregate demand shock, due to the relative price increase of sector 1's product in response to a positive preference shock.

# 3 The full-fledged model

In the previous sections I have addressed a parsimonious two-sector, two-period model where the inputs to production are fixed. I will now present the full-fledged model which allows the labor input of each firm to vary over time. However, each firm faces quadratic adjustment costs when adapting the size of its labor force. For ease of exposition I will not include capital in the model. However, note that including capital will not change the qualitative results compared to the labor-only case, provided that capital is a separate good and that each firm faces adjustment costs. I will address capital stock variation in the next section.

## 3.1 Households

The representative household's preferences are described by the utility function:

$$E_0 \sum_{t=0}^{\infty} \beta^t U\left(X_t, h_t\right) \tag{31}$$

where $X_t$ is the level of habit-adjusted consumption and $h_t$ is the number of hours worked. The level of aggregate habit-adjusted consumption, $X_t$ is defined as:

$$X_t = \left[ \int_0^1 \left(C_{it} - \theta S_{it}\right)^{1-\frac{1}{\eta}} di \right]^{\frac{1}{1-\frac{1}{\eta}}} \tag{32}$$

where the habit stock $S_{it}$ is predetermined apart from a preference shock:

$$S_{it+1} = (1-\rho)\, C_{it} + \rho S_{it} + \varepsilon_{it+1} \tag{33}$$

These habits imply a demand for variety $i$ of the form:

$$C_{it} = p_{it}^{-\eta} X_t + \theta S_{it} \tag{34}$$

where $p_{it} \equiv P_{it}/P_t$ is the relative price of good $i$ relative to the nominal price index $P_t \equiv \left[ \int_0^1 P_{it}^{1-\eta} di \right]^{\frac{1}{1-\eta}}$.[14]

## 3.2 Firms

Goods are produced by monopolistically competitive firms. Each good is manufactured using labor via the following production technology:

$$Y_{it} = G_t Z_{it} h_{it} \tag{35}$$

[14] When instead of a mass of firms, there is a discrete number of firms $i \in \{1, ..., N\}$ with weights $w\left(i\right)$, aggregate consumption is given by $X_t = \left[ \sum_{i=1}^{N} w\left(i\right)\left(C_{it} - \theta S_{it}\right)^{1-\frac{1}{\eta}} di \right]^{\frac{1}{1-\frac{1}{\eta}}}$, the demand function is given by $C_{it} = \left(\frac{p_{it}}{N w(i)}\right)^{-\eta} X_t + \theta S_{it}$ and the aggregate price index is given by $P_t \equiv \left[ \sum_{i=1}^{N} \left(\frac{1}{N}\right)^{1-\eta} w\left(i\right)^{\eta} P_{it}^{1-\eta} di \right]^{\frac{1}{1-\eta}}$

where $Y_{it}$ is the output of good $i$ and $h_{it}$ is firm $i$'s labor force. I assume that the dynamics of the components of the Solow residual are given by:

$$\frac{G_{t+1}}{G_t} = e^{\bar{g}} \tag{36}$$

$$z_{it+1} = \rho_{iz} z_{it} + \varepsilon^z_{i,t+1} \tag{37}$$

where $z_{it+1} \equiv ln(Z_{it})$ and $\varepsilon^z_{it} \sim N\left(0, \sigma^2_{iz}\right)$. In this specification, $G_t$ represents the economy-wide deterministic trend growth. Note that the process $Z_{it}$ is a firm-dependent mean-reverting process. These dynamics imply that the economy as a whole grows at a trend $\bar{g}$ and that individual firms' outputs vary around this trend. As such the output of firms are cointegrated, in the sense that they share the same deterministic trend.

Firms are price-setters who satisfy demand at the announced prices:

$$Y_{it} \equiv Z_{it} G_t h_{it} \geq C_{it} \tag{38}$$

I assume that firms faces quadratic adjustment costs to labor given by:

$$LAC_{it} = b\left(\frac{h_{it}}{h_{it-1}} - 1\right)^2 \tag{39}$$

There exists a large body of empirical work on the adjustment costs to labor and capital at the plant level.[15] At the macro level, these adjustment costs are required to generate sizeable risk premia.[16] Such short-term frictions make the supply side of the economy relatively inelastic. In my model, this implies that if the consumption surplus ratio of a particular good is currently low, consumption can not quickly adjust upward despite a high marginal utility of doing so. Instead, this demand pressure will temporarily drive up the price of that good.

The consumption demand faced by the monopolist producing good $i$ is given by

$$C_{it} = p_{it}^{-\eta} X_t + \theta S_{it}, \tag{40}$$

[15]See Cooper and Haltiwanger (2000) and Cooper and Willis (2004) and the references therein.
[16]See also Jermann (1998) and Rouwenhorst (1995).

where habit evolves according to:

$$S_{it+1} = \rho S_{it} + (1-\rho) C_{it} + \varepsilon_{it+1}. \tag{41}$$

The Lagrangian of firm $i$'s problem can then be written as:

$$E_0 \sum_{t=0}^{\infty} \frac{\Lambda_t}{\Lambda_0} \left[ \begin{array}{c} p_{it} C_{it} - W_t h_{it} - LAC_{it} + \kappa_{it} \left\{ Z_{it} G_t h_{it} - C_{it} \right\} \\ +\nu_{it} \left\{ p_{it}^{-\eta} X_t + \theta S_{it} - C_{it} \right\} + \zeta_{it} \left\{ \rho S_{it} + (1-\rho) C_{it} + \varepsilon_{it+1} - S_{it+1} \right\} \end{array} \right] \tag{42}$$

where $\frac{\Lambda_t}{\Lambda_0}$ represents the stochastic discount factor as further defined in the next section. The state variables of firm $i$ are the habit stock $S_{it}$, the state of the technology $Z_{it}$ and the labor force $h_{it}$. Taking first order conditions with respect to $C_{it}, S_{it}, h_{it}$ and $p_{it}$ we obtain the following four equations:

$$[C_{it}] \;:\; p_{it} - \kappa_{it} - \nu_{it} + (1-\rho) \zeta_{it} = 0 \tag{43}$$

$$[S_{it}] \;:\; E_t \left[ \frac{\Lambda_{t+1}}{\Lambda_t} \left( \theta \nu_{it+1} + \rho \zeta_{it+1} \right) \right] = \zeta_{it} \tag{44}$$

$$[p_{it}] \;:\; C_{it} - \eta \nu_{it} p_{it}^{-\eta-1} X_t = 0. \tag{45}$$

$$[h_{it}] \;:\; E_t \left[ \frac{\Lambda_{t+1}}{\Lambda_t} \left( b \frac{h_{it+1}}{h_{it}^2} \left( \frac{h_{it+1}}{h_{it}} - 1 \right) \right) \right] - \frac{b}{h_{it-1}} \left( \frac{h_{it}}{h_{it-1}} - 1 \right) - W_t + \kappa_{it} G_t Z_{it} \tag{46}$$

The first of these four equations balances the marginal cost and benefit from a one unit increase of consumption. The Lagrange multiplier $\nu_{it}$ measures the value of an additional unit of demand in this period. This value is equal to the selling price of the good $p_{it}$ minus the production cost $\kappa_{it}$ plus the present-value of having $(1-\rho)$ additional units of habit in the next period. The present value of having one additional unit of habit in the next period equals $\zeta_{it}$, so the value of having $1-\rho$ such units equals $(1-\rho)\zeta_{it}$.

The second equation balances the marginal costs and benefits of increasing the habit of the households, which due to the persistence of the habit stock is a dynamic tradeoff. An additional unit of habit in this period leads to $\rho$ additional units of habit in the next period. Having an additional unit of habit allows the firm to raise prices as the price elasticity of the consumers' demand is now lower, generating an additional revenue equal to $\theta\nu_{it+1}$. Note that the optimal price response depends on the time non-separability of the consumers' preferences measured by $\theta$. The third equation equates the marginal costs and benefits of changing the price of the good by one unit. Finally the fourth equation represents the dynamic tradeoff of adjusting each firm's labor force.

### 3.3 The representative household's maximization

I assume that the preferences of the representative household are given by:

$$U\left(X_t\right) = \frac{X_t^{1-\gamma}}{1-\gamma} + \pi_t \frac{\left(1-h_t\right)^{1-\chi}}{1-\chi} \tag{47}$$

where:

$$\pi_t = \mu G_t^{1-\gamma} \tag{48}$$

In this expression, the constant $\mu$ captures the tradeoff between leisure and aggregate habit-adjusted consumption, which I calibrate such that the share of time devoted to work equals 20 percent. The term $G_t^{1-\gamma}$ ensures that leisure shares the same time trend as aggregate habit adjusted consumption. The representative household then optimizes utility subject to:

$$X_t + \int_0^1 \theta p_{it} S_{it} di + E_t\left[M_{t,t+1} d_{t+1}\right] = d_t + W_t h_t + \Phi_t \tag{49}$$

where $d_{t+1}$ represents a set of Arrow-Debreu securities. Let $\Lambda_t$ denote the Lagrange multiplier associated with the budget constraint. The first order conditions of the households are then given by:

$$\Lambda_t = \beta^t X_t^{-\gamma} \tag{50}$$

$$\pi_t \frac{\left(1-h_t\right)^{-\chi}}{X^{-\gamma}} = W_t \tag{51}$$

Further define the stochastic discount factor as:

$$M_{t,t+1} \equiv \frac{\Lambda_{t+1}}{\Lambda_t} = \beta \left(\frac{X_{t+1}}{X_t}\right)^{-\gamma}. \tag{52}$$

Define the riskfree rate $R_t^f$ as the inverse of the expected value of the stochastic discount factor:

$$R_t^f \equiv \frac{1}{E_t\left(M_{t,t+1}\right)} \tag{53}$$

The value of the firm equals the discounted value of real future cash flows:

$$V_{it} = E_t \sum_{j=0}^{\infty} M_{t,t+j} \Phi^i_{t+j} \tag{54}$$

which equals the relative price of firm $i$ times the demand for good $i$, minus labor costs and labor adjustment costs:

$$\Phi_{it} \equiv p_{it} C_{it} - W_t h_{it} - LAC_{it} \tag{55}$$

## 3.4 Asset pricing equations

I assume that firms do not issue shares or debt, and finance their capital stock solely through retained earnings. The return on each firm's stock, $R_{i,t+1}$ satisfies the pricing equation:

$$E_t \left[ M_{t,t+1} R_{i,t+1} \right] = 1 \tag{56}$$

where the return is given by:

$$R_{i,t+1} = \frac{PD_{i,t+1} + 1}{PD_{it}} \frac{\Phi_{i,t+1}}{\Phi_{it}} \tag{57}$$

in which $PD_{i,t+1}$ is the price-dividend ratio of the firm and $\Phi_{it}$ are the profits of the firm as defined above.

## 3.5 Solving and Calibrating the Model

To find a stationary equilibrium, I first normalize all variables by the deterministic trend, as further explained in Appendix B. I then solve the model by perturbation, as discussed in Appendix A. As before I assume in the quarterly calibration that there are two groups of firms each with aggregate mass 0.5 and that within each group there is perfect symmetry, implying that each firm within a group faces the same habit stock and the same realization of the productivity shock. I then calibrate the model using similar parameter values as in the two-period setup presented earlier. The table below summarizes the calibrated parameters.

| Variable | Symbol | Value |
|---|---|---|
| Subjective discount factor | $\beta$ | 1.01 |
| Risk aversion | $\gamma$ | 5 |
| Elasticity of substitution | $\eta$ | 5.3 |
| Time non-separability parameter | $\theta$ | 0.81 |
| Persistence of the habit stock | $\rho$ | 0.90 |

I calibrate the volatility of the productivity shocks such that the aggregate output and consumption growth volatility equals 0.72 percent. I set the correlation of the productivity shocks between the two sectors equal to 0.2. Finally, I calibrate the adjustment cost parameter $b$ such that the volatility of the aggregate number of hours worked matches the aggregate of the intensive and the extensive margin of aggregate labor in the data.[17]

## 3.6 Productivity shocks

I first consider a setting with only productivity shocks and set the volatility of the preference shocks equal to zero. Table 1 summarizes the aggregate statistics of the model, including aggregate output growth, the riskfree rate and the average return and volatility of the aggregate stock market. The table shows that the model matches the aggregate level of the risk free rate and the risk premium. The model also matches the volatility of aggregate stock returns, but overestimates the volatility of the riskfree rate as in Jermann (1998).[18] In the model, there is no investment and as such, output and consumption are equal. In the data investment is substantially more volatile than consumption. The quarterly investment growth rate volatility equals 2.65 percent and the quarterly consumption growth rate volatility is 0.55 percent. Output, which is the sum of these two components has a quarterly output volatility of 1 percent. Given that in the model output and consumption are equal, either the consumption growth rate will be too volatile or output will not be sufficiently volatile. I calibrate the volatility of the productivity shocks such that the volatility of consumption growth (and therefore output growth) in the model equals 0.72 percent.

I then study the dynamics of the difference in expected returns between the two sectors

[17] In fact, I match the standard deviation of the Hodrick and Prescott (1997) filtered logarithms of the total hours worked (employment times hours per worker) between 1964 and 2004. This statistic is based on private non-farm production workers, which are the only ones for whom hours are observed.

[18] By including capital in the production function, which I address in the next section, the volatility of the riskfree rate can be substantially reduced, provided that the habit formation process is persistent.

and compare it to the difference in product prices and the difference in the consumption surplus ratios. The three panels of Figure 3 plot a sample path of 400 quarters for respectively the difference in expected returns, $E_t(R_{1t+1} - R_{2t+1})$, the difference in the product prices, $p_{1t} - p_{2t}$ and the difference in consumption surplus ratios $SR_{1t} - SR_{2t}$. Recall that the consumption surplus ratio is defined as:

$$SR_{it} = \frac{C_{it} - \theta S_{it}}{C_{it}} \tag{58}$$

The graph illustrates that the model generates a near perfect positive correlation between the difference in expected returns and the difference in consumption surplus ratios, and a near perfect negative correlation between the difference in product prices and the difference in consumption surplus ratios. This results in a strong negative correlation between the product price difference and the difference in expected returns. In other words, the model predicts that, empirically, a difference in product prices can be used to generate a cross-sectional spread in expected returns. The values of the above-mentioned correlations are summarized in the lower panel of Table 1.

## 3.7 Preference Shocks

I then consider the influence of preference shocks. The results are summarized in Table 2. The literature does not provide much guidance how to calibrate the quarterly volatility of the preference shocks. When I calibrate this volatility to 0.3 percent, which seems conservative, the model generates an annual volatility of stock returns of 20 percent, which is close to the data, and it generates a high volatility of net payouts equal to 42 percent. Furthermore the model then matches the aggregate risk premium of 6 percent. It is interesting to note that the volatility of quarterly output growth, and therefore of quarterly consumption, is very low and equal to a mere 0.1 percent. This is due to the fact that there are no shocks to aggregate productivity and the labor force only adjusts slowly to preference shocks. Even though consumption growth is not very volatile, habit-adjusted aggregate consumption growth is. There is now an independent source of variation in the stochastic discount factor which allows the equity risk premium to be high even though consumption growth is not.

I then study the difference in expected returns between the two sectors. As before the model generates a negative correlation between the expected return difference and the product price difference. However, the magnitude of this negative correlation is smaller compared to the productivity shock case. As before, the product price difference is almost perfectly correlated with the difference in the consumption surplus ratios. The expected return difference, on the other hand, is driven by the difference in the habit levels of the two sectors, which is correlated but not equal to the difference in the consumption surplus ratio. In the case of productivity shocks, there are two state variables that drive the difference in expected returns, the level of productivity and the habit level. In contrast, in the case of preference shocks, there is no variation in productivity and therefore the difference in expected returns is driven by the difference in the habit level. The exact values of the above-mentioned correlations are summarized in the lower panel of Table 2

# 4 Capital Stock Variation

So far, I have not included capital as an input to production. However, it is straightforward to include capital in the production function and obtain comparable cross-sectional results to the model in the previous section, provided that capital is a separate good and that each firm's capital stock faces adjustment costs. These assumptions ensure that there is limited substitution of input factors across sectors, which is required to generate a negative relationship between the difference in product prices and the difference in expected returns.

In this section I include capital in the production function to compare the deep habits model to the standard one sector production economy with habits as in Jermann (1998). In this comparison I assume that there is perfect symmetry between all firms, which implies that all firms face the same productivity shocks and have the same habit level. For ease of exposition I will assume that capital is a composite good, but similar results can be obtained when assuming that capital is a separate good.

Assume that the production function is given by:

$$Y_{it} = e^{z_{it}} \left(G_t h_{it}\right)^{\alpha} K_{it}^{1-\alpha} \tag{59}$$

Assume further that households own and invest in physical capital. At the beginning of a given period $t$, the representative household owns capital in the amount of $K_t$ that it can rent out at the rate $u_t$. The capital stock evolves over time according to:

$$K_{t+1} = (1-\delta) K_t + G\left(\frac{I_t}{K_t}\right) K_t \tag{60}$$

where $I_t$ is the total investment defined by:

$$I_t = \left[ \int_0^1 I_{it}^{1-1/\eta} di \right]^{\frac{1}{1-1/\eta}} \tag{61}$$

which implies that capital is a composite good. The function $G$ is an adjustment cost function given by:

$$G\left(\frac{I_t}{K_t}\right) = a_1 + \frac{a_2}{1-\frac{1}{\tau}} \left(\frac{I_t}{K_t}\right)^{1-\frac{1}{\tau}} \tag{62}$$

where $a_1$ and $a_2$ are chosen to match the steady state properties.[19] By solving the dual problem of minimizing total investment expenditure, $\int_0^1 P_{it} I_{it} di$ subject to the aggregation constraint I find:

$$I_{it} = \left(\frac{P_{it}}{P_t}\right)^{-\eta} I_t \tag{63}$$

Note that in equation 61 the elasticity of substitution between varieties of individual investment is also given by the parameter $\eta$. In other words, for simplicity I assume that the elasticity of substitution for investment and consumption is the same. Note, however, that this assumption can easily be relaxed.

To compare the aggregate time series properties of both models, I now consider the symmetric case where all firms are identical. This implies that all firms have identical habit stocks and identical productivity shocks. In this case, the subscript i can be dropped and the prices are set equal to 1. The first order conditions of the households remain unchanged

[19] The derivatives of $G\left(\frac{I_t}{K_t}\right) K_t$ with respect to $K_t$ and $I_t$ are given by respectively:

$$\begin{aligned}
\frac{\partial G\left(\frac{I_t}{K_t}\right) K_t}{\partial K_t} &= G\left(\frac{I_t}{K_t}\right) - G'\left(\frac{I_t}{K_t}\right)\frac{I_t}{K_t} = a_1 + \frac{a_2}{\tau - 1}\left(\frac{I_t}{K_t}\right)^{1-\frac{1}{\tau}} \\
\frac{\partial G\left(\frac{I_t}{K_t}\right) K_t}{\partial I_t} &= a_2 \left(\frac{I_t}{K_t}\right)^{-\frac{1}{\tau}}
\end{aligned}$$

and the first order conditions of the firm(s) simplify to:

$$[C_t] \quad : \quad 1 - \kappa_t - \nu_t + (1-\rho)\,\zeta_t = 0 \tag{64}$$

$$[S_t] \quad : \quad E_t\left[\frac{\Lambda_{t+1}}{\Lambda_t}\left(\theta\nu_{t+1} + \rho\zeta_{t+1}\right)\right] = \zeta_t \tag{65}$$

$$[p_t] \quad : \quad c_t - \eta\nu_t x_t = 0. \tag{66}$$

$$[\nu_t] \quad : \quad c_t = x_t + \theta s_{it} \tag{67}$$

I then compare the simulated moments from this model to the simulated moments from Jermann's (1998) model. To enhance the comparability between the two models even further, I calibrate the models to fit the same data period as Jermann (1998). I solve both Jermann's model and the deep habits model using a 3rd order perturbation method. This allows me to study the dynamics of the equity risk premium as well as its level.

The results are summarized in Table 3. The bottom panel of the table summarizes the parameters used to simulate from each model. I generate 1000 simulations of 240 quarterly observations and report the average over all simulations. I consider both the case where productivity shocks are permanent ($\rho_z = 1$) and where productivity shocks are highly persistent but transitory ($\rho_z = 0.99$). I calibrate the volatility of the productivity shocks to match the volatility of quarterly output growth, which equals 1 percent.

The table shows that both models are well able to match the unconditional moments of the data, including the volatility of consumption growth, investment growth, the equity risk premium and the level of the riskfree rate. By increasing the persistence of the habit stock ($\rho$), which Jermann (1998) sets equal to zero, the model is close to matching the volatility of the riskfree rate as well. Whereas the volatility of dividends seems too low in Jermann's model, the deep habits model generates too volatile dividends compared to the standard measure of per share dividends. However, recent work by Bansal and Yaron (2006) and Yogo and Larrain (2007) suggests that the total net payout of firms is in fact more volatile than per share dividends. In particular, Yogo and Larrain (2007) find that the volatility of net payout growth equals 38 percent per year, which is close to the volatility generated by the deep habits model.

The models' success in explaining the unconditional moments of the financial variables is contrasted by their poor performance in matching the conditional moments of the data. Most importantly, the variation in the price-dividend ratio is almost entirely driven by variation in expected dividend growth rates and the riskfree interest rate and not by variation in expected excess returns. The unconditional standard deviation of quarterly expected excess returns is only 0.1 percent as opposed to a standard deviation of quarterly expected dividend growth rates of 3.1 percent. Given that the persistence of both variables is approximately equal, the variance decomposition of the price-dividend ratio is dominated by riskfree rate and expected dividend growth rate variation.[20] The variation in expected returns can be substantially increased by including preference shocks, that is shocks to the habit formation process.[21] However, even in this case the model still generates substantial variation in expected growth rates. This expected dividend growth rate variation is in contrast to the habit formation model in an endowment economy as proposed by Campbell and Cochrane (1999).

Finally, and interestingly, it seems that even when productivity shocks follow a random walk, expected consumption growth is time-varying and persistent induced by the high capital adjustment costs and persistence in the habit formation process, which smoothes out the influence of the productivity shocks, even when these productivity shocks are independently and identically distributed (i.i.d.). The high capital adjustment costs are necessary to match the level of the risk premium. The high persistence of the habit process (0.85) helps to match the low volatility of the risk free rate. In a recent paper, Kaltenbrunner and Lochstoer (2007) argue that in a general equilibrium framework with Epstein-Zin preferences, highly persistent expected consumption growth rates, as proposed in Bansal and Yaron (2004), arise endogenously from the consumption smoothing behavior of consumers even when productivity shocks are i.i.d.. However, it seems that habit formation models with production and capital adjustment costs also produce such persistent expected consumption (and dividend) growth rates.[22]

# 5 Empirical Evidence

The deep habits model suggests a negative cross-sectional relationship between the product prices of firms and the expected return on their stock. I empirically investigate this link

[20]Furthermore, the correlation between expected excess returns and expected dividend growth rates is low (not reported), which seems in contrast with the data (see for example Binsbergen and Koijen (2007) and Lettau and Ludvigson (2005)).

[21]Such preference shocks are also required to explain the value premium in a habit formation context as argued by Lettau and Wachter (2007).

[22]Note that this suggests that in a production economy the question may not be so much whether expected dividend and consumption growth rates are time-varying or not, but rather whether consumers care about such time variation in their preferences.

by sorting firms into quintile portfolios based on recent price increases and decreases. I use monthly data from the Producer Price Index (PPI) Program. The PPI measures the average change over time in the selling prices received by domestic producers for their output.

A direct test of the model would be to rank firms based on the price elasticity of their demand curves. Unfortunately, these price-elasticities are unobservable. If the demand elasticity of firms is constant, the slope of the demand curve can be uncovered through an instrumental variables analysis involving exogenous shocks of the supply curve. However, in my model demand elasticities are time-varying as each good's price elasticity of demand is proportional to the consumption surplus ratio of that good. Instead I will focus on price changes within industries. These price changes are directly observable through the PPI index.

## 5.1 Data

The PPI tracks price changes for practically the entire output of domestic goods-producing sectors: agriculture, forestry, fisheries, mining, scrap, and manufacturing. Further, in recent years, the PPI has extended coverage to many of the non-goods producing sectors of the economy, including transportation, retail trade, insurance, real estate, health, legal, and professional services and new PPIs are gradually being introduced for the products of industries in the utilities, finance, business services, and construction sectors of the economy.[23]

The PPI sample I use includes over 25,000 establishments providing approximately 100,000 price quotations per month. Participating establishments report price data primarily through the mail. Goods and services included in the PPI are weighted by value-of-shipments data contained in the 1997 economic censuses. I use aggregated PPI data for industries based on the two digit Standard Industrial Classification (SIC) code between 1983 and 2003. After 2003, the PPI indexes based on SIC codes is discontinued and replaced by the North American Industry Classification System (NAICS). My choice of the SIC based PPI index as well as the data period and the level of SIC detail are motivated by the desire to maximize the compatibility between Center for Research in Security Prices (CRSP) and PPI data.

Merging CRSP data and PPI data based on the two-digit SIC codes results in monthly observations between 1983 and 2003 for 35 different industries. I then sort firms into five

[23]Source: http://www.bls.gov/ppi/

portfolios based on the percentage change of their PPI in the previous month. Quintile 1 contains firms whose PPI change was the lowest in the previous month, that is, who have the largest price decrease. Quintile 5 contains firms whose PPI change was the highest. I then compute value-weighted returns within each of these quintiles. I will refer to the portfolio that goes long in quintile portfolio 1 (Deflationary) and short in quintile portfolio 5 (Inflationary), as the DMI (Deflationary Minus Inflationary) portfolio.

## 5.2 Results

The first panel of Table 4 reports the results from the time series regressions of the net excess returns of each of the quintile portfolios as well as the DMI portfolio on a constant term and the four factors. The four factors, which I acquire from Kenneth French's website, include the excess return on the market (mktrf), the book-to-market portfolio (hml), the size portfolio (smb) and momentum (umd). The Newey and West (1987) adjusted standard errors are reported in brackets. The results show that there is a downward monotonic pattern of the pricing error (or alpha) as the quintiles increase, with an alpha of 0.37 percent for quintile 1 and a pricing error of -0.21 percent for quintile 5. However, from quintile 4 to quintile 5, there seems to be a slight, statistically insignificant, increase in the pricing error from -0.29 to -0.21 percent. The DMI portfolio earns a monthly alpha of 0.58 percent, with a t-statistic of 2.31, which is significant at the 5 percent level. Interestingly, the loading of the DMI portfolio on the book-to-market factor is negative and statistically significant. This negative loading increases the alpha compared to the CAPM benchmark which I report in panel 2 of Table 4. Even though the CAPM alpha of 0.40 percent is smaller than the four-factor alpha, it is still significant at the 10 percent level with a p-value of 0.075. Finally, panel 3 of Table 4 reports the average return on each of the quintiles as well as the standard deviation of the mean. The average monthly return on the DMI portfolio equals 0.54 percent, which with a standard deviation of 0.29 percent is statistically significant at the 10 percent level.

The results in Table 4 are generated by sorting on the producer price index change in the previous month. The producer price index in a given month is computed based on individual price quotes from firms for their products. As these price quotes are public information, one would expect that when a firm changes its price, this change is immediately reflected in its stock price. That being said, the PPI index, which is an aggregate of these price quotes within an industry, is not reported until the second week of the next month. To rule out that my results are driven by ex post sorting on price increases, I also sort firms based on price changes over a 4-month period starting in month $t-5$ and ending at $t-2$. The results are reported in Table 5.

Table 5 reports the results from the time series regressions of the net excess returns of each of the quintile portfolios as well as the DMI portfolio on a constant term and the four factors. As before, there is a downward pattern of the alpha as the quintiles increase, with a monthly alpha of 0.47 percent for quintile 1 and an alpha of -0.08 percent for quintile 5. However, similar to Table 4, the pattern is slightly upward sloping for the last two quintiles. However this increase is not statistically significant. The DMI portfolio earns a monthly alpha of 0.54 percent, with a t-statistic of 2.01, which is significant at the 5 percent level. Again, the loading of the DMI portfolio on the book-to-market factor is negative. Finally, panel 3 of Table 5 reports the average return on each of the quintiles as well as the standard deviation of the mean. The average monthly return on the DMI portfolio equals 0.68 percent. Because the standard deviation is 0.27 percent, this is statistically significant at the 5 percent level.

I conclude that empirically there seems to be a strong relationship between the expected returns on a firm's stock and the price it charges for its product. It seems that the CAPM is able to explain part of this relationship. However the quintile portfolios based on recent price changes do generate a statistically significant alpha relative to the CAPM. Furthermore, including the other three factors of the four-factor model increases the alpha even further as firms with recent price decreases earn high expected returns, but load negatively on the book-to-market factor.

# 6 Robustness Checks

## 6.1 Z-scores of the PPI

In the previous section I have sorted firms into quintile portfolios based on their recent percentage price changes. This sorting generates a statistically significant alpha with respect to both the unconditional CAPM and the four factor model. In this section I explore the possibility that these results are driven by relatively few sectors whose percentage product price change are either highly volatile or have a mean that differs substantially from the percentage changes of the aggregate producer price index. To address this issue, I sort firms not based on percentage price changes, but based on Z-scores. That is, I compute for each industry the average percentage price change over time and its standard deviation. I then compute the Z-score by demeaning each months industry price change and then divide this demeaned value by its corresponding standard deviation. I then sort stocks into quintile portfolios based on the previous month's Z-score. I find that sorts based on this criterion deliver almost identical results to those reported in the previous section.

## 6.2 Industry competition

As I discussed before, my model also relates to the recent literature on the cross-section of expected returns and product market competition. Hou and Robinson (2006) show that US firms in the quintile of the most competitive industries earn annual returns that are nearly 4% higher than those of similar firms in the quintile of the most concentrated industries. The market power that Hou and Robinson (2006) consider is related to the price setting behavior that I study in this paper. However, in my model, low expected returns are not a unconditional characteristic of an industry or firm but are a consequence of the current low income and price elasticities of demand faced by a particular firm or industry, which are time-varying and proportional to the consumption surplus ratio. When I construct the quintile portfolios, I indeed find that firms (and industries) frequently rotate across quintiles, as discussed in the next subsection. In contrast, firm sorts based on each industry's Herfindahl-Hirschman Index (HHI), as in Hou and Robinson (2006), can be used to generate a spread in expected returns up to several decades into the future. In Table 6 I include the return spread on the HHI portfolios as an addititional factor. The table shows that the DMI portfolio that I construct does not significantly load on the HHI factor and the generated alpha is still significant at the 5% significance level.

## 6.3 Markov matrices

To confirm that firms and industries frequently rotate across the quintile, I compute in table 7 the quarterly Markov probabilities of each firm in my dataset. The (i,j) element represents the probability of a firm switching from quintile i to quintile j over a one quarter horizon. The matrix shows that even though there is persistence in the quintiles, there is substantial variation across industries. For example, when computing the 3-year Markov probabilities by taking the reported matrix to the power 12, it is easy to see that these probabilities are nearly equal to the unconditional probability distribution of 0.20 for each quintile.

## 7 Discussion and Extensions

In this paper I have argued that the deep habits model can help to explain part of the variation in the cross-section of expected returns. In particular, the model explains why there are expected return differences between firms with recent price decreases and recent price increases. However, so far the model has not addressed the question of why there is a value or a size premium. This question is particularly interesting in a habit formation context because recently Lettau and Wachter (2007) and Santos and Veronesi (2006) have raised the issue that growth firms have high duration cash flows and are therefore more susceptible to discount rate risk. Because in habit formation models the shocks to the consumption surplus ratio (which drives expected returns) and shocks to consumption growth are perfect correlated, growth firms should carry a premium relative to value firms. Lettau and Wachter (2007) argue that to solve this problem, variation in the discount factor should be independent of cash flow shocks. They then model the variation in the discount factor in a reduced form setting and argue for a zero (or negative) correlation with cash flow growth shocks. As they assume that cash flow growth shocks are the only shocks that are priced, this allows for a zero or even negative risk premium on discount rate shocks.

Lettau and Wachter (2007) suggest that the discount rate variation could be due to a preference shocks, but it is not obvious why such preference shocks would carry a zero or negative price of risk. In contrast, the deep habits model endogenously generates a negative risk premium on preference shocks for those firms with a high habit level, because such firms can increase their prices the most in response to these systemic shocks. Furthermore, in the aggregate, the model generates a markup of prices over marginal costs which increases in response to a positive aggregate preference shock, again providing a (partial) hedge against systematic preference shocks. As such, the deep habits model seems a promising framework in which to study the value premium, which I will address in future research.

## 8 Conclusion

I study the cross-section of expected returns in a general equilibrium framework where instead of forming habits over some aggregate consumption bundle, agents form habits over individual varieties of goods. Goods are produced by monopolistically competitive firms, whose price-elasticity of demand depends on the habit formation for their specific good. As such, the model generates a strong relationship between the expected return on a firm's stock and the selling price of its product, which are both driven by the firm's habit stock. Firms with a high habit stock earn low expected returns and charge high prices for their product. I investigate this relationship empirically by sorting firms into five quintiles based on recent price changes, as measured by the producer price index. This sorting generates a statistically significant annual alpha of 6 percent that can not be explained by the four-factor model. I show that the CAPM seems to price the PPI portfolios better than the four-factor model, because firms with recent price decreases earn high expected returns, but load negatively on the book-to-market factor.

# References


Abel, A. B. (1990): "Asset Prices Under Habit Formation and Catching Up With the Jones," *American Economic Review*, 80, 38–42.

Ait-Sahalia, Y., J. A. Parker, and M. Yogo (2004): "Luxury Goods and the Equity Premium," *Journal of Finance*, 59(6), 2959–3004.

Bansal, R., and A. Yaron (2004): "Risks for the Long-Run: A Potential Resolution of Asset Pricing Puzzles," *Journal of Finance*, 59(4), 1481–1509.

——— (2006): "The Asset Pricing-Macro Nexus and Return-Cash Flow Predictability," Unpublished paper, Duke University.

Binsbergen, J. v., and R. Koijen (2007): "Predictive Regressions: A Present-Value Approach," Unpublished paper, Duke University and NYU Stern.

Campbell, J. Y., and J. H. Cochrane (1999): "By Force of Habit: A Consumption-Based Explanation of Aggregate Stock Market Behavior," *Journal of Political Economy*, 107, 205–251.

——— (2000): "Explaining the Poor Performance of Consumption-Based Asset Pricing Models," *Journal of Finance*, 55(6), 2863–2878.

Cochrane, J. H., and L. P. Hansen (1992): "Asset Pricing Explorations for Macroeconomics," in *NBER Macroeconomics Annual: 1992*, ed. by O. J. Blanchard, and S. Fischer, pp. 115–165. MIT Press, Cambridge, MA.

Constantinides, G. M. (1990): "Habit-formation: A Resolution of the Equity Premium Puzzle," *Journal of Political Economy*, 98, 519–543.

Cooper, R., and J. Haltiwanger (2000): "On the Nature of Capital Adjustment Costs," NBER working paper 7925.

Cooper, R., and J. Willis (2004): "The Cost of Labor Adjustment: Inferences From the Gap," Working paper Federal Reserve Bank of Kansas.

Dixit, A. K., and J. E. Stiglitz (1977): "Monopolistic Competition and Optimum Product Diversity," *American Economic Review*, 67(3), 297–308.

Gala, V. (2006): "Investment and Returns," PhD Dissertation, University of Chicago.

Gomes, J. F., L. Kogan, and M. Yogo (2006): "Durability of Output and Expected Stock Returns," Wharton.

Guadagni, P., and J. D. Little (1983): "A Logit Model of Brand Choice Calibrated on Scanner Data," *Marketing Science*, 2(3), 203–238.

Heaton, J. (1995): "An Empirical Investigation of Asset Pricing with Temporally Dependent Preference Specifications," *Econometrica*, 63, 681–717.

Hodrick, R., and E. C. Prescott (1997): "Postwar U.S. Business Cycles: An Empirical Investigation," *Journal of Money, Credit, and Banking*, 29, 1–16.

Hou, K., and D. T. Robinson (2006): "Industry Concentration and Average Stock Returns," *Journal of Finance*, 61(4), 1927–1956.

Jermann, U. (1998): "Asset Pricing in Production Economies," *Journal of Monetary Economics*, 41(2), 257–275.

Juillard, M. (1996): "Dynare : A Program for the Resolution and Simulation of Dynamic Models with Forward Variables Through the Use of a Relaxation Algorithm," CEPREMAP Working Paper 9602.

Kaltenbrunner, G., and L. Lochstoer (2007): "Long-Run Risk through Consumption Smoothing," Unpublished paper.

Lettau, M., and S. C. Ludvigson (2005): "Expected Returns and Expected Dividend Growth," *Journal of Financial Economics*, 76, 583–626.

Lettau, M., and J. A. Wachter (2007): "Why is Long-Horizon Equity Less Risky? A Duration-Based Explanation of the Value Premium," *Journal of Finance*, 62, 55–92.

Mehra, R., and E. C. Prescott (1985): "The Equity Premium Puzzle," *Journal of Monetary Economics*, 15, 145–161.

Newey, W. K., and K. D. West (1987): "A Simple, Positive Semidefinite, Heteroskedasticity and Autocorrelation Consistent Covariance Matrix," *Econometrica*, 55, 703–708.

Papanikolaou, D. (2007): "Investment-specific technology shocks and asset prices," Working Paper, Nortwestern University.

Ravn, M., S. Schmitt-Grohe, and M. Uribe (2006): "Deep habits," *Review of Economic Studies*, 73, 195–218.

Rotemberg, J., and M. Woodford (1999): "The Cyclical Behavior of Prices and Costs," p. 10511135.

Rouwenhorst, K. G. (1995): "Asset Pricing Implications of Equilibrium Business Cycle Models," in *Frontiers of Business Cycle Research*, ed. by T. F. Cooley, pp. 294–330. Princeton University Press, Princeton, New Jersey.

Santos, T., and P. Veronesi (2006): "Habit Formation, the Cross Section of Stock Returns and the Cash Flow Risk Puzzle," Unpublished paper, University of Chicago.

Schmitt-Grohe, S. (2005): "Perturbation Methods for the Numerical Analysis of DSGE Models," Manuscript, Duke University.

Whited, T., L. Xiaolei, and L. Zhang (2007): "Investment-based expected stock returns," 2(3), 203–238.

Yogo, M. (2006): "A Consumption-Based Explanation of the Cross Section of Expected Stock Returns," *Journal of Finance*, 61(2), 539–580.

Yogo, M., and B. Larrain (2007): "Does Firm Value Move Too Much to be Justified by Subsequent Changes in Cash Flow?," *Journal of Financial Economics*, Forthcoming.

Zhang, L. (2005): "The value premium," *Journal of Finance*, 60(1), 67–103.

# Appendix A: Perturbation

In the derivations below I follow the notation of Schmitt-Grohe (2005), which implies a reassignment of the symbols $y_t$ and $x_t$ to represent the whole vector of control variables and state variables respectively.[24]. The set of first order conditions that solve the model can be summarized as:

$$E_t f\left(y_{t+1}, y_t, x_{t+1}, x_t\right) = 0 \tag{68}$$

where $x_t$ has dimensions $n_x \times 1$ and denotes the vector with the predetermined (or state) variables. The state variables can in turn be partitioned into the endogenous state variables, in this case the habit stock of each firm and its labor force, and the exogenous state variables which includes the productivity variables $Z_{it}$ and (potentially) the preference shocks. The vector $y_{t+1}$, with dimension $n_y \times 1$, contains the control variables which includes the relative prices of all the goods, the consumption of each good and the aggregate habit-adjusted consumption. Assume that the exogenous state variables follow the law of motion:

$$Z_{it+1} = \Gamma Z_{it} + \sigma \Sigma \varepsilon_{t+1} \tag{69}$$

where $\sigma$ is the so-called perturbation parameter which equals 0 when determining the deterministic steady state of the model and which equals 1 in the stochastic version of the model. The vector $\varepsilon_{t+1}$ is assumed to be independently and identically distributed, with mean zero and variance/covariance matrix $I$. The matrix $\Gamma$ is assumed to satisfy the usual stationarity conditions.

The solution to the model is of the form:

$$y_t = \hat{g}\left(x_t\right) \tag{70}$$

and

$$x_{t+1} = \hat{h}\left(x_t\right) + \eta \sigma \varepsilon_{t+1} \tag{71}$$

Define $n = n_x + n_y$. The function $f$ then maps $R^{n_y} \times R^{n_y} \times R^{n_x} \times R^{n_x}$ into $R^n$, because there are $n$ equations and $2n_y + 2n_x$ variables, that is $y_{t+1}, y_t, x_{t+1}$ and $x_t$. The matrix $\eta$ is given by:

$$\eta = \begin{bmatrix} \varnothing \\ \Sigma \end{bmatrix} \tag{72}$$

The key idea of perturbation is to interpret the solution to the model as a function of the state vector $x_t$ and of the perturbation parameter $\sigma$ which scales the amount of uncertainty in the economy, leading to:

$$y_t = g\left(x_t, \sigma\right) \tag{73}$$

and

$$x_{t+1} = h\left(x_t, \sigma\right) + \eta \sigma \varepsilon_{t+1} \tag{74}$$

[24]See also Juillard (1996)

where the function $g$ maps $R^{n_x} \times R^{+}$ into $R^{n_y}$ and the function $h$ maps $R^{n_x} \times R^{+}$ into $R^{n_x}$.

Given this interpretation, a perturbation method finds a local approximation of the functions $g$ and $h$. By a local approximation, we mean an approximation that is valid in the neighborhood of a certain point $(\bar{x}, \bar{\sigma})$. Taking a Taylor series approximation of the functions $g$ and $h$ around the point $(x, \sigma) = (\bar{x}, \bar{\sigma})$ we have:

$$\begin{aligned} g(x_1, x_2, \sigma) &= g(\bar{x}_1, \bar{x}_2, \bar{\sigma}) + \sum_{i=1}^{2} g_{x_i}(\bar{x}_1, \bar{x}_2, \bar{\sigma})(x_i - \bar{x}_i) + g_{\sigma}(\bar{x}_1, \bar{x}_2, \bar{\sigma})(\sigma - \bar{\sigma}) \\ &+ \sum_{i=1}^{2} g_{x_i x_i}(\bar{x}_1, \bar{x}_2, \bar{\sigma})(x_i - \bar{x}_i)^2 + g_{x_1 x_2}(\bar{x}_1, \bar{x}_2, \bar{\sigma})(x_1 - \bar{x}_1)(x_2 - \bar{x}_2) \\ &+ \sum_{i=1}^{2} g_{x_i \sigma}(\bar{x}_1, \bar{x}_2, \bar{\sigma})(x_i - \bar{x}_i)(\sigma - \bar{\sigma}) + g_{\sigma\sigma}(\bar{x}_1, \bar{x}_2, \bar{\sigma})(\sigma - \bar{\sigma})^2 + ... \end{aligned} \tag{75}$$

and:

$$\begin{aligned} h(x_1, x_2, \sigma) &= h(\bar{x}_1, \bar{x}_2, \bar{\sigma}) + \sum_{i=1}^{2} h_{x_i}(\bar{x}_1, \bar{x}_2, \bar{\sigma})(x_i - \bar{x}_i) + h_{\sigma}(\bar{x}_1, \bar{x}_2, \bar{\sigma})(\sigma - \bar{\sigma}) \\ &+ \sum_{i=1}^{2} h_{x_i x_i}(\bar{x}_1, \bar{x}_2, \bar{\sigma})(x_i - \bar{x}_i)^2 + h_{x_1 x_2}(\bar{x}_1, \bar{x}_2, \bar{\sigma})(x_1 - \bar{x}_1)(x_2 - \bar{x}_2) \\ &+ \sum_{i=1}^{2} h_{x_i \sigma}(\bar{x}_1, \bar{x}_2, \bar{\sigma})(x_i - \bar{x}_i)(\sigma - \bar{\sigma}) + h_{\sigma\sigma}(\bar{x}_1, \bar{x}_2, \bar{\sigma})(\sigma - \bar{\sigma})^2 + ... \end{aligned} \tag{76}$$

where for ease of exposition I adapt the notation such that there is only one control variable and only one state variable of each type, that is, one endogenous state variable $x_1$ and one exogenous state variable $x_2$. The terms $g_{\sigma\sigma}(\bar{x}_1, \bar{x}_2, \bar{\sigma})(\sigma - \bar{\sigma})^2$ and $h_{\sigma\sigma}(\bar{x}_1, \bar{x}_2, \bar{\sigma})(\sigma - \bar{\sigma})^2$ measure the influence of the uncertainty in the model on the control and the state variables, respectively. Note that it is straightforward to include the asset pricing equations in the set of equations in $f$.

$$E_t[M_{t,t+1} R_{i,t+1}] = 1 \tag{77}$$

$$R_{i,t+1} = \frac{PD_{i,t+1} + 1}{PD_{it}} \frac{\Phi_{i,t+1}}{\Phi_{it}} \tag{78}$$

Both the price dividend ratio of each firm and the return on each asset are now approximated by an $n^{th}$-order polynomial of the state variables in the same way as in equations 75 and 76. So for example the Taylor approximation of the return $R_t$, which I denote by $R(x_1, x_2, \sigma)$, can be written as:

$$\begin{aligned} R(x_1,x_2,\sigma) &= R(\bar{x}_1,\bar{x}_2,\bar{\sigma}) + \sum_{i=1}^{2} R_{x_i}(\bar{x}_1,\bar{x}_2,\bar{\sigma})(x_i-\bar{x}_i) + R_\sigma(\bar{x}_1,\bar{x}_2,\bar{\sigma})(\sigma-\bar{\sigma}) \\ &+ \sum_{i=1}^{2} R_{x_i x_i}(\bar{x}_1,\bar{x}_2,\bar{\sigma})(x_i-\bar{x}_i)^2 + R_{x_1 x_2}(\bar{x}_1,\bar{x}_2,\bar{\sigma})(x_1-\bar{x}_1)(x_2-\bar{x}_2) \\ &+ \sum_{i=1}^{2} R_{x_i\sigma}(\bar{x}_1,\bar{x}_2,\bar{\sigma})(x_i-\bar{x}_i)(\sigma-\bar{\sigma}) + R_{\sigma\sigma}(\bar{x}_1,\bar{x}_2,\bar{\sigma})(\sigma-\bar{\sigma})^2 + ... \end{aligned} \tag{79}$$

As before, $R_{\sigma\sigma}(\bar{x}_1,\bar{x}_2,\bar{\sigma})(\sigma-\bar{\sigma})^2$ measures the influence of the uncertainty in the model on the return, whose expectation equals the risk premium. From equation 79 we can see that a first order approximation of the policy function will not generate a risk premium at all, which is also referred to as the certainty equivalent principle. A second order approximation will generate a constant risk premium equal to the expectation of $R_{\sigma\sigma}(\bar{x}_1,\bar{x}_2,\bar{\sigma})(\sigma-\bar{\sigma})^2$. To obtain a risk premium that varies linearly with the state variables, we need terms of the form:

$$R_{\sigma\sigma x_i}(\bar{x}_1,\bar{x}_2,\bar{\sigma})(\sigma-\bar{\sigma})^2(x_i-\bar{x}_i) \tag{80}$$

To obtain such terms we need a third-order approximation of the policy function. In general, for an $n^{th}$-order approximation of the risk premium dynamics we need an approximation of the policy functions of order $n+2$. If we are interested in the effect of the interaction of exogenous and endogenous state variables on the risk premia of the assets, we need at least a 4th order approximation of the policy function.

What remains to be discussed is how to solve for the $n^{th}$ order derivatives of the functions $g$ and $h$ evaluated at the point $(\bar{x},\bar{\sigma})$. To identify these derivatives, substitute the proposed solution given by equations 75 and 76. into equation 68. and define:

$$F(x,\sigma) \equiv E_t f\left(g\left(h(x,\sigma)+\eta\sigma\varepsilon'\right), g(x,\sigma), h(x,\sigma)+\eta\sigma\varepsilon', x_t\right) = 0 \tag{81}$$

Here I drop time subscripts and use a prime to indicate variables dated in period $t+1$. Because $F(x,\sigma)$ must be equal to zero for any possible values of $x$ and $\sigma$, it must be the case that the derivatives of any order of $F$ must also be equal to zero:

$$F_{x^k\sigma^j}(x,\sigma) = 0 \quad \forall x,\sigma,j,k,$$

where $F_{x^k\sigma^j}(x,\sigma)$ denotes the derivative of $F$ with respect to $x$ taken $k$ times and with respect to $\sigma$ taken $j$ times. Solving this exactly identified system of equations results in the values for each of the $n^{th}$ order derivatives.

# Appendix B: Normalization

To find a stationary equilibrium, I divide all variables by the deterministic trend $G_{t-1}$:

$$\{c_{it}, \lambda_t, x_t, s_{it}, w_t, \varphi_{it}\} \equiv \left\{ \frac{C_{it}}{G_{t-1}}, \frac{\Lambda_t G_{t-1}^{\gamma}}{\beta^t}, \frac{X_t}{G_{t-1}}, \frac{S_{it}}{G_{t-1}}, \frac{W_t}{G_{t-1}}, \frac{\Phi_{it}}{G_{t-1}} \right\}$$

Note that:

$$\lambda_t = \beta^{-t} \Lambda_t \left(G_{t-1}\right)^{\gamma} = X_t^{-\gamma} \left(G_{t-1}\right)^{\gamma} = x_t^{-\gamma}$$

We then find the following normalized first order conditions of the firms:

$$\begin{aligned}
[C_{it}] \quad &: \quad p_{it} - \kappa_{it} - \nu_{it} + (1-\rho)\,\zeta_{it} = 0 \\
[S_{it}] \quad &: \quad E_t \left[ M_{t,t+1} \left( \theta \nu_{it+1} + \rho_i \zeta_{it+1} \right) \right] = \zeta_{it} \\
[p_{it}] \quad &: \quad c_{it} - \eta \nu_{it} p_{it}^{-\eta-1} x_t = 0. \\
[h_{it}] \quad &: \quad E_t \left[ M_{t,t+1} \left( b \frac{h_{it+1}}{h_{it}^2} \left( \frac{h_{it+1}}{h_{it}} - 1 \right) \right) \right] - \frac{b}{h_{it-1}} \left( \frac{h_{it}}{h_{it-1}} - 1 \right) - w + \kappa_{it} e^{\bar{g}} Z_{it}
\end{aligned}$$

The normalized demand curve is then given by:

$$c_{it} = p_{it}^{-\eta} x_t + \theta s_{it},$$

where habit evolves according to:

$$s_{it+1} e^{\bar{g}} = \rho s_{it} + (1-\rho)\, c_{it} + \varepsilon_{it+1}.$$

The normalized first order conditions for the representative consumer are given by:

$$\begin{aligned}
\mu' \frac{(1-h_t)^{-\chi}}{x^{-\sigma}} &= w_t \\
\lambda_t &= x_t^{-\gamma} \\
M_{t,t+1} &= \beta e^{-\gamma \bar{g}} \frac{\lambda_{t+1}}{\lambda_t}
\end{aligned}$$

I then solve this set of normalized first order conditions using perturbation methods as described in Appendix A.

| Model | Deep habits | Data |
|---|---|---|
| **St. Dev. Real Vars** | | |
| $\sigma(\Delta Y)$ (percent quarterly) | 0.72 | 1.00 |
| $\sigma(\Delta C)$ | 0.72 | 0.51 |
| $\sigma(\Delta I)$ | - | 2.55 |
| **Means Financial Vars (percent annual)** | | |
| $R_{ft}$ | 0.95 | 0.80 |
| $E[R_{t+1} - R_{ft}]$ | 5.34 | 6.18 |
| **St. Dev. Financial Vars (percent annual)** | | |
| $\sigma(R_{ft})$ | 11.72 | 5.67 |
| $\sigma(R_t)$ | 19.43 | 16.54 |
| $\sigma(\Delta\Phi_t)$ Dividends | 39.80 | 14.13 |
| $\sigma(\Delta\Phi_t)$ Net Payout | 39.80 | 37.80 |
| **Correlations (quarterly)** | | |
| $\rho(E_t(R_{1t+1} - R_{2t+1}), p_{1t} - p_{2t})$ | -0.92 | - |
| $\rho(SR_{1t} - SR_{2t}, p_{1t} - p_{2t})$ | -0.82 | - |
| $\rho(SR_{1t} - SR_{2t}, E_t(R_{1t+1} - R_{2t+1}))$ | 0.98 | - |

**Table 1: Productivity shocks**
The table reports the aggregate statistics of the two sector full-fledged deep habits model with productivity shocks. The volatility of the productivity shocks is calibrated such that aggregate output growth has a volatility of 0.72 percent. Aggregate output (Y), aggregate consumption (C) and aggregate dividends ($\Phi$) are equal to the sum of output, consumption and dividends of each of the two sectors. Note that the unconditional risk premium on the market $E[R_{t+1} - R_{ft}]$ is equal to the risk premium on each firm's equity given that, apart from the realizations of the productivity shocks, the model is symmetric. The bottom panel reports the unconditional correlations between the difference in the conditional risk premia of the two sectors with the product price difference and the consumption surplus ratio difference.

| Model | Deep habits | Data |
|---|---|---|
| **St. Dev. Real Vars** | | |
| $\sigma(\Delta Y)$ (percent quarterly) | 0.07 | 1.00 |
| $\sigma(\Delta C)$ | 0.07 | 0.51 |
| $\sigma(\Delta I)$ | - | 2.55 |
| **Means Financial Vars (percent annual)** | | |
| $R_{ft}$ | 1.23 | 0.80 |
| $E[R_{t+1} - R_{ft}]$ | 6.34 | 6.18 |
| **St. Dev. Financial Vars (percent annual)** | | |
| $\sigma(R_{ft})$ | 15.72 | 5.67 |
| $\sigma(R_t)$ | 22.43 | 16.54 |
| $\sigma(\Delta\Phi_t)$ Dividends | 42.80 | 14.13 |
| $\sigma(\Delta\Phi_t)$ Net Payout | 42.80 | 37.80 |
| **Correlations (quarterly)** | | |
| $\rho(E_t(R_{1t+1} - R_{2t+1}), p_{1t} - p_{2t})$ | -0.20 | - |
| $\rho(SR_{1t} - SR_{2t}, p_{1t} - p_{2t})$ | -0.92 | - |
| $\rho(SR_{1t} - SR_{2t}, E_t(R_{1t+1} - R_{2t+1}))$ | 0.34 | - |
| $\rho(S_{1t} - S_{2t}, E_t(R_{1t+1} - R_{2t+1}))$ | -0.94 | - |

**Table 2: Preference shocks**
The table reports the aggregate statistics of the two sector full-fledged deep habits model with productivity shocks. The quarterly volatility of the preference shocks is calibrated to 0.3 percent. Aggregate output (Y), aggregate consumption (C) and aggregate dividends ($\Phi$) are equal to the sum of output, consumption and dividends of each of the two sectors. Note that the unconditional risk premium on the market $E[R_{t+1} - R_{ft}]$ is equal to the risk premium on each firm's equity given that, apart from the realizations of the productivity shocks, the model is symmetric. The bottom panel reports the unconditional correlations between the difference in the conditional risk premia of the two sectors with the product price difference and the consumption surplus ratio difference.

| Model | Deep habits ($\rho_z = 0.99$) | Deep habits ($\rho_z = 1$) | Jermann ($\rho_z = 0.99$) | Jermann ($\rho_z = 1$) | Data |
|---|---|---|---|---|---|
| **St. Dev. Real Vars** | | | | | |
| $\sigma(\Delta Y)$ (percent quarterly) | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| $\sigma(\Delta C)/\sigma(\Delta Y)$ | 0.53 | 0.59 | 0.49 | 0.55 | 0.51 |
| $\sigma(\Delta I)/\sigma(\Delta Y)$ | 2.71 | 2.55 | 2.64 | 2.57 | 2.65 |
| $\sigma(E_t[\Delta C])$ (percent quarterly) | 0.13 | 0.15 | 0.34 | 0.16 | - |
| **Autocorrelation Real Vars** | | | | | |
| $\rho(\Delta C_t, \Delta C_{t-1})$ | 0.12 | 0.13 | 0.59 | 0.31 | 0.30 |
| $\rho(E_t[\Delta C_{t+1}, E_{t-1}(\Delta C_t)])$ | 0.94 | 0.93 | 0.75 | 0.58 | - |
| **Means Financial Vars (percent annual)** | | | | | |
| $R_{ft}$ | 0.95 | 0.50 | 0.82 | 0.03 | 0.80 |
| $E_t[R_{t+1} - R_{ft}]$ | 6.59 | 6.09 | 6.18 | 6.39 | 6.18 |
| **St. Dev. Financial Vars (percent annual)** | | | | | |
| $\sigma(R_{ft})$ | 7.92 | 6.81 | 11.46 | 12.00 | 5.67 |
| $\sigma(R_t)$ | 20.00 | 19.70 | 19.86 | 19.00 | 16.54 |
| $\sigma(\Delta\Phi_t)$ (Dividends) | 39.80 | 29.50 | 8.44 | 8.00 | 13.6 |
| $\sigma(\Delta\Phi_t)$ (Net Payout) | 39.80 | 29.50 | 8.44 | 8.00 | 38.3 |
| **St. Dev. Financial Vars (percent quarterly)** | | | | | |
| $\sigma(E_t(R_{t+1} - R_{ft}))$ | 0.10 | 0.11 | 0.09 | 0.12 | - |
| $\sigma(E_t[\Delta\Phi_{t+1}])$ | 3.16 | 3.20 | 2.76 | 3.65 | - |
| **Autocorrelation Financial Vars (quarterly)** | | | | | |
| $\rho(E_t[\Delta\Phi_{t+1}], E_{t-1}[\Delta\Phi_t])$ | 0.95 | 0.93 | 0.58 | 0.19 | - |
| $\rho(E_t[R_{t+1} - R_{ft}], E_{t-1}[R_t - R_{ft-1}])$ | 0.92 | 0.90 | 0.77 | 0.24 | - |
| **Parameters** | | | | | |
| $\beta$ | 1.005 | 1.005 | 1.01 | 1.01 | - |
| g | 0.004 | 0.004 | 0.005 | 0.005 | - |
| $\delta$ | 0.025 | 0.025 | 0.025 | 0.025 | - |
| $\alpha$ | 0.64 | 0.64 | 0.64 | 0.64 | - |
| $\rho$ | 0.85 | 0.85 | 0.00 | 0.00 | - |
| $\rho_z$ | 0.99 | 1 | 0.99 | 1 | - |
| $\theta$ | 0.86 | 0.86 | 0.82 | 0.82 | - |
| $\sigma$ | 5 | 5 | 5 | 5 | - |
| $\tau$ | 0.21 | 0.21 | 0.23 | 0.23 | - |

**Table 3: Comparing the deep habits model to the standard one sector habit model with production.**
Comparison of the symmetric deep habits model with the model employed in Jermann (1998). The top panel summarizes the moments of the real variables in the model, including output, consumption and investment. The second panel summarizes the moments of the financial variables, including dividends, the riskfree rate and the return on equity. The third panel summarizes the parameters used to simulate from each of the models

| | Constant | Mktrf | hml | smb | umd |
|---|---|---|---|---|---|
| Quintile 1 - Rf | 0.0037 | 1.0374** | 0.0343 | 0.0904 | -0.0040 |
| | (0.0023) | (0.0567) | (0.0857) | (0.0697) | (0.0486) |
| Quintile 2 - Rf | 0.0017 | 1.1099** | -0.3958** | -0.0134 | -0.1305** |
| | (0.0019) | (0.0472) | (0.0713) | (0.0580) | (0.0404) |
| Quintile 3 - Rf | 0.0003 | 0.9510** | -0.1606** | 0.0361 | -0.1440** |
| | (0.0017) | (0.0411) | (0.0622) | (0.0506) | (0.0353) |
| Quintile 4 - Rf | -0.0029 | 0.8884** | 0.0445 | -0.0447 | 0.0300 |
| | (0.0020) | (0.0491) | (0.0742) | (0.0603) | (0.0421) |
| Quintile 5 - Rf | -0.0021 | 0.9588** | 0.2821** | -0.0766 | 0.0343 |
| | (0.0017) | (0.0423) | (0.0640) | (0.0520) | (0.0363) |
| DMI (Q5-Q1) | 0.0058** | 0.0786 | -0.2478** | 0.1671 | -0.0383 |
| | (0.0024) | (0.0580) | (0.1157) | (0.1309) | (0.0794) |
| Quintile 1 - Rf | 0.0038 | 1.0371** | - | - | - |
| | (0.0022) | (0.0480) | - | - | - |
| Quintile 2 - Rf | -0.0017 | 1.2667** | - | - | - |
| | (0.0020) | (0.0433) | - | - | - |
| Quintile 3 - Rf | -0.0020 | 1.0297** | - | - | - |
| | (0.0017) | (0.0365) | - | - | - |
| Quintile 4 - Rf | -0.0023 | 0.8631** | - | - | - |
| | (0.0019) | (0.0415) | - | - | - |
| Quintile 5 - Rf | -0.0002 | 0.8420** | - | - | - |
| | (0.0018) | (0.0382) | - | - | - |
| DMI (Q5-Q1) | 0.0040* | 0.1951** | - | - | - |
| | (0.0023) | (0.0825) | - | - | - |
| Quintile 1 - Rf | 0.0110* | - | - | - | - |
| | (0.0038) | - | - | - | - |
| Quintile 2 - Rf | 0.0071 | - | - | - | - |
| | (0.0043) | - | - | - | - |
| Quintile 3 - Rf | 0.0052 | - | - | - | - |
| | (0.0035) | - | - | - | - |
| Quintile 4 - Rf | 0.0037 | - | - | - | - |
| | (0.0032) | - | - | - | - |
| Quintile 5 - Rf | 0.0056* | - | - | - | - |
| | (0.0031) | - | - | - | - |
| DMI (Q5-Q1) | 0.0054* | - | - | - | - |
| | (0.0029) | - | - | - | - |

**Table 4: Quintile portfolios sorted on the lagged PPI change**
Return regression of the quintile portfolios sorted on the percentage Producer Price change in the previous month. The first panel reports the time series regression of the excess portfolio returns of each quintile on the four factors: the market return minus the riskfree rate (Mktrf), the book-to-market factor (hml), the size factor (smb) and momentum (umd). The panel reports both the regression for each quintile as well as the difference between quintile 5 (Deflationary) minus quintile 1 (Inflationary). The second panel reports CAPM regression and the third panel reports the average return in each quintile. Newey-West standard errors are reported in brackets below. The symbols (*) and (**) indicate significance at the 10 and 5 percent level, respectively.

| | Constant | Mktrf | hml | smb | umd |
|---|---|---|---|---|---|
| Quintile 1 - Rf | 0.0047* | 1.015** | 0.1246 | 0.1329* | 0.0709 |
| | (0.0026) | (0.0638) | (0.0967) | (0.0782) | (0.0546) |
| Quintile 2 - Rf | 0.0018 | 0.9765** | -0.3726** | 0.0024 | -0.0905* |
| | (0.0025) | (0.0598) | (0.0907) | (0.0734) | (0.0512) |
| Quintile 3 - Rf | -0.0014 | 0.9664** | -0.1097 | 0.0692 | -0.0872* |
| | (0.0025) | (0.0597) | (0.0906) | (0.0733) | (0.0512) |
| Quintile 4 - Rf | -0.0006 | 0.7991** | 0.1068 | 0.0207 | -0.0825* |
| | (0.0023) | (0.0565) | (0.0856) | (0.0693) | (0.0484) |
| Quintile 5 - Rf | -0.0008 | 0.8433** | 0.2622** | -0.0394 | 0.0016 |
| | (0.0021) | (0.0512) | (0.0777) | (0.0628) | (0.0439) |
| DMI (Q1-Q5) | 0.0055** | 0.1481** | -0.1376 | 0.1722** | 0.0693 |
| | (0.0027) | (0.0660) | (0.1001) | (0.0810) | (0.0565) |
| Quintile 1 - Rf | 0.0059** | 0.9561** | - | - | - |
| | (0.0025) | (0.0543) | - | - | - |
| Quintile 2 - Rf | -0.0009 | 1.1228** | - | - | - |
| | (0.0025) | (0.0528) | - | - | - |
| Quintile 3 - Rf | -0.0028 | 1.0253** | - | - | - |
| | (0.0024) | (0.0510) | - | - | - |
| Quintile 4 - Rf | -0.0007 | 0.7718** | - | - | - |
| | (0.0023) | (0.0481) | - | - | - |
| Quintile 5 - Rf | 0.0006** | 0.7421** | - | - | - |
| | (0.0021) | (0.0448) | - | - | - |
| DMI (Q1-Q5) | 0.0053** | 0.2140** | - | - | - |
| | (0.0027) | (0.0573) | - | - | - |
| Quintile 1 - Rf | 0.0126** | - | - | - | - |
| | (0.0039) | - | - | - | - |
| Quintile 2 - Rf | 0.0069 | - | - | - | - |
| | (0.0043) | - | - | - | - |
| Quintile 3 - Rf | 0.0044 | - | - | - | - |
| | (0.0040) | - | - | - | - |
| Quintile 4 - Rf | 0.0047 | - | - | - | - |
| | (0.0033) | - | - | - | - |
| Quintile 5 - Rf | 0.0058* | - | - | - | - |
| | (0.0031) | - | - | - | - |
| DMI (Q1-Q5) | 0.0068** | - | - | - | - |
| | (0.0027) | - | - | - | - |

**Table 5: Quintile portfolios sorted on the monthly PPI change between t-5 and t-2.** Return regressions of the quintile portfolios sorted on the percentage Producer Price change over the 4-month period starting at t-5 and ending at t-2. The first panel reports the time series regression of the excess portfolio returns of each quintile on the four factors: the market return minus the riskfree rate (Mktrf), the book-to-market factor (hml), the size factor (smb) and momentum (umd). The panel reports both the regression for each quintile as well as the difference between quintile 5 (Deflationary) minus quintile 1 (Inflationary). The second panel reports CAPM regressions and the third panel reports the average return in each quintile. Newey-West standard errors are reported in brackets below. The symbols (*) and (**) indicate significance at the 10 and 5 percent level.

| | Cofficient | Std. Error | t-statistic | 95% Conf. Interval | |
|---|---|---|---|---|---|
| cons | 0.0058 | 0.0027 | 2.1843 | 0.0006 | 0.0110 |
| mktrf | 0.0787 | 0.0588 | 1.3393 | -0.0371 | 0.1945 |
| smb | 0.1674 | 0.1297 | 1.2902 | -0.0883 | 0.4231 |
| hml | -0.2471 | 0.1132 | -2.1840 | -0.4701 | -0.0241 |
| umd | -0.0382 | 0.0814 | -0.4697 | -0.1986 | 0.1222 |
| herfspread | -0.0203 | 0.2629 | -0.0771 | -0.5384 | 0.4979 |

**Table 6: Robustness with respect to industry competition**
To assess the robustness of my PPI portfolio results to the Herfindahl Hirschmann Index (HHI) portfolios as in Hou and Robinson (2006), I include their return spread (herfspread) as an additional factor in the regression analysis. The table reports a time series regression with the DMI portfolio returns on the left hand side and the 4 factors augmented with the HHI factor on the right hand side.

| | Quintile 1 | Quintile 2 | Quintile 3 | Quintile 4 | Quintile 5 |
|---|---|---|---|---|---|
| Quintile 1 | 0.694 | 0.177 | 0.044 | 0.031 | 0.054 |
| Quintile 2 | 0.166 | 0.542 | 0.214 | 0.055 | 0.023 |
| Quintile 3 | 0.042 | 0.212 | 0.500 | 0.190 | 0.057 |
| Quintile 4 | 0.027 | 0.063 | 0.210 | 0.535 | 0.164 |
| Quintile 5 | 0.058 | 0.030 | 0.034 | 0.164 | 0.715 |

**Table 7: Markov Probabilities**
The matrix reports the Markov probabilities of firms changing from one quintile to another over a one quarter horizon. The $(i, j)$ element of the matrix indicates the probability of going to quintile j, while currently residing in quintile i.

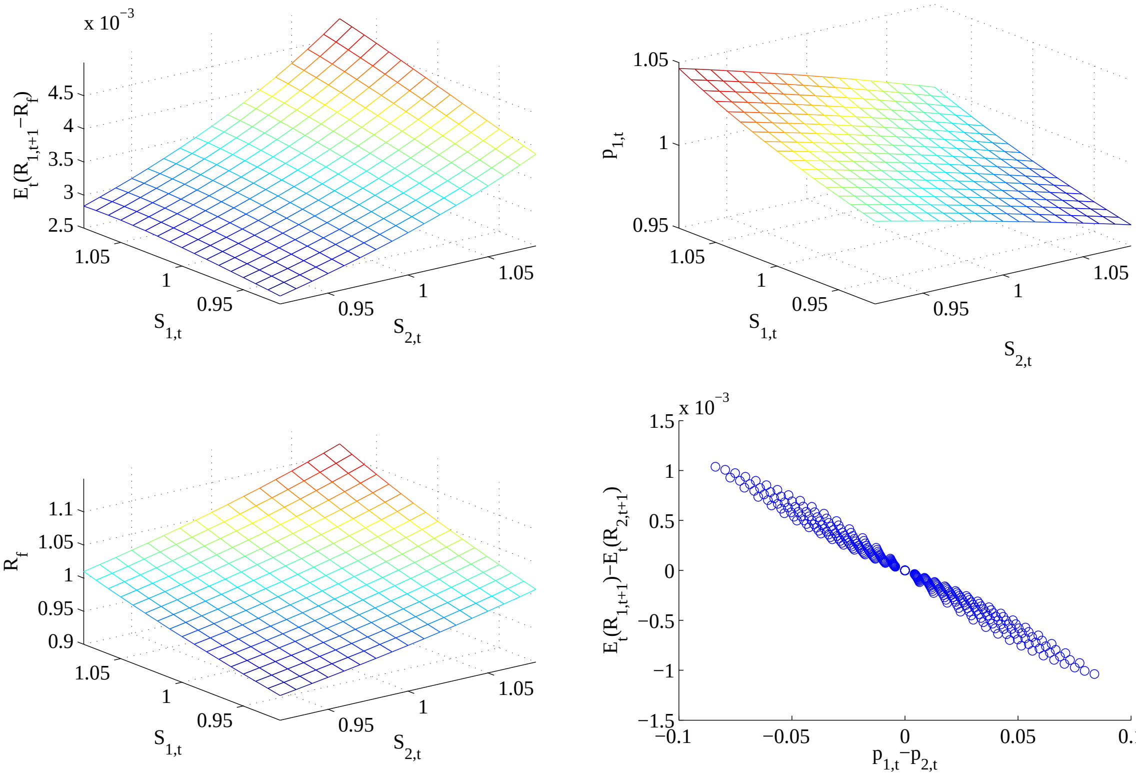


**Figure 1: Productivity shock**

The graph contains four subplots. The top left plot shows the risk premium on the equity of sector 1 as a function of the habit level of sector 1 and sector 2. The top right graph plots the product price charged by sector 1 as a function of the habit levels in sector 1 and sector 2. The bottom left plot depicts the riskfree interest rate as a function of the habit levels in sector 1 and sector 2. The bottom right graph plots the expected return difference between sector 1 and sector 2 against the product price difference between both sectors. The aggregate product price level, which is a weighted average of the prices in each of the two sectors, is normalized to 1.

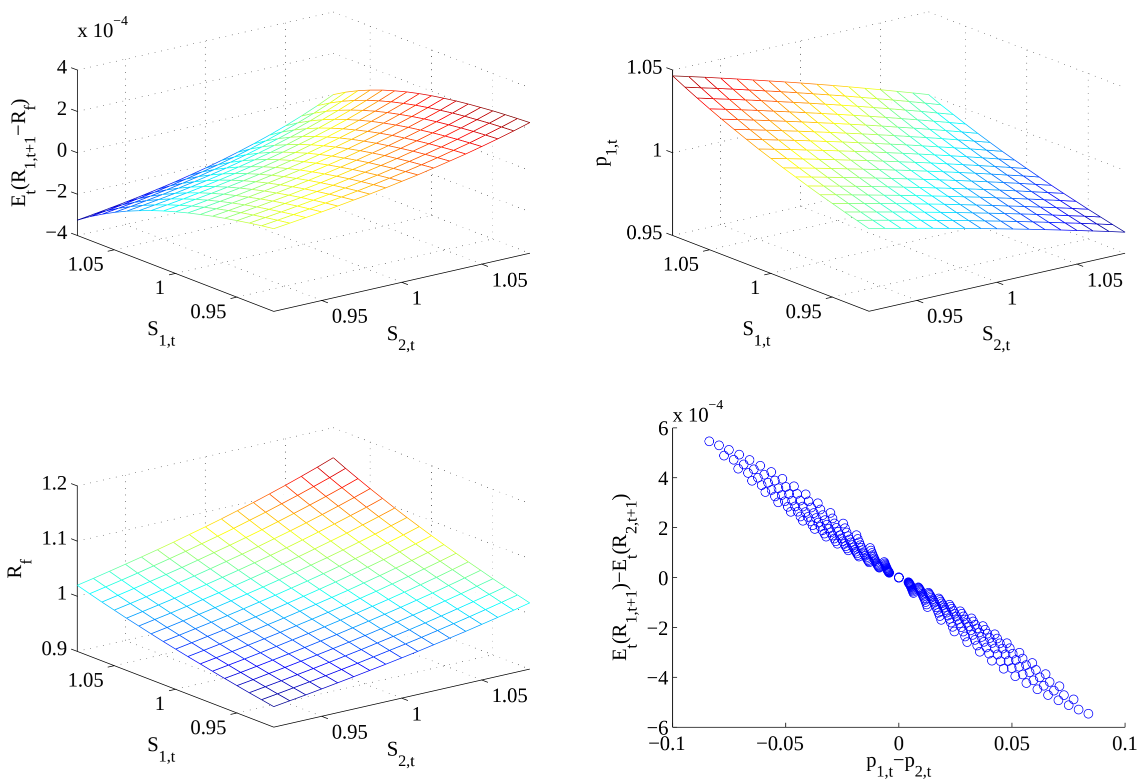


**Figure 2: Preference shock**

The graph contains four subplots. The top left plot shows the risk premium on the equity of sector 1 as a function of the habit level of sector 1 and sector 2. The graph shows that as the habit level of sector 1 increases relative to that of sector 2, the risk premium on the stock of sector 1 decreases. The top right graph plots the product price charged by sector 1 as a function of the habit levels in sector 1 and sector 2. The bottom left plot depicts the riskfree interest rate as a function of the habit levels in sector 1 and sector 2. The bottom right graph plots the expected return difference between sector 1 and sector 2 against the product price difference in sector 1 and sector 2. The aggregate price level, which is a weighted average of the prices in each of the two sectors, is normalized to 1.

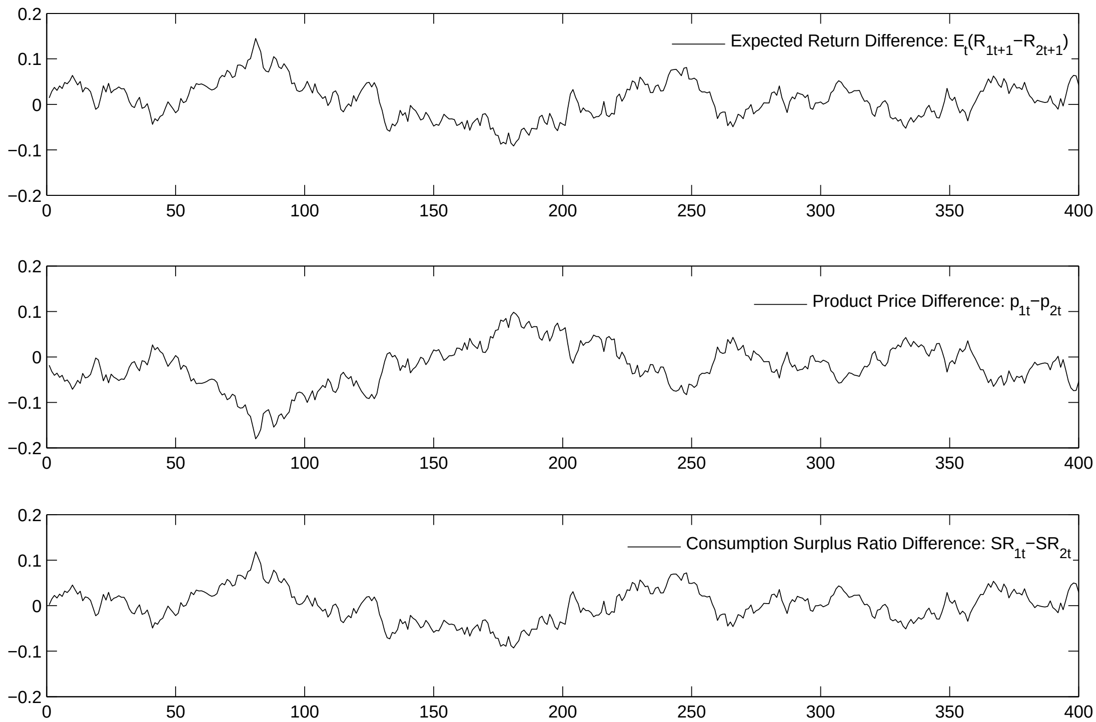


**Figure 3: Productivity shocks**
The graph contains three subplots. The top graph plots a simulated sample path of 400 quarters of the difference in quarterly expected returns between the two sectors, $E_t(R_{1t+1} - R_{2t+1})$ as a function of time in percent. For example, a value of 0.1 implies that the quarterly difference in expected returns equals 0.1%. The second graph plots the corresponding product price difference between the two sectors, given by $p_{1t} - p_{2t}$. Note that the aggregate price index, which is a weighted average of the two prices, is normalized to 1. As such, if the difference equals 0.10, this implies that sector 1's price is roughly 5 percent below the aggregate index and sector 2's price is 5 percent above. Finally, the third plot contains the difference in consumption surplus ratios between the two sectors, $SR_{1t} - SR_{2t}$, where $SR_{it} = (C_{it} - \theta S_{it}) / C_{it}$. To obtain a benchmark for the size of this variation in the consumption surplus ratios, note that the steady state value of each sector's consumption surplus ratio equals 0.19.