

## BUSINESS CYCLES IN A HABIT FORMATION MONETARY MODEL

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*This paper sets up a habit persistence monetary model in line with Campbell and Cochrane(1995) with transaction costs in consumption. It compares the quantitative properties of the habit formation model with data. It shows that the habit persistence model fails to explain the interest rate and employment fluctuations as well as the movement of consumption due to a locally large value of relative risk aversion.*

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### I. INTRODUCTION

In monetary economics and finance, it is common practice to employ a representative agent model in order to derive some restrictions on consumption and asset returns and compare them with the actual data. Because the aggregate consumption data for the G-7 countries is smooth, it seems that the way in which the agent's preference evaluate small gambles about certainty is critical for providing a good fit to the data. But the common constant-relative-risk-averse, expected utility function fails in this respect, as pointed out by many economists. Mehra and Prescott (1985) argue that the representative agent, expected additive utility model, sensibly restricted, cannot account for both the 0.8 percent average real return on debt and the nearly 7.0 percent average real return on equity that the U.S. data show for the 1889-1978 period. In related modelling exercises, Grossman, Melino, and Shiller (1987), Cecchetti and Mark (1990), and Kandel and Stambaugh (1991) report that the represent agent model

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with a degree of relative risk aversion in the range of 20-30 perform fairly well. On the other hand, Kocherlakota (1988) shows that a representative agent model with a negative time preference can match the above historical average.

In recent years, models with habit formation have been quite successful in linking consumption and asset prices. Constantinides(1990) showed that once a habit formation is added to the standard model with power utility and lognormal distribution, the equity premium puzzles disappear. More recently, Boldrin, Christiano, and Fisher (1995) replaced the power specification of utility with the habit persistence specifications proposed by Constantinides (1990) and investigated the implications of the model on the equity premium puzzle. Campbell and Cochrane(1995) present a model such that the habit formation is external,<sup>1</sup> as in Abel's(1990) "keeping up with the Joneses" formulation and succeed in explaining many asset pricing puzzles including the risk free rate puzzle.

Even though the external habit formation models are said to be quite successful in generating the relationship between consumption and asset prices, they are so in an endowment economy without money which is a typical economic environment in finance literature, stock market dividends equal consumption. They usually do not ask how consumption, labor and investment are determined, which is one of the utmost important issues in macroeconomics. How do consumption, labor, and investment as well as the price fluctuate when consumers choose consumption and leisure optimally in response to various shocks in the presence of habit formation? Do they match well with data and improve our understanding about business cycle? These are the questions that I would like to investigate in this paper.

I begin by setting up a habit formation dynamic general equilibrium model with transaction costs in consumption in line with Campbell and Cochrane(1995). Then, using this model, I investigate the dynamic quantitative properties of the model and explore the questions about business cycles. For example, I discuss whether this model can give rise to liquidity effects of a monetary policy. I also explore whether the comovements of output and other endogenous variables are consistent in the data.

The main findings of this paper can be summarized as follows. First, when there exists a substantial degree of habit formation in consumption, an expansionary monetary shock to the home country leads to a tiny response of consumption and interest rates. This reflects the strong effect of the locally small intertemporal elasticity of substitution in consumption and leisure. Second, the introduction of habit formation distorts the close comovement of employment and output by making households desire very smooth consumption profile. Finally, the habit formation model fails in generating relative variations of endogenous variables and the cross correlation between output and other endogenous variables

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<sup>1</sup> This says that an individual's habit level depends on the history of aggregate consumption rather than the individual's own past consumption.

as in the data. In this respect, its performance is inferior to the performance of a no-habit persistence model.

The organization of the paper is as follows. In section II I specify a habit formation models with a transaction cost in which the transaction cost is reduced when a representative household use money in purchasing goods. In section III, I discuss the equilibrium conditions and its implications. I discuss the state space analysis and quantitative implications in section IV and section V. Finally I give a concluding remarks in section VI.

## II. THE MODEL WITH HABIT FORMATIONS

### 2.1 The Household

#### 2.1.1. Preferences

The economy consists of a continuum of identical infinite-lived households. Following Abel(1990), and Campbell and Cochrane(1995), suppose that a representative household derives utility from the level of consumption relative to a time-varying subsistence or habit level and from the leisure. In particular, I assume that the habit is external in the sense that it is determined by the aggregate consumption of the nation as a whole, and not by the consumption of any individual household as in Campbell and Cochrane(1995). This simplifies greatly the analysis. The utility function of the representative household takes the form:

$$E_t \sum_{j=0}^{\infty} \beta^j u(C_{t+j}, L_{t+j}; H_{t+j}), \quad (1)$$

where

$$u(C_{t+j}, L_{t+j}; H_{t+j}) = \frac{[(C_{t+j} - H_{t+j})^{1-\theta} L_{t+j}^{\theta}]^{1-\sigma} - 1}{1-\sigma}, \quad \sigma \neq 1, \quad (2)$$

and  $H_t$  is the level of habit and  $L_t$  is the level of leisure.  $\theta$  is the utility curvature parameters about consumption and leisure. The utility of a representative household depends on a power utility of the difference between consumption and habit.<sup>2</sup> The stochastic sequence of habits  $\{H_t\}_{t=0}^{\infty}$  is regarded as exogenous by the household and tied to the stochastic sequence of aggregate consumption  $\{C_t\}_{t=0}^{\infty}$  as follows. Define the surplus consumption ratio as

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<sup>2</sup> Abel(1990) calls this 'Catching up with Joneses'.

$$S_t = \frac{C_t - H_t}{C_t}. \quad (3)$$

When habit  $S_t$  is held constant as consumption  $C_t$  varies, the local coefficient of relative risk aversion(RRA) are

$$\frac{-C_t u_{11}}{u_1} = \frac{\sigma}{S_t}. \quad (4)$$

Here risk aversion rises as the surplus consumption ratio  $S_t$  decreases.  $\sigma$  is no longer the coefficient of relative risk aversion in this model. Since  $S_t$  is varying over time, RRA is moving as well. In bad times,  $S_t$  is small, which means that the households are more risk averse. I need to specify how the habit  $S_t$  evolves over time to aggregate consumption. As in Campbell and Cochrane(1995), suppose that the log surplus consumption ratio follows an AR(1) process:

$$s_{t+1} = (1 - \phi)\bar{s} + \phi s_t + \mu(s_t)(c_{t+1} - c_t - \gamma_g), \quad (5)$$

where small letters represent the natural logarithms and  $\gamma_g$  is the average detrended consumption growth rate,  $\gamma_g = E[\Delta c_{t+1}]$ . The parameter  $\phi$  governs the persistence of the log surplus consumption ratio, and the sensitivity function  $\mu(s_t)$  controls the sensitivity of  $s_{t+1}$ . That is, it governs the log habit  $s_{t+1}$  to innovations in consumption growth  $\varepsilon_{t+1}$ .  $\mu(s_t)$  is defined as follows:

$$\mu(s) = \begin{cases} \frac{1}{\bar{S}} \sqrt{1 - 2(s - \bar{s})}, & s \leq s_{\max} \\ 0, & s \geq s_{\max} \end{cases} \quad (6)$$

As in Campbell and Cochrane, let

$$\bar{S} = \sigma_v \sqrt{\frac{\sigma}{1 - \phi}}, \quad \bar{s} = \log \bar{S}, \quad \text{and} \quad s_{\max} = \bar{s} + \frac{1}{2}(1 - \bar{S}^2).$$

Rewriting equation (5),

$$s_{t+1} = (1 - \phi)\bar{s} + \phi s_t + \mu(s_t)(c_{t+1} - c_t - \gamma_g) \quad (7)$$

$$= (1 - \phi)\bar{s} + q(t) + \mu(s_t)(c_{t+1} - \gamma_g), \quad (8)$$

where  $q(t) = \phi s_t - \mu(s_t)c_t$ . The function  $\mu(s)$  in (6) controls the sensitivity of the habit  $s$  to changes in consumption. The price of risk depends on  $\mu(s)$  as in Campbell and Cochrane(1995). It is desirable to have a non-constant  $\mu(s)$  if one

wants to generate state-dependent risk prices. Campbell and Cochrane(1995) choose  $\mu(s)$  so that the risk free rate is constant for all  $s$ . However, there is no a priori reason to use the specification in (5) and not much is lost when the constant  $\mu$  is chosen. As I use a log-approximation method to analyze the dynamics of the model in next section, I assume a constant  $\mu$ -function as in Lettau and Uhlig(1995).

### 2.1.2. Budget Constraints and Transaction Costs

Assume that money reduces the costs of consumption transactions and the cost of time to shopping can be represented by a function of consumption levels and real balances, as in Feenstra(1986). That is, when a household has real balance holdings equal to  $m_t$ , it must expend additional  $\Phi(C_t, m_t)$  units of goods to consume  $C_t$  units as transaction costs. As in Feenstra(1986), we assume that each transaction cost function is homeogenous of degree one in both arguments with  $\Phi_1 \geq 0$ ,  $\Phi_2 < 0$ ,  $\Phi_{11} \geq 0$ ,  $\Phi_{22} \geq 0$ , and  $\Phi_{12} < 0$ .

First, a representative household faces the time constraint such that

$$L_t + N_t \leq 1, \text{ where } N_t \text{ is the labor supply at time } t. \quad (9)$$

Next, consider the household's budget constraint. The timing of markets and the transactions facing the household need to be specified. I assume that the household observes the current state of the world at the beginning of period  $t$ , and then it participates in the financial market with nominal wealth  $\Theta_t$ , carried over from period  $t-1$ . The household can lend or borrow an amount of  $B_t$  in financial markets and receives the lump-sum transfers of currency,  $T_t$  before the asset market opens. It also chooses the amount of currency,  $M_t$  to purchase the consumption goods at the goods market.

In addition to money and bonds, the household can invest in physical capital,  $K_t$ . For analytical simplicity, I assume that the household owns only its own capital stock to rent to firm and there is no firm specific capital stock. Since we do not empirically observe large discrete capital stock adjustments, it is reasonable to introduce an adjustment cost in capital stock installments. If there are costs of installing capital, the capital stock will move more sluggishly. I assume that there are deadweight costs of installing capital stock. To preserve the simple model structure as far as possible, I will adopt the Uzawa-Lucas-Prescott form of investment adjustment costs.

$$K_{t+1} = \phi(I_t/K_t)K_t + (1 - \delta_k)K_t, \quad (10)$$

where  $0 < \delta_k < 1$  is the rate of depreciation, and  $\phi(I_t/K_t)$  is an increasing, concave, twice continuously differentiable function with  $\phi(0) = \delta_k$ ,  $\phi'(\delta_k) = 1$ .

$I_t$  is the composite investment at period  $t$ , and  $K_t$  is the composite capital stock at period  $t$ . This formulation implies that Tobin's  $q$  is equal to  $1/\psi'$  ( $I_t/K_t$ ) which equals one in the steady state. At the end of each period, the household receives wages, rents for capital, and dividends from each firm. Thus its budget constraint and wealth at the beginning of the period  $t+1$  are given by,

$$M_{t+1} + B_{t+1} \leq \Theta_{t+1} + T_{t+1}. \quad (11)$$

and

$$\Theta_{t+1} = M_t + (1 + i_t)B_t + \Pi_t - P_t(C_t + \Phi(v_t)) - P_t I_t + W_t N_t + D_t K_t, \quad (12)$$

where money velocity, is defined as

$$v_t = \frac{P_t C_t}{M_t}.$$

Here  $P_t$ ,  $\Pi_t$ ,  $W_t$ ,  $D_t$ ,  $r_t$  denotes a price level, firm's nominal profits, nominal wages, nominal rental rate for capital stock, and the real interest rate, respectively. In addition, households are assumed to be subject to the borrowing constraint that prevents them from engaging in Ponzi game.

## 2.2. The Firm

The representative firm maximizes profit

$$\Pi_t = \max_{K_t^d, N_t^d} P_t Y_t - D_t K_t^d - W_t N_t^d, \quad (13)$$

where

$$Y_t = A_t F(K_t^d, z_t N_t^d) \quad (14)$$

is output and  $K_t^d$  and  $N_t^d$  are demanded capital and labor at time  $t$ .  $z_t$  and  $A_t$  are the labor augmenting permanent technology progress, and transitory technology process at period  $t$ . I assume that the technology shock follows an  $AR(1)$  process. The permanent changes in the total factor productivity,  $z_t$  are taken as growing deterministically, i.e.  $\gamma_z = \frac{z_t}{z_{t-1}}$  for all  $t$  as in King, Plosser and Robelo (1988, hereafter KPR(1988)).

$$\log A_t = \rho \log A_{t-1} + \xi_{At}, \quad -1 < \rho < 1, \quad (15)$$

where  $E(\xi_{A_t}) = 0$  and  $\xi_{A_t}$  is i.i.d. over time.

### 2.3. The Government

Suppose that the government levies lump-sum taxes,  $T_t$ , and supplies money,  $M_t$  to finance its expenditures,  $G_t$ . Its period-by-period budget constraint is

$$\frac{\omega_t M_{t-1}}{P_t} + T_t = G_t. \quad (16)$$

Here  $\omega_t$  is the rate of growth of the nominal money supply,

$$\omega_t = \frac{M_t - M_{t-1}}{M_{t-1}}. \quad (17)$$

## III. EQUILIBRIUM

### 3.1. First Order Conditions

The first order necessary conditions for a solution to the household problem posed by (1) to (12) are the budget constraints with the following Euler equations:

$$\theta(S_t C_t)^{\theta - \gamma\theta - 1} (1 - N_t)^{(1 - \theta)(1 - \gamma)} = \Lambda_t P_t [1 + \Phi(v_t) + v_t \Phi'(v_t)] \quad (18)$$

$$(1 - \theta)(S_t C_t)^{\theta(1 - \gamma)} (1 - N_t)^{-\gamma - \theta + \theta\gamma} = \Lambda_t W_t \quad (19)$$

$$\Lambda_t (1 - (v_t)^2 \Phi'(v_t)) = \beta E_t [\Lambda_{t+1}] \quad (20)$$

$$\Lambda_t = \beta E_t [\Lambda_{t+1}] \quad (21)$$

$$\Lambda_t P_t \psi'^{-1}(X_t) = \beta E_t [\Lambda_{t+1} P_{t+1} \psi'^{-1}(X_{t+1}) \chi(X_{t+1}) + D_{t+1} \Lambda_{t+1}] \quad (22)$$

$$s_{t+1} = (1 - \phi)\bar{s} + \phi s_t + \mu(s_t)(c_{t+1} - c_t - \gamma_g), \quad (23)$$

$$K_{t+1} = \phi(I_t/K_t)K_t + (1 - \delta_k)K_t, \quad (24)$$

$$X_t = \frac{I_t}{K_t}, \quad (25)$$

where  $\Phi = \Phi(v_t)$ ,  $v_t = \frac{c_t}{m_t}$ ,  $m_t = \frac{M_t}{P_t}$ .

Here  $\chi(X_{t+1}) = \phi(X_{t+1}) - \psi'(X_{t+1})X_{t+1} + 1 - \delta_k$  and  $\Lambda_s, \Delta_s$  are Langrange multipliers associated with the household's budget constraint and capital stock adjustment respectively. In the later quantitative evaluations, I will assume that  $\phi(\frac{C_t}{M_t/P_t}) = A(\frac{C_t}{M_t/P_t})^\xi$ , where  $\xi > 0$ .

Equation (18), the first order condition for the consumption goods, says that the marginal utility of consumption goods equals the sum of the marginal utility of wealth and that of the liquidity service of currency. Equation (19) relates the marginal utility of leisure to the marginal utility of the wage rate. Equation (20) and (21) refer the intertemporal decision of the household, i.e. the decision of money holdings and net foreign asset holdings, respectively. In particular, these

equations imply that the demand for the real balance is a decreasing function of the nominal interest rate. Equation (22) which is the first order condition with respect to the representative household's investment represents the evolution of Tobin's  $q$  over time. Though I need not specify the functional form for adjustment cost function,  $\psi$ , I should specify three parameters which describe the behavior around the steady state. First, I must specify the steady state value of Tobin's  $q$  and the share of investment in national product. Since the steady state value of Tobin's  $q$  is 1.0, I also set the value of this variable to 1.0 in steady state. And I will take the same investment share in steady state as in a model without adjustment cost. Next, I have to specify the parameter which determines the elasticity of marginal adjustment cost function. As there has been no study about this adjustment cost parameter value, I will present several results through sensitivity analysis in next section.

The profit maximization conditions of the representative firm are given by

$$\frac{D_t}{P_t} = \alpha \frac{Y_t}{K_t}, \quad (26)$$

$$\frac{W_t}{P_t} = (1 - \alpha) \frac{Y_t}{N_t}. \quad (27)$$

The clearing conditions for the goods as well as the asset markets are given by

$$Y_t = C_t + I_t + G_t, \quad (28)$$

$$M_t^s = M_t^d, \quad (29)$$

$$B_t^s = B_t^d, \quad (30)$$



market, labor market, money and bond market. Specifically, an equilibrium is an allocation of agents  $\{C_t, S_t, K_{t+1}, X_t, I_t, H_t, B_t, M_t\}_{t=0}^{\infty}$ , a sequence of prices and costate variables  $\{P_t, \Lambda_t, D_t, W_t, i_t\}_{t=0}^{\infty}$ , satisfying equilibrium conditions (18)-(30), given  $K_0, P_{-1}$  and the exogenous stochastic processes  $\{\omega_t, \xi_{A_t}, \xi_{g_t}\}_{t=0}^{\infty}$  satisfying (15)-(17).

### 3.2. State-Space Analysis

To analyze the dynamic implications of the model, I log-linearize the equilibrium conditions as in KPR(1988). Let's represent the log-linearized version of the economy system in a state space.

$$N_{t+1} = \Pi N_t + C \varepsilon_{t+1}, \quad (31)$$

$$X_t = M N_t, \quad (32)$$

where  $N_{t+1}$ , and  $\varepsilon_{t+1}$  are the vector of state variables, and vector of innovations at time  $t$  and  $X_{t+1}$  is the vector of control variables at time  $t$ . In simulations, I assume that the exogenous stochastic processes  $Z_t = \{\omega_t, \xi_{A_t}, \xi_{g_t}\}_{t=0}^{\infty}$  are jointly covariance-stationary stochastic processes and have the following time series representation:

$$Z_{t+1} = \Phi Z_t + \xi_{t+1}, \quad (33)$$

with  $E_t \xi_{t+1} = 0$ ,  $E_t \xi_t \xi_t' = V$  as in Cardia(1991).

With these apparatus, I analyze the response of the economy to shocks of technology and monetary policy using essentially the method of KPR(1988) in next section. That is, I restrict my attention to the case of small fluctuations of the endogenous variables around a steady state growth path. Since most of the following analysis will be done in stationary terms, it is more convenient to define a symmetric rational equilibrium in terms of a stationary one.

### 3.3. Stationary Transformed Economy

When there exists a growth trend in  $z_t$ , endogenous variables will exhibit trend in equilibrium, if it exists as well. Thus a stationary solution for the transformed variables will exist if the equilibrium conditions in terms of these variables do not contain  $z_t$ . A stationary equilibrium exists for the transformed (detrended) variables if the transformed variables do not involve  $z_t$ . The real variables of the economy are divided by  $z_t$ , and real balance for money is deflated by  $z_t$  at each time.

As standard frequency domain techniques are used to compute the complex matrix spectral density function of all variables as in Lettau and Uhlig(1995), no

simulations are necessary to obtain results for Hodrick-Prescott filtered series.

#### IV. QUANTITATIVE IMPLICATIONS

##### 4.1. Parameter Values

All parameter values used in this paper are reported in Table 1. Most of them are taken from Campbell and Cochrane(1995) and Rotemberg and Woodford(1992). In particular, one needs to note the intertemporal elasticities of consumption and labor supply because these parameter values are important in the quantitative implications of the model. Even though many RBC models assume that unit elasticity of intertemporal substitution,  $\varepsilon_C = \sigma_C^{-1} = 1$  which is taken from Hansen and Singleton(1982), many empirical studies on consumption tell us to be more cautious and conservative in choosing the value. Thus the baseline model of this paper takes lower values of intertemporal elasticity of consumption,  $\sigma_C = 2$ , *i.e.*  $\varepsilon_C = 1/2$ . The intertemporal elasticities of consumption and labor supply are much smaller than those in Rotemberg and Woodford (1992). The value of elasticity of  $i/k$  with respect to Tobin's  $q$ ,  $\eta_q$  is the cost adjustment elasticity which reflects the volatility of investment. Since previous studies have not estimated this cost adjustment parameter, I will choose 15 as the value in the baseline model as in Baxter and Crucini(1993). I also preform a dynamic quantitative analysis when there is no capital adjustment as most typical RBC models do.

[Table 1] The Calibrated Parameters

Parameter	Value	Description of Parameters
$\gamma$	1.004	steady state quarterly growth rate of technology
$s_H$	0.58	steady state labor share
$\delta$	0.025	rate of depreciation of capital stock
$r_h$	0.011	steady state rate of return
$\varepsilon_C(\sigma_C^{-1})$	0.5	intertemporal elasticity of consumption
$\varepsilon_w$	1	intertemporal elasticity of labor supply
$-\frac{1}{1+\xi}$	0.5	log-log interest rate elasticity of money demand
$\varepsilon_{nk}$	1	elasticity of substitution between capital and labor
$\phi$	0.97	serial correlation of the habit formation
$s_G$	0.10	steady state government spending share
$\eta_q$	15, $\infty$	elasticity of $i/k$ to Tobin's $q$

$$10^{-2} \times V = \begin{bmatrix} 0.9^2 & 0 & 0 \\ 0 & 0.89^2 & 0 \\ 0 & 0 & 1.45^2 \end{bmatrix}, \quad \Phi = \begin{bmatrix} 0.986 & 0 & 0 \\ 0 & 0.490 & 0 \\ 0 & 0 & 0.9579 \end{bmatrix}.$$

With the transaction cost function of  $\phi\left(\frac{C_t}{M_t/P_t}\right) = A\left(\frac{C_t}{M_t/P_t}\right)^\xi$ , with  $\xi > 0$ , the log-log money demand elasticity to the interest rate is  $\frac{1}{1+\xi}$ . I will take Lucas's(1993) estimate for this elasticity which equals -0.5 for the U.S. and determine the parameter values. The parameter values related to the habit formation are taken from Campbell and Cochrane(1995). In particular, the values of the serial correlation parameter  $\phi$  of the habit formation is set to 0.97. The steady state surplus consumption ratio  $\bar{S}$  and the maximum surplus consumption ratio  $\bar{S}_{\max}$  are set to 0.049 and 0.081.

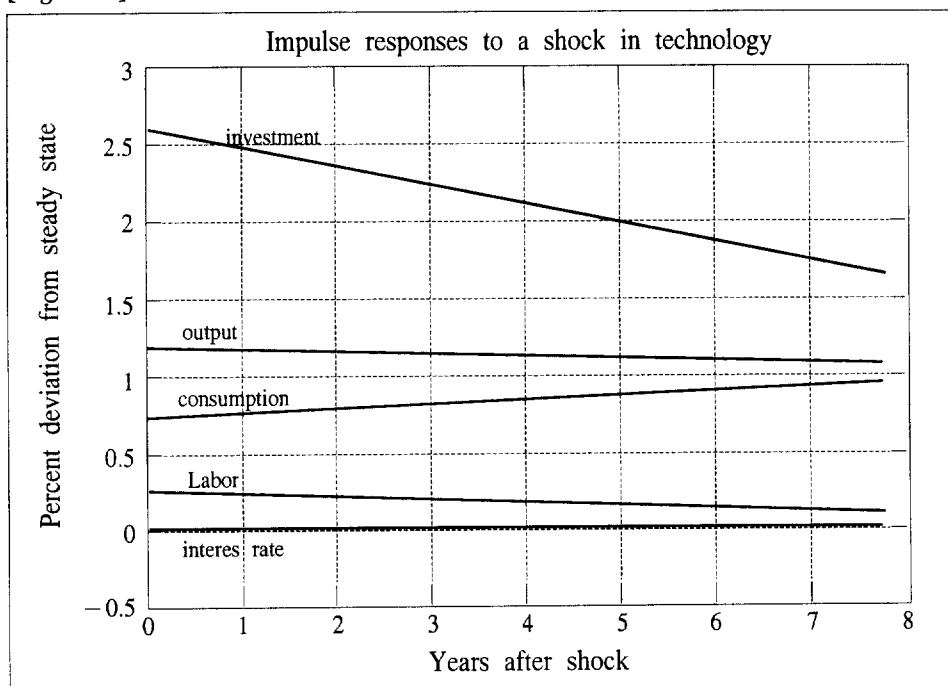
## 4.2. Implications of the Model

In this subsection I review the main goal of this paper and see whether the habit formation model with transaction cost can explain the business cycle properties of the economy. I compare the moments of the model with properties of data drawn from major industrial economies. I also compare a habit formation model with a model without habit formation.

### 4.2.1. The Impulse Responses of Positive Real and Monetary Shocks

The first issue that I address is if actual data impulses correspond to the

[Figure 1] No Habit Formation



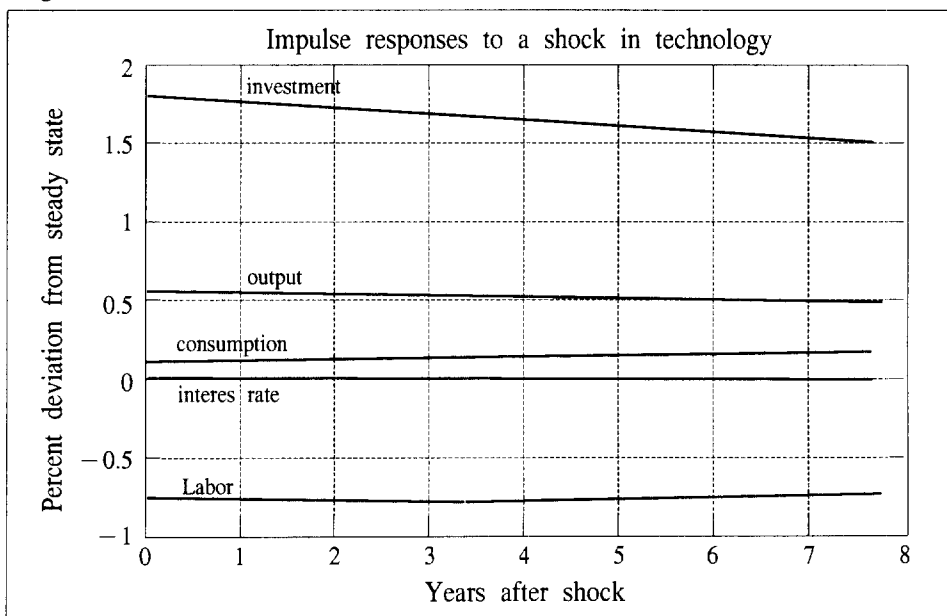
dynamic responses of real activities and prices to monetary shocks implied by this habit persistence model.

First, let's compare the impulse response of the model without habit formation and the habit formation model when the capital adjustment cost exists. Consider the response of the endogenous variables to real shocks. In the flexible price monetary model without habit persistence in consumption, a positive real shock leads to a substantial increase of consumption and investment as well as a substantial increase of labor as in Figure 1.

As a positive real shock improves the productivity, the marginal cost of production decreases. As a result, price goes down. The impulse response of a habit formation model shows that the response of consumption is tiny. This is due to a habit formation in consumption. While the household in the model without habit formation uses the opportunity of increased productivity to work harder to build up capital, the household in the habit formation model will have an incentive to do so. As the household with habit formation does not want and expect to change its consumption in the future, it does not work hard even if a favorable environment to work harder forms. The response of labor to a positive real shock is negative as in Figure 2. The impulse responses of the other endogenous variables to a real shock in the habit formation model are very similar to those of no habit formation model.

Second, consider the impulse response of the endogenous variables to a monetary shock. In a model without habit formation investment increases a little to a positive monetary shock, while consumption decreases to the shock as in

[Figure 2] Habit Formation



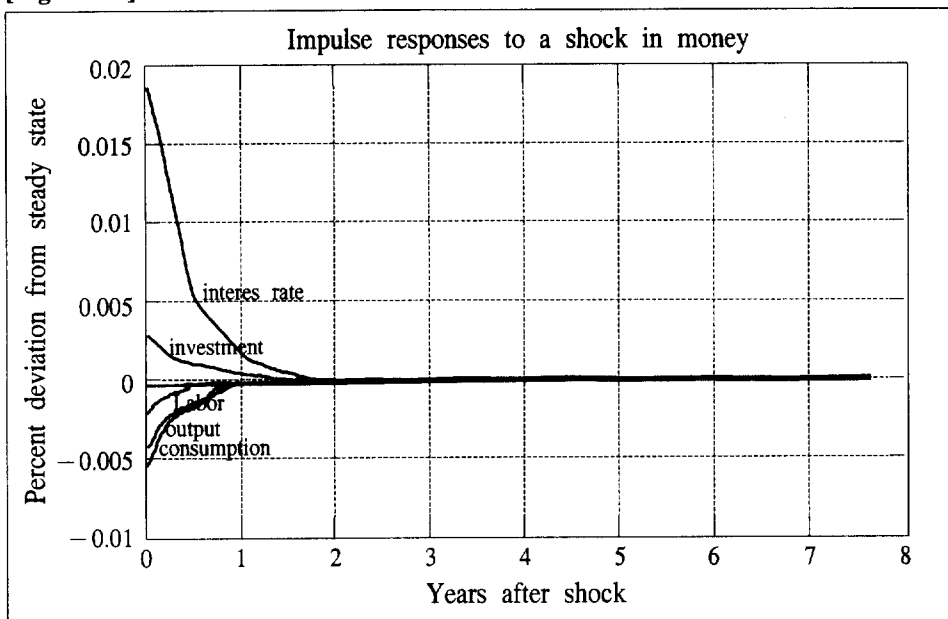
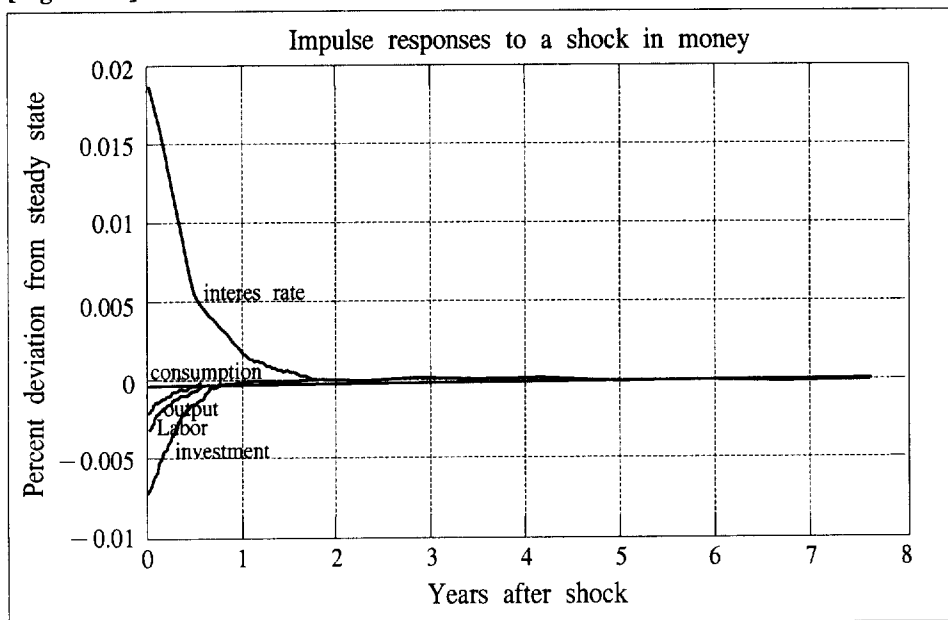
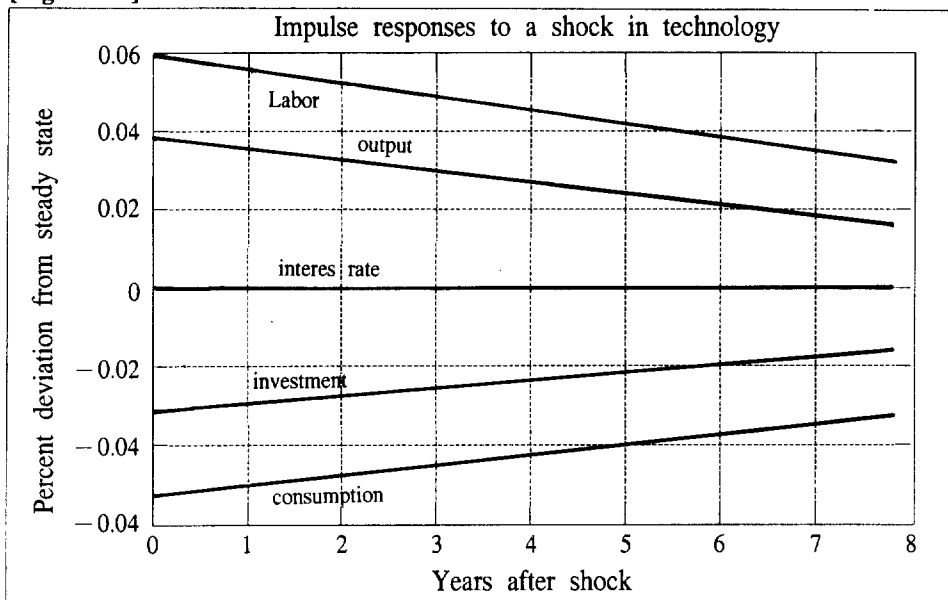
**[Figures 3]** No Habit Formation**[Figures 4]** Habit Formation

Figure 3. This reflects the fact that consumption requires money to reduce transaction costs, while investment does not. In the habit formation model, the effects of a positive monetary shock on consumption is very small because the

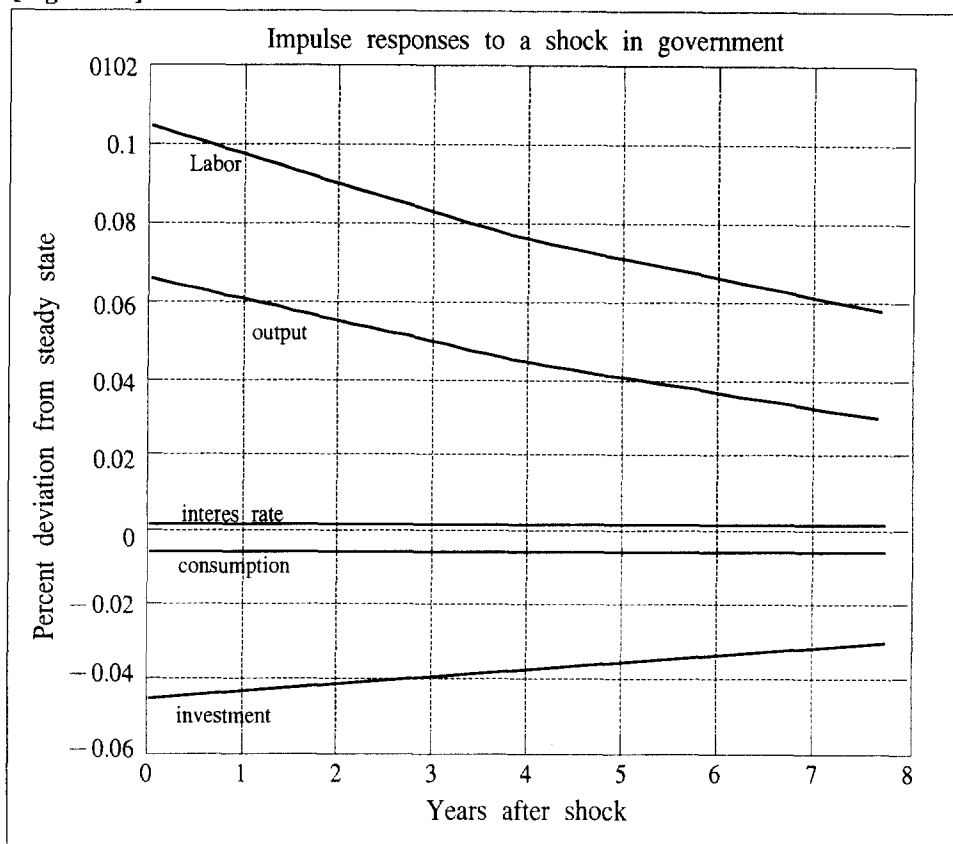
[Figures 5] No Habit Formation



habit formation makes the household locally very risk averse,<sup>3</sup> which implies a very low local elasticity of substitution. That is, the household wants to smooth consumption extremely, making consumption very unresponsive to shocks as in Figure 4. The labor supply and output in a habit formation model decrease just a little to a positive monetary shock as in a flexible price model without habit formation. Price increases to the shock in both models, though not reported in the paper.

Next, consider the effect of government spending shock on the economy. The

[Figures 6] Habit Formation



the model. The column labelled 'Data' in Table 2 is reproduced from Fiorito and Kollintzas(1994) where moments are calculated for actual time series that have been Hodrick-Prescott filtered. This column reports composite data moments of six countries(Australia, Canada, Finland, Germany, Japan, and United Kingdom).

First, consider the standard deviation of the variables in a habit formation model. A prominent feature is the excessively small variations of consumption relative to other real variables as can be seen in Table 4 where some selected moments of data are presented. The standard deviation of consumption in data is between .8 and 1.2. However, the standard deviation of consumption in the baseline habit formation model is too small compared to it. This is due to the fact that consumers respond very little to monetary shocks and to real shocks in the habit formation model. When I decrease the capital adjustment cost, the standard deviation of investment increases while that of consumption changes little. This is because households do not adjust their consumption profile, but adjust capital stock to the shock. Note that the standard deviations of output, consumption, labor and investment match well with those of data when there is no habit formation.

**[Table 2]** Moments of Data

Variable	S.D.	Cross	Corr.	with	Output					
		$X_{t-4}$	$X_{t-3}$	$X_{t-2}$	$X_{t-1}$	$X_t$	$X_{t+1}$	$X_{t+2}$	$X_{t+3}$	$X_{t+4}$
Canada										
$Y$	1.39	0.04	0.27	0.51	0.78	1.00	0.78	0.51	0.27	0.04
$C$	1.27	0.16	0.40	0.57	0.72	0.79	0.65	0.44	0.27	0.06
$I^f$	4.60	-0.29	-0.07	0.18	0.40	0.53	0.52	0.41	0.32	0.21
$I^e$	7.13	-0.35	-0.18	0.03	0.27	0.43	0.51	0.53	0.50	0.34
$N$	1.25	-0.21	0.00	0.22	0.45	0.67	0.71	0.59	0.44	0.37
$P^g$	1.71	-0.51	-0.50	-0.46	-0.41	-0.34	-0.20	-0.07	0.04	0.14
$P^c$	1.77	-0.41	-0.45	-0.43	-0.35	-0.32	-0.22	-0.15	-0.01	0.05
Japan										
$Y$	1.53	0.19	0.38	0.59	0.78	1.00	0.78	0.59	0.38	0.19
$C$	1.33	0.08	0.28	0.42	0.56	0.72	0.54	0.40	0.22	0.01
$I^f$	4.57	0.04	0.23	0.45	0.64	0.83	0.78	0.69	0.51	0.29
$I^e$	5.96	0.02	0.17	0.38	0.58	0.74	0.73	0.69	0.54	0.34
$N$	0.68	0.00	0.06	0.24	0.26	0.27	0.19	0.24	0.18	0.06
$P^g$	1.84	-0.46	-0.51	-0.52	-0.48	-0.43	-0.34	-0.21	-0.10	-0.01
Germany										
$Y$	1.69	0.23	0.35	0.46	0.67	1.00	0.67	0.46	0.35	0.23
$C$	1.53	0.26	0.37	0.46	0.58	0.69	0.55	0.49	0.38	0.32
$I^f$	4.90	0.26	0.37	0.42	0.60	0.84	0.54	0.42	0.37	0.29
$I^e$	6.09	0.36	0.48	0.52	0.61	0.73	0.58	0.49	0.39	0.23
$I^e$	1.02	-0.11	-0.08	0.08	0.15	0.29	0.30	0.25	0.17	0.05
$P^g$	0.97	-0.35	-0.34	-0.28	-0.24	-0.15	0.07	0.23	0.33	0.35
$P^c$	1.01	-0.53	-0.52	-0.45	-0.42	-0.39	-0.27	-0.21	-0.14	-0.04



[Table 3] Moments of Data(Continued)

Variable	S.D.	Cross	Corr.	with	Output					
						$X_{t-4}$	$X_{t-3}$	$X_{t-2}$	$X_{t-1}$	$X_t$
						$X_{t+1}$	$X_{t+2}$	$X_{t+3}$	$X_{t+4}$	
France										
$Y$	0.90	0.10	0.30	0.54	0.77	1.00	0.77	0.54	0.30	0.10
$C$	0.86	0.42	0.63	0.73	0.72	0.62	0.30	0.44	0.14	0.25
$I^f$	2.70	0.06	0.26	0.46	0.66	0.78	0.69	0.57	0.41	0.25
$I^e$	3.90	-0.23	0.39	0.58	0.70	0.74	0.53	0.31	0.12	-0.06
$N$	0.56	-0.20	-0.09	0.13	0.35	0.60	0.68	0.61	0.51	0.40
$P^g$	1.31	-0.48	-0.53	-0.60	-0.61	-0.60	-0.47	-0.34	-0.25	-0.18
$P^c$	1.61	-0.57	-0.63	-0.64	-0.61	-0.55	-0.41	-0.25	-0.11	0.03
UK										
$Y$	1.54	0.07	0.20	0.37	0.55	1.00	0.55	0.37	0.20	0.07
$C$	1.67	0.13	0.30	0.39	0.46	0.67	0.42	0.38	0.26	0.10
$I^f$	3.57	-0.04	0.08	0.23	0.33	0.60	0.53	0.38	0.31	0.23
$I^e$	4.88	-0.07	0.05	0.21	0.38	0.56	0.51	0.47	0.44	0.32
$N$	1.00	-0.19	-0.09	0.13	0.26	0.43	0.51	0.58	0.55	0.54
$P^g$	2.33	-0.22	-0.34	-0.45	-0.54	-0.57	-0.48	-0.39	-0.23	-0.09
$P^c$	2.81	-0.22	-0.25	-0.37	-0.43	-0.36	-0.31	-0.15	-0.08	0.03

Source: Fiorito and Kollintzas(1994) and IMF.

$Y$ : output,  $C$ : consumption,  $I^f$ : fixed investment,  $I^e$ : equipment investment,  $N$ : net capital formation,  $P^g$ : government expenditure,  $P^c$ : private expenditure.

**[Table 4]** Moments of the Benchmark Model  $S = 0.05$ 

Variable	S.D.	Cross	Corr.	with	Output					
		$X_{t-4}$	$X_{t-3}$	$X_{t-2}$	$X_{t-1}$	$X_t$	$X_{t+1}$	$X_{t+2}$	$X_{t+3}$	$X_{t+4}$
$\phi = 15$		$\bar{S} = 1$								
$Y$	1.78	-0.26	-0.27	-0.13	0.30	1.00	0.30	-0.13	-0.27	-0.26
$C$	0.90	-0.24	-0.21	-0.04	0.35	0.98	0.21	-0.19	-0.31	-0.26
$I$	4.71	-0.27	-0.30	-0.17	0.24	0.99	0.31	-0.09	-0.25	-0.25
$N$	0.62	-0.27	-0.31	-0.20	0.20	0.98	0.33	-0.06	-0.22	-0.23
$P$	1.24	0.13	0.09	-0.03	-0.26	-0.57	-0.08	0.16	0.21	0.18
$\phi = \infty$		$\bar{S} = 1$								
$Y$	1.66	-0.26	-0.27	-0.13	0.28	1.00	0.28	-0.13	-0.27	-0.16
$C$	1.11	-0.25	-0.24	-0.08	0.32	0.98	0.24	-0.16	-0.29	-0.27
$I$	3.61	-0.26	-0.29	-0.26	0.24	0.99	0.31	-0.10	-0.25	-0.25
$N$	0.39	-0.26	-0.31	-0.20	0.18	0.95	0.33	-0.05	-0.21	-0.22
$P$	1.45	0.17	0.15	0.03	-0.26	-0.71	-0.15	0.14	0.23	0.20
$\phi = 15$		$\bar{S} = 0.05$								
$Y$	0.92	-0.26	-0.27	-0.13	0.27	1.00	0.27	-0.13	-0.27	-0.26
$C$	0.70	-0.22	-0.20	-0.04	0.34	0.96	0.19	-0.21	-0.32	-0.27
$I$	3.27	-0.26	-0.27	-0.14	0.26	0.98	0.28	-0.12	-0.26	-0.25
$N$	0.81	0.22	0.22	0.07	-0.29	-0.90	-0.22	0.15	0.27	0.24
$P$	1.23	0.12	0.09	0.01	-0.23	-0.54	-0.08	0.14	0.20	0.16
$\phi = \infty$		$\bar{S} = 1$								
$Y$	2.11	-0.15	-0.02	0.19	0.51	1.00	0.51	0.19	-0.02	-0.15
$C$	2.07	0.01	0.13	0.30	0.52	0.82	0.37	0.06	-0.04	-0.24
$I$	9.25	-0.33	-0.27	-0.11	0.23	0.85	0.55	0.31	0.14	0.02
$N$	0.80	-0.26	-0.21	-0.07	0.23	0.79	0.30	-0.01	-0.18	-0.27
$P$	1.45	0.15	0.13	0.02	-0.35	-0.67	-0.13	-0.01	0.18	0.24

Next, consider the contemporaneous correlation between output and other endogenous variables. In the flexible price model without habit formation, consumption, labor, and investment comove very closely as in data. But the sign of the correlation between output and employment is opposite to that of the actual data when there is a habit formation. In the habit formation model, the correlation between output and employment decreases because households which wish to maintain their consumption profile do not change their labor supply to the shock. The price moves countercyclically in both habit formation model and no-habit formation model as in data.

## V. CONCLUDING REMARKS

This paper specifies a habit formation economy such that a risk premium varies over time as in Campbell(1996) and Campbell and Cochrane(1995) who have recently proposed a simple asset pricing model with habit formation. It investigates the impacts of various shocks in a habit formation general equilibrium model with a transaction cost, and compares the habit formation model with a model without habit formation in many aspects. It shows that the habit formation model generates too small variations of consumption as well as paradoxical movements of labor compared to data. This reflects the strong effect of the locally small intertemporal elasticity of substitution in consumption and leisure.

In the future, it is desirable to incorporate the sticky price property with the habit formation and look at the effect of monetary and real shocks on consumption and interest rates.

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