CHAPTER 4

Estimating a Wealth Effect on Consumption

4.1 Introduction

The amount of asset holdings is one of essential factors which determine household consumption expenditures. The theoretical link between household consumption and wealth is clearly specified in life cycle models developed during the 1950s in a number of important contributions such as Modigliani and Brumberg (1954) and Modilgliani and Ando (1963). They model a consumer's decision as a problem in which the consumer intertemporally allocates the total amount of resources available over the lifetime. Since a consumer with a concave utility function wants to smooth consumption expenditures over time, she does not spend all of an increase in wealth immediately. Solving the standard life-cycle model, the marginal propensity to consume out of an increase in wealth can be derived as a function of preference parameters, interest rate, and the remaining length of lifetime.[50] Since the life cycle model provided solid microfoundations to the study of consumption which was previously dominated by the Keynesian models[51], the wealth effect on consumption has been built into almost all practical models of consumption.

Recent developments in time series econometrics — in particu-

[50]For example, a typical consumption function has a form: $C_t = (1 - R^{-1}(R\beta)^{1/\rho})(W_t + H_t)$ where W_t is wealth holdings, H_t is present discount value of labor income, for an infinitely living consumer with a CRRA utility function and without uncertainty.

[51]The Keysian models assume that consumption is a simple function of current disposable income with no wealth effect.

lar, substantial progress in cointegration analysis — have led to a new method to estimate the wealth effect on consumption.

The new approach, or "Vector Error Correction Model (VECM)" approach, relies on the existence of a stable long-run relationship between consumption, income, and wealth. We show a typical estimate in this framework and explain how to interpret the results. One of the implications derived from the estimation results is that consumption responds immediately and fully to permanent innovations in income and wealth rather than adjusting sluggishly to the shocks.

A separate, and older, literature developed after Hall (1978) pointed out the random-walk property implied by theoretical models of consumption. According to the pure permanent income hypothesis, variables lagged $t-1$ or earlier should not help predict consumption growth in period t. However, in practice, most of forecast models of consumption use lagged macro variables including lagged wealth growth in regressions since consumption spending seems to adjust sluggishly in the data. (Brayton and Tinsley (1996)) They justify their estimating specification by arguing that consumers may not always behave exactly as predicted by the simplest version of the PIH theory and may adjust their spending with a delay since it takes time for them to make a decision on purchase. (Davis and Palumbo (2001))

It is fair to say that the VECM approach of estimating the wealth effect has recently become very popular among economists. However, this approach does not have a theoretically coherent background in the same sense that typical macro forecast models ignore what a microeconomic consumption theory tells about consumption dynamics by assuming the ad-hoc adjustment lags in spending. This paper ar-

gues that the new method is misguided in estimating the MPC out of wealth shock and propose an alternative approach which is theoretically founded and consistent with important empirical features of consumption such as the excess sensitivity of consumption to past information and the excess smoothness of consumption movements.

Our approach proposes estimating the wealth effect based on the Euler equation of a habit formation model. We demonstrate that the habit model can explain the forecastability of consumption by lagged wealth growth. Furthermore, we present a simple method to estimate the MPC out of wealth shock in our framework and generate a wealth effect estimate which is comparable to the estimates found in the existent literature. The immediate MPC out of a wealth shock is estimated around 0.9 percent while the long-run MPC out of a wealth shock is found to be around 4 percent. Habits reduce the immediate MPC significantly and make adjustments of consumption with respect to an initial shock gradual and smooth.

The rest of the paper proceeds as follows. Section 4.2 lays out the VECM approach and estimates a system of three variables: consumption, income and wealth. Then, we point out several problems in this approach, motivating our preferred method. Section 4.3 describes our approach, the Euler equation approach with a habit-forming consumer, and estimates both the immediate and long-run MPC out of wealth shocks. Finally, Section 4.4 concludes.

4.2 The Vector Error Correction Model Approach

In this section, we start by deriving the fundamental formula on which the VECM approach is based, then describe the estimation method used for statistical analysis. This approach builds up on the notion that a general household budget constraint *with a couple of strict assumptions* implies that log consumption, log labor income, and log asset wealth are cointegrated. Hence, first, we show how a simple wealth accumulation equation can be manipulated to arrive at the cointegrating relationship among consumption, income, and wealth in logs. After deriving the relationship, we explain why the assumptions on which it is based are problematic.

Let us start from the following general budget constraint:

$$W_{t+1} = R_{t+1}(W_t + Y_t - C_t) \tag{4.1}$$

where W_t is the amount of asset holdings at the beginning of period t, Y_t is labor income, C_t is consumption, and R_{t+1} is the gross rate of return on savings between time t and $t+1$. By iterating the above budget constraint forward, we can obtain the intertemporal budget constraint:

$$W_t + \sum_{i=0}^{\infty} \frac{1}{R_{t+1}R_{t+2}...R_{t+i}} Y_{t+i} = \sum_{i=0}^{\infty} \frac{1}{R_{t+1}R_{t+2}...R_{t+i}} C_{t+i} \tag{4.2}$$

Let us call the second term on the left hand side Γ_t and the term on the right hand side Φ_t. Notice that Γ_t evolves as follows.

$$\Gamma_{t+1} = R_{r+1}(\Gamma_t - Y_t) \tag{4.3}$$

$$\frac{\Gamma_{t+1}}{\Gamma_t} = R_{t+1}\left(1 - \frac{Y_t}{\Gamma_t}\right) \tag{4.4}$$

Taking the logarithm of both sides,

$$\begin{aligned}
\log \Gamma_{t+1} - \log \Gamma_t &\approx r_{t+1} + \log(1 - \exp(\log Y_t - \log \Gamma_t)) && (4.5)\\
&\approx r_{t+1} + \left(1 - \frac{1}{1 - Y/\Gamma}\right)(\log Y_t - \log \Gamma_t - \log Y + \log \Gamma) && (4.6)\\
&= r_{t+1} + \left(1 - \frac{1}{\gamma}\right)(\log Y_t - \log \Gamma_t) + k && (4.7)
\end{aligned}$$

where we use Taylor expansion around $\log Y - \log \Gamma$ from the first to the second row; $1 - Y/\Gamma = \gamma$; k absorbs all the unimportant constant terms. The left hand side can be expanded as

$$\log \Gamma_{t+1} - \log \Gamma_t = \Delta \log Y_{t+1} + \log Y_t - \log \Gamma_t - (\log Y_{t+1} - \log \Gamma_{t+1}) \quad (4.8)$$

Substituting this expression in Equation (4.7), we can reach

$$\frac{1}{\gamma}(\log Y_t - \log \Gamma_t) = (\log Y_{t+1} - \log \Gamma_{t+1}) - \Delta \log Y_{t+1} + r_{t+1} + k \quad (4.9)$$

Iterating this forward, we obtain

$$\log Y_t - \log \Gamma_t = \sum_{i=1}^{\infty} \gamma^i (r_{t+1} - \Delta \log Y_{t+i}) + k_y \quad (4.10)$$

Proceeding in the same way for Ψ_t[52],

$$\log C_t - \log \Psi_t = \sum_{i=1}^{\infty} \gamma^i (r_{t+1} - \Delta \log C_{t+i}) + k_c \quad (4.11)$$

Going back to the original intertemporal budget constraint (4.2) and

[52] We assume $\gamma = 1 - Y/\Gamma = 1 - C/\Psi$

applying log-linearization to it,

$$W_t + \Gamma_t = \Psi_t \tag{4.12}$$

$$\log \Psi_t - \frac{\Gamma}{\Psi} \log \Gamma_t - \frac{W}{\Psi} \log W_t = k \tag{4.13}$$

$$\log C_t - \frac{\Gamma}{\Psi} \log Y_t - \left(1 - \frac{\Gamma}{\Psi}\right) \log W_t = \tag{4.14}$$

$$\sum_{i=1}^{\infty} \gamma^i \left(\frac{\Gamma}{\Psi} \Delta \log Y_{t+i} - \Delta \log C_{t+i} + \left(1 - \frac{\Gamma}{\Psi}\right) r_{t+i} \right) \tag{4.15}$$

We substitute Equation (4.10) and (4.11) for $\log \Gamma_t$ and $\log \Psi_t$ in the last row. Then, Equation (4.15) is the one used as a rationale for the VECM approach. If $\Delta \log Y_t$, $\Delta \log C_t$, and r_t are all stationary variables, the right hand side is stationary, and so is the left hand side. In that case, three variables on the left hand side, $\log C_t$, $\log Y_t$, and $\log W_t$, should be cointegrated with a single cointegrating vector and each variable may be expressed as a function of two common trends and one temporary shock. Given the above result, the VECM framework focuses on the system of these three variables, trying to estimate the cointegrating relationship and the short-run adjustment process when a deviation from the long-run trend occurs. With a couple of more assumptions on the structure of the error process, one can also identify permanent and temporary components of shocks to the three-variable system.

A theoretical problem of the cointegrating approach can be pointed out in the above derivation. In obtaining Equation (4.15), we had to assume that the ratio of market wealth to total wealth Γ/Ψ, or equivalently the ratio of market wealth to human wealth is stationary. Neither partial nor general equilibrium theory provides a plausible rational for

this stationarity assumption.

In any sensible macroeconomic models, the long-run relationship between (the logs of) consumption, income and wealth is bound to be determined by the steady state interest rate, productivity growth rate, population growth rate, and tax rate and so on. If any of these parameters change permanently over the time frame examined, and that is highly likely to be the case, considering the fact that there is much empirical evidence of structural breaks in the US economy (Stock and Watson (1996)), any efforts to find one unique cointegrating relationship between three variables would be futile. Even without any important changes in fundamental parameter values of the model, it is doubtful that transitional dynamics towards the steady state is fast enough to identify the steady state relationship with the amount of data available.

4.2.1 Data and Preliminary Analysis

The appendix contains a detailed description of the data used in this paper. The net value of wealth, W_t, is a real, per capita household net worth, which includes financial wealth as well as tangible wealth (housing wealth and consumer durables). We use a real, per capita consumption expenditure on nondurables and services as a measure of C_t. Labor income, Y_t, is wage and salary disbursement plus transfer income after subtracting off personal contributions for social insurance. To deflate nominal variables, we use the implicit price deflator for personal consumption. Our data span from the second quarter of 1952 to the third quarter of 2003.

Figure 4.1 shows the time-series movements of log real wealth, log

real stock wealth, and log real non-stock wealth. As one can see, stock wealth is the main source of total fluctuations in asset values, though it is smaller than non-stock wealth as a fraction of total wealth.

All the variables used in this paper are tested for the existence of a unit root and the results are presented in Table 4.1. ADF test statistics indicate that all of the variables except consumer sentiment index and unemployment rate (in levels) reject a null of no unit root at the 1 percent significant level hence should be first-differenced.

4.2.2 Estimation in the VECM Approach

Commonly, econometric analysis in the VECM approach is done in two steps. The first step is to estimate the long-run cointegrating relationship among consumption, labor income, and wealth (in logs). The second step is to estimate the short-run adjustment process towards the long-run common trend, assuming that the cointegrating relationship estimated in the first step is true. Rigorously speaking, there could be one or two cointegrating vectors among three variables, hence, one needs to first test the number of cointegrating vectors before proceeding further. Lettau and Ludvigson (2004) argue that there exists only one cointegrating vector, which we also assume in this section for the sake of argument.[53] However, the very existence of unique cointegrating relationship among three variables is yet questionable as we explain later in this section.

In the first step, the long-run cointegrating relationship among $\log C_t$, $\log Y_t$, and $\log W_t$ is estimated by the dynamic least squares

[53] They use Johansen's procedures to estimate the number of cointegrating relationships.

procedure (Stock and Watson (1993)), where the coefficient on consumption is normalized to one.

$$\log C_t = \mu + \beta_y \log Y_t + \beta_w \log W_{t-1} + \epsilon_t \tag{4.16}$$

If three variables are cointegrated, the dynamic least squares estimates for β_y and β_w are superconsistent and shown in Table 4.2. Moreover, the cointegraing residual, $\hat{ec}_t = \log C_t - \hat{\beta}_y \log Y_t - \hat{\beta}_w \log W_{t-1}$, should be an I(0) variable and capture temporary deviations from the long-run trend. The cointegrating vector is denoted as $\beta = (1, -\beta_y, -\beta_w)'$. According to the estimate, $\hat{\beta} = (1, -0.608, -0.404)'$, consumption would increase by 6.6 cents in the long run with respect to a permanent dollar increase in wealth and by 61 cents with resect to a dollar increase in income.[54]

A cointegrated set of variables $X_t = (\log C_t, \log Y_t, \log W_{t-1})'$ have a Vector Error Correction Model (VECM) specification:

$$\begin{aligned} \Delta X_t &= \nu + \alpha\beta' X_{t-1} + \Pi(L)\Delta X_{t-1} + e_t \\ &= \nu + \alpha \cdot ec_{t-1} + \Pi(L)\Delta X_{t-1} + e_t \end{aligned} \tag{4.17}$$

where ΔX_t is a vector of log first differences, $(\Delta \log C_t, \Delta \log Y_t, \Delta \log W_t)'$. $\Pi(L)$ is a finite order distributed lag operator. The vector, $\alpha = (\alpha_c, \alpha_y, \alpha_w)'$, captures adjustment of each variable to a one-period lagged deviation from the long-run relationship. The VECM is estimated after substituting the cointegrating residual $\hat{ec}_{t-1}$ obtained from the first step in Equation (4.17). Table 4.3 presents the results with a first-order

[54]These numbers are converted into levels from logs by using the consumption-wealth and consumption-income ratios in the most recent quarter (second quarter 2001).

specification of $\Pi(L)$. By comparing the magnitude of three $\alpha's$, it is known which variable does most of adjustment when a deviation from the long-run trend occurs. The larger the α is, the more of adjustment the variable does to restore the long-run relationship. According to the estimates, only α_w is statistically significantly different from zero, meaning that only wealth adjusts to eliminate a temporary deviation from the long-run trend. The similar results are found by Lettau and Ludvigson (2004).

Given the estimated VECM parameters, Lettau and Ludvigson (2004), Fernandez-Corugedo, Price and Blake (2003) and others further try to decompose asset value fluctuations into permanent and temporary components with the methodology which exploits the cointegrating relationship in the system. (King, Plosser, Stock and Watson (1991), Gonzaro and Granger (1995) and Gonzalo and Ng (2001)) Since the cointegrating relationship imposes certain restrictions on the long-run multipliers of shocks to the system, it is possible to identify two permanent shocks and one temporary shock out of three estimated residuals from the VECM.[55] Applying the permanent/transitory decomposition, Lettau and Ludvigson (2004) find that the majority of asset fluctuations is of temporary nature and have little effect on consumption spending. Consumption would certainly respond to *permanent* movements in income and wealth, as warranted by the cointegrating relationship, but almost none to temporary movements in income and wealth. Since most of asset value movements are estimated as

[55] A permanent shock η_{Pt} should satisfy $\lim_{h\to\infty} \partial E_t[x_{t+h}]/\partial \eta_{Pt} \neq 0$. A temporary shock η_{Tt} should satisfy $\lim_{h\to\infty} \partial E_t[x_{t+h}]/\partial \eta_{Tt} = 0$. Gonzaro and Granger (1995) suggest a matrix $G = \begin{bmatrix} \alpha'_\perp \\ \beta' \end{bmatrix}$ to transform residuals into permanent and temporary shocks, where $\alpha'_\perp \gamma = 0$.

temporary, asset value fluctuations are largely unrelated to consumption movements. Such a conclusion crucially hinges on the estimated values of adjustment coefficients, α. A large magnitude of α means, in the permanent/temporary decomposition framework, that the variable is driven more by temporary shocks than by permanent shocks. On the other hand, a small magnitude of α indicates that the variable consists more of permanent components, or common trends, than of temporary component. Similar to their results, our estimate of α_c is not significantly different from zero, suggesting that consumption would not do much adjustment when a deviation from the long-run trend occurs and that consumption movements are mainly due to permanent innovations in income and wealth.[56] In sum, based on the zero adjustment of consumption to temporary deviations from the common trend, one might argue that consumption does not adjust sluggishly, rather responds immediately to permanent innovations in income and wealth. In contrast to $\hat{\alpha}_c$ and $\hat{\alpha}_y$, the adjustment coefficient of wealth $\hat{\alpha}_w$ is significantly positive, by which one might interprets that most of temporary deviations from the common trend are equilibrated by subsequent movements in asset values.

4.2.3 Problems with the VECM Approach

There are a couple of serious problems in the VECM approach. In this section, we point out these problems and motivate our preferred approach to estimate the wealth effect on consumption, which will be discussed in detail in the next section.

[56] Lettau and Ludvigson (2004) calculate that over 95 percent of the variance for the forecast error of consumption is explained by two permanent innovations at all horizons.

First of all, there is a question on the very existence of unique, stable cointegrating relationship among consumption, income, and wealth. As we already mentioned in the theory section, theoretical grounds for the existence of long-run stable relationship between three variables is questionable in either partial or general equilibrium models. If there is no such relationship, the entire argument in the VECM approach would be problematic, since this approach highly relies on the estimation of a stable cointegrating vector.

According to the formula (Equation (4.15)), the cointegrating vector, $(1, -\beta_y, -\beta_w)$, should correspond to $(1, \Gamma/\Psi, 1-\Gamma/\Psi)$, where Γ/Ψ is the ratio of the present discounted value of human wealth to total wealth (total wealth = human wealth plus market wealth). There, we had to assume that the human to physical wealth ratio is stationary in order to obtain the stable cointegrating vector among the logs of consumption, income, and wealth. However, stationarity of the wealth ratio is a rather strong assumption and a recent literature has found substantial evidence of instability in such cointegrating vectors. (Brennan and Xia (2002), Hahn and Lee (2001))

Secondly, the standard VECM approach looks at only three variables and ignores other variables which can predict consumption growth. We can extract the consumption dynamics equation from the VECM system.

$$\Delta \log C_t = \nu_c + \alpha_c \hat{ec}_{t-1} + \Gamma_c(L)[\Delta \log C_{t-1}\ \Delta \log Y_{t-1}\ \Delta \log W_{t-2}]' + e_{ct} \tag{4.18}$$

The consumption equation includes one error correction term and lagged growth rates of consumption, income, and wealth. As shown in the

bottom row of Table 4.3, these regressors explain only 13 percent of variation in consumption growth. In consumption literature, it is well known that variables other than lagged wealth and income growth can also explain consumption growth. (Carroll, Fuhrer, and Wilcox (1994) and Bacchetta and Gerlach (1997)) If a set of variables constituting the system are actually larger than just three variables included, an omitted variable bias would make any interpretation of estimation results hard to believe. Furthermore, if any of variables in the system contains measurement error, one would get downward-biased parameter estimates and the residuals would not translate themselves into identifiable white noise shocks. As we will discuss below, when aggregate consumption expenditures contain measurement error, the residuals from consumption growth equation would follow a serially correlated process mixing up white noise shocks and measurement errors.

Finally, this approach ignores the optimal consumption dynamics which should be derived from the consumer theory. The consumer model solves for the optimal path of consumption as a result of intertemporal optimization, or an Euler equation. In the framework of the pure PIH theory, the optimal consumption path follows a random walk with a drift term. ($\Delta \log C_t = \nu_c + \Delta \log C_{t-1} + e_{ct}$) Though more elaborate consumer models would lead to consumption dynamics different from a simple random walk, it is not clear which consumer model would justify the consumption growth equation in the VECM without restrictions (Equation (4.18)).

4.3 The Euler Equation Approach

In this section, we introduce an alternative approach to estimate the wealth effect on consumption. Our approach is based on the Euler equation of a habit-forming consumer.

The simplest habit formation model assumes that a consumer maximizes an infinite stream of discounted utility, subject to the budget constraint (4.1).

$$\max_{\{C_s\}} E_t \sum_{s=t}^{\infty} \delta^{s-t} U(C_s - \rho C_{s-1}) \tag{4.19}$$

where δ is the time discount factor, C_{t-1} is the habit stock to which the consumer compares the amount of current consumption, and ρ captures the degree of habit persistence. For a given amount of current consumption, a larger habit stock lowers utility. Assuming a CRRA outer utility function for $U(\cdot)$, the Euler equation for the habit-forming consumer is approximated as,

$$\Delta \log C_t = \mu + \rho \Delta \log C_{t-1} + \epsilon_t \tag{4.20}$$

where ϵ_t is a white noise process capturing the innovations to income and wealth. (Dynan (2000)) The Euler equation tells us that the growth rate of consumption is serially correlated through habit forming behavior captured by ρ. Simple ordinary least squares estimation of the above Euler equation might not yield a consistent value for ρ for two reasons. First, time aggregation in quarterly data would cause ϵ_t to be a MA(1) process with a positive coefficient rather than a white noise process. (Working(1960)) Then, $\log C_{t-1}$ would be correlated with the

error term and an estimation of ρ would be upward-biased. Second, aggregate consumption expenditure data might suffer from a large measurement error, as a substantial proportion of quarterly consumption data is either imputed or interpolated. (See Wilcox(1992) and Sommer (2003))[57] Also, the actual consumption data is subject to transitory fluctuations such as weather-related fluctuations that are not incorporated into the theoretical specification. The existence of a transitory measurement error or a transitory noise in the growth rate of consumption would bias an estimate of ρ downwards. Let us specify these two sources of biases in the following manner.

$$\Delta \log C_t^* = \mu + \rho \Delta \log C_{t-1}^* + \upsilon_t + \theta \upsilon_{t-1} \tag{4.21}$$

$$\log C_t = \log C_t^* + \tau_t \tag{4.22}$$

where $\log C_t^*$ is a "true" log-level consumption, θ captures the MA(1) coefficient caused by time-aggregation, and a measurement error in consumption expenditure is specified as a white noise τ_t.[58] Combining two equations above, the Euler equation with habit formation in terms of measured consumption expenditures becomes,

$$\begin{aligned} \Delta \log C_t &= \mu + \rho \Delta \log C_{t-1} + \upsilon_t + \theta \upsilon_{t-1} \\ &\quad \tau_t + (1-\rho)\tau_{t-1} - \rho \tau_{t-2} \qquad (4.23) \\ &= \mu + \rho \Delta \log C_{t-1} + \xi_t \qquad (4.24) \end{aligned}$$

[57] In retail sales data which account for approximately one half of aggregate consumption, imputation is used to fill missing values for non-respondents, amounting to as high as 25 percent of the total retail sales. (Bureau of Economic Analysis, 2000) The major component of service consumption, housing, is not directly measured but imputed.

[58] Sommer (2003) assumes that the measurement error process follows an MA(1) rather than a white noise.

The error term ξ_t in the Euler Equation has a MA(2) structure which mixes innovations to income and wealth v_t and consumption measurement errors τ_t. To obtain a consistent estimate of ρ, we need to utilize instruments for the lagged consumption growth.

4.3.1 Wealth Effect in the Euler Equation Approach

Before we proceed to estimating the Euler equation (4.23), we would like to show how a concept of the wealth effect fits in our approach.

There is substantial evidence that consumption growth is forecastable against the random-walk property of consumption in the pure permanent income hypothesis. (Campbell and Mankiw (1989), and Carroll, Fuhrer, and Wilcox (1994)) Lagged wealth growth is among many variables which can forecast consumption growth. Then, significant coefficient estimates on lagged and/or contemporaneous wealth growth terms in regressions of consumption growth have been interpreted as a measure of the wealth effect.

In past empirical work, wealth effect estimation in the Euler equation framework has been mostly done with cross-section or panel data sets. Case, Quigley and Shiller (2001) estimate a stock wealth effect and a housing wealth effect on consumption separately by regressing consumption growth on changes in stock and housing wealth and changes in income in a panel of countries as well as states of the US. They find a statistically significant and rather large effect of housing wealth on consumption, but a relatively small or insignificant effect of financial wealth on consumption. Using household panel data from the Consumer Expenditure Survey, Dynan and Maki (2001) find a direct impact

of contemporaneous and lagged changes in stock prices on the spending of households that own stock market wealth. Their estimate of the stock wealth effect is 5-15 cents with respect to a one dollar increase in stock wealth, with the effect occurring gradually over a couple of years.

To see if there are any significant lagged wealth effects on consumption growth in our aggregate quarterly data, the following regression is run,

$$\Delta \log C_t = \mu + A(L)\Delta \log W_{t-1} + \epsilon_t \tag{4.25}$$

where A(L) is a lag operator. We do not include the contemporaneous wealth growth term in the regression, since the term would be seriously correlated with the error ϵ_t. As Table 4.4 displays, lagged wealth effects are significantly positive up to four quarters back and we soundly reject a null that there is no lagged wealth effect on consumption growth with a p-value of 0.000. This result is another evidence against the pure random walk property of consumption. We noted earlier that time-aggregation in quarterly data is likely to cause an innovation to consumption growth ϵ_t to be a MA(1) process rather than a white noise. Hence, Column 2 of Table 4.4 shows the estimation result when lagged wealth growth at $t-1$ is instrumented, and we again reject the null of no wealth effect at a less than 1 percent significance level. The finding that up to four quarters past information about wealth value movements is significant in consumption growth regressions simply confirms a well-known puzzle that consumption exhibits "excess smoothness": Consumption seems to respond with a delay with respect to wealth shocks, while, according to the standard PIH model, consumption should jump immediately to current "news" about lifetime resources.

There are more variables other than lagged wealth growth which have been found to predict consumption growth well. Campbell and Mankiw (1989) argue that any variables which can predict current income growth also predict current consumption growth since a fraction of consumers spend all of their disposable income at every period, hence for these "rule-of-thumb" consumers current consumption is equal to current income. Campbell and Mankiw's interpretation still leaves some empirical features of consumption dynamics unanswered. For example, Carroll, Fuhrer and Wilcox (1994) show that lagged consumer sentiment indices have a forecasting power for current consumption growth above and beyond its ability to predict current income growth. Furthermore, micro data sets show no evidence that many households behave as a "rule-of-thumb" consumer and set $C = Y$ making no saving. Some other papers point out that not only the predicted current income growth but also its lagged terms also forecast consumption growth. (Demery and Duck (2000) and Reis (2003)) The excess sensitivity of consumption to past information is again suggestive of slow adjustment of consumption to shocks. Using the VAR estimation, Furher (2003) demonstrates that consumption expenditure exhibits a significant delay and hump-shaped response to shocks. He further argues that the observed short-run consumption dynamics to shocks can be explained well by including habit formation in the consumer utility function.

Sommer (2003) also argues that a simple habit formation model can explain the correlation of consumption growth with predicted current income growth and lagged consumer sentiment indices. However, he does not consider another correlation of consumption growth with

lagged wealth growth. Instead, our focus is to reinterpret the correlation between consumption and wealth growth in a habit formation model. As the Euler equation (4.20) clearly shows, habits give an incentive to smooth growth rate of consumption. Consequently, consumption growth responds to innovations in income and wealth only gradually, therefore, lagged variables that contain some information on innovations to income and wealth can forecast current and future consumption growth unlike the case of the pure PIH. Moreover, the habit formation model tells us that after controlling the lagged consumption term, lagged information should not help forecast current consumption growth any more. Hence, if the simple habit formation model is true, the lagged wealth effects previously found in the consumption growth regression (4.25) should all be gone when we also include the lagged consumption growth term.

$$\Delta \log C_t = \mu + \rho \Delta \log C_{t-1} + A(L) \Delta \log W_{t-1} + \xi_t \tag{4.26}$$

We therefore want to test whether the coefficients in A(L) are all equal to zeros. As we mentioned in the previous section, the error term ξ_t follows an MA(2) process reflecting both time aggregation and measurement errors in consumption expenditures. Therefore, we will test a null that the simple habit forming model is true by using the two stage least squares method. To ensure that our instruments are not correlated with ξ_t (i.e. the instrument set are valid), variables in the instrument set are all lagged for at least three quarters. A set of instruments include variables which are commonly used in the literature. Namely we choose to include consumer sentiment index, changes in fed-

eral funds rate, and lagged growth rates of consumption, income, and wealth.

The regression results are reported in Column 3 and 4 of Table 4.4. Since wealth growth rates at $t-1$ and $t-2$ could be correlated with the MA(2) error term ξ_t, they are also instrumented in Column 3.[59] The estimated autoregressive coefficient ρ is statistically significant around 0.78. The test statistics are shown in the row labelled "P-Value" and fail to reject the null that all the lagged wealth effects are jointly zeros at a larger than 10 percent significant level. This finding supports an interpretation that the simple habit formation model is a good characterization of the actual consumption dynamics. In the other words, the lagged wealth effects found in the regression (4.25) are due to serial correlation in consumption growth caused by habit forming behavior. Column 4 drops the instrumented lagged wealth growth terms and keep only the wealth effects orthogonal to ξ_t. Again, the p value is large enough not to reject the null of no lagged wealth effects on consumption beyond habit persistence.

Column 5 and 6 restrict all lagged wealth effects to zeros as they are found jointly insignificant in the former columns. The degree of habit persistence ρ is estimated as high as 0.756 when instrumented in Column 6. Comparing with an ρ estimate of 0.410 without instrumenting in Column 5, it seems that the measurement error (downward) bias is dominantly large relative to the time aggregation (upward) bias.

Sommer (2003) finds that once the habit term $\Delta \log C_{t-1}$ is included, the excess sensitivity of consumption to lagged consumer senti-

[59]We add changes in stock price index to the instrument set to predict wealth growth rates separately from consumption growth.

ment indices disappears although lagged sentiment indices have a substantial predicting power for consumption growth in themselves. Our findings that lagged wealth effects are also eliminated after including the habit term strengthen the case for habit formation models of consumption.

4.3.2 The Marginal Propensity to Consume out of Wealth Shock

We saw that all the lagged wealth effects are gone once serial correlation in consumption growth is properly considered as the Euler equation of a habit-forming consumer suggests. Then, how can we know about the size of a wealth effect on consumption expenditures in our framework? The fact that lagged wealth growth rates have a predicting power for consumption growth as in Equation (4.25) means that there exists a wealth shock affecting consumption growth in the first place. Such an initial wealth shock would continue to have its effect on future consumption growth through habit forming preference. Since we already have an estimate of the habit persistence parameter ρ in hand, we know how much of the initial shock will be carried over into future consumption growth. Hence, the answer is that we can back out the immediate marginal propensity to consume out of wealth shock given the estimated ρ.

Go back to the Euler equation of a habit-forming consumer.

$$\Delta \log C_t = \mu + \rho \Delta \log C_{t-1} + \epsilon_t \tag{4.27}$$

Any initial shocks to consumption should show up in the error term ϵ_t

and be carried over into future consumption through ρ.

$$\begin{aligned}
\Delta \log C_t - \rho \Delta \log C_{t-1} &= \mu + \epsilon_t && (4.28)\\
\Delta \log C_t - \rho^2 \Delta \log C_{t-2} &= \mu(1+\rho) + \epsilon_t + \rho\epsilon_{t-1} && (4.29)\\
&\vdots \\
\Delta \log C_t - \rho^k \Delta \log C_{t-k} &= \tilde{\mu} + \epsilon_t + \rho\epsilon_{t-1} + \cdots + \rho^{k-1}\epsilon_{t-k+1} && (4.30)
\end{aligned}$$

Past shocks ϵ_{t-s} have decreasing effects on the "adjusted" current consumption growth, $\Delta \log C_t - \rho^k \Delta \log C_{t-k}$, with a decaying rate of ρ.

Let us define the immediate effect on log consumption out of log wealth shock as $\alpha = \partial\epsilon_t / \partial \Delta \log W_t$. Log wealth shock at time $t-s$ should constitute part of ϵ_{t-s}. Therefore, the effect of log wealth shock at time $t-1$ on the adjusted consumption growth at time t is $\rho\alpha$. In the same way, the effect of log wealth shock at time $t-s$ on the adjusted consumption growth at time t is $\rho^s\alpha$ for any integer s. Using this logic, we can collect the accumulated effects of lagged log wealth shocks on the adjusted consumption growth as follows.

$$\begin{aligned}
& \Delta \log C_t - \rho^k \Delta \log C_{t-k} \\
= \; & \tilde{\mu} + \rho^2\alpha\Delta \log W_{t-2} + \cdots + \rho^{k-1}\alpha\Delta \log W_{t-k+1} + \tilde{\eta}_t \\
= \; & \tilde{\mu} + \alpha(\rho^2 \Delta \log W_{t-2} + \cdots + \rho^{k-1}\Delta \log W_{t-k+1}) + \tilde{\eta}_t \quad (4.31)
\end{aligned}$$

Consider a set of equations from $k=3$ to $k=5$.

$$\begin{aligned}
\Delta \log C_t - \rho^3 \Delta \log C_{t-3} &= \mu_3 + \alpha(\rho^2 \Delta \log W_{t-2}) + \tilde{\eta}_{3t} \\
\Delta \log C_t - \rho^4 \Delta \log C_{t-4} &= \mu_4 + \alpha(\rho^2 \Delta \log W_{t-2} + \rho^3 \Delta \log W_{t-3}) + \tilde{\eta}_{4t}
\end{aligned}$$

$$\Delta \log C_t - \rho^5 \Delta \log C_{t-5} = \mu_5 + \alpha(\rho^2 \Delta \log W_{t-2} + \rho^3 \Delta \log W_{t-3} + \rho^4 \Delta \log W_{t-4}) + \tilde{\eta}_{5t} \quad (4.32)$$

Each of the above four equations can be estimated separately, after substituting the estimated ρ. If the simple habit formation model is true and the immediate effect on log consumption out of log wealth shock α is stable, all the equations share the same coefficient on the term involving lagged wealth shocks. Hence, we can also test if all the equations share the common coefficient α, and if that is true, we can estimate the set of equations simultaneously by imposing the common effect on log consumption out of log wealth shock. The results are shown in Table 4.5. In all regressions, we also include income shock terms in addition to wealth shock terms since these two shocks are major ones to drive consumption dynamics and likely to be correlated with each other. We confirm that the immediate wealth effects on log consumption are stable across the regressions and estimate that the α is about 6 percent and the immediate effect on log consumption out of log income shock is around 12 percent. The estimated α is not itself an MPC, since the model is written in terms of growth rates and α measures the relationship between the growth rate of consumption and the growth rate of wealth. To obtain an estimate of the MPC from α, we multiplied it by the ratio of consumption to wealth in the most recent data. (Or the ratio of consumption to income in the case of the MPC out of income shock.) The estimated immediate MPC out of wealth shock as such is about 1 percent. However, there is a simple way to obtain an MPC directly from regressions: We can use the ratio of changes in wealth to the initial level of consumption in place of the

growth rates. Namely, we use

$$dC_t = (C_t - C_{t-1})/C_{t-6} \tag{4.33}$$

$$dW_t = (W_t - W_{t-1})/C_{t-6} \tag{4.34}$$

in place of $\Delta \log C_t$ and $\Delta \log W_t$. We use 6 periods lagged consumption as the initial consumption since C_{t-6} is the earliest lagged variable appearing in a set of equations (4.32). The results are in Columns 2 and 2-R of Table 4.5. It turns out that the directly estimated MPCs are very close to the calculated MPCs from the growth rate regressions. The MPC out of wealth shock is about 0.9 percent and the MPC out of income shock is about 12 percent.

So far we assumed that wealth shock (or income shock) is simply equal to a growth rate or a change in wealth (or income). However, the simple wealth (or income) growth rate would contain both a predictable component and an unpredictable component. Ideally, only the unpredictable part of wealth (or income) movements should be used in estimating the MPCs out of wealth (or income) shocks.

Identifying predictable and unpredictable movements of wealth (or income) requires having a model of what income or wealth is expected to be. A model for expected income or wealth growth may be given as a function of a set of variables known at $t-1$, $\{E_{t-1}[\Delta \log Z_t] = f_Z(X_{t-1}) \ ; \ Z = Y, W\}$. Then, unpredictable shocks to income and wealth may be defined as the one-step ahead forecast errors in income and wealth. (i.e. $e_{Zt} = \Delta \log Z_t - f_Z(X_{t-1}) \ ; \ Z = Y, W$) We also show the results in which we use the estimated shocks in place of the simple growth rates in Columns 3 and 3-R of Table 4.5. The estimation result

for the MPC out of unexpected wealth shock is not considerably different from the one with simple growth rates, as wealth growth rates are hard to predict. On the other hand, the MPC out of unexpected income shocks are estimated larger than the one with simple growth rates.

For habit forming consumers, the short-run MPCs are smaller than the long-run MPCs, since it takes several periods to adjust fully to a single shock. The long-run MPCs out of shocks are defined as $MPC_Z^L = MPC_Z^S/(1-\rho)$ for $Z = Y, W$, where MPC_Z^S is a short-run MPC. As summarized in the last rows of Table 4.5, the long-run MPCs are estimated to be 4 percent for wealth shock and 48 percent for income shock. Carroll (2000) demonstrates that habits dramatically reduce the immediate MPCs out of permanent shocks to income. Indeed, with the strong habit persistence parameter estimated in this paper, the short-run MPC out of wealth shock is less than one-quarter of the long-run MPC, which is within the range of common estimates in the wealth effect literature.

4.4 Conclusion

In this paper, we explored two approaches to estimate the wealth effect on consumption. We argue that an increasingly used VECM approach does not give us reliable estimates of the MPCs out of wealth shock. Instead, we propose an alternative approach to estimate the short-run and long-run MPCs out of wealth shock, which accommodates empirical features of consumption dynamics such as the excess sensitivity to past information and the excess smoothness of consump-

tion movements. We use the Euler equation of a habit-forming consumer to characterize consumption dynamics.

We show that in a habit model consumption growth is serially correlated and that wealth shock to consumption has a long-lasting effect on consumption growth. We demonstrate how to obtain the short-run and long-run MPCs out of wealth shock in two stages. First, we estimate the consumption serial correlation coefficient, which tells us how much of an initial shock is carried over into future consumption growth. In the second step, given the serial correlation parameter, we can back out the MPC out of wealth shock.

Habits can reduce the immediate MPC out of shocks substantially. Our estimate of the immediate MPC out of wealth shock is around 0.9 percent, while the long-run MPC out of wealth shock is more than four times as large as the immediate effect, amounting to around 4 percent. Our estimate is within the range of typical estimates of the MPC out of wealth.

Table 4.1: Unit Root Test

	level	first difference
$\log C_t$	-0.109	-6.090
$\log Y_t$	-1.066	-7.109
$\log W_t$	-0.532	-6.140
r_t	-2.437	-5.000
sp_t	-0.233	-3.855
u_t	-3.014	-6.273
sentiment_t	-2.951	-5.937

Note: ADF statistics are shown. Four lags are included in regressions. Critical values are -3.487 and -2.885 for 1 percent and 5 percent levels. r_t is federal funds rate; sp_t is S&P's stock market index; u_t is unemployment rate.

Table 4.2: Dynamic Least Squares Regression

$$\log C_t = \mu + \beta_y \log Y_t + \beta_w \log W_{t-1} + \epsilon_t$$

μ	β_y	β_w
-0.805	0.608	0.404
(-4.697)	(6.254)	(4.328)

Note: Sample period is 1953q1-2003q1. t statistics are corrected in the way described in Hayashi (2000) and shown in parenthesis. We use four lags and leads of first differences of $\Delta \log Y_t$ and $\Delta \log W_t$ in the regression.

Table 4.3: Estimation of the VECM

	$\Delta \log C_t$	$\Delta \log Y_t$	$\Delta \log W_{t-1}$
$\hat{ec}_{t-1}$	-0.006	-0.015	0.200
	(-0.427)	(-0.619)	(3.323)
$\Delta \log C_{t-1}$	0.256	0.484	0.985
	(3.073)	(3.477)	(2.833)
$\Delta \log Y_{t-1}$	0.098	0.067	0.208
	(1.920)	(0.790)	(0.977)
$\Delta \log W_{t-2}$	-0.002	0.012	0.004
	(-0.123)	(0.405)	(0.050)
R^2	0.126	.109	.100

Note: Sample period is 1953q2-2003q2. t statistics are in parenthesis. Each equation is estimated with ordinary least squares method. $\hat{ec}_{t-1}$ is an estimated deviation from common trend shared by three variables. Wealth is a stock value measured at the end of period, while other variables are flow values over a quarter. Hence, wealth is lagged one period more than others.

Table 4.4: Consumption Euler Equation

$\Delta \log C_t$	1-OLS	2-IV	3-IV	4-IV	5-OLS	6-IV
$\Delta \log C_{t-1}$			0.782	0.694	0.410	0.756
			(5.674)	(5.816)	(6.350)	(6.675)
$\Delta \log W_{t-1}$	0.066	0.106	-0.003			
	(3.885)	(2.146)	(-0.056)			
$\Delta \log W_{t-2}$	0.014	0.011	-0.055			
	(1.130)	(0.884)	(-1.313)			
$\Delta \log W_{t-3}$	0.037	0.039	0.027	0.025		
	(3.104)	(3.033)	(1.696)	(1.629)		
$\Delta \log W_{t-4}$	0.033	0.030	0.005	0.010		
	(2.859)	(2.389)	(0.366)	(0.714)		
$\bar{R}^2$	.149	.228	.531	.464	.170	.533
OID test	NA	.465	.698	.565	NA	.533
P Value	0.000	0.000	0.215	0.120	NA	NA

First Stage Statistics

	$\Delta \log W_{t-1}$	$\Delta \log C_{t-1}$	$\Delta \log C_{t-1}$		$\Delta \log C_{t-1}$
Partial R^2	.147	.213	.276		.305
F-stats(p value)	1.56(.069)	5.58(.000)	6.07(.000)		5.73(.000)
		$\Delta \log W_{t-1}$			
Partial R^2		.107			
F-stats(p value)		1.34(.183)			
		$\Delta \log W_{t-2}$			
Partial R^2		.121			
F-stats(p-value)		1.69(.054)			

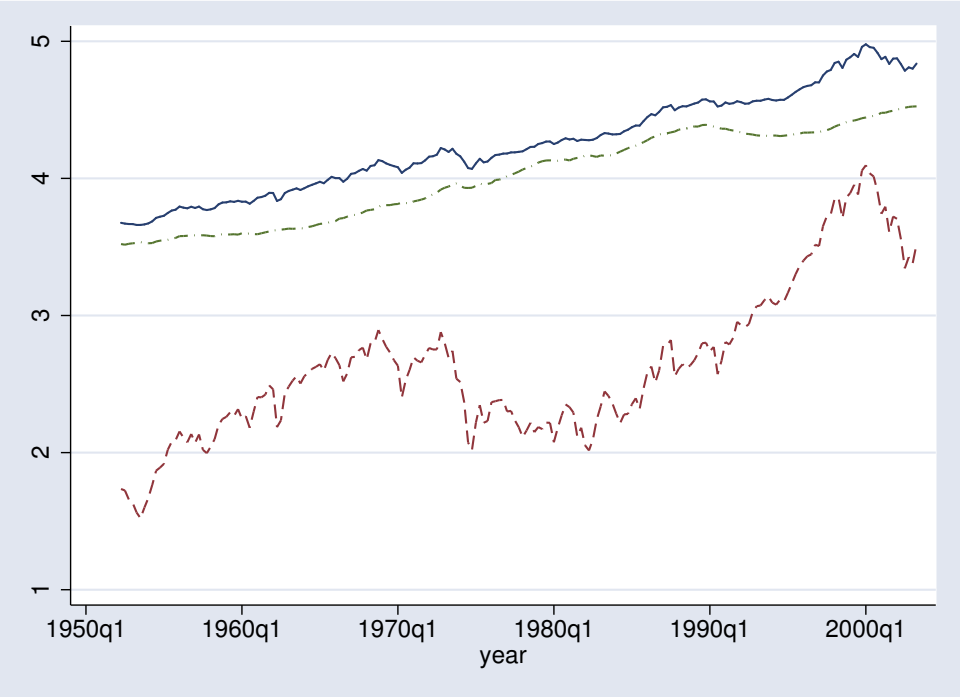
Note: Sample period is from 1962q2 to 2003q3. t statistics are in parenthesis for the second stage regressions. p values are for a null that all lagged wealth effects are zeros. Instruments include consumption growth, income growth wealth growth, changes in federal funds rate, and consumer sentiment index (unemployment expectation). All instruments are lagged for an appropriate number of periods.

Table 4.5: MPCs out of Wealth and Income Shocks

	1	1-R	2	2-R	3	3-R
Eq 1						
Wealth shock	.063	.057	.009	.009	.050	.049
	(4.04)	(5.32)	(3.90)	(5.16)	(3.32)	(4.74)
Income shock	.071	.120	.072	.116	.220	.233
	(1.73)	(4.82)	(7.84)	(5.10)	(5.23)	(8.03)
Eq 2						
Wealth shock	.056		.009		.048	
	(4.65)		(4.51)		(4.16)	
Income shock	.103		.101		0.234	
	(3.51)		(3.71)		(7.19)	
Eq 3						
Wealth shock	.052		.008		.049	
	(4.60)		(4.46)		(4.61)	
Income shock	.118		.114		.233	
	(4.70)		(4.94)		(7.88)	
P Value						
Wealth	.62		.67		.99	
& Income	.58		.61		.99	
SR-MPC						
Wealth		.0092		.0086		.0079
Income		.1200		.1162		.2327
LR-MPC						
Wealth		.0378		.0353		.0325
Income		.4924		.4770		.9550

Note: Column 1 uses a simple growth rate as a shock; Column 2 uses a normalized change defined as Equation (4.33) and (4.34); Column 3 uses an estimated shock. p values are for a null that all the coefficients on aggregated wealth shocks across equations are the same and that all the coefficients on aggregated income shocks are also the same.

Figure 4.1: Log Per Capita Real Wealth



— total wealth, – · – · – non stock wealth, – – – stock wealth

APPENDIX B

Data Description for Chapter 4

Consumption (C_t)	Real per capita consumption is measured as expenditures on nondurables and services, divided by price index and population. The data are quarterly, seasonally adjusted at annual rate. The source is National Income and Product Accounts from Bureau of Economic Analysis.
Income (Y_t)	Real per capita labor income is measured as wage and salary disbursement + transfer payments to persons - personal contributions for social insurance, divided by price index and population. The data are quarterly, seasonally adjusted at annual rate. The source is National Income and Product Accounts from the Bureau of Economic Analysis.
Wealth (W_t)	Real per capita wealth is measures as net worth held by households and NPOs, divided by price index and population. The data are quarterly, amount outstanding at the end of period. The source is Flow of Funds Accounts from the Board of Governors of the Federal Reserve System.

Price Index	Price Index used to deflate nominal variables is the implicit price deflator for personal consumption expenditures. (1996 = 100) The source is National Income and Product Accounts from the Bureau of Economic Analysis.
Population	The number of population is in millions. The source is National Income and Product Accounts from the Bureau of Economic Analysis.
Federal funds rate	The average over monthly series. The source is the Board of Governors of the Federal Reserve System.
Consumer Sentiment Index	The source is the Surveys of Consumers from the Survey Research Center at the University of Michigan.
Unemployment Rate	The average over monthly series. The source is from the Bureau of Labor Statistics.
Stock Price Index	Standard & Poor's stock price index is taken from Robert Shiller's web site.

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