Modeling Financial Innovation in the Demand for Money using Structural Time Series Approach: The Case of the US

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Abstract

This paper argues the importance of adequately modeling the effect of innovation when estimating the money demand function for the US. The structural time series model is therefore employed to allow for stochastic trend as a flexible proxy for innovation. The results confirm the use of a stochastic formulation of the trend as a proxy for innovation to obtain plausible estimates of the long run income and interest rate elasticities.

1. Introduction and Literature Review

There is a vast literature for modeling the demand for money. The most empirical studies use cointegration approach to test the long run relationship among the determinants of the demand for money; this is a traditional approach, which is well documented in Hendry and Juselius, (2000 and 2001). For empirical researches of the demand for money in US, which used this approach, see for example, Hoffman and Rashches (1991) and Baba et al (1992), Hafer and Jansen (1991) and Hafer and Hein (1984). However, Harvey (1997) argues that the cointegration approach being unnecessary or misleading or both, hence there is nothing to keep individual series moving together in the long run. In addition, Harvey (1997) asserts that this is a general shortcoming of pure time series methodologies and in general such models are possibly to have poor statistical properties. Furthermore, for the recent development of money demand, see for example, Duca and VanHoose (2004).

However, most of empirical studies aim to estimate the key elasticities of the demand for money: income and interest rate. Therefore, it is crucial when estimating these elasticities to be reliable and lack of biases and hence, lead to a better understanding of the past and therefore improve the future.

1 It is worth mentioning that cointegration approach allows a deterministic trend.
projections. Therefore, it is essential when modeling the demand for money to include the economic variables and to account for the unobserved variables that might be hard to measure, such as financial innovations and deregulations. For more information about developments of financial market in the US (see, Glennon and Lane (1996). Moreover, they argue that, “the pattern of financial innovation was neither smooth nor continuous. Financial innovations caused major adjustments in demand for monied assets”. p 213. Therefore, it is important to modeling such innovations with adequate proxy that fit with the data and the developments in financial market. Therefore, we may argue that Structural Time Series Model (STSM) introduced by Harvey (1989), allows to model the developments in financial market, hence it permits for a non-linear stochastic trend, which may be a good proxy for such developments.

Arrau et al (1995) declare, “Traditional specifications of money demand often yield parameter estimates that are not economically plausible, are subject to highly autocorrelated errors, and frequently result in persistent over prediction of money demand” (p.318). Moreover, they argue that some of these problems may be due to failure to account for the impact of financial innovation. In addition to that, Arrau et al (1995) find that in all countries irrespective of how it is modeled, financial innovations play a significant role in determining money demand and its fluctuations. And he concludes that the importance of financial innovations in explaining shocks to money demand as well as its variability increases with inflation being present in the case.

Moreover, Lieberman (1977) points out that “technological change could affect the demand for money and regression estimates might be biased if the structural changes due to technological innovations are not taken into account. Even so, researchers have dismissed technological change from their studies, typically relegating their observations to footnotes” (p. 307).

Furthermore, Judd and L. Scandding (1982), conclude “the most likely cause of the observed instability in the demand for money after 1973 is innovation in financial arrangements. These innovations, which allowed the public to economize on its holding of transactions balances” (p. 1014).

Therefore, the aim of this paper is to model the demand for money in the US during the period 1976 to 2007, in away that leads to more reliable and plausible estimates of the economic variables. However, such estimates may rely on the specification of the demand for money function. And hence, it is crucial to include the effect of financial innovation in the money demand- in addition to other economic variables- using the most appropriate way to model it. Traditionally, the effects of financial innovation in the money demand function is modeled using a deterministic trend or dummy variables and even at most ignored it. This study models financial innovation in the demand for money using a STSM that allows the intercept and the slope to vary over time. For the best of our knowledge, there has been no study used this approach to modeling the impact of financial innovation for money demand function in the US.

The plan of the paper is as follows. Section 2 presents econometric methodology. Section 3 discusses the results over alternative of trend (innovation) specification. Finally, Section 4 presents conclusions.

2. Econometric Methodology
Given the discussion above, we assume that the demand for money is specified by the following function

\[ A(L)m_t = \mu_t + B(L)y_t + C(L)r_t + \varepsilon_t \]  

(1)

Where \( A(L) \) is the polynomial lag operator \( 1 - \phi_1 L - \phi_2 L^2 \ldots \phi_p L^p \) and \( B(L) \) is the polynomial lag operator \( \delta_0 + \delta_1 L + \delta_2 L^2 \ldots \delta_p L^p \), and \( C(L) \) the polynomial lag operator \( \pi_0 + \pi_1 L + \pi_2 L^2 \ldots \pi_p L^p \), \( m_t \) is the natural logarithm for appropriate type of real money balance in billion of US$ for the

\(^2\) Contrary to Arrau et al (1995) approach which, allows only the intercept to vary over time.
transaction money demand and broad money demand, $y_t$ is the natural logarithm of Gross Domestic product (GDP) (income), which measured in billion US$ at 2000, and $r$ is the natural logarithm of interest rate in percent. All variables are taken from the database of Federal Reserve Bank of St. Louis (FRED). The long run income and interest rate elasticities are calculated as follows respectively, $B(L)/A(L)$ and $C(L)/A(L)$.

The trend component $\mu_t$ is assumed to consists of level and slope that evolve stochastically as random walks,

$$
\mu_t = \mu_{t-1} + \beta \eta + \eta_t \\
\beta_t = \beta_{t-1} + \zeta
$$

(2)

(3)

Where $\eta_t \sim \text{NID}(0, \sigma^2_\eta)$ and $\zeta_t \sim \text{NID}(0, \sigma^2_\zeta)$. Eq. (2) and (3) indicate the level and the slope of the trend, respectively. While $\sigma_\eta$ and $\sigma_\zeta$ are independent disturbances with variances $\sigma^2_\eta$ and $\sigma^2_\zeta$ respectively. The shape of the underlying trend depends upon the variances (also known as the hyperparameters). The presence of $\sigma_\eta$ permits the level to shift up and down, whereas the existence of $\sigma_\zeta$ allows the slope to evolve. Different shapes of the trend may be found that depend on the variances of the disturbances. First, smooth trend model in which $\sigma^2_\eta=0$, but $\sigma^2_\zeta>0$ allows for stochastic slope. Second, a random walk with drift model in which $\sigma^2_\zeta=0$, but $\sigma^2_\eta>0$. Finally, a deterministic trend which emerges when both $\sigma^2_\eta$ and $\sigma^2_\zeta$ are equal zero. There are a number of alternatives to estimate the stochastic trend depending on the values of the hyperparameters, as illustrated in Harvey (1989).

Moreover, in addition to the stochastic model presented above, two more models were estimated to test the appropriate specification of the trend, which reflects the innovation. Therefore, the trend specifications are summarized as follows.

Model 1: A stochastic trend that depends at least either $\sigma^2_\eta \neq 0$ or $\sigma^2_\zeta \neq 0$.

Model 2: A deterministic linear trend that specified as $\mu_t = \alpha + \beta t$

Model 3: No trend specified $\mu_t = \alpha$

3. **Results**

Table (1) presents an overview of the empirical estimates for narrow money demand M1 for the US over the period 1976 to 2007. The over parameterized model of Equation (1) is estimated using three different specification of the trend.

Model 1, with a stochastic trend specification, passes all the diagnostic tests with no indication of residual serial correlation, non-normality or heteroscedasticity. The estimated hyperparameters of the trend of the level and the slope are not zero, suggesting that both level and slope are stochastic. The preferred specification includes current interest rate variable and it requires the income variable to be lagged two periods. This suggests that almost instantaneous adjustment of narrow money demand to the interest rate change. The estimated long run and interest rate elasticities are 0.479 and −0.241 respectively. The estimated growth value of the trend (innovation) at the end of the period is −1.563%
which indicates that after controlling the effect of income and interest rate, the innovation cause a reduction of narrow money demand by 1.563% each year.

Model 2 with a deterministic linear trend. The estimated narrow money demand model needs three lagged periods of interest rate and two lagged periods of income. However, the model not passes all the diagnostic tests. In addition, it produces a wrong expected economic sign of the interest rate. Comparing Model 1 and Model 2, we may argue on economic ground and statistical ground that the inclusion of a deterministic linear trend is not an appropriate proxy for the innovation. Moreover, it is essential to test for the restriction of the deterministic linear trend on the stochastic trend via the LR test. It clearly indicates that the restriction is not valid. Therefore, the preferred specification is Model 1. Moreover, it seems Model 3 produces almost the same results on economic ground and statistical ground as Model 2.

Table (2) records the estimated results of the broad money demand M2 for the US over the period 1976 to 2007. The specified model of equation 1 is estimated using a stochastic trend and a deterministic trend as proxies for the effect of innovation, also the model is estimated with ignoring the effect of innovation. Therefore, these specifications ease the comparison of the estimated model.

Models 1, with a stochastic trend specification, the misspecification tests reject the existence of serial correlation, heteroscedasticity and non-normality. The estimated hyperparameter of the level is zero but not for the slope, indicating that the stochastic trend variation is via the slope and the preferred model is the smooth trend model. The preferred specification of Equation 1 includes the current interest rate variable and requires the income variable to be lagged two periods. This indicates an instantaneous adjustment of the broad money demand to the interest rate change. The estimated long run income and interest elasticities are 1.295 and –0.10 respectively. The estimated growth value of the trend at the end of the period is +2.01 p.a, which suggest that after controlling the effect of income and interest rate, the innovation cause a shift to the right of the broad money demand function. Hence, the demand for broad money increases by 2.01% each year.

Model 2, with a deterministic trend, the estimated broad money demand is not passes all the diagnostic tests. In addition, it produces a wrong expected economic sign of the income variable. Comparing model 1 and model 2, we may argue that modeling financial innovation in the demand for money by a deterministic trend is not an adequate proxy. Furthermore, a LR test is implemented in order to test the validity of the inclusion of a deterministic linear trend on the stochastic trend. The results of the LR test suggest that the restriction is not valid. Moreover, Model 3 produces insignificant income parameter and positive interest rate parameter, which is opposite to economic theory.

4. Conclusions
This paper’s contribution is to modeling the effect of financial innovation with appropriate proxy in order to obtain plausible estimates for the economic variables. In this paper we have shown the importance of the inclusion the effect of innovation, when estimating the demand for money in its stochastic form. Hence the results show the impact of innovation on the US narrow and broad money demand functions. Therefore, it is crucial to include the effect of financial innovation of its stochastic form in money demand function when implemented monetary policy and to improve the forecasting ability that based on parameters estimates.

| Table 1: The Estimated STSM results for Narrow Money Demand (M1) Functions for the US |
|---|---|---|---|
| Variables | Model 1 | Model 2 | Model 3 |
| $m_{t-1}$ | 0.564** | 0.882** | 0.915** |
| $m_{t-3}$ | -0.465** | -0.190** | -0.140** |
| $r$ | -0.217** | -0.190** |   |
Table 1: The Estimated STSM results for Narrow Money Demand (M1) Functions for the US -continued

| $r_{t-1}$ | 0.243** | 0.237** |
| $r_{t-3}$ | 0.432*** | 0.740** |
| $y_t$ | -0.605** | -0.561** |
| $y_{t-2}$ | Stochastic | Deterministic | No trend |

**Type of the trend**

- Stochastic
- Deterministic
- No trend

**Growth rate at the end of the period**

-1.563 p.a

**Long-run estimate**

- Income ($Y$)
  - 0.479

- Interest rate ($R$)
  - -0.241

**Diagnostics equation residual**

- Standard error
  - 0.019

- Normality
  - 4.418

- Heteroscedasticity
  - H(10) = 1.136

- r(1)
  - -0.027

- r(8)
  - -0.252

- DW
  - 2.10

- Box- Ljung Q
  - $Q_{(8,6)} = 3.760$
  - $Q_{(6,6)} = 27.590$

- $R^2$
  - 0.990

**Estimated Hyperparameters**

- Irregular
  - 0.00

- Level
  - 0.017

- Slope
  - 0.007

- LR tests

**Test $\chi^2(1)$**

- 12.300**

**Estimation period**

- 1976-2007

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Table 2: The Estimated STSM results for Broad Money Demand (M2) Functions for the US

<table>
<thead>
<tr>
<th>Variables</th>
<th>Model 1</th>
<th>Model 2</th>
<th>Model 3</th>
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<tbody>
<tr>
<td>$m_{t-1}$</td>
<td>1.466**</td>
<td>-0.670**</td>
<td>0.878**</td>
</tr>
<tr>
<td>$m_{t-2}$</td>
<td>0.527**</td>
<td>-0.111**</td>
<td>-0.125**</td>
</tr>
<tr>
<td>$m_{t-3}$</td>
<td>-0.293**</td>
<td>-0.125**</td>
<td>0.141**</td>
</tr>
<tr>
<td>$r$</td>
<td>-0.083**</td>
<td>0.107**</td>
<td>0.141**</td>
</tr>
<tr>
<td>$r_{t-1}$</td>
<td>0.063**</td>
<td>0.113</td>
<td></td>
</tr>
<tr>
<td>$r_{t-2}$</td>
<td>0.303*</td>
<td>0.192</td>
<td></td>
</tr>
</tbody>
</table>

**Type of the trend**

- Stochastic
- Deterministic
- No trend

**Growth rate at the end of the period**

- 2.01 p.a

**Long-run estimate**

- Income ($Y$)
  - 1.295

- Interest rate ($R$)
  - -0.10

**Diagnostics equation residual**

- Standard error
  - 0.012

- Normality
  - 3.295

- Heteroscedasticity
  - H(10) = 3.295

- r(1)
  - -0.040

- r(8)
  - -0.064

- DW
  - 1.89

- Box- Ljung Q
  - $Q_{(8,6)} = 6.653$
  - $Q_{(6,6)} = 10.057$

- $R^2$
  - 0.997

**Estimated Hyperparameters**

- Irregular
  - 0.005

- Level
  - 0.000

- 0.016

- 0.000

- 0.023
<table>
<thead>
<tr>
<th>Slope</th>
<th>LR tests</th>
<th>Estimation period</th>
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<tr>
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<tr>
<td>0.008</td>
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</tr>
<tr>
<td>n/a</td>
<td>n/a</td>
<td>1976-2007</td>
</tr>
</tbody>
</table>

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- Normality is the Bowman-Shenton statistic, approximately distributed as $\chi^2$.
- The heteroscedasticity, distributed approximately $F(h,h)$.
- $r(\tau)$ the residual autocorrelation at lag $\tau$, distributed approximately as $N(0,1/T)$.
- DW-Durbin-Watson statistic, distributed approximately as $N(2,4/t)$.
- Q(p,d)- Box-Ljung Q statistic based on the first P residuals autocorrelations and distributed approximately as $\chi^2$.
- $R^2$ is the coefficient of determination.

References


