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INVESTIGATING THE RELATIONSHIP BETWEEN FINANCIAL INNOVATION AND MONEY DEMAND IN MALAYSIA: AN ARDL APPROACH TO CO-INTEGRATION

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Abstract: *Given the recent financial innovation developments in Malaysia, we are eager to find out if the demand for money is still stable. Given that there has been no previous study on money demand in Malaysia with a focus on different systems and using the most recent data, this paper contributes to the relevant literature by estimating the Malaysian money demand including financial innovation proxies in three different systems: payment instrument (credit card, charge card, debit card, e-money), payment system (RENTAS, Interbank GIRO, FPX and Debit Card) and payment channel (ATM, Mobile Banking, Internet Banking). The relationship between these new innovations and money demand will be investigated one by one. In this paper, we will attempt to answer key questions as follow: 1) if demand for money in Malaysia is stable, 2) if it is stable, estimating short-run and long-run coefficients of the variables that are used as proxies for the financial innovations, and 3) obtaining the speed of adjustment towards long-run equilibrium. The results indicate that only two of these financial variables (charge card, FPX and Direct Debit) for whome the error correction term was negative and significant have a positive and significant impact on the demand for money in the long-run.*

Keywords: *Malaysia, Money Demand, Financial Innovations, Stability, ARDL, Cointegration*

Introduction

Before introducing financial innovations in the mid-1970s, most of studies used to conclude a stable money demand, using only interest rate and output (Goldfeld & Sichel, 1990). However, after introducing financial innovation, this is not the case anymore. Arrau and Gregorio (1993), Ireland (1995), Arrau et al. (1995), Attanasio et al. (2002), Hafer and Kutan (2003), Mannah-Blankson and Belyne (2004), Alvarez and Lippi (2009), Hye (2009) and Nagayasu (2012) have analyzed money demand with inclusion of financial innovation.

New payment technologies have helped individuals to move away from holding cash to assets by using ATMs, Debit cards, Internet banking, mobile banking, ect.[1] Very few studies have investigated the effect of financial innovation on money demand in Malaysia. Another examples of these few studies is that of Eu Chye Tan (1997) who concluded a stable long run yet unstable short run money demand in the presence of liberalization and innovation in the Malaysian financial system.

The traditional theories of money demand with income and interest rates as the main determinants of money demand misses an important element called financial innovation (such as new payment instruments). Due to recent growth of financial innovations, it is playing an increasing role in determining the level of the demand for money. Ignoring these innovations could lead to misspecification of the money demand (Arrau et al, 1995) and therefore, unstable money demand (Goldfeld and Sichel, 1990) and unpredictable changes in the money demand (Hafer and Kutan, 2003). Issues such as autocorrelated errors, persistent over prediction, implausible parameter estimates and biased money demand results occurs as a result of excluding financial innovation in the money demand specification (Arrau et al, 1995 and Lieberman, 1977). Judd and Scadding (1982) state that financial innovation help to reduce transaction costs which justifies the necessity to capture financial innovation in the money demand specification. Including a proxy for financial innovation in the traditional (conventional) money demand function solves the problem of shift in the money demand as a result of this innovation.

Investigating the stability of the demand for money and the short-run and long-run dynamics of the money demand function money in Malaysia is the focus of this study. Introducing new payment systems and instruments (payment instruments such as credit card or charge card and payment systems such as Interbank Giro or FPX and Direct Debit) definitely have significant impact on the stability of the money demand function. Ignoring these innovations leads to biased or misleading estimates of the money demand equation. Deriving speed of adjustment with regards to each variable proxying the effect of a specific innovation is an important issue that needs to be addressed. Policy makers need to know how long it takes for equilibrium to be restored in this dynamic model depending on each innovation. Short-run effect of these innovation is another question that has to be answered in a dynamic analysis.

The general objective is to find out if demand for money in Malaysia is stable, to estimate short-run and long-run coefficients of the variables that are used as proxies for the financial innovations, and to obtain the speed of adjustment towards long-run equilibrium. Payment instruments include Cheques, Credit cards, Charge cards, Debit cards. Payment systems include Direct Debit and Financial Process Exchange, Interbank GIRO and RENTAS. Payment channels include Internet banking, Mobile banking, Automated Teller Machines. We include financial innovations in the model one by one and estimate the model.

[1] Such as charge cards, credit cards, e-money.

There are many questions involved in this study. However, the most important of all can be classified as bellow which help to answer this question if financial innovation plays a crucial role in explaining money demand in Malaysia as it has important implications for future policy design which is of great interest to central bank authorities: 1) If there is short-run causality running from financial variables to money demand? 2) If there is long-run causality running from financial variables to money demand? 3) How long does it take for the dynamic model when it includes financial variable(s) to restore equilibrium? In other words, how long does it take for the whole system (including financial variable(s) to get back to the long-run equilibrium? 4) Which financial variables have the biggest/smallest impact on money demand in the short-run/long-run? And 5) Which financial variables have positive/negative impact on money demand in the long-run/long-run?

This research is an attempt to close the gap between previous studies and the need for an updated research with the use of the most recent data that covers selected countries for which there has been no previous similar studies. This research is also of utmost importance as it investigates the sources of the instability of the demand for money to enable us to determine the effectiveness of monetary policy. The existence of a stable demand function is important for the conduct of monetary policy. Therefore, it is essential to know if money demand function is unstable due to the introducing new payment technologies as it helps policy makers to choose appropriate instruments for conducting monetary policy. If these financial innovations have impacted the demand for money, then it is justified to conduct macro-economic stabilization through regulating the growth of the money supply and interest rate changes. As such this research project will be of importance to monetary policy makers at Central Banks.

While most research has yielded great insight to the money demand literature, a vital question that is worth investigating is if the demand for money is still stable given the recent financial innovation developments in Malaysia. Given the limited number of studies on money demand in Malaysia, this paper contributes to the relevant literature by estimating the Malaysian money demand including financial innovation proxies in three different systems: payment instrument, PI (credit card, charge card, debit card, e-money), payment system, PS (RENTAS, Interbank GIRO, FPX and Debit Card) and payment channel, PC (ATM, Mobile Banking, Internet Banking). This study hopes to shed some light on the relationship between these new innovations and money demand one by one. Also, this study is likely to inform policy makers and guide their decision making particularly in terms of monetary policy.

In this paper, we will attempt to answer key questions as follow: 1) if demand for money in Malaysia is stable, 2) if it is stable, estimating short-run and long-run coefficients of the variables that are used as proxies for the financial innovations, and 3) obtaining the speed of adjustment towards long-run equilibrium. Next, we review the theoretical and empirical literature followed by a brief overview of the conventional demand for money and econometric approach (methodology). Data presentation, model specification and the estimation results will appear next and it ends up with summary.

Literature review

The instability of the money demand function could be a consequence of the effect of financial innovations. Muscatgelli & Spinelli (2000) for Italy, Karfakis & Sidiropoulos (2000) for Greece, Greene (2002) for U.S., Bahmani-Oskooee & Chomsisengphet (2002) for eleven developed countries, Narayasu (2003) for Japan, Hacker & Hatemj-J (2005) for Sweden are examples of the studies that applied modern econometric techniques of time series, cointegration and error-correction model to investigate stability of the money demand function. Sriram (2002) for Malaysia, Pradhan and Subramanian (2003) for India, Cheong

(2003) for Korea, Gabriel, et al. (2003) for Portugal, Wu et al. (2005) for Taiwan, Bahmani-Oskooee & Rehman (2005) for six Asia developing countries, Bjornladn (2005) for Venezuela focused on whether or not financial liberalization in developing countries caused money demand unstable. However, the studies on the stability of the demand for money have not been conclusive.

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.

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.

Among major studies, we highlight those that focused on applying ARDL method. The nost important of all can be mentioned as follow. Akinlo (2006) used quarterly data (1970:1–2002:4) by applying ARDL approach along with CUSUM and CUSUMSQ tests for Nigeria and concluded that M2 was cointegrated with income, interest rate and exchange rate and it was somewhat stable using CUSUM test. Samreth (2008) estimated the money demand function for Cambodia using monthly data over the period 1994:12-2006:12 by applying ARDL approach and showed that there was a cointegrating relationship between M1, Industrial Production Index, Consumer Price Index, and Nominal Exchange Rate in money demand function and that money demand function was stable (using CUSUM and CUSUMSQ tests). Long and Samreth (2008) examined if short and long run monetary models of exchange rate is valid for monetary exchange rate model of the Philippines using ARDL approach and showed that there was both short and long run relationships between variables in the monetary exchange rate model and that the estimated parameters were stable. Baharumshah, et al. (2009) studied M2 in China using quarterly data over the period 1990:4 &2007:2 by applying ARDL approach to cointegration and concluded that there was a stable, long-run relationship between M2 and real income, inflation, foreign interest rates and stock prices. Achsani (2010) applied the vector error correction model (VECM) and autoregressive distributed lag (ARDL) approach to examine the M2 money demand for Indonesia using quarterly data during 1990:1-2008:3 and showed that for the purpose of predicting stable money demand function of Indonesia, the ARDL model was more appropriate compared to VECM. Ndirangu and Nyamongo (2015) employed the ARDL approach to cointegration for Kenya and used the currency outside banks/time deposit ratio as a proxy for financial development. They were among those few who accounted for financial innovation in the money demand specification.

Ndirangu and Nyamongo (2015) are among those few who attempt to account for financial innovation in the money demand specification by employing the ARDL approach to cointegration for Kenya. They used the currency outside banks/time deposit ratio as a proxy for financial development. The current study overcomes this limitation by incorporating financial innovation in the money demand specification using separate measures of payment instruments (credit card, charge card, debit card, e-money), payment channels (RENTAS, Interbank GIRO, FPX and direct debit) and payment channels (ATM, mobile banking, Internet banking) to capture the effect of financial innovations.

In this section, we are trying to address key issues as follow. 1) To examine the empirical relationship between M2 nominal monetary aggregates, nominal income, nominal interest rate and the numbers of automated teller machines using ARDL cointegration model. 2) To determine the stability of M2 money demand function. 3) To examine the long-run stability of the nominal money demand function.

Financial Innovations in Malaysia

Innovations in payment systems in Malaysia

Huge cost savings (up to 1% of GDP) can be achieved by migrating from paper-based payments to electronic payments. Improved efficiency of the payment system due to these innovations will enhance the efficiency to the entire economy. Manual processing of cash and cheques requires a huge amount of resources while electronic payments does not. Electronic payment help improve productivity levels and lower the cost of doing business. Moreover, extended financial services to the unbanked communities as a result of using electronic payments will enable them to benefit from lower cost of financial services. More intensive use of electronic payments plays a vital role in achieving higher economic growth and improving the competitiveness of the economy.

Bank Negara Malaysia (BNM) aims at fostering the country's migration to electronic payments to achieve the cost savings and therefore, to increase the efficiency of the payment systems. According to Financial Sector Blueprint 2011-2020 released by BNM, enhanced use of electronic payment is recognized as one of nine focus areas to drive Malaysia's transition to a high-income economy. The Bank' agenda is summarized in table (1).

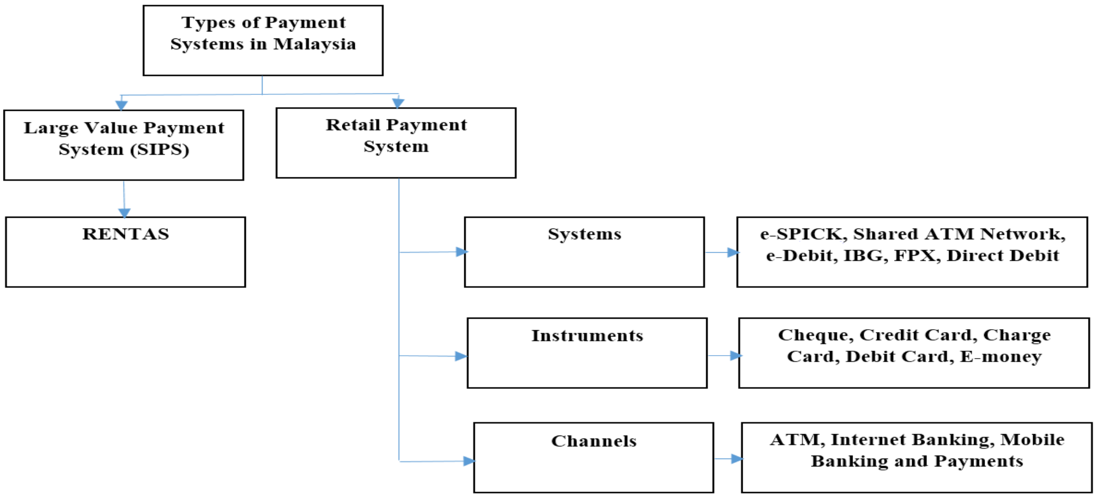
Table 1: Key Performance Indicators

Indicators	Target by 2020
E-payment transactions per capita	200
Debit card transactions per capita	30
No. of EFTPOS terminals per 1,000 inhabitant	25
Number of cheques cleared	100 million

Source: Bank Negara Malaysia

The Bank and the payments industry have been working together to remove barriers to greater adoption of electronic payments, and to ensure the smooth transition to electronic payments by improving the infrastructure to provide a platform for greater use of Internet banking services and debit card as a convenient substitute for cash and as a more cost-efficient payment instrument. As a result of these efforts, the number of electronic payment transactions made per capita increased from 14.3 in 2003 to 56 transactions in 2012, and that more than 80% of retail payment transactions are conducted electronically. In order to accelerate the transition to electronic payments, it is advised to encourage the public to use electronic payment methods.

Figure 1: Payment Systems In Malaysia



Source: Bank Negara Malaysia

Malaysian Payment Systems

In Malaysia, the large value payment system, RENTAS (Real Time Electronics Transfer of Funds and Securities), enables the transfer and settlement of high-value interbank payments and securities. Malaysian Electronic Clearing Corporation Sdn. Bhd. (MyClear) (owned by Bank Negara Malaysia) operates RENTAS which allows transactions to be completed safely and in a timely manner that in turn contributes to the overall economic performance.

In general, the retail payments in Malaysia can be divided into three - Retail Payment Systems, Retail Payment Instruments and Retail Payment Channels.

Types of retail payment systems includes: 1) National Electronic Cheque Information Clearing System (eSPICK), 2) Shared ATM Network, Interbank GIRO, 3) Financial Process Exchange, and 4).

Types of retail payment instruments includes: 1) Cheques, 2) Credit cards, 3) Charge cards, 4) Debit cards, and 5) E-money.

Types of retail payment channels includes: 1) Internet banking, 2) Mobile banking, 3) Mobile payment.

InterBank GIRO: The Interbank GIRO (IBG) refers to a payment system that provides funds transfer services amongst its participating financial institutions.

Direct Debit: Direct debit, which is operated by MyClear Sdn Bhd, is an interbank collection service for regular and recurring payments enabling automated collection directly from a customer’s bank account at multiple banks with a single authorization.

Financial Process Exchange: Financial Process Exchange (FPX) offer online payment for electronic commerce (e-commerce) transactions. It an Internet-based multi-bank payment platform that leverages on the Internet banking services of banking institutions.

Types of retail payment instruments include the following:

Cheques: A cheque is a paper-based payment instrument. It is a form of written order directing a bank to pay money to the beneficiary.

Credit Cards: Buying goods and services is made possible by credit cards with a credit line given by credit card issuer. Payments for the transactions using credit cards will be settled at a later date.

Charge Cards: The functionality of a charge card is similar to a credit card. However, charge card holders must settle their outstanding amount in full by the due date every month.

Debit Cards: A debit card is a payment card where the transaction amount is deducted directly from the cardholder's bank account upon authorisation.

E-money: E-money is a payment instrument that contains monetary value that has been paid in advance by the user. E-money users can use their e-money to purchase goods and services from merchants. When users pay using e-money, the amount will be automatically deducted from their e-money balance. E-money is accessible via the internet and mobile phones.

Types of retail payment channels include the following:

Internet Banking: a computer with Internet access, a web browser and a registered account for Internet banking service from one’s banking institution are all that Internet Banking needs for performing common banking transactions in a fast and convenient way.

Mobile Banking: Mobile banking is similar to Internet banking in that it needs a mobile phone (instead of computer) that is equipped with the features required by one’s bank that provides this service.

Mobile Payment: Mobile payment allows individuals to make payments to selected merchants by using his/her mobile phones provided he/she has registered and opened an account with mobile payment service providers.[2]

Methodology

Theoretical Approach: Conventional Demand for Money Function

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

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

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 as the best proxy). We start the empirical estimation of money demand functions with introducing the long-run, log linear function that is of the form

$$\text{Log}\ (\frac{M_t^*}{P_t}) = \alpha + \beta_1 \log Y_t + \beta_2 R_t + \varepsilon_t$$

[2] Bank Negara Malaysia

Desired stock of nominal money is denoted by M^*, P is the price index that we use to convert nominal balances to real balances, Y is the scale variable, and R is the opportunity cost variable. The conventional money demand $M^d = (Y_t, R_t)$ is misspecified and leads to the bias that gets into the estimated coefficients. Therefore, it has to be enriched with financial innovation (r*) so that it can be represented implicitly as $M^d = (Y_t, R_t, r^*)$, (Serletis, 2007) that is:

$$\text{Log}\left(\frac{M_t^*}{P_t}\right) = \alpha + \beta_1 \log Y_t + \beta_2 R_t + \beta_3 r_t^* + \varepsilon_t$$

The coefficient of interest β_3 which represents the effect of financial innovation on money demand is expected to be negative according to most of the literature on financial innovation (see Arrau et al (1995), Lippi and Secchi (2009) and Attanasio et al (2002)) although a few studies such as Hye (2009) and Mannah-Blankson and Belyne (2004) do indicate a positive relationship. The coefficients on income β_1 and the Treasury bill rate β_2 are expected to be positive and negative respectively as money demand theory predicts. The data are quarterly, from 2008(Q1) to 2015(Q4).

The conventional theory of demand for money is the basis for this specification. We use a traditional specification of the conventional demand for money using ARDL model where $\left(\frac{M_t^*}{P_t}\right)$ which is M2 denotes nominal demand for money, GDP denotes nominal gross domestic product, R is the nominal interest rate (tressury bill), Financial Innovation is the proxy for capturing the effect of financial innovations on the demand for money, and e_t is the error term. Data is collected from the official website of the Bank Negara Malaysia (BNM).

The study follows a traditional money demand specification by Holly (1999), Rinaldi (2001), Anderson-Reid (2008), Hamori (2008), Hataiseree (2010), Rauf and Khan (2012), Oyelami and Yinusa (2013), Kasekende (2016), ect.

Inflation has been used as a proxy for the opportunity cost of holding money by Suliman and Dafaalla (2011) for Sudan and Bahmani-Oskooee and Gelan (2009) for several African countries and Salisu et al (2013). This is due to limited financial markets, lack of well-regulated interest rates and shortage of data on interest rates.

As some researchers (Tahir 1995; Sriram 1999; and Bahmani-Oskooee and Gelan, 2009) state, inflation is often used as a proxy for the opportunity cost of holding money because of limited financial markets, lack of well-regulated interest rates and shortage of data on interest rates. Fortunately, we had access to data on interest rate for Malaysia and other countries under investigation (in appendices) so we did not need to include this variable in our models.

Econometric Approach: Autoregressive Distributed Lag (ARDL) Models

The need of incorporating I(0) and I(1) variables in same estimation was addressed by Pesaran et al. (2001) who introduced ARDL. If the variables are all stationary I (0) then OLS is suitable and if they are all non-stationary I (1) then VECM (Johanson Approach) is recommended. Conventional OLS is not appropriate if at least one variable is I (1). Due to the fact that non-stationary variables change in time, OLS estimates show high t values by mistake as they become inflated due to common time component. Also, R square of the model becomes higher than the Durban Watson Statistic. ARDL is offered as a solution to this problem by containing lags of both the dependent variable and independent variables as regressors (Greene, 2008) and provides answer to the question if long-run money demand of Malaysia can be influenced by the impact of financial innovation during 2008 Q1-2015 Q2. It has the capability of examining long-run and cointegrating relationships among variables (M Hashem Pesaran, Shin, & Smith, 1999) which gives it an advantage edge over other single equation cointegration procedures.

ARDL is able to estimate the long and short-run parameters of the model simultaneously yet avoid the problems posed by non-stationary data. Also, there is no need to determine the order of the integration amongst the variables in advance. Other approaches, however, do require that the variables have the same order of integration. In addition, it is statistically much more significant approach for the determination of the cointegration relationship in small samples, while allowing different optimal lags of variables. We show that some proxies for financial innovation do have a positive long run impact on money demand in this sample while others don't. There has been no general consensus over the last several decades about the link between financial innovation and money demand. There is no way to say for sure if this relationship is positive or negative. Recent empirical studies offer contradictory evidence. As a result, the current verdict on the financial innovation-money demand relationship has remained inconclusive.

An ARDL is a least squares regression containing lags of the dependent and explanatory variables. ARDLs are usually denoted with the notation ARDL ($p, q_1, \ldots, q_k$), where p is the number of lags of the dependent variable, q_1 is the number of lags of the first explanatory variable, and q_k is the number of lags of the kth explanatory variable.

An ARDL model may be written as:

$$y_t = \alpha + \sum_{i=1}^{p} \gamma_i y_{t-i} + \sum_{j=1}^{k} \sum_{i=0}^{q_j} X'_{j,t-i} \beta_{j,i} + \epsilon_i$$

Some of the explanatory variables, x_j, may have no lagged terms in the model (q_j=0). These variables are called static or fixed regressors. Explanatory variables with at least one lagged term are called dynamic regressors. To specify an ARDL model, you must determine how many lags of each variable should be included (i.e. specify p and $q_1, \ldots, q_k$). Fortunately, simple model selection procedures are available for determining these lag lengths. Since an ARDL model can be estimated via least squares regression, standard Akaike, Schwarz and Hannan-Quinn information criteria may be used for model selection. Alternatively, one could employ the adjusted R^2 from the various least square's regressions.

"ARDL" stands for "Autoregressive-Distributed Lag". Researchers have used these regression models for decades, but only recently, they proved to be very useful for testing cointegration, and estimating long-run and short-run dynamics no matter if the variables are stationary or non-stationary. It can include a mixture of both. An ARDL regression model in the basic form can be expressed as below:

$$y_t = \beta_0 + \beta_1 y_{t-1} + \ldots + \beta_p y_{t-p} + \alpha_0 x_t + \alpha_1 x_{t-1} + \alpha_2 x_{t-2} + \ldots + \alpha_q x_{t-q} + \varepsilon_t$$

where ε_t is a random "disturbance" term? The model is "autoregressive", in the sense that y_t (here y_t is MOD which is the money demand) is "explained (in part) by lagged values of itself. It also has a "distributed lag" component, in the form of successive lags of the "x" (here x is GDP, IR and FD, that are gross domestic product, interest rate and the variable that is used as proxy for financial innovation, respectively) explanatory variable. We call the model above ARDL(p,q). Regarding the fact that we have lagged values of the dependent variable as regressors in this model, it will produce *biased* coefficient estimates if we attempt to estimate it by OLS. If the disturbance term, ε_t, is autocorrelated, then Instrumental Variables estimation has to be applied as the OLS will lead to an *inconsistent* estimation.

First, recall the model above:

$$y_t = \beta_0 + \beta_1 y_{t-1} + \ldots + \beta_p y_{t-p} + \alpha_0 x_t + \alpha_1 x_{t-1} + \alpha_2 x_{t-2} + \ldots + \alpha_q x_{t-q} + \varepsilon_t \quad (1)$$

where ε_t is a random "disturbance" term, that is assumed to be serially independent? Because there are both differences and levels of the series, this model need to be modified. In dealing with the estimation of this model, we may face different possibilities as follow: 1) All of the series are I (0), and hence stationary. In this case, which is the simplest case, an OLS estimation can be applied using data in their levels, 2) All of the series are integrated of the same order (e.g., I (1)), but they are not cointegrated. In this case, an OLS estimation can be applied using data in their differenced and not their level, 3) All of the series are integrated of the same order, and they are cointegrated. In this case, two approaches can be considered: (i) OLS estimation using data in their levels that yields the long-run equilibrating relationship between the variables. (ii) OLS estimation using an error-correction model (ECM) that represents the short-run dynamics of the relationship between the variables, and 4) Some of the variables may be stationary, some maybe I (1) and it is also possible that some of the I (1) variables are cointegrated. It is the most complicated case. This is the case where we need to apply ARDL model developed by Pesaran and Shin (1999) and Pesaran et al. (2001) to obtain both long-run and short-run relationships. The advantages of the ARDL / Bounds Testing methodology over conventional cointegration testing are as follow: 1) series that are integrated of the different orders such as I (0) and I (1) can be used, 2) The model constitutes of a single equation that makes it easy to implement and interpret, 3) We can assign different lag-lengths to different variables.

In order to estimate ARDL model, we need to follow 10 steps: 1) doing unit root test to make sure none of the variables are I(2), 2) formulating a model with lagged difference and one lagged level of the variables, 3) finding the optimum lag using AIC/SC criterion and estimating the model using this optimum lag, 4) making sure that the errors of this model are serially uncorrelated, 5) making sure that the model is dynamically stable, 6) performing Bound Test to see if there is evidence of a long-run relationship between variables, 7) estimating the long-run model and obtaining the error correction term if the outcome of the previous step is positive, 8) estimating lagged model using this error correction term. In other words, estimate the long-run equilibrium relationship between the variables, 9) making sure that the errors of this model are serially uncorrelated and that the model is dynamically stable and 10) using the results of the model estimated in previous step to measure short-run dynamics effects (testing the causality running from independent variable to dependent variable one by one) and estimating the long-run equilibrating relationship between the variables (or simply long-run coefficients).

A generic ARDL model consists of lags of the dependent variable, and lags (and maybe the current value) of the regressors. We assume that our model consists of a dependent variable, y, and two other explanatory variables, x_1 and x_2. Generally speaking, there will be (k + 1) variables, that is a dependent variable and k explanatory variables. A conventional ECM for cointegrated data is of the form:

$$\Delta y_t = \beta_0 + \Sigma\beta_i \Delta y_{t-i} + \Sigma\gamma_1 \Delta x_{1t-j} + \Sigma\delta_k \Delta x_{2t-k} + \varphi z_{t-1} + e_t \quad (2)$$

Here, z, the "error-correction term", is the OLS residuals series from the long-run "cointegrating regression",

$y_t = \alpha_0 + \alpha_1 x_{1t} + \alpha_2 x_{2t} + v_t$ (3)

The ranges of summation in (1) are from 1 to p, 0 to q_1, and 0 to q_2 respectively. Now, we start to follow the required steps for the estimation:

Step1: We use the ADF test to make sure that none of the series are I(2).

Step 2: We formulate the following model:

$$\Delta y_t = \beta_0 + \Sigma\beta_i \Delta y_{t-i} + \Sigma\gamma_1 \Delta x_{1t-j} + \Sigma\delta_k \Delta x_{2t-k} + \theta_0 y_{t-1} + \theta_1 x_{1t-1} + \theta_2 x_{2t-1} + e_t \quad (4)$$

This model pretty much resembles a traditional ECM with the difference that the error-correction term, z_{t-1} was replaced with the terms y_{t-1}, x_{1t-1}, and x_{2t-1}. From (3), it can be seen that the lagged residuals series is $z_{t-1} = (y_{t-1} - \alpha_0 - \alpha_1 x_{1t-1} - \alpha_2 x_{2t-1})$, where the α's are the OLS estimates of the α's. Therefore, in equation (4) we include the same lagged levels as in a traditional ECM, with the difference that their coefficients are not restricted. This is why equation (4) is called an "unrestricted ECM".

Step 3: The ranges of summation in the various terms in (4) are from 1 to p, 0 to q1, and 0 to q2 respectively. Here, the optimum maximum lags, p, q1, and q2 has to be chosen using the "information criteria" such as AIC, SC (BIC), HQ, etc though in general the Schwarz criterion (SC) is used. Each criterion begins with 2 lags penalizing for including more lags. Better result can be achieved by choosing the smaller information criterion. The significance of the coefficients in the model has to be considered as well.

Step 4: The errors of equation (4) has to be serially independent. This requirement has to be met in our final model with the maximum lags for the variables. Then, we use the LM test to check if the errors are serially independent.

Step 5: This model needs to be "dynamically stable". This requirement will be met if cumulative sum lies strictly between lower control limit and upper control limit.

Step 6: Now it is time for the "Bounds Test". Recall from equation (4):

$$\Delta y_t = \beta_0 + \Sigma\beta_i \Delta y_{t-i} + \Sigma\gamma_1 \Delta x_{1t-j} + \Sigma\delta_k \Delta x_{2t-k} + \theta_0 y_{t-1} + \theta_1 x_{1t-1} + \theta_2 x_{2t-1} + e_t \quad (5)$$

An "F-test" of the hypothesis, H_0: $\theta_0 = \theta_1 = \theta_2 = 0$; has to be performed against the alternative that H_0 is not true. What we are going to do is testing the absence of a long-run equilibrium relationship between the variables in the same way as a conventional cointegration testing. This absence coincides with zero coefficients for y_{t-i}, x_{1t-1} and x_{2t-1} in equation (5). If H_0 is rejected, it means that there is a long-run relationship. However, there is a problem with this approach. The distribution of F-test statistic is totally non-standard and exact critical values for this test aren't available for an arbitrary mix of I(0) and I(1) variables. However, Pesaran et al. (2001) provide lower and upper bounds on the critical values. In calculating the lower bound and the upper bound, it is assumed that all of the variables are I(0) and I(1), respectively. The variables are considered to be I(0) if the computed F-statistic falls below the lower bound. This leads us to believe that there is no cointegration. Cointegration exists if the F-statistic exceeds the upper bound. Finally, if the F-statistic falls between the bounds, the test is inconclusive.

Step 7: Assuming that the bounds test leads to the conclusion of cointegration, we can meaningfully estimate the long-run equilibrium relationship between the variables:

$$y_t = \alpha_0 + \alpha_1 x_{1t} + \alpha_2 x_{2t} + v_t \tag{6}$$

as well as the usual ECM:

$$\Delta y_t = \beta_0 + \Sigma\beta_i \Delta y_{t-i} + \Sigma\gamma_1 \Delta x_{1t-j} + \Sigma\delta_k \Delta x_{2t-k} + \varphi z_{t-1} + e_t \tag{7}$$

where $z_{t-1} = (y_{t-i} - \alpha_0 - \alpha_1 x_{1t-1} - \alpha_2 x_{2t-1})$, and the a's are the OLS estimates of the α's in (6).

Step 8: It is time to extract long-run effects from the unrestricted ECM. Noting equation (4), and the long-run equilibrium, $\Delta y_t = 0$, $\Delta x_{1t} = \Delta x_{2t} = 0$, leads us to the long-run coefficients for x_1 and x_2 are - (θ_1/θ_0) and - (θ_2/θ_0) respectively.

Step 9 involve obtaining long-run coefficients and step 10 involves testing short-run causality.[3]

Estimating Money Demand Using ARDL For FPX And Direct Debit

In estimating the effect of financial innovation (technology payments) proxied by the value of transactions of payment instruments on the demand for money (denoted by r_t^* above), we estimate a semi log-linear specification of the form:

$$\text{Log LMOD} = \beta_0 + \beta_1 \text{Log LGDP} + \beta_2 \text{IR} + \beta_3 \text{Log (LFD)} + e_t$$

Where we use FPX and Direct Debit transactions as proxy for financial innovation (r_t^*). In this traditional specification of the conventional demand for money using ARDL, MOD denotes currency in circulation, GDP denotes nominal gross domestic product, IR is the interest rate (Treasury bill rate), FD is the nominal value of FPX and Direct Debit transactions (all in million Ringgits, and in logarithm form except for IR) and e_t is the error term. In terms of the notation that was introduced earlier, we have (k + 1) = 4 variable, so k = 3 when it comes to the bounds testing. The Pesaran et al (2001) autoregressive distributed Lag (ARDL) bounds approach is used in this estimation procedure. The stability tests such as the cumulative sum of recursive residuals (CUSUM) and cumulative sum of squares recursive residuals (CUSUMSQ) tests will be applied.

Table 2: Unit Root Results of The Level and The Difference of The Variables for Payment Instrument Model

Level	LMD/LMOD	LGDP	IR/INR	LFD
Probability	0.3867	0.4495	0.0293	0.0918
First difference	D(LMD)/D(LMOD)	D(LGDP)	D(IR)/D(INR)	D(LFD)
Probability	0.0081	0.0017	0.0002	0.0010

Next, we need to make sure that neither of our time-series are I (2). The p-values from using the ADF test to the levels and the first-differences of the series are shown in table 2. As can be seen, neither series is I (2). All of the series except INR are I (1). INR is I (0). The requirement for standard cointegration testing (such as that of Engle and Granger, or

[3] Eviews.com

Johansen) is that all of the series must be integrated of the same order. Obviously, there is no way to meet this requirement in all cases. This is where the ARDL / Bounds Testing methodology can help as it does not need to satisfy this requirement.

Step 2 requires formulating an unrestricted ECM with different lags. In step 3 we choose the one with lowest value of AIC and SIC based on AIC and SIC criterion. However, regarding the limited number of our observations which is only 32, estimating the model with more than 2 lags is not possible so we estimate using 2 lags:

Table 3: Estimation Output of The Step 3

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	2.761132	1.454677	1.898107	0.0759
D(LMD(-1))	0.469505	0.206396	2.274772	0.0370
D(LMD(-2))	-0.058605	0.178387	-0.328525	0.7468
D(LGDP(-1))	0.092654	0.096340	0.961737	0.3505
D(LGDP(-2))	0.033265	0.090768	0.366481	0.7188
D(IR(-1))	0.014305	0.014836	0.964170	0.3493
D(IR(-2))	-0.033638	0.013420	-2.506511	0.0234
D(LFD(-1))	0.002620	0.027972	0.093678	0.9265
D(LFD(-2))	-0.053484	0.027791	-1.924496	0.0723
LMD(-1)	-0.139577	0.100567	-1.387907	0.1842
LGDP(-1)	-0.090056	0.139974	-0.643374	0.5291
IR(-1)	0.027333	0.016295	1.677419	0.1129
LFD(-1)	0.032788	0.020765	1.579004	0.1339

Step 4 involves checking that the errors of this model.

Table 4: Breusch-Godfrey Serial Correlation Lm Test

F-statistic	0.898231	Prob. F(2,14)	0.4295
Obs*R-squared	3.298042	Prob. Chi-Square(2)	0.1922

According to the result in table 4, we do not have a problem with serial correlation.

Step 5 involves checking the dynamic stability of this ARDL model. We use QUSUM and QUSUM of Squares Tests for this purpose.

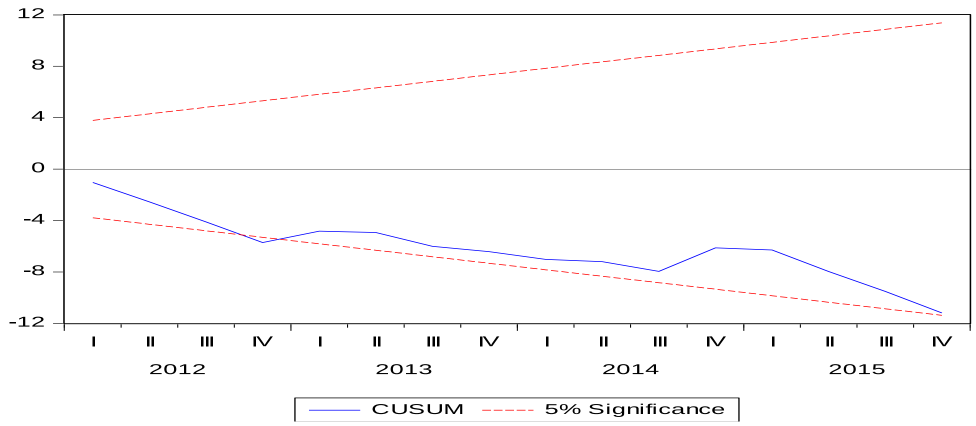


Figure 2: Qusum Tests

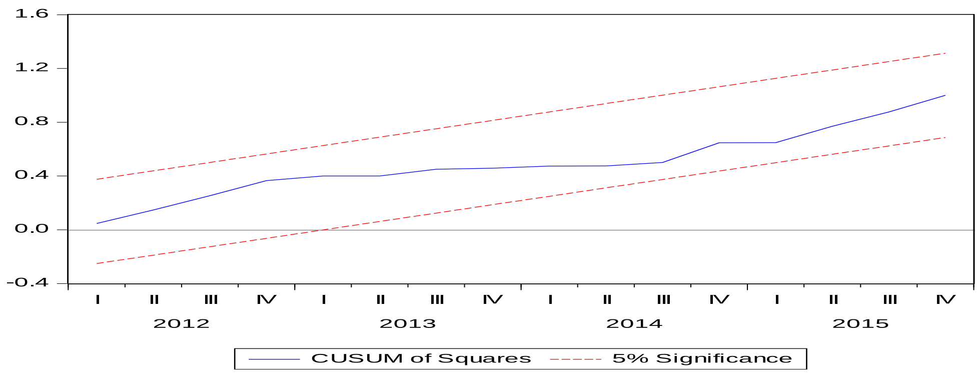


Figure 3: QUSUM Of Squares Tests

According to Figure 1 and Figure 2 above, it seems to be well as the plotted line is entirely between the two dotted lines meaning that money demand is stable. Before proceeding to the Bounds Testing, we test for normality and heteroskedasticity tests that are successfully passed.

Step 6 is the Bounds Test itself. We want to test if the coefficients of lagged dependent and independent variables are zero in our estimated model so we use Wald Test:

Table 5: Wald Test. Null Hypothesis: C (10) =C (11) =C (12) =C (13) =0

Test Statistic	Value	df	Probability
F-statistic	3.362673	(4, 16)	0.0353
Chi-square	13.45069	4	0.0093

Restrictions are linear in coefficients. F-statistics is greater than lower bound but less than upper bound. However, it is close to upper bound so most probably so there is evidence of long-run association between variables.

Here, we need to use table CI (iii) on p.300 of Pesaran et al. (2001) to find lower and upper bounds. F-statistics should be compared with Pesaran critical value at 5 percent level with unrestricted intercept and no trend as we haven't constrained the intercept of our model, and there is no linear trend term included in the ECM. According to Pesaran table, lower bound is 2.45 and upper bound is 3.61

In step 7, we estimate the long-run model to obtain the residuals:

Table 6: Estimation Output of The Step 7

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	10.81512	2.119791	5.101973	0.0000
LGDP	0.152299	0.192519	0.791084	0.4355
IR	0.028143	0.026725	1.053078	0.3013
LFD	0.165299	0.026808	6.166074	0.0000

In step 8, after we estimate the levels model above by OLS, and construct the residuals series, (Zilberfarb), we can fit a regular (restricted) ECM. However, the estimated model shows the evidence of serial correlation so we fit a model by omitting D (LMD (-1)) and obtain:

Table 7: Estimation Output of The Step 8

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.014687	0.006605	2.223582	0.0385
D(LMD(-1))	0.580253	0.185219	3.132793	0.0055
D(LMD(-2))	-0.057708	0.179910	-0.320759	0.7519
D(LGDP(-1))	0.001324	0.060149	0.022017	0.9827
D(LGDP(-2))	-0.005043	0.065051	-0.077531	0.9390
D(IR(-1))	0.013982	0.013802	1.013020	0.3238
D(IR(-2))	-0.031065	0.011795	-2.633680	0.0164
D(LFD(-1))	0.001686	0.027993	0.060234	0.9526
D(LFD(-2))	-0.044410	0.027525	-1.613458	0.1231
ECT(-1)	-0.224536	0.083321	-2.694823	0.0143

Now, we check again for the serial correlation and stability as below:

Table 8: Breusch-Godfrey Serial Correlation Lm Test

F-statistic	0.348541	Prob. F(2,17)	0.7106
Obs*R-squared	1.142301	Prob. Chi-Square(2)	0.5649

According to LM Test, there is no evidence of serial correlation. Then we check for the stability:

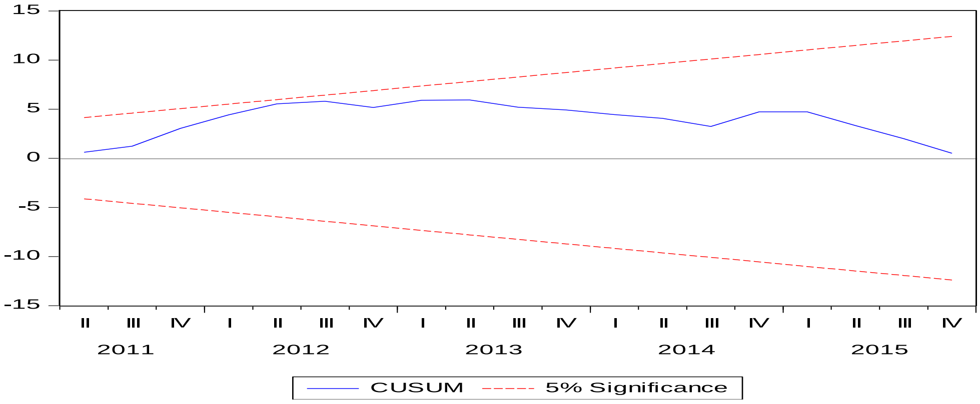


Figure 4: Stability Test Based on QUSUM Tests

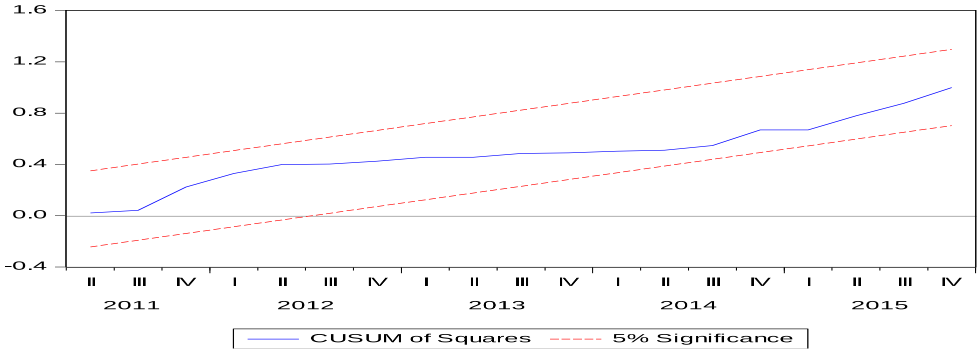


Figure 4: Stability Test Based on QUSUM Of Squares Tests

Fortunately, this final ECM is dynamically stable. The coefficient of the error-correction term, ECT (-1) which is one lagged ECT, is negative and significant. If there was cointegration between MD (money demand) and independent variables, we would expect a negative and significant one. The magnitude of this coefficient implies that nearly 22.4% of any disequilibrium between MOD and independent variables is corrected within one period (one quarter). In other words, the whole system gets back to the long-run equilibrium at the speed of 22.4 percent. It means that it takes a bit more than 4 quarters (1/0.22) or almost 1 year to correct the disequilibrium.

In step7, long-run coefficients can be obtained from the estimated coefficients in table 3 by dividing the coefficients of the lagged independent variables by the coefficient of the lagged dependent variable. An increase of 1 percent in FD will lead to an increase of 0.23 percent [-(0.032788/-0.139577) = 0.23491] in money demand:

The last step involves testing short-run causality running from each of the independent variables to dependent variable. In doing so, we conduct Wald test:

Table 9: Short-Run Causality

Variable/Tests	F-statistics (Prob)	Chi-square (Prob)	Short-run Causality
GDP	0.9967	0.9967	No
IR	0.0485	0.0284	Yes
FD	0.2875	0.2640	No

After estimating money demand with the inclusion of payment instruments as a proxy for financial innovation, we did repeat the same process for estimating money demand with other financial variables using the following model:

Log LMD = $\beta_0 + \beta_1$Log LGDP +β_2 IR + β_4Log (LFI) + e_t

Which FI represents each of the financial innovation (FIs) variables. The results are summarized in table 10 below.

Table 10: Summary of The Results of Each Financial Variable (Individually)

Variable type	Variable	Breusch-Godfrey Serial Correlation LM Test (probability)	Normality Test (probability)	Heteroskedasticity Test: Breusch-Pagan-Godfrey (probability)	Stability Test (CUSUM & CUSUM of SquaresTests)	Bound Test: Test of the Existence of long-run association	Adjustment toward long-run equilibrium ECT/t-statistics	Long-run coefficient	Existence of short-run relationship
PI	CRC	YES	YES	YES	YES	YES	-0.158498 (-0.0635)	1.2	NO
	CHC	YES	YES	YES	YES	YES	-0.252254 (-2.821259)	0.69	NO
	DEC	YES	YES	YES	YES	NO	-	-	-
	EMO	YES	YES	YES	YES	NO	-	-	-
PS	RE	YES	YES	YES	YES	NO	-	-	-
	IG	YES	YES	YES	YES	YES	-0.02818 (-0.354954)	57.2	NO
	FD	YES	YES	YES	YES	YES	-0.224536 (-2.694823)	0.23	NO
PC	ATM	YES	YES	YES	YES	NO	-	-	-
	MB	YES	YES	YES	YES	NO	-	-	-
	IB	YES	YES	YES	YES	NO	-	-	-

As shown in table 10, all of the FIs pass the diagnostic and stability tests, however, only four of them (CRC, CHC, IG and FD) pass the Bound Test that proves of the existence of a long-run association between variables (dependent and independent variables altogether) and only two of these four have negative and significant error correction term which is an indication of adjustment towards long-run equilibrium. For CHC, the speed of adjustment is 0.25 meaning that it takes almost 4 years to restore equilibrium in this dynamic model while that for FD is 0.22 that means it takes a bit longer to adjust to long-run equilibrium compared to CHC. Also, no FIs has short-run causality running from these variables to money demand.

Summary

Both long and short run nominal money demand functions of Malaysia with money defined as M2 have been estimated using ARDL approach to cointegration technique. The period under review is 2008Q1–2015Q4. Investigating the effect of the financial innovation variables on the demand for money reveals that only CHC and FD pass the Bound Test with negative and significant error correction term. However, there is no evidence of a short-run causality running from any financial innovation variables to money demand.

According to the result of applying the first approach in our estimated ARDL model (which consistes of 10 model estimates, one estimation for each financial variable), some short-run coeffients of the financial variables are positive and some are negative, meaning that there is no conclusive result as to the effect of financial variables in the short-run. In the long-run, all of the coeffients of the financial variables which pass the bound test (credit card, charge card, Interbank GIRO and FPX and Direct Debit), are positive. However, only two of them (charge card, FPX and Direct Debit) for whome the error correction term was negative and significant have a positive and significant impact on the demand for money in the long-run.

According to the results of applying the first approach, all of the models financial variables (one by one, to be more precise, a model with the first financial variable included, a model with the second financial variable included,…, a model with the last financial variable included) pass the diagnostic and stability tests, however, only four of them (the models including credit card, charge card, Interbank GIRO and Direct Debit and Financial Process Exchange, one by one) pass the Bound Test that proves of the existence of a long-run association between variables (dependent and independent variables altogether) and only two of these four (the models including charge card and Direct Debit and Financial Process Exchange) have negative and significant error correction term which is an indication of adjustment towards long-run equilibrium. For charge card, the speed of adjustment is 0.25 meaning that it takes almost 4 years to restore equilibrium in this dynamic model while that for "Direct Debit and Financial Process Exchange" is 0.22 that means it takes a bit longer to adjust to long-run equilibrium compared to charge card. Also, no models including each of financial variables have short-run causality running from these variables to money demand.

In an ARDL model, the variable of interest is a function of the past values of itself (auto-regressive) and the current and past values of other variables (distributed lag). Advantages of ARDL over conventional cointegration testing include: a) Mixture of I(0) and I(1) data is allowed in this model. b) Just a single-equation set-up is involved in this model. This set-up makes implementing and interpreting the model and the results simple and c) We can assign different lag-lengths to different variables in the model.

In estimating a model, we encounter 4 general scenarios regarding the integrated order of variables. 1) All of the series are I(0), and therefore stationary. In this case, the data in their levels can be modeled using OLS estimation. 2) All of the series are integrated of the same order (e.g., I(1)), but they are not cointegrated. In this case, each series can be differenced and a standard regression model will be then be estimated using OLS. 3) All of the series are integrated of the same order, and they are cointegrated. In this case, we can estimate two types of models: a) An OLS regression model using the levels of the data. This will provide the long-run equilibrating relationship between the variables, b) An error-correction model (ECM), estimated by OLS. The short-run dynamics of the relationship between the variables will be represented by this model and 4) Some of the variables in question may be stationary, some may be I(1) and there is also the possibility of cointegration among some of the I(1) variables. In this case, we use ARDL to extract both long-run and short-run relationships.

The existence of a stable demand function is important for the conduct of monetary policy. Therefore, it is essential to know if money demand function is unstable due to the introducing new payment technologies as it helps policy makers to choose appropriate instruments for conducting monetary policy. If these financial innovations have impacted the demand for money, then it is justified to conduct macro-economic stabilization through regulating the growth of the money supply and interest rate changes. As such this research project will be of importance to monetary policy makers at Central Banks and Bank Negara Malaysia in particular.

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