INVESTIGATING THE IMPACT OF FINANCIAL INNOVATION ON THE VOLATILITY OF THE DEMAND FOR MONEY IN THE UNITED STATED IN THE CONTEXT OF AN ARCH/GARCH MODEL

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Abstract

This paper investigates the effect of financial innovation on real money demand in the United States using GARCH estimation technique between 1990 and 2016. Ratios of broad money stock to GDP and growth in net domestic credit to GDP were included in a conventional money demand function to account for the financial innovation. The results indicate that neither external shocks (financial innovation) nor internal shocks (previous years' information) influence the volatility of the money demand.

Keywords: money demand, ARCH/GARCH, financial innovation, internal/external shock
JEL classification: C13, C40, C51, E40, E44

1. Introduction

Understanding the relationship between money demand and its determinants has always been vital for monetary policy and therefore, has been a focal point for many researchers all over the world. A stable and predictable money demand is a requirement for monetary policy to be effective. Since the introducing of new payment technologies, this traditional money demand relationships have changed making traditional money demand function instable. High auto correlated errors, implausible parameter estimates and persistent over prediction can also be attributed to the ignorance of the rapid growth in financial innovation (Arrau et al., 1995; Judd and Scadding, 1982; Lieberman, 1977). The impact of financial innovation has been very obvious in developing countries (Lieberman, 1977 and Arrau and De Gregorio, 1991). The effect of financial innovation on the demand for money in some developed countries has been attested in studies such as Lippi and Secchi (2009), Attanasio et al. (2002) Arrau and De Gregorio (1993) and Alvarez and Lippi (2009).

This paper investigates the effect of financial innovation on money demand in the United States, using for the period 1990 to 2016 using a totally different approached. It specifies a money demand equation that takes account of financial innovation and estimates it using ARCH/CARCH estimation techniques to evaluate the likely impact of the innovations. Section 2 provides a review of the literature, followed by the model specification and estimation method in section 3. Section 4 presents the results and conclusions are considered in sections 5.

2. Literature review

The quantity of money demanded is linked to the real sector of the economy which is backed by a range of theories (Sriram, 2000). The quantity theory of money, which sees income as the primary determinant of money (Serletis 2007) is the basis for classical economists who claim that money is a medium of exchange and is used primarily for transactions. It is also referred to as transactions theories that include the Baumol-Tobin model, the shopping time model and the cash in advance models. However, Keynes and the

Keynesians argue that money is also used for speculation and therefore, include interest rate in the money demand function to reflect the role of money as a store of value. This view of money is referred to portfolio theories that include the overlapping generation models and the Tobin's theory of liquidity preference.

In empirical work however, income and interest rates both are considered as the main determinants of money demand. In recent years, researchers started to include financial innovation in the money demand function due to its role in in reducing transaction costs. Excluding financial innovation could lead to serious misspecification and an unstable money demand (Arrau et al., 1995; Goldfeld and Sichel, 1990).

Melnik and Yashiv (1994) describe financial innovation as the "introduction of new liquid assets that partially replace traditional money in agent's portfolios, technological progress in banking services that reduces the costs of transactions and changes in the regulatory environment that facilitate transactions." Frame and White (2004) express financial innovation as something new that fulfils participant's demands through reduced costs, reduced risks and improved products. Arrau et al. (1995) see financial innovation as a permanent change to the money demand that is caused by technological processes and not by interest rates and GDP) and Arrau and De Gregorio (1991) describe it to include deregulation as well.

Financial innovations can have either positive impact or negative impact on the money demand depending on the payment instruments. While ATMS/ Debit cards could lead to a decline in demand for cash through reduced transaction costs, the use of cell phone technology does not necessarily reduce cash demand. ATM concentration, bank concentration, M2/M1 and M3/M1 and dummy variables capturing periods of innovation, growth rate in private sector credit are examples of the proxies that have been used by researchers to measure financial innovation indirectly.

Researchers have to use various proxies to measure financial innovation as it is difficult to measure it directly. Lippi and Secchi (2009), Fischer (2007), Sichei and Kamau (2012) and Attanansio et al. (2002) are among those who used ATM concentration as proxy. In order to take shifts in money demand into account, dummy variable was used by Hafer and Kutan (2003). Bank concentration was considered by Nagayasu (2012) while growth in private sector credit as a percent of GDP was used by Michalopoulos et al. (2009). Arrau et al. (1995) used a time trend and a stochastic trend that follows a random walk and Hye (2009) and Mannah-Blankson and Belyne (2004) used M2/M1 for capturing financial innovation. Most of these studies however, indicate that financial innovation has had a negative effect on the demand for money justifying the importance of inclusion of this factor in the money demand specification.

3. Methodology

3.1. Background

3.1.1. ARCH(q) model specification

We suppose the error terms is denoted by ε_t (return residuals, with respect to a mean process) in order to use an ARCH process for modelling a time series. A stochastic piece z_t and a time-dependent standard deviation σ_t are the two components of these ε_t which illustrate the typical size of the terms so that:

$$\varepsilon_t = \sigma_t z_t \qquad (1)$$

z_t is in fact arandom variable z_t with a strong white noise process. We may model the series σ_t^2 by:

$$\sigma_t^2 = \alpha_0 + \alpha_1 \varepsilon_{t-1}^2 + \ldots + \alpha_q \varepsilon_{t-q}^2 = \alpha_0 + \sum_{i=1}^{q} \alpha_i \varepsilon_{t-i}^2 \quad (2)$$

Where $\alpha_0 > 0$ and $\alpha_i \geq 0, i > 0$

Engle (1982) suggested a methodology based on the Lagrange multiplier test to obtain the lag length of ARCH errors as below:

First, we need to estimate the best fitting autoregressive model AR(q).

$$y_t = \alpha_0 + \alpha_1 y_{t-1} + \ldots + \alpha_q y_{t-q} + \varepsilon_t = \alpha_0 + \sum_{i=1}^{q} \alpha_i y_{t-i} + \varepsilon_t (3)$$

Second, the squares of the error $\hat{\varepsilon}^2$ should be obtained and needs to be regressed on a constant and *q* lagged values:

$$\hat{\varepsilon}^2 = \hat{\alpha}_0 + \sum_{i=1}^{q} \hat{\alpha}_i \hat{\varepsilon}_{t-i}^2 \qquad (4)$$

Where *q* is the length of ARCH lags.

Third, α_i = 0 for all *i* = *1, ..., q* when there are no ARCH components which is the null hypothesis. Alternatively, where there are ARCH components, at least one of the estimated α_i coefficients have to be significant. In case of the null hypothesis of no ARCH errors with a sample of *T* residuals, the test statistic $T'R^2$ follows $\mathcal{X}^2$ distribution with *q* degrees of freedom. Here, the number of equations in the model is denoted by T' which fits the residuals versus the lags (i.e. $T' = T - q$). Next, we have to compare $T'R^2$ with the Chi-square table value. There is an ARCH effect in the ARMA model if $T'R^2$ is greater than the Chi-square table value.

3.1.2. GARCH

If we assume an autoregressive moving average model (ARMA) model for the error variance, then it will be a generalized autoregressive conditional heteroskedasticity GARCH (*p*, *q*) model (where *p* is the order of the GARCH terms σ^2 and *q* is the order of the ARCH terms ε^2):

$$y_t = x_t' b + \varepsilon_t \qquad (5)$$

$$\varepsilon_t | \psi_t \sim N(0, \sigma_t^2)$$

$$\sigma_t^2 = \omega + \alpha_1 \varepsilon_{t-1}^2 + \dots + \alpha_q \varepsilon_{t-q}^2 + \beta_1 \sigma_{t-1}^2 + \dots + \beta_p \sigma_{t-p}^2 = \omega + \sum_{i=1}^{q} \alpha_i \varepsilon_{t-i}^2 + \sum_{i=1}^{p} \beta_i \sigma_{t-i}^2 \qquad (6)$$

Generally, the White test is the best for heteroskedasticity. However, when it comes to time series data, it can be interpreted as testing ARCH and GARCH errors.

3.1.3. GARCH (p, q) model specification

We establish the lag length *p* of a GARCH(*p*, *q*) process as follow: First, the best fitting AR(*q*) model has to be estimated:

$$y_t = \alpha_0 + \alpha_1 y_{t-1} + \dots + \alpha_q y_{t-q} + \varepsilon_t = \alpha_0 + \sum_{i=1}^{q} \alpha_i y_{t-i} + \varepsilon_t \, (7)$$

Second, we need to compute and plot the autocorrelations of ε^2 by:

$$\rho = \frac{\sum_{t=i+1}^{T} (\hat{\varepsilon}_t^2 - \hat{\sigma}_t^2)(\hat{\varepsilon}_{t-1}^2 - \hat{\sigma}_{t-1}^2)}{\sum_{t=1}^{T} (\hat{\varepsilon}_t^2 - \hat{\sigma}_t^2)^2} \quad (8)$$

Third, the standard deviation of ρ(*i*) for large samples is $1/\sqrt{T}$. GARCH errors are distinguished when Individual values are larger than the standard deviation of ρ(*i*). We use the Ljung-Box Q-statistic (which follows $\mathcal{X}^2$distribution with *n* degrees of freedom) up to T/4 values of *n* to estimate the total number of lags. Rejecting the null of no ARCH or GARCH errors means that such errors exist in the conditional variance.

3.2. Model specification

The general form of the theory of money demand can be represented as below:

$$\frac{M_t}{P_t} = \Phi(R_t, Y_t) \qquad (9)$$

where M_t is the demand of nominal money balances, P_t is the price index that is used to convert nominal balances to real balances, Y_t is the scale variable relating to activity in the real sector of the economy (here, GDP as the best proxy for such a variable), and R_t is the opportunity cost of holding money (here, the interest rate or IR as the best proxy).

We start the empirical estimation of money demand functions with introducing the long-run, linear function that is of the form

$$LMD_t = \alpha + \beta_1 \, LGDP_t + \beta_2 IR_t + \varepsilon_t \quad (10)$$

Where LMD is the logarithm of real money, LGDP is the logarithm of GDP (scale variable) , and IR is the opportunity cost variable (Serletis, 2007). The expected signs of the coefficients in Equation (13) are positive for GDP and negative for interest rate (i.e. $\beta_1 > 0$, and $\beta_2 < 0$). In addition, the properties of the error sequence (ε_t) are an integral part of the theory. If (ϵ) has a stochastic trend, then the deviation from the money market equilibrium will not be eliminated (Enders, p. 357). This theory assumes that the ε_t sequence is stationary.

The data are annually, from 1960 to 2016. The official website of the World Bank was used as the source of data.

GDP (at purchaser's prices) is the sum of gross value added by all resident producers in the economy plus any product taxes and minus any subsidies not included in the value of the products. It is calculated without making deductions for depreciation of fabricated assets or for depletion and degradation of natural resources. GDP is in constant 2011 international dollars (PPP, purchasing power parity). Dollar figures for GDP are converted from domestic currencies using 2010 official exchange rates.

Real interest rate (expressed as percent) is the lending interest rate adjusted for inflation as measured by the GDP deflator.

Broad money (in constant 2011 international dollars ,PPP) is the sum of currency outside banks; demand deposits other than those of the central government; the time, savings, and foreign currency deposits of resident sectors other than the central government; bank and traveler’s checks; and other securities such as certificates of deposit and commercial paper.

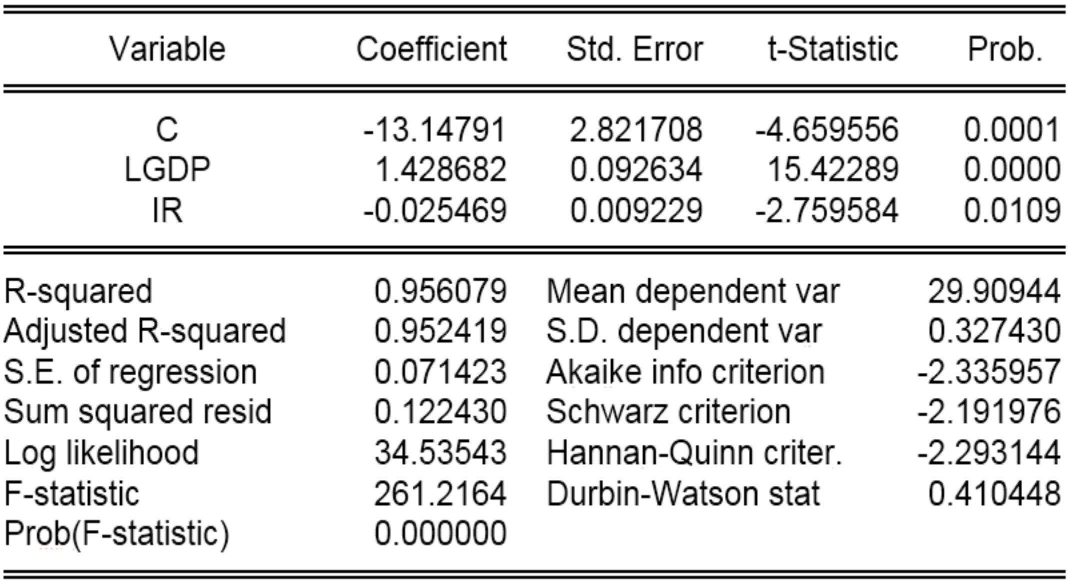
Growth in domestic credit provided by financial sector (% of GDP) and Broad money (% of GDP) are not explicitly included in the money demand function. In the context of an ARCH/GARCH model, we consider them as external shocks to the system. Domestic credit provided by the financial sector is denoted by DC and Broad money (% of GDP) is denoted by MDR in the estimation results.

Domestic credit provided by the financial sector includes all credit to various sectors on a gross basis, with the exception of credit to the central government, which is net. The financial sector includes monetary authorities and deposit money banks, as well as other financial corporations where data are available (including corporations that do not accept transferable deposits but do incur such liabilities as time and savings deposits). Examples of other financial corporations are finance and leasing companies, money lenders, insurance corporations, pension funds, and foreign exchange companies.

4. Estimation

Here, we shall develop a GARCH (2,0) model meaning that there is 2 arch but no garch. The variables are all stationary. However, there are two more conditions for developing such a model. First, there should be clustering volatility and second, there should be arch effect. We investigate these two conditions one by one. In order to do that, first we need to estimate the model.

Table 1: Estimation results

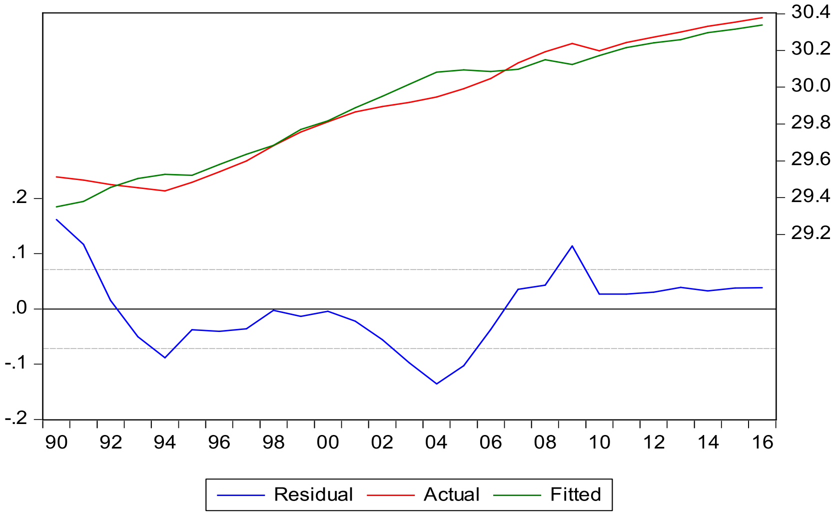


Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-13.14791	2.821708	-4.659556	0.0001
LGDP	1.428682	0.092634	15.42289	0.0000
IR	-0.025469	0.009229	-2.759584	0.0109

R-squared	0.956079	Mean dependent var	29.90944
Adjusted R-squared	0.952419	S.D. dependent var	0.327430
S.E. of regression	0.071423	Akaike info criterion	-2.335957
Sum squared resid	0.122430	Schwarz criterion	-2.191976
Log likelihood	34.53543	Hannan-Quinn criter.	-2.293144
F-statistic	261.2164	Durbin-Watson stat	0.410448
Prob(F-statistic)	0.000000		

Estimated coefficients are all significant and bear the expected signs. Addusted R-squared is high and Prob (F-statistic) indicate that the regression is overall significant. Now, we check the residuals of the model.

Figure 1: Residuals of the estimated model



Here, we note that a period of high volatility (1990-1994) is followed by a period of low volatility (1994-2000) then comes another period of high volatility (2000-2010) followed by the second period of low volatility (2011-2016). It justifies the clustering volatility meaning that the first requirement to run a garch model is met. We double check this result by using ARCH test to find out whether or not there is arch effect.

Table 2: Heteroskedasticity Test: ARCH

F-statistic	7.268462	Prob. F(1,24)	0.0126
Obs*R-squared	6.043790	Prob. Chi-Square(1)	0.0140

Prob. Chi-Square of 0.0140 which is less than 0.05 indicates that there is arch effect as we can reject the null hypothesis that states there is no arch effect. Now that the requirements are met, we can run the ARCH/GARCH model.

Table 3: Estimation of GARCH model

Variable	Coefficient	Std. Error	z-Statistic	Prob.
C	-13.12007	0.150310	-87.28664	0.0000
LGDP	1.429726	0.004524	316.0348	0.0000
IR	-0.036322	0.007224	-5.028028	0.0000
Variance Equation				
C	0.002990	0.005611	0.532931	0.5941
RESID(-1)^2	0.689508	0.756346	0.911631	0.3620
RESID(-2)^2	0.012504	0.182861	0.068382	0.9455
MDR	-2.80E-05	6.56E-05	-0.426450	0.6698
DC	9.88E-05	0.000110	0.901900	0.3671
T-DIST. DOF	127.0292	9000.025	0.014114	0.9887

R-squared	0.948770	Mean dependent var	29.90944
Adjusted R-squared	0.944501	S.D. dependent var	0.327430
S.E. of regression	0.077137	Akaike info criterion	-2.568863
Sum squared resid	0.142801	Schwarz criterion	-2.136917
Log likelihood	43.67965	Hannan-Quinn criter.	-2.440423
Durbin-Watson stat	0.466585		

The upper section of the table above id the mean model and the lower section concludes the variance model which is the GARCH model that can be expressed as:

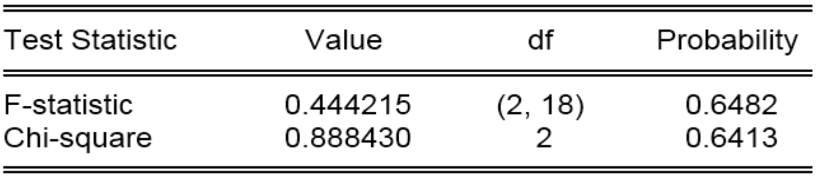
GARCH = C(4) + C(5)*RESID(-1)^2 + C(6)*RESID(-2)^2 + C(7)*MDR + C(8)*DC

This GARCH is in fact the variance of the residuals of the money demand which has been derived from the mean model. RESID(-1)^2 and RESID(-2)^2 indicate arch(1) and arch(2) effects, respectively. However, there is no garch effect. That is because, it is basically a GARCH (2,0) as mentioned before. As we see from table 3, neither RESID(-1)^2 nor RESID(-2)^2 are significant meaning that previous years' information (information in t-1 and t-2 perods) about money demand volatility cannot influence it. In other words, RESID(-1)^2 and RESID(-2)^2 which represent internal causes do not affect the volatility of the demand for money.

Now, we check if external volatilities can influence the volatility of the money demand. MDR (Broad money expressed as % of GDP) and DC (Domestic credit provided by financial sector expressed as % of GDP) are external or outside shocks. From table 3, we note that none of these external shocks have impacted the volatility of the money demand either.

Nest, we check if internal shocks (RESID(-1)^2 and RESID(-2)^2) jointly can influence the volatility of the money demand. In order to do so, we use Wald test as below.

Table 4: Wald test

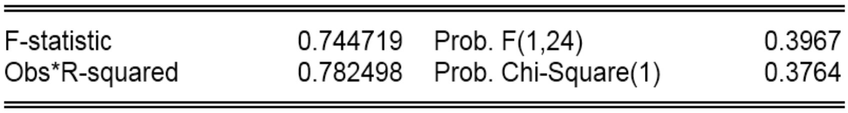


Test Statistic	Value	df	Probability
F-statistic	0.444215	(2, 18)	0.6482
Chi-square	0.888430	2	0.6413

Chi-square probability of 0.6413 which is greater than 0.05 indicate that we cannot reject the Null Hypothesis: C(5)=C(6)=0 meaning that internal shocks jointly do not affect the volatility of the money demand. In other words, arch(1) and arch(2) jointly cannot influence the volatility of the money demand.

Now, we have to check whether our GARCH(2,0) model that we have estimated, has ARCH affect and serial correlation or not. First, we check for the arch affect.

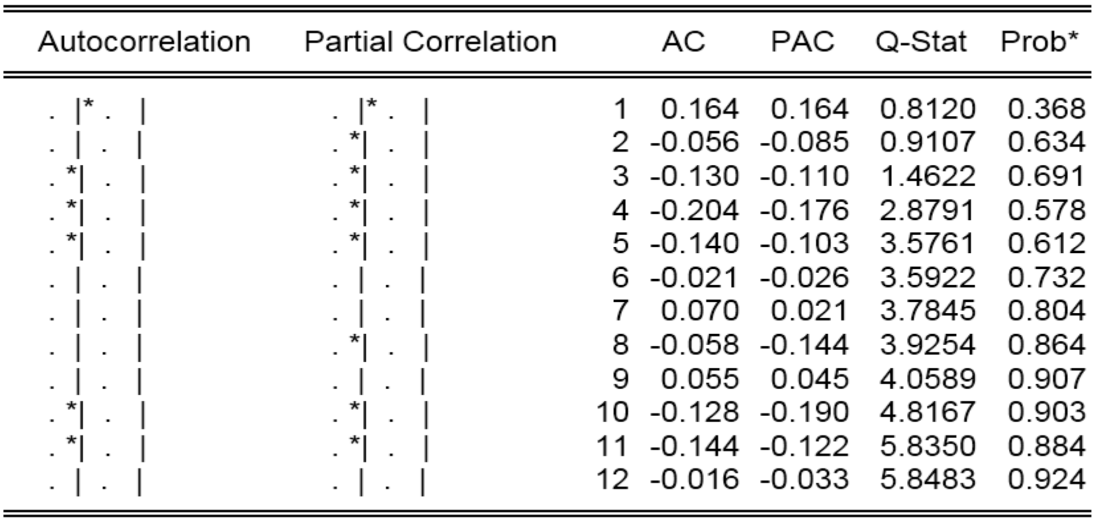
Table 5: Heteroskedasticity Test: ARCH



F-statistic	0.744719	Prob. F(1,24)	0.3967
Obs*R-squared	0.782498	Prob. Chi-Square(1)	0.3764

Prob. Chi-Square above indicate that we cannot reject the null hypothesis of no heteroskedasticity meaning that there is no arch affect. Fortunately, this outcome is in line with the result that internal shocks do not affect the volatility of the money demand meaning that there is no arch affect. Now we check the serial correlation to make sure that our estimated model is free from this statistical issue. This rest us assured that the results are valid.

Table 6: Serial correlation detection



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Autocorrelation      Partial Correlation         AC      PAC    Q-Stat   Prob*

  .  |* .  |          .  |* .  |            1   0.164   0.164   0.8120   0.368
  .  |  .  |          . *|  .  |            2  -0.056  -0.085   0.9107   0.634
  . *|  .  |          . *|  .  |            3  -0.130  -0.110   1.4622   0.691
  . *|  .  |          . *|  .  |            4  -0.204  -0.176   2.8791   0.578
  . *|  .  |          . *|  .  |            5  -0.140  -0.103   3.5761   0.612
  .  |  .  |          .  |  .  |            6  -0.021  -0.026   3.5922   0.732
  .  |  .  |          .  |  .  |            7   0.070   0.021   3.7845   0.804
  .  |  .  |          . *|  .  |            8  -0.058  -0.144   3.9254   0.864
  .  |  .  |          .  |  .  |            9   0.055   0.045   4.0589   0.907
  . *|  .  |          . *|  .  |           10  -0.128  -0.190   4.8167   0.903
  . *|  .  |          . *|  .  |           11  -0.144  -0.122   5.8350   0.884
  .  |  .  |          .  |  .  |           12  -0.016  -0.033   5.8483   0.924
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The p-values are all more than %5 meaning that we cannot reject null hypothesis (stating that there is no serial correlation). In other words, we conclude that there is no serial correlations.

5. Conclusion

This paper investigates the effect of financial innovation on money demand in the United States using GARCH estimation techniques between 1990 and 2016. We use a conventional money demand function with real GDP (gross domestic product as the scale variable) and real IR (interest rate as the opportunity cost of money). Ratios of broad money stock to GDP and growth in net domestic credit to GDP were included in the money demand function in the context of a GARCH model to account for the financial innovation (external shocks). Internal shocks conclude the previous years' information (information in period t-1 and period t-2) about the volatility of the real demand for money. The results indicate that while estimated coefficients of GDP and IR are all significant and bear the expected signs, neither external shocks (financial innovation) nor internal shocks (previous years' information) influence the volatility of the money demand in the United States during 1990-2016.

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