Price Search, Consumption Inequality, and Expenditure Inequality over the Life Cycle

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Abstract

In this paper, we incorporate a price search decision into a life cycle model and differentiate consumption from expenditure. Consumers with low wealth and bad income shocks search more for cheaper prices and pay less, which makes their consumption higher than in a model without search option. A plausibly calibrated version of our model predicts that the cross-sectional variance of consumption is about 17% smaller than the cross-sectional variance of expenditure throughout the life cycle. Price search has an alternative productive activity role for lower-income people to increase their consumption levels. We discuss other implications of price search over the life cycle as well.

Keywords: Consumption inequality, price search, incomplete markets, life cycle models, partial insurance.

J.E.L. Classification: D10, D91, E21.

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1 Introduction

In this paper, we study the role of price search in the age-inequality profiles of consumption and expenditure. We incorporate a price search decision into a quantitative life-cycle model and differentiate consumption from expenditure. A plausibly calibrated version of the model predicts a significant difference (about 17%) in age-inequality profiles of consumption and expenditure throughout the life cycle.

Our model economy features an incomplete markets framework. In general, the models with incomplete markets ignore the partial insurance role of price search and dispersion in prices.[1] However the empirical literature has documented significant dispersion in prices paid for identical goods.[2] For instance, Aguiar and Hurst (2007) document that, in the U.S. data, richer people pay higher prices for identical goods. Also, they report that prices paid for identical goods change over the life cycle, which is a result of a change in price search due to a change in the cost of time. Using the U.S. data, Sorensen (2000) documents dispersion in prices paid for the same medicine. Dahlbay and West (1986) report price dispersion in automobile insurance companies in Canadian data. Pratt et al. (1979) document price dispersion in several categories of goods. Baye et al. (2004) document dispersion in prices for identical goods posted in the internet. These documented facts

[1]See Heathcote et al. (2009)for a detailed survey on the partial insurance mechanisms in incomplete markets.

[2]Baye et al. (2006) provide a detailed survey on the dispersion in prices paid for identical goods.

motivate a quantitative study on the role of price search over the life cycle. Motivated by the reported facts on the dispersion in prices in the empirical literature, this paper focuses on the partial insurance role of price search in the age-inequality profiles of consumption and expenditure. We believe that filling this gap in the literature is important to understand consumption inequality over the life cycle.

We solve a life-cycle model, in which we allow agents to search for cheaper prices in addition to the consumption/saving decision. As a result of idiosyncratic income shocks, people are ex-post heterogeneous in terms of their income realizations and wealth accumulations. If agents search more for cheaper prices, they pay less and consume more; however, they enjoy less leisure due to time constraints. Optimality implies that the marginal return to and the marginal cost of price search are equalized. The marginal return to price search comes from additional consumption, and it is smaller for individuals who already have high consumption. That implies that agents with low wealth and bad income shocks search more and pay less, which we interpret as partial insurance through price search. Our results show that the cross-sectional variance of consumption is roughly 17% smaller than the cross-sectional variance of expenditure throughout the life cycle.

Among many other studies in the quantitative life-cycle literature, this paper is closely related to Guvenen (2007), Storesletten et al. (2004), and Karahan and Ozkan (2010). Those papers study the role of income processes on the age-inequality profile of consumption. Kaplan (2010) extends a similar model with unemployment risk to better match age-inequality profiles of consumption and labor allocations over the life cycle. There is a common implicit assumption in those models that says the price of a consumption good is unique, and therefore consumption is equal to expenditure. However, as we mentioned above, there is a large empirical literature that rejects this assumption. Our paper differs from the standard life-cycle studies in the sense that it differentiates consumption from expenditure. We show that this distinction plays a quantitatively significant role in the age-inequality of consumption.

The paper continues as follows. In section 2, we document some important features of the data. We explain the model in section 3 and give the details of the calibration in section 4. In section 5, we report the results, and in section 6 we conclude.

2 Model

We extend a standard incomplete markets model with a price search technology, which allows individuals to search for cheaper prices and partially insure against bad income shocks. We do it in a life-cycle framework to study the age-inequality profiles of consumption and expenditure. The environment is incomplete due to uninsurable idiosyncratic income shocks. The population consists of a continuum of individuals who work for T periods and afterwards enjoy retirement until period T^*. Each component of the model is explained in detail below.

2.1 Households

At each period, the individuals have two decisions: one is the consumption/saving decision, and the other is the leisure/price search decision. The individual can enjoy more consumption by searching for cheaper prices; however, he/she enjoys less leisure in that case. The individuals maximize life time expected value of discounted utility:

$$E \sum_{t=0}^{T^*} \beta^t u(c_t^i, l_t^i) \tag{1}$$

where, $u(\cdot)$ is period utility, β is the time discount factor, c_t^i and l_t^i are consumption and leisure of individual i at time t.

Individual i has the following time constraint at period t:

$$s_t^i + l_t^i + n_t^i = 1 \tag{2}$$

where, s_t^i and l_t^i are the time spent on price search and leisure for individual i at period t. The variable n_t^i denotes labor supply. It is a constant value, $\bar{n}$, during employment, and 0 after retirement.

There is an incomplete asset market, where individuals can borrow or save through a risk-free interest-bearing asset. Individual i faces the following budget constraint at time t:

$$p(s_t^i)c_t^i + a_{t+1}^i = y_t^i + (1+r)a_t^i \tag{3}$$

where, $p(\cdot)$ is the price of a consumption good that depends on the individual search time. Consumption and saving at the current period are denoted by c_t^i and a_{t+1}^i, respectively. Current period labor income is denoted with y_t^i, and the labor income process will be explained in detail later on.

2.2 Price Search Technology

We follow Aguiar and Hurst (2007) in price function, because they estimated the parameters of this form in the U.S. data, which we will calibrate accordingly in the benchmark model. It is a log linear form:

$$\log(p) = \theta_0 + \theta \log(s)$$

where θ is the return to search on prices. In the log linear form, doubling search decreases prices by $100 * \theta$ percent. Aguiar and Hurst (2007) estimate the return to search, θ, net of how much and what type of goods purchased by the shopper. They use an AC Nielsen data set to estimate the parameters.

2.3 Earning and Pension Processes

For the earning process, we follow the literature. At each period, the individual is assumed to receive a persistent and a transitory income shock. This is a standard model for labor earnings and has been estimated in several studies.[3] The log earnings follow the following process:

$$\log(y_t^i) = \beta_0 + \beta_1 t + z_t^i + \epsilon_t^i, \quad \text{with } \epsilon_t^i \sim (0, \sigma_\epsilon^2)$$

where β_0 is a scale parameter, β_1 is return to experience, t is the years of experience , z_t^i is the persistent income shock and ϵ_t^i is the transitory income shock. The persistent income shocks follow an $AR(1)$ process:

$$z_t^i = \rho z_{t-1}^i + \nu_t^i, \quad \text{with} \quad z_0 = 0 \text{ and } \quad \nu_t^i \sim N(0, \sigma_\nu^2)$$

We discuss the calibration of the earning process parameters in section 3.

For the pension process, we follow Guvenen (2007), which mimics the U.S. Social Security system. After retirement, the pension of each agent is determined by the ratio of his income in the last working period to the average income in the last working period, $\frac{y_T}{\bar{y}_T}$. The pension function, $\Gamma, (\frac{y_T}{\bar{y}_T})$ is as follows:

$$= \gamma \times \begin{cases} 0.9\frac{y_T}{\bar{y}_T}, & \text{if } \frac{y_T}{\bar{y}_T} < 0.3 \\ 0.27 + 0.32(\frac{y_T}{\bar{y}_T} - 0.3), & \text{if } 0.3 < \frac{y_T}{\bar{y}_T} < 2 \\ 0.81 + 0.15(\frac{y_T}{\bar{y}_T} - 2), & \text{if } 2 < \frac{y_T}{\bar{y}_T} < 4.1 \\ 1.1 & \text{if } 4.1 < \frac{y_T}{\bar{y}_T}. \end{cases}$$

[3]For example: MaCurdy (1982), Storesletten (2004), Guvenen (2009).

2.4 Utility Function

We use a utility function that is quite standard in the literature and is specified as follows:

$$u(c_t, l_t) = \frac{c_t^{(1-\sigma)}}{1-\sigma} + \phi_t \log(l_t).$$

The parameter ϕ_t affects the utility enjoyed from leisure time. It could also be interpreted as the cost of the time the agent spends on price search.

2.5 Recursive Formulations

During the working periods, each individual solves the following optimization problem:

$$V_t^i(a_t^i, z_t^i, \epsilon_t^i) = \max_{c_t^i, s_t^i, a_{t+1}^i} \{u(c_t^i, l_t^i) + \delta E[V_{t+1}^i(a_{t+1}^i, z_{t+1}^i, \epsilon_{t+1}^i)|z_t^i, \epsilon_t^i]\}$$

s.t.

$$p(s_t^i)c_t^i + a_{t+1}^i = y_t^i + (1+r)a_t^i$$

$$s_t^i + l_t^i + n = 1$$

$$a_{t+1}^i \geq \Psi_t^i$$

for $t \in \{1, 2, ..., T\}$

In the above problem, c_t^i is consumption, s_t^i is the time used for price search, l_t^i is leisure, a_t^i is the asset level, a_{t+1}^i is saving, and y_t^i is earnings at period t. Agents can borrow up to a borrowing limit Ψ_t^i, which depends on his/her income realization one period before. The return on savings is denoted with r, and the time discount factor with β. We have an exogenous labor supply n, and the total available time is normalized to 1. Note that the agent can enjoy the same amount of consumption with different expenditure levels. The agent can spend more time to find cheaper prices which will allow her to enjoy a certain amount of consumption with small expenditure levels.

After retirement, individuals receive a constant pension that depends on the earnings in the last period of their working life. The individual's problem becomes deterministic due to the constant pension after retirement:

$$
\begin{aligned}
& V_t^i(a_t^i, y^i) = \max_{c_t^i, s_t^i, a_{t+1}^i} \{u(c_t^i, l_t^i) + \delta V_{t+1}^i(a_{t+1}^i, y^i)\} \\
& \text{s.t.} \\
& p(s_t^i)c_t^i + a_{t+1}^i = y^i + (1+r)a_t^i \\
& s_t^i + l_t^i = 1 \\
& a_{t+1}^i \geq \Psi_t^i \\
& y^i = \Gamma(y_T^i) \\
& \text{for } t \in \{T+1, ..., T^*\} \text{ with } V_{T^*+1}^i = 0
\end{aligned}
$$

Each individual's pension is determined by $\Gamma(\cdot)$ function. The time endowment is looser for retired people, since they do not work. Note that the constant labor supply n does not appear in their time constraint.

3 Calibration

We calibrate the model in two stages. In the first stage, we directly use the values of some parameters that are well established in the related literature. This gives us the opportunity to understand the role of price search in the standard life cycle models. We calibrate the time period yearly, and each individual starts working at age 20 and retires at 65.[4] Each individual starts working life with the asset level set at 0. We set $\delta = 0.966$ and $r = 0.04$, which are standard for yearly calibrated models. The value of the relative risk-aversion parameter, σ, is set to 2. We repeated the computation with other values, too. The parameters of income process - β_0, β_1, ρ, σ_ε^2 and σ_v^2 - are taken from Guvenen (2009), which provides one of the most recent estimations of income processes.[5]

In the second stage, we calibrate parameters θ_0, ϕ_t to match chosen moments in the data. Note that we allow ϕ to change over the life cycle. We do that in order to match the empirical life cycle profile of average prices paid. We target the log deviation of average prices from age 25 over the life cycle. We normalize the average price paid in the whole population to 1 by calibrating θ_0. For a set of parameters we compute the policy functions and simulate a population of $N = 10000$ individuals. We repeat this process until

[4] We assume high school graduates start working at age 18 and college graduates at age 22. We take the average of the two ages, because we don't distinguish between education levels in the model.

[5] Guvenen (2009) estimates two different types of income processes, namely Restricted Income Process and Heterogeneous Income Process. We pick the first one, because it matches our model's empirical target (age-inequality profile of expenditures) well.

Table 1: Benchmark Model Parameters

Parameter		Value
δ	Time discount factor	0.966
r	Interest rate	0.0416
σ	Relative risk aversion	2
T	Retirement age	65
T^*	Death age	85
θ_0	Scale parameter in prices	0.76
θ_1	Return to price search	-0.1
β_1	Return to experience	0.009
ρ	Persistence of income shocks	0.988
σ_ε^2	Variance of transitory shock	0.061
σ_v^2	Variance of noise	0.015

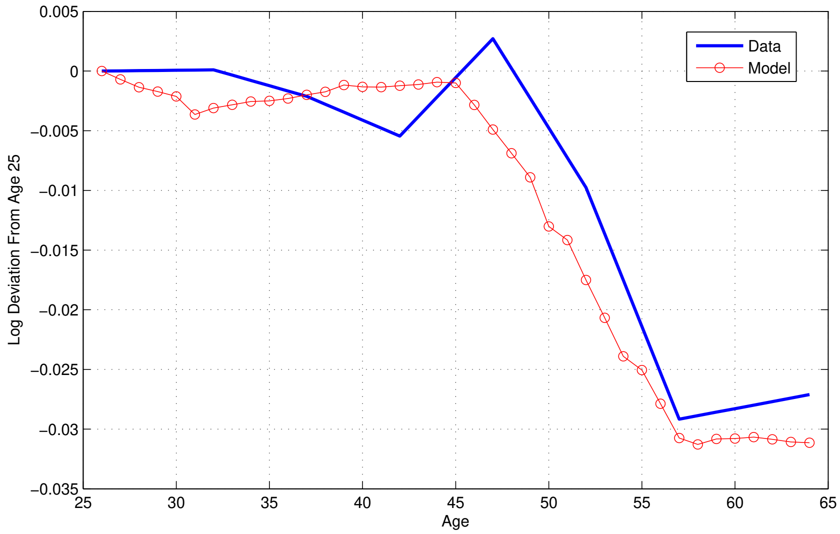
we match the chosen moments. The benchmark parameters are reported in Table 1. Figure 1 compares the model-generated log deviation of average prices to the data.

4 Results

4.1 Age-Inequality Profiles of Consumption and Expenditure

In the earlier studies, consumption was assumed to be equal to expenditure, which implied exactly equal age-inequality profiles for consumption and expenditure. In this paper, we differentiate consumption from expenditure by

Figure 1: Life-cycle profile of Prices: Model vs Data

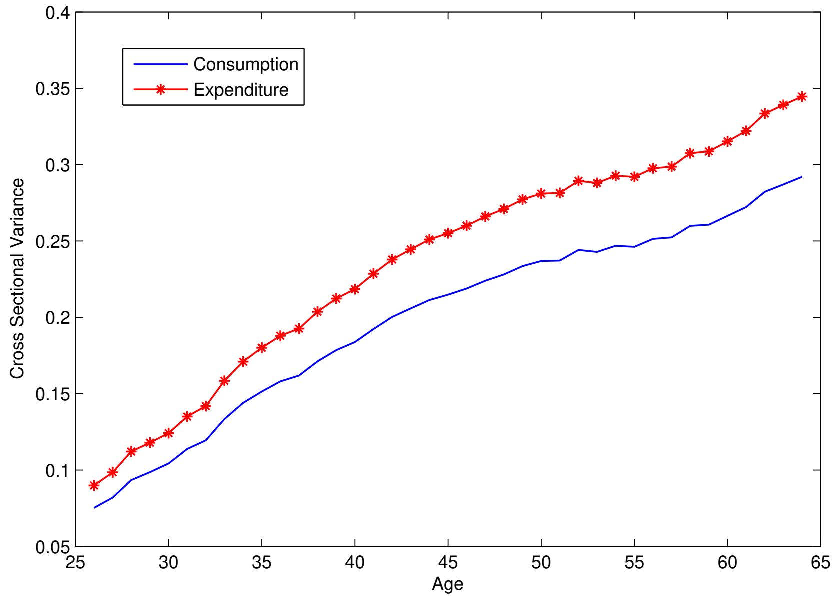


Notes: Empirical estimations for the prices paid over the life cycle are taken from Aguiar and Hurst (2007).

introducing price search into the model. Our model predicts a higher expenditure inequality than consumption inequality throughout the life cycle. The cross-sectional variance of log expenditure starts from 0.09 at age 25 and increases up to 0.35 at age 65. However, the variance of log consumption is about 0.07 at age 25 and it is about 0.27 at age 65. Figure 2 illustrates the age-inequality profiles of consumption and expenditure.

In order to understand the gap between the consumption variance and the expenditure variance throughout the life cycle, we decompose the expenditure

Figure 2: Cross Sectional Variance: Consumption vs Expenditure



variance:

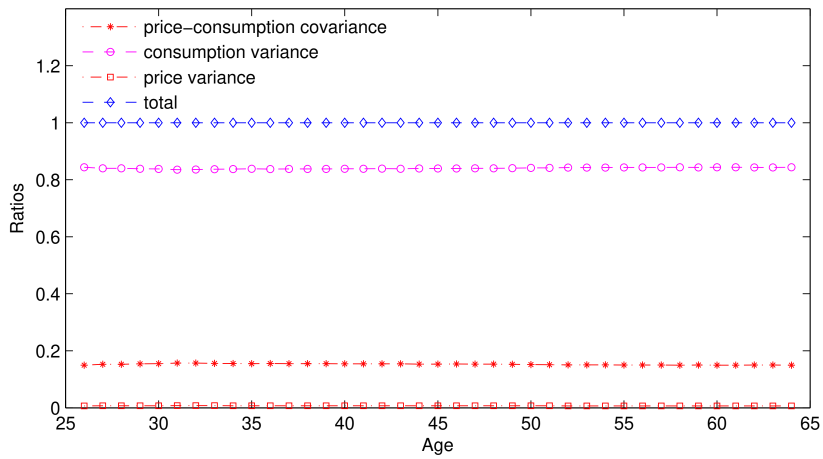
$$e = p \times c \tag{4}$$

$$var(\log e) = var(\log c) + var(\log p) + 2cov(\log c, \log p) \tag{5}$$

We calculate each component of $var(\log e)$ from the model's results. Throughout the life cycle, the model predicts that around 17% of the variance in log expenditure comes from the covariance between consumption and prices. About 82% of the expenditure variance comes from consumption variance. Figure 3 summarizes our findings.

We visit the optimality condition for price search to understand the pos-

Figure 3: Decomposition of Cross Sectional Expenditure Variance



itive covariance between consumption and prices.

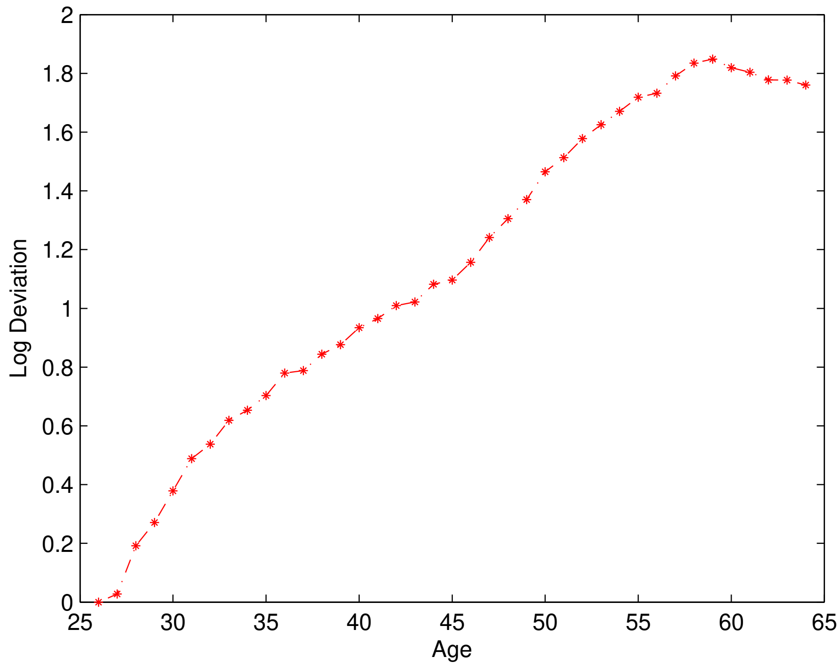
$$-\frac{u_1(c_t, l_t)}{p(s)} p'(s_t) c_t = u_2(c_t, l_t) \tag{6}$$

Plugging the utility and price functions into equation 6, we get the following equation, which gives the relationship between search and consumption:

$$\frac{c_t^{1-\sigma}}{s_t}\theta_1 = \frac{\phi_t}{1-s_t}$$

The first-order condition for price search implies a diminishing marginal return with consumption. Wealthier people who consume at high levels have less incentive to increase their consumption by sacrificing leisure. Note that the cost of price search is forgone utility from leisure. People with higher income and wealth spend more time on non-search activities instead of search-

Figure 4: Cross Sectional Variance of Log Search: Model



ing prices to increase their consumption. People with lower income and wealth spend more time on price search to increase their consumption levels. Price search has a productive activity role for lower-income and lower-wealth people to increase consumption levels.

4.2 Age-Inequality Profile of Search

Figure 4 shows the age-inequality profile of search over the life cycle. The model predicts an increasing inequality profile for search.

The underlying reason for the increasing profiles of search is the idiosyncratic income shocks over the life cycle. As people deviate from each other in terms of income and wealth over the life-cycle, they also deviate from each other in terms of time spent searching for cheaper prices, and that leads to an increasing dispersion in search and prices.

4.3 The Role of Risk Aversion

In this section, we study the effect of risk aversion on search behavior and the age-inequality profiles of consumption and expenditure. Figure 5 shows the cross-sectional variance of consumption and expenditure for risk aversion parameter values of 2 and 3. As a result of the increase in risk-aversion, the precautionary savings increase, which makes the age-inequality profile of consumption flatter compared to the lower risk-aversion case. A flatter age-inequality profile of consumption increases the gap between the age-inequality profiles of consumption and expenditure. In particular, the gap between the two series increases roughly from 17% to 30%, as illustrated in Figure 5.

On the other hand, an increase in risk aversion makes the age-inequality profile of price search flatter. This is a result of a substitution between the two insurance mechanisms. As individuals increase partial insurance through precautionary savings, they decrease the partial insurance through price search. For the same reason, the rate of increase for the average search gets smaller when we increase the risk aversion. This can be seen in the optimality condition with respect to price search in equation (6). Figures 6 and 7 illustrate the results.

Figure 5: Effect of Risk Aversion: Consumption vs Expenditure

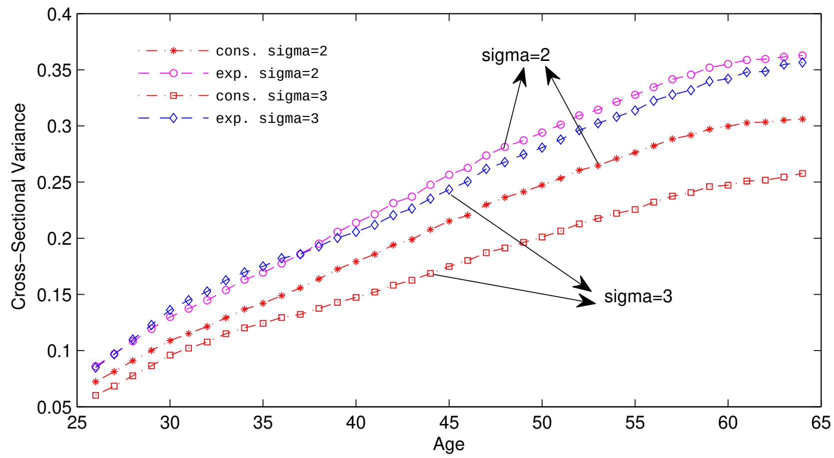


Figure 6: Effect of Risk Aversion: Average Search

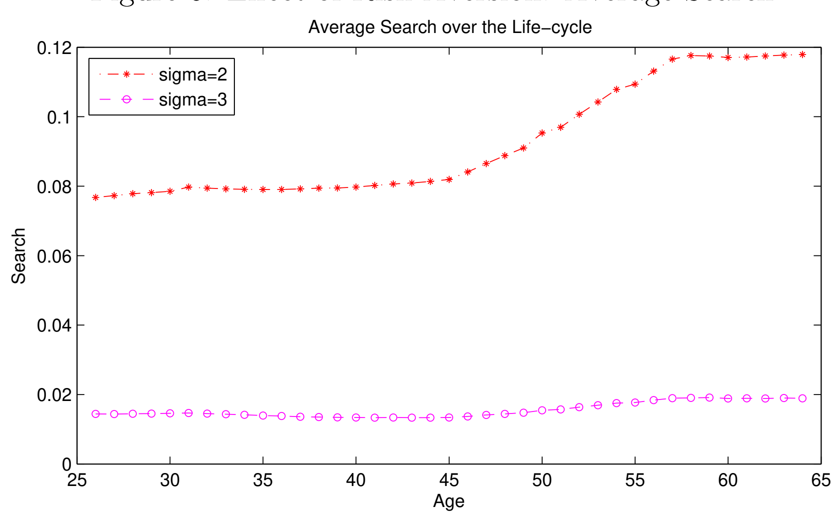
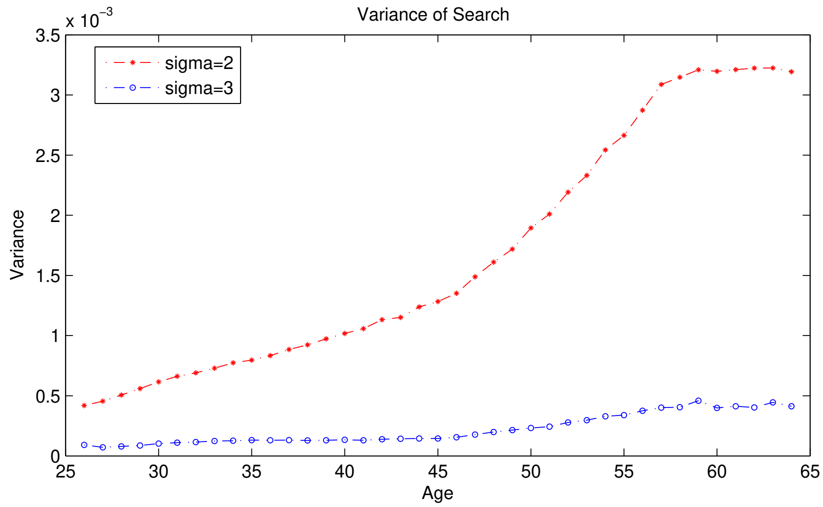


Figure 7: Effect of Risk Aversion: Variance of Search

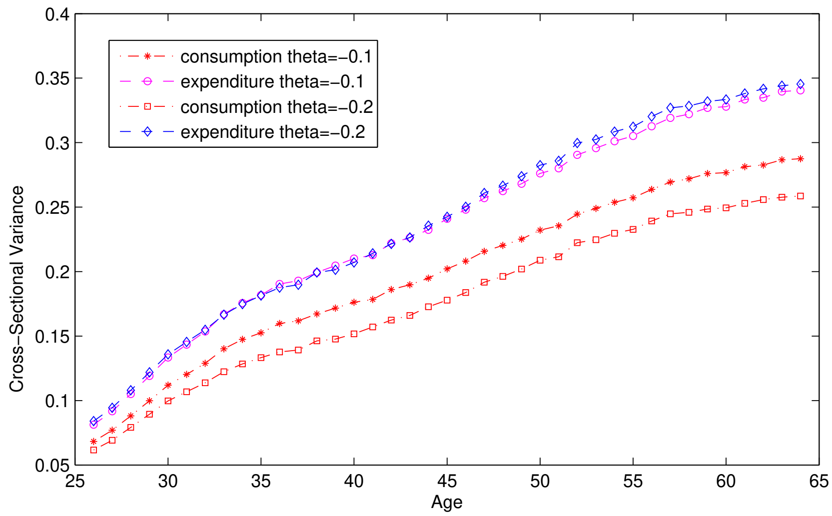


4.4 The Role of Search Technology

We solve the model with two values of the parameter θ to determine its role in the quantitative results. In the benchmark model, we use a value of -0.1, which is the estimated value in Aguiar and Hurst (2007) for the U.S. data. We also solve the model with a value of -0.2. This exercise shows the implications of a technological innovation in price search, such as the internet.

As illustrated in Figure 8, the gap between the age-inequality profiles of consumption and expenditure increases as a result of an increase in price search technology. The higher return to price search brings more partial insurance and the variance in consumption decreases. As the return to search increases, the increase in the search time of the poor and low-income individuals is higher than the increase in the search time of the wealthy and

Figure 8: Effect of Price Search Technology: Consumption vs Expenditure



high-income individuals. As a consequence, the variance and the average of search time increase with a higher return to search technology, which is illustrated in Figures 9 and 10.

5 Discussion and Conclusion

In this paper, we study the role of price search on the age-inequality profiles of consumption and expenditure. We introduce a price search decision into a life-cycle model, differentiate consumption from expenditure, and study the joint behavior of shopping strategies, individual prices, and consumption/saving decisions. The model predicts an increasing age-inequality profile for search, prices, consumption, and expenditure. Our quantitative study - using an estimated income process and price search functions from

Figure 9: Effect of Search Technology: Average Search

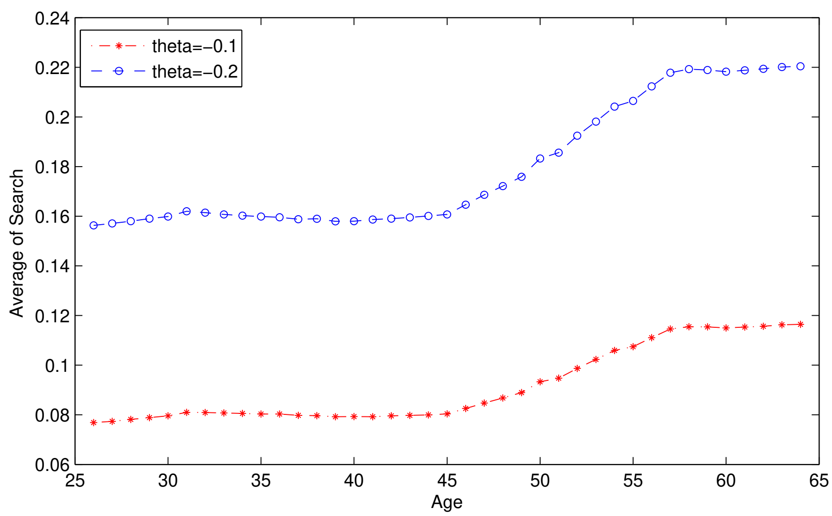
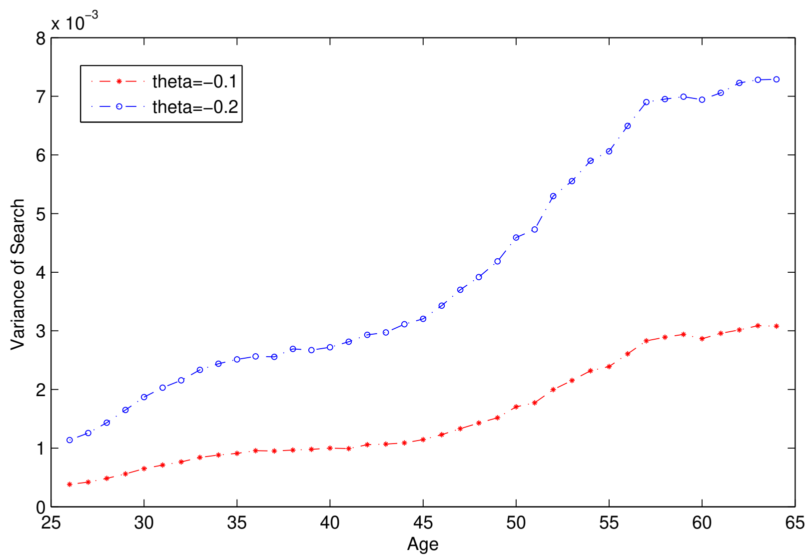


Figure 10: Effect of Search Technology: Variance of Search



the literature - predicts that consumption inequality is significantly different from expenditure inequality when agents can search for prices. A plausibly calibrated version of our model predicts that the cross-sectional variance of consumption is about 17% smaller than the cross-sectional variance of expenditure throughout the life cycle. In the earlier studies,[6], consumption inequality was implicitly assumed to be the same as expenditure inequality.

Although we focused on age-inequality profiles, the model can be extended to further explain empirical observations. For instance, Aguiar and Hurst (2009) document different patterns in different expenditure categories. Price search could be helpful in explaining the different patterns because some categories might be more sensitive to price search. The life-cycle search profile may have different implications for the expenditure patterns of different categories due to their different sensitivities. Carroll and Summers (1989) document different expenditure patterns for different education groups. Again, price search together with income processes could be helpful to explain the expenditure patterns. Different price search technologies or time cost profiles for different education or occupation groups could be helpful in explaining the different expenditure patterns. In this paper we used average cost of time (the coefficient of leisure in the utility function) over the life cycle. It is likely that the variance of the opportunity cost of time changes over the life cycle to varying degrees for different education and occupation groups. Potentially it will have important implications on

[6] For example; Storesletten et al. (2004), Krueger and Perri (2006), Guvenen (2007).

inequality in general.

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