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LONG-RUN STABILITY OF MONEY DEMAND AND MONETARY POLICY: THE CASE OF SOUTH KOREA

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ABSTRACT

The current paper aims to investigate the stability of money demand in the case of Korea. Since the economic reforms in Korea faced considerable structural changes, it was difficult to formulate a stable money demand function. The use of unit root and cointegration tests with structural breaks suggest that economic and financial deregulations have influenced the stability of money demand. The cointegration results suggest a cointegration vector in all models, implying a long-run relationship. Furthermore, the estimated long-run equations show that the elasticity of long-run industrial production to real money is positive and very close to one. Finally, the exogeneity test shows a long-run, one-way, causal relationship from industrial production to M1 and a bi-directional causality between M1 and interest rate in both models. In the case of M3, there are long-run, one-way, causal relationships from industrial production and interest rate to M3 in both models.

Contribution/Originality: The originality of the paper lies in the examination of the money demand stability of Korea both for narrow money (M1) as well as broad money (M3) using monthly data from 1980:01–2020:12 in the form of log-log and semi-log specifications. It consists of the low interest rate period after the world financial crisis and the economic reforms in Korea.

1. INTRODUCTION

Money demand is defined as the amount of cash reserves investors choose to have in their portfolio. In order to define the determinants of an investor's portfolio, several economic schools suggest different theories about the determinants of money demand.

The two main schools of thought with strong viewpoints related to the role of money, income and prices come from Cambridge and Friedman. According to the Cambridge school of thought (Marshall, 1926; Pigou, 1917), money demand is considered as a fixed percentage of income. This proportional relationship between money demand and income is equal to one, in other words, a certain proportional change in income entails the same proportional change in money demand. Friedman (1956) formulated a new quantitative theory about money demand which constituted the "monetary theory" or "monetarism". According to monetarists, money has a leading role in determining income and prices in an economy. More specifically, they claim that an increase in the amount of money in an economy through monetary policy leads to an increase in prices and inflation. They believe that the fluctuation in money demand has an impact on real product only in the short run, while in the long run it only affects the level of prices. Essentially, we could say that the monetaristic model represents a synthesis between Keynesianism and classic economics (Dornbusch, Fischer, & Startz, 2021).

These theories have had a great influence in global economies in all post-war decades until now. During the 1950s and 1960s, the Federal Reserve System, or the FED (the central bank of the United States), and other central banks of western countries based their monetary policies on their attempt to define the interest rates. During the 1970s and ever since, the prevalence of monetarism in the official policy of central banks is ultimate, and they now mostly "ignore" the interest rate and set goals in relation to the growth rate of money demand. During the 1980s and later, real data did not comply fully with the predictions of monetaristic models. The 1990s was the decade of technology acceleration, worldwide political changes, and significant rises as well as significant falls in the stock markets. But economies in general developed and inflation was under control. Between 2001–2010, those responsible for economic policies of central banks did not predict the increasingly significant role of investment banks and hedge funds in the global financial system, which had been extended while also being flexible, with the involvement of funds outside the regulatory framework of traditional commercial banks. The crisis which followed the short-term liquidity of the banking system in the USA made government intervention essential for the immediate provision of monetary funds, putting the monetaristic model in second place, but also bringing fear of economy destabilization and increased inflation. These were fears which were deemed of secondary importance in relation to the efforts of government, central banks and various centers to tackle the prolonged world economy recession, which started in 2007 and continued until at least 2010. For example in the USA, the monetarist central banker of the FED, Alan Greenspan, was replaced by neo-Keynesian Ben Bernanke (Dornbusch et al., 2021).

The rest of the paper is organized as follows: Section 2 presents characteristics of the South Korean Economy; some previous studies which have examined money demand in the case of Korea are examined in Section 3; Section 4 includes the data overview; the demand function stability is presented in Section 5; Section 6 includes the empirical investigation of the study; and finally, Section 7 presents the conclusions and policy implications of the analysis.

2. ECONOMY OF SOUTH KOREA

South Korea's economy is a highly developed mixed economy. It holds the fourth biggest GDP in Asia and the is the tenth biggest in the world. South Korea remains one of the fastest growing countries in the world, even after the crises, and has the opportunity to play a dominant role in the world economy. The education system in South Korea and the generation of highly educated people are, to a great extent, responsible for the technological improvements and the rapid economic development of the country. South Korea is greatly dependent on exports in order to sustain economic development and the development of electronics, textiles, shipments, cars and steel, which are some of its most significant exports. The country has become a leader in shipment, including oil tankers and platforms for oil drilling. Electronics is one of the major exporting industries in South Korea. Also, the car industry is another big exporter in South Korea. Having no natural resources, South Korea has adapted to an economic strategy oriented toward exports in order to fuel its economy, and in 2019 was the eighth biggest exporter and the eighth biggest importer in the world.

The 1989 economic recession, due to the sudden decrease in exports, caused deep concern. For the first half of the 1990s, the South Korean economy enjoyed a steady and robust growth of both private consumption and GDP. However, things changed quickly in 1997 with the Asian financial crisis. After recovering from the crisis at the end of 1990s, the economy continued its strong growth in 2000 with a 9.08% increase in GDP. The deceleration of the world economy, the drop of exports, and the perception that corporate and financial reforms had ceased all caused a drop in development to 3.8% in 2001 (Koo & Kiser, 2001). Like most industrial economies, Korea suffered a considerable regression during the recession of 2007. The growth continued to be negative until 2009. During the 2007 crisis, the currency of Korea saw huge fluctuations with a reduction of 34% against the dollar.

The International Monetary Fund has praised the resilience of the South Korean economy against various economic crises invoking low government debt and high fiscal reserves, which were promptly mobilized to address any expected emergency economic situations. The World Bank described South Korea as one of the faster growing economies of the next generation. South Korea is one of the few developed countries which was in a position to prevent a recession during the global financial crisis, and its rate of economic growth reached 6.2% in 2010, a sudden growth from the economic growth rates of 2.3% in 2008 and 0.2% in 2009 when the global financial crisis struck. The South Korean economy recovered again with a record surplus balance of US$70.7 billion in its current account at the end of 2013, an increase of 47% from 2012, in the midst of global economic uncertainty and considerable production of technology exports (Kim & Kim, 2018).

Despite the high production potential of the South Korean economy and its apparent structural stability, South Korea suffers ongoing damage to its credit ability in the stock market due to its fragile relationship with North Korea, which in turn has a negative effect in the financial markets of South Korea.

The South Korean economy decreased in the first quarter of 2020, which marked its worst performance since the world financial crisis. Economic activity declined sharply and the Korean authorities reacted promptly to the spread of the coronavirus in order to support the economy. However, the GDP has still shrunk, even though it was less than the GDP of the other OECD countries.

The government's fiscal policy was to restrict the effects of the crisis, which is why the GDP surplus in 2019 was moved into the 2020 budget as a deficit of up to 3%. The Covid-19 crisis caused further deflationary pressures, to which the Bank of Korea reacted quickly by reducing the interest rates twice in 2020 by 50 and 25 basis points, respectively, and implementing a series of measures in order to increase liquidity to deal with the crisis. As there is not much time left for further interest rate decreases, the Bank of Korea should be ready to adopt non-conventional measures of monetary policy which exceed liquidity support, such as bond purchases in order to decrease long-run interest rates. In the current juncture, economic development is expected to be sluggish and the inflationary pressures are expected to remain low due to Covid-19. Therefore, the Bank of Korea should maintain its accommodative direction of monetary policy (OECD, 2020).

3. EMPIRICAL LITERATURE REVIEW FOR KOREA

The stability of money demand and its determinants are the two main aspects of money demand theory. When it comes to determinants, the classists put emphasis on income as the sole determinant of money demand, while other economists, such as Keynes, Tobin and Friedman, consider interest rates, bond and equity returns, and returns of physical products as determinants. However, they disagreed on the role that interest rates play on the money demand function. The Keynesians underlined the negative effects of interest rates on money demand, while Friedman accepted the role of interest rates on the money demand function but claimed that a change in interest rates had a minor effect on demand. Those two aspects of money demand have inspired researchers to examine the functions of money demand in various countries.

A considerable amount of research has been conducted on money demand stability using multivariate cointegration techniques. The results of these studies depend on the underlying variables, the econometric techniques applied for the stability test, the data frequency, and the development level of a country. One of the papers that examined the demand for money in the case of Korea is by Mohsen & Sungwon (2002), who investigated the stability of M1, M2 and M3 money demand in Korea using quarterly data from 1973:1–1997:2. The results from the Johansen cointegration test suggest that a cointegrated vector exists between M2, income, interest rate and real nominal exchange rate. Then, the application of CUSUM and CUSUMSQ tests on the residuals of the correction function suggest that the M2 money demand function is not stable.

Hwang (2002) used the semi-logarithmic money demand function in the case of Korea for M1 and M2 using the short-run and long-run interest rates for quarterly data from 1973:1 to 1997:2. Using the maximum likelihood cointegration method by Johansen, his study showed that the long-run interest rate is a better indicator of interest rate to measure the cost of holding money in Korea.

Previous studies based on money demand in South Korea have neglected the fact that monetary developments in a country can influence the demand for money in other countries. In his study, Arize (1989) considered short-term foreign interest rates to estimate money demand in South Korea for the period between 1973:1 and 1985:4. The study also included a number of diagnostic tests and a stability test, and the empirical findings suggest that exchange rates affect the demand for real money in South Korea.

The study by Cho & Ramirez (2016) estimated the demand for money in Korea from 1973:3 to 2014:4. Using the Johansen cointegration methodology, they found a long-run relationship between the model variables. The study also estimated the error correction model (ECM) as well as a vector error correction model (VECM) by performing forecasts and Granger causality tests between the variables. They concluded that, in the broader definition of money, M2 serves as a relatively better measure of the money aggregate than M1 when evaluating the stability of money demand. Long-run interest rates seem to provide better outcomes than the short-run interest rate for money demand in Korea.

Finally, Lee, Hung, & Wang (2019) examined the function of money demand in South Korea using three cointegration methods. They suggest that money demand and the determinants of real exchange rates are cointegrated. Income and exchange rates have a statistically significant positive impact on money demand, while domestic interest rates and stock prices have statistically significant negative effects on money demand. It is interesting to note that domestic interest rates are inelastic, implying that there is a limit to which monetary authorities can use domestic interest rates to decrease the money demand in South Korea.

4. DATA OVERVIEW

Narrow money is one of the categories of money supply that contains coins and currency, deposits, and other liquid assets that a central bank holds. The literature for developing countries shows that the models on narrow money work better when they reflect a weak banking system and low financial development. However, narrow money over time accommodates new means created by evolving institutional and economic structures within the system. Broad money is another category for measuring money supply and contains narrow money together with assets that can easily liquidate for the purchase of goods and services. Many countries determine the measurement of money in various ways. This paper uses both money definitions, narrow and broad, to determine money demand in South Korea. The sample period covers monthly data from 1980:01 to 2020:12. More details on the data description can be found in Appendix A.

Narrow money (M1) includes banknotes and coins as well as the deposits of households and companies. Broad money includes currency, deposits with an agreed maturity of up to two years, deposits redeemable at notice and repurchase agreements, money market fund shares/units and debt securities up to two years. M3 is a measure of money supply that includes M2 as well as savings deposits, institutional money market funds, repurchase agreements and liquid assets. M3 is used by economists to estimate the entire money supply, and by central banks to guide monetary policy in order to test inflation, consumption, growth and liquidity in medium- and long-term periods. The industrial production indicator (IPI) is an economic indicator mainly for industrial exporting countries like Korea that measures levels of production and the capacity of a country relative to a base year. This indicator is useful for policy makers and investors on specific line business and is considered an important macroeconomic indicator because fluctuations in industrial sectors represent the largest part of fluctuations in total economic growth. The utilization of productivity's ability is a useful indicator reflecting the power of money demand. Overcapacity shows weak demand. The monthly interest rate of return is used as an opportunity cost of holding real balances. All variables used are in natural logarithms except for interest rate which is in a linear and logarithmic form. To avoid possible distortions of dynamic properties in the model, seasonally unadjusted data are employed from the Federal Reserve Bank of St. Louis and Organization for Economic Cooperation and Development (OECD) databases. Figure 1 presents a graphs of series data that seem to be non-stationary. While the narrow money index (M1), broad money index (M3), industrial production index (IPI) and consumer price index (CPI) present a large increase until 2010, this increase diminishes during the last decade. Furthermore, the discount interest rate reduces over the years, reaching zero during the last decade.

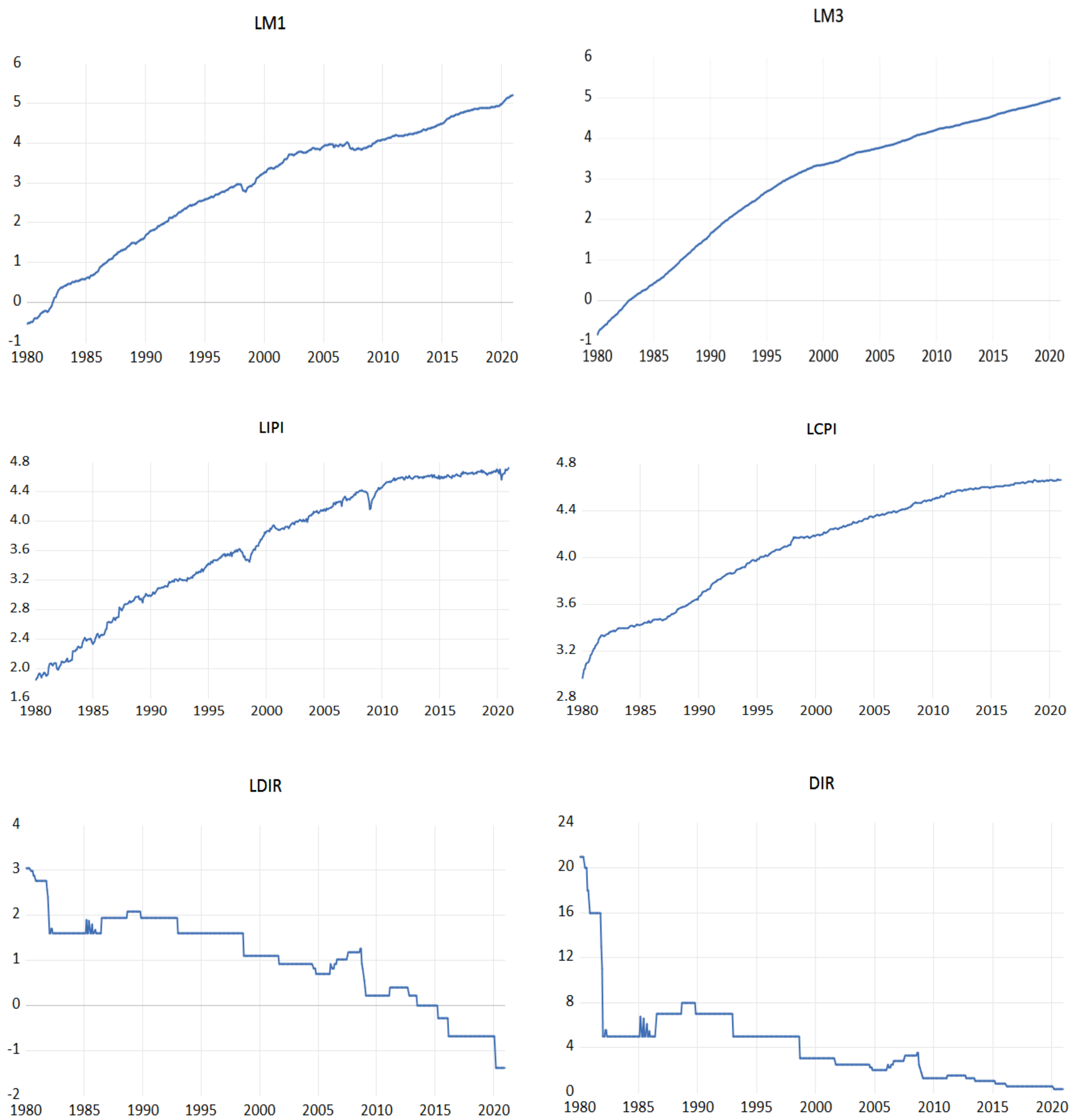


Figure 1. Logarithmic values of the narrow money (LM1) index, industrial production index (LIPI), consumer price index (LCPI), discount interest rate (LDIR), and discount interest rate (DIR) from 1980:01–2020:12.

5. MONEY DEMAND IN THE LONG RUN

"No proposition in macroeconomics has received more attention than that there exists, at the level of the aggregate economy, a stable demand for money function." (Laidler, 1982).

Money supply measures are useful for the application of monetary policy. They assist policy makers to comprehend possible inflationary trends. Central banks use lower interest rates to increase money supply with the aim of reviving the economy. On the contrary, in an inflationary setting, the interest rates increase and money supply decreases leading to lower prices. In other words, when there is more money, the economy tends to accelerate because companies have easy access to finance. On the contrary, if there is less money in the system, the economy slows down and prices drop. In this framework, broad money is regarded as one of the measures that central bankers use to determine the necessary interventions to influence the economy.

The stability of money demand is regarded as one of the most crucial issues in theoretical and applied macroeconomics. The effectiveness of monetary policy depends on the extent of stability on the money demand function. Moreover, the stability of money demand offers the possibility of forecasting the impact of money supply on fundamental economic variables, such as inflation, real output and interest rate.

The money demand function is one of the most examined macroeconomic aspects that aims to assist monetary authorities to comprehend what motivates economic agents to possess money. The stability of money demand states that money supply has a potential impact on economic activity and on inflation. A steady money demand indicates the effectiveness of monetary policy (Albulescu & Pepin, 2018).

Analysis of the money demand function has brought no consensus on how nominal interest rate, as an independent variable, should be used (in a linear or logarithmic form). For example, Meltzer (1963); Hoffman & Rasche (1991) and Lucas (2000) used the logarithm form of interest rate, while Cagan (1956); Lucas (1988); Stock & Watson (1993); Ball (2001) and Ireland (2009) used a semi-logarithmic function, i.e., the interest rate without a logarithm.

Determination of the correct specification of the money demand function is important for the following reasons:

- Different specifications of the money demand function come from different economic money demand models.
- Different specifications of the money demand function have different consequences on the welfare cost of inflation.
- Different specifications of the money demand function have different consequences on the exercise of monetary policy near the zero lower bound. On the logarithmic form, money demand becomes infinitely large on zero, which is the lower bound, so that the opportunity cost of money possession cannot be below zero. In the semi-logarithmic form of money demand, the marginal utility becomes zero on a finite level of real money and negative beyond this level (see Watanabe & Yabu (2018), Rognlie (2016) and Eggertsson, Ragnar, & Ella (2017)). The policy on negative interest rates shows that, in a semi-logarithmic money demand function, the negative opportunity cost derived from a negative interest rate can disregard Friedman's rule in an adverse direction, thus deteriorating economic welfare.

Most of the papers follow semi-logarithmic specification for long-run money demand. In this paper, for the long-run money demand function in Korea, we use both semi-logarithmic (Equation 1) and logarithmic functions (Equation 2) using monthly data from 1980:01 to 2020:12.

Semi-log specification: $$\ln m_t = \beta_0 + \beta_1 \ln IPI_t + \beta_2 DIR_t + e_t \tag{1}$$

Log-log specification: $$\ln m_t = \beta_0 + \beta_1 \ln IPI_t + \beta_2 \ln DIR_t + e_t \tag{2}$$

with $m_t = \frac{M}{CPI}$ where M is the real monetary aggregate (M_1 or M_3), M_1 is the narrow money index (2015 = 100) seasonally adjusted, M_3 is the broad money index (2015 = 100) seasonally adjusted, CPI is the consumer price index (2015 = 100) seasonally adjusted, IPI is the industrial production index (2015 = 100) seasonally adjusted, and DIR is the discount interest rate seasonally adjusted. β_0 is a positive constant, β_1 is the industrial production elasticity of money demand with expected positive elasticity, β_2 is the absolute value of the semi-elastic interest of money demand with expected negative elasticity.

If there is a long-run relationship among m_t, IPI and DIR, then cointegration is considered as a statistical equivalent of a long-run concept in economics. Friedman (1956) suggested that in the examination of the money demand function, there should be an underlying stationary long-run equilibrium relationship among real money, real income and opportunity cost to maintain the balance of real money. According to the Cambridge and Keynesian approaches, the relationship between the real demand for money and the level of real income is direct and the relationship between real money demand and interest rate is inverse. In developing economies, where the financial sector is poorly developed, the expected inflation is the most widely used variable as an opportunity cost of holding money. In the economies with high and/or chronic inflation, the expected inflation rate is suitable to use for the money demand function, but it is also necessary to introduce the suitable variable of exchange rate as an effect of monetary substitution (Boucekkine, Laksaci, & Touati-Tliba, 2021).

6. EMPIRICAL INVESTIGATION

6.1. Unit Root Test

The Dickey & Fuller (1981) and Phillips & Perron (1988) tests as well as the rule of Dolado, Jenkinson, & Sosvilla-Rivero (1990) were applied to create a suitable model. In the beginning, the general equation employed in this study contains constant and deterministic trends. If the coefficients of both trend and constant are not statistically significant, we continue with the equation with the constant only. If the coefficient of the constant is still not statistically significant, then we use the equation with no element for unit root testing. In the augmented Dickey–Fuller (ADF) test, the estimation could be biased if the lag length is pre-designated without a rigorous determination, so in this paper we adopt the modified Akaike criterion (MAIC) as suggested by Ng & Perron (2001) for optimal lag length. The Phillips–Perron (PP) test differs from the augmented Dickey–Fuller test mainly in the examination of autocorrelation and heteroscedasticity errors. Instead of augmenting the equation with first differences, Phillips and Perron modified the estimation criterion t in the Dickey–Fuller equations using non-parametric methods. In this way, the non-randomness of the residuals is not taken into account. The Phillips–Perron criterion depends on a spectral estimator with zero frequency residuals. The Newey & West (1994) estimator aims to correct the heteroscedasticity and autocorrelation of residuals. It is worth pointing out that while we find the suitable number of lags on the differences of the dependent variable in the Dickey–Fuller test, for the PP test, the p-lag (bandwidth) must be denoted by the estimator of the covariance matrix of parameters (Newey & West, 1994). Table 1 presents the results of the Dickey–Fuller and Phillips–Perron tests.

6.2. Unit Root Test and Structural Breaks

The results of traditional tests can be biased because there is no information about the structural breaks appearing on time series. The proper information for the unknown structural variations help policy makers in the long run by examining these structural variations. Zivot & Andrews (1992) suggested three models for testing unit root:

Table 1. Unit root test results.

Augmented Dickey–Fuller				
	Levels		**First Differences**	
Variable	**C**	**C,T**	**C**	**C,T**
LM1	-3.11(7)**	-2.25(7)	-5.87(6)*	-6.47(6)*
LM3	-4.41(6)*	-2.29(6)	-2.70(5)***	-4.62(5)*
LIPI	-2.69(0)***	-1.34(0)	-22.77(0)*	-23.04(0)*
LCPI	-1.96(12)	-1.78(2)	-5.99(12)*	-14.32(1)*
DIR	-5.00(1)*	-5.63(2)*	-19.55(0)*	-19.74(0)*
LDIR	-0.34(00	-1.97(0)	-21.87(0)*	-21.86(0)*
Phillips–Perron				
	Levels		**First Differences**	
Variable	C	C,T	C	C,T
LM1	-4.01[10]*	-2.24[10]	-10.56[6]*	-10.93[9]*
LM3	-13.36[13]*	-3.63[13]**	-10.94[11]*	-17.45[12]*
LIPI	-3.22[16]**	-1.10[15]	-22.90[11]*	-23.57[15]*
LCPI	-5.36[11]*	-2.96[12]	-15.53[10]*	-16.11[8]*
DIR	-4.90[2]*	-5.24[1]*	-19.86[5]*	-19.94[3]*
LDIR	-0.36[2]	-2.17[4]	-21.87[1]*	-21.86[1]*

Notes:
1. *, ** and *** show significance at the 1%, 5% and 10% levels, respectively.
2. The numbers within parentheses followed by ADF statistics represent the lag length of the dependent variable used to obtain white noise residuals.
3. The lag lengths for the ADF equation were selected using the modified Akaike's Information Criterion (MAIC).
4. The MacKinnon (1996) critical value for rejection of hypothesis of unit root was applied.
5. The numbers within square brackets followed by the PP statistics represent the selected bandwidth based on the method by Newey & West (1994) using the Bartlett kernel.
6. C = Constant, T = Trend.

Model A allows a time variation in the levels of the time series.

$$y_t = \hat{\mu}^A + \hat{\vartheta}^A DU_t(\hat{\lambda}) + \hat{\beta}^A t + \hat{\alpha}^A y_{t-1} + \sum_{j=1}^{k} \hat{\gamma}_j^A \Delta y_{t-j} + \hat{e}_t \tag{3}$$

Model B allows a time variation in the slope of the trend equation.

$$y_t = \hat{\mu}^B + \hat{\beta}^B t + \hat{\rho}^B DT_t^*(\hat{\lambda}) + \hat{\alpha}^B y_{t-1} + \sum_{j=1}^{k} \hat{\gamma}_j^B \Delta y_{t-j} + \hat{e}_t \tag{4}$$

Model C combines time variations in the time series levels and in the slope of the trend equation.

$$y_t = \hat{\mu}^C + \hat{\vartheta}^C DU_t(\hat{\lambda}) + \hat{\beta}^C t + \hat{\rho}^C DT_t^*(\hat{\lambda}) + \hat{\alpha}^C y_{t-1} + \sum_{j=1}^{k} \hat{\gamma}_j^C \Delta y_{t-j} + \hat{e}_t \tag{5}$$

where DU_t is a dummy for the mean shift appearing in every possible variation (TB), while DT_t^* is the corresponding variable for the mean shift and trend.

$$DU_t(\lambda) = \begin{cases} 1, & if \quad t > \mathrm{T}\lambda \\ 0 & in \quad any \quad other \quad case \end{cases} \tag{6}$$

$$\mathrm{DT}_\tau^*(\lambda) = \begin{cases} t - T\lambda, & if \quad t > \mathrm{T}\lambda \\ 0 & in \quad any \quad other \quad case \end{cases} \tag{7}$$

The results of the Zivot-Andrews tests are presented in Table 2 and Figure 2. All series carry a unit root on their levels, which is rejected at first differences. This ensures that all series are integrated of order one I(1) and will be taken into account. The results of the Zivot-Andrews tests show that the breakpoint occurred in 2007 for narrow money (M1), in 1997 for broad money (M3), in 1998 for industrial production, in 1987 for the consumer price index, and in 1986 for interest rates.

Table 2. Zivot-Andrews unit root tests results with structural break.

Variable	Model A	Year of break	Model B	Year of break	Model C	Year of break
Level						
LM1	-4.17[4]	2005 M08	-2.82[4]	1992 M11	-3.10[4]	1989 M10
LM3	-5.88[3]*	1986 M10	-6.41[3]*	1994 M04	-7.23[3]*	1989 M10
LIPI	-2.75[0]	2012 M06	-3.44[0]	2005 M12	-3.43[0]	2005 M11
LCPI	-5.01[2]**	1999 M01	-3.23[2]	2003 M03	-4.42[2]	1990 M01
DIR	-6.37[4]*	1998 M09	-6.11[4]*	2014 M11	-6.09[4]*	2014 M11
LDIR	-4.03[3]	1986 M07	-4.20[3]	2007 M08	-4.29[3]	2006 M02
First Differences						
LM1	-7.84[4]*	2012 M10	-7.89[4]*	2007 M04	-8.03[4]*	2005 M07
LM3	-7.40[4]*	1996 M06	-6.97[4]*	2004 M01	-7.75[4]*	1999 M03
LIPI	-12.84[3]*	1998 M08	-12.43[4]*	1996 M06	-12.83[4]*	1998 M08
LCPI	-8.38[4]*	1987 M03	---	---	-9.73[4]*	1987 M01
DIR	---	--	---	---	-11.03[4]*	1986 M09
LDIR	-11.47[2]	2008 M10	---	---	-11.67[2]*	1986 M10

Notes:
1. * and ** show significance at the 1% and 5% levels, respectively.
2. Critical values of the Zivot-Andrews unit root tests with structural break are stable: -5.34, -4.93 and -4.58; trend: -4.80, -4.42 and -4.11, constant and trend: -5.57, -5.08 and -4.82 for 1%, 5% and 10% levels of significance, respectively.
3. In square brackets the time lags are underlined for the corresponding equations.

A time series can contain more than one structural break. For this purpose, we use the Bai & Perron (2003) and Bai & Perron (1998) tests to test for multiple structural breaks. Bai & Perron (1998) examined a multiple linear regression with T observations and possible variation (structural) points $m+1$. For break $j = 0,1,\ldots,m$, they denote $T_j \in \{T\}_m$ to be the first date for each variation. Afterwards, the changes in j^{th} meaning $T_j,\ldots,T_{j+1}-1$ are denoted in the model by Bai & Perron (2003) as the following:

$$y_t = X_t''\beta + Z_t'\delta_j + \varepsilon_t \tag{8}$$

where X is a matrix of regressors in which parameters are stable after changes, and Z is a matrix of regressors where parameters change with structural breaks.

Bai & Perron (1998) considered estimating multiple structural changes in a linear model and developed three tests:

- Global maximizer test.
- Global L Breaks vs. None (double maximum test).
- Sequentially determined breakpoints.

The last test developed by Bai & Perron (1998) is a sequential test of L versus $L+1$ structural changes:

$$SupF_T(L+1|L) = \left[S_T\left(\hat{T}_1,\ldots,\hat{T}_L\right) - \min_{1\le i\le L} \inf_{r\in\Lambda_{i,\varepsilon}} S_T\left(\hat{T}_1,\ldots,\hat{T}_{i-1},r,\hat{T}_i,\ldots,\hat{T}_L\right)\right] \Big/ \hat{\sigma}^2 \tag{9}$$

where

$$\Lambda_{i,n} = \left[r, \hat{T}_{i-1} + \left(\hat{T}_i,\ldots,\hat{T}_{i-1}\right)n \le r \le \hat{T}_i - \left(\hat{T}_i,\ldots,\hat{T}_{i-1}\right)n\right],$$

$S_T\left(\hat{T}_1,\ldots,\hat{T}_{i-1},r,\hat{T}_i,\ldots,\hat{T}_L\right)$ is the sum of squared residuals resulting from the least squares estimation from each m-partition $\left(T_1,\ldots,T_m\right)$ and $\hat{\sigma}^2$ is a consistent estimator of σ^2 under the null hypothesis (Önel, 2005).

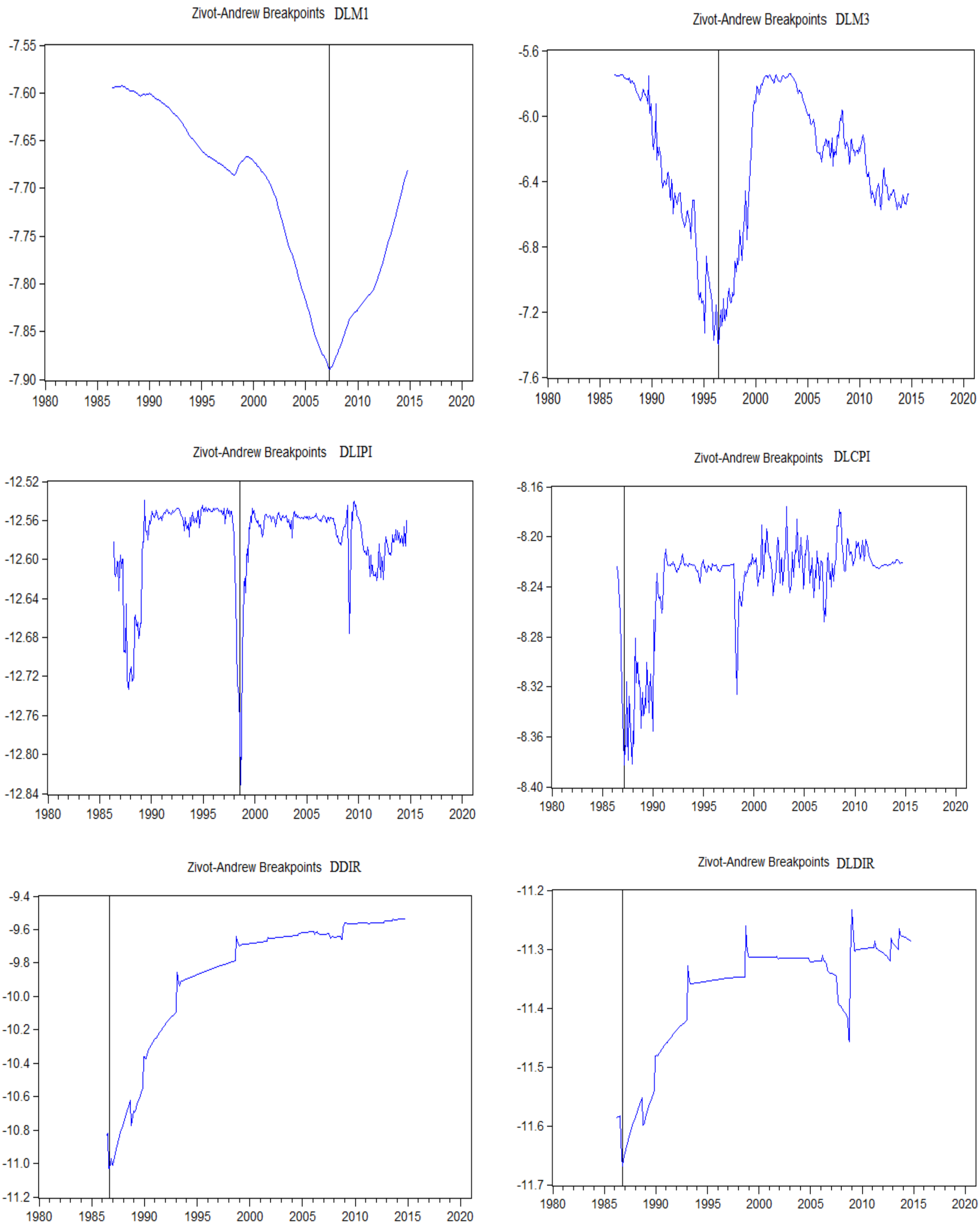


Figure 2. Zivot-Andrews unit root test results with structural break at first differences.

Table 3 refers to the number of structural breaks chosen from the sequentially determined breakpoints test of Bai and Perron. For M1 and M3, the sequential procedure chooses three structural breaks, while for the rest of the variables, the Bai and Perron test chooses one structural break. Structural breaks occurred in 1986, 1998 and 2002 for M1, in 1986, 1998 and 2002 for M3, and in 1987 and 1986 for industrial production and interest rate, respectively.

Table 3. Bai and Perron's test results for structural breaks (sequentially determined breakpoints).

First Differences						
	Model A		Model B		Model C	
Variable	F-Statistic	Year of break	F-Statistic	Year of break	F-Statistic	Year of break
LM1	47.9	2002 M04	98.2	1993 M10	12.3	2005 M08
	11.6	2008 M05	29.3	2002 M04	13.0	1998 M07
	- ----	-----	28.7	1986 M06	-----	-----
LM3	689	1990 M03	438	1998 M12	56.6	1999 M03
	30.9	1996 M06	132	1995 M02	22.0	1986 M03
	21.8	2002 M12	55.2	2002 M12	-----	----
LIPI	5.88	---	17.1	1987 M05	1.99	----
LCPI	53.9	1998 M03	69.1	1998 M03	46.7	1987 M01
	5.75	---	13.0	1991 M09	3.02	---
DIR	15.3	1986 M03	3.68	---	14.4	1986 M08
LDIR	2.84	---	1.74	---	4.21	---

Note: Critical values of Bai and Perron are constant: 8.58, 10.13 and 11.14; trend: 8.58, 10.13 and 11.14; constant + trend: 11.47, 12.95 and 14.03 for the 5% level of significance for 1, 2, and 3 break dates, respectively.
Critical values of the Bai & Perron (2003) journal test are derived from econometrics at the 5% level of significance.

According to the empirical results of Zivot-Andrews and Bai-Perron tests, we can summarize the following dates of structural breakpoints and determine the most critical economic and financial facts for Korea that will fit with the structural breaks of these series.

The first date of the structural breaks is 1986–1987. What caused the structural breaks in these years? In 1986, the processing industries represented 30% of GDP. Gaining from the domestic reinforcement and help from abroad, Korean industries introduced modern technologies in newly built infrastructure increasing industrial production quickly. Government intervention reduced and there was liberalization on imports and foreign investments to promote competitiveness. These reforms resulted in the attraction of millions of workers to urban production centers, changing the country's landscape.

The second date is close to 1998. During the early 1990s, the Korean economy had a stable and strong development mainly in the industrial sector. However, the Asian economic crisis in 1997 changed everything. Speculators attacked many Asian currencies and the Korean won was underestimated to a large extent. The situation worsened due to the problem of non-performing loans in many Korean commercial banks. In December 1997, the IMF approved a loan of 21 billion dollars as a lifesaver. In 1998, the government closed one third of commercial banks in Korea and throughout the year the Korean economy shrank.

The third date is close to 2002. After the recovery from the crisis at the end of the 1990s, the economy continued its strong development with a GDP increase in 2000. However, the economy of South Korea was affected by the attack on September 11. The slowdown of the global economy, the downfall of exports, and the halt of corporate and financial reforms all contributed to the drop in development in 2002. The restructuring of industrial groups in Korea, bank privatization, and the creation of a liberalized economy remain the most important unfinished reforms in Korea.

The fourth date is close to 2007. Like most industrial economies, Korea had seen a decrease in development during the depression that began in 2007 and continued until 2009. Most sectors of the economy fell, especially the production sector. Car exports and semiconductors, two crucial pillars of the economy, decreased by approximately 34%. Like the 1997 crisis, the Korean currency experienced severe volatility reducing by 34% against the dollar.

6.3. Testing the Long-Run Relationship in Money Demand

After the unit root test, the question that arises is whether a long-run equilibrium exists on the money demand function. Johansen (1988) suggested two statistical measures for testing the number of cointegrated vectors, the L-max and the trace statistics. The cointegration of a time series means that the components could provide a dynamic specification through the error correction model (ECM) that tends toward a stationary money demand function. It must be highlighted that the adoption of the best strategy for finding the long-run relationship between money demand, development and interest rate is considered the basis for the success of monetary policies.

Table 4. Johansen's maximum likelihood cointegrating tests.

$H_0 \mid H_1$	L-max test	5% Critical value	$H_0 \mid H_1$	Trace test	5% Critical value
Model A: (LM1, LIPI, DIR)					
$r \leq 0 \mid r=1$	42.2*	24.2	$r \leq 0 \mid r=1$	52.2*	35.0
$r \leq 1 \mid r=2$	9.73	17.1	$r \leq 1 \mid r=2$	9.95	18.4
$r \leq 2 \mid r=3$	0.21	3.84	$r \leq 2 \mid r=3$	0.21	3.84
Model B: (LM1, LIPI, LDIR)					
$r \leq 0 \mid r=1$	29.2*	24.2	$r \leq 0 \mid r=1$	38.1*	35.0
$r \leq 1 \mid r=2$	7.87	17.1	$r \leq 1 \mid r=2$	8.86	18.4
$r \leq 2 \mid r=3$	0.99	3.84	$r \leq 2 \mid r=3$	0.99	3.84
Model C: (LM3, LIPI, DIR)					
$r \leq 0 \mid r=1$	44.4*	24.2	$r \leq 0 \mid r=1$	62.4*	35.0
$r \leq 1 \mid r=2$	16.8	17.1	$r \leq 1 \mid r=2$	17.9	18.4
$r \leq 2 \mid r=3$	1.12	3.84	$r \leq 2 \mid r=3$	1.12	3.84
Model D: (LM3, LIPI, LDIR)					
$r \leq 0 \mid r=1$	29.9*	24.2	$r \leq 0 \mid r=1$	46.7*	35.0
$r \leq 1 \mid r=2$	16.36	17.1	$r \leq 1 \mid r=2$	16.8	18.4
$r \leq 2 \mid r=3$	0.48	3.84	$r \leq 2 \mid r=3$	0.47	3.84

Note: * denotes significance at the 1% level.

In this paper, the Akaike criterion (AIC) is adopted for the determination of optimal lag numbers. The Akaike criterion suggests seven lags for all VAR examined models. The results in Table 4 present the L-max and Trace statistics for all models.

The results of the Johansen cointegration test show that the trace test and maximum eigenvalue confirm the existence of one cointegrated vector at the 5% level of significance in all four models implying the existence of a long-run relationship.

The cointegrated vectors are normalized in relation to real money, and we get the following:

Model A: (LM1, LIPI, DIR) LM1= 0.999LIPI-0.170DIR (10)

Model B: (LM1, LIPI, LDIR) LM1= 0.994LIPI-0.681LDIR (11)

Model C: (LM3, LIPI, DIR) LM3=1.009 LIPI -0.181DIR (12)

Model D: (LM3, LIPI, LDIR) LM3=1.000 LIPI -0.710LDIR (13)

From the above equations, we can see that the elasticity of long-run industrial production in relation to real money is positive and close to one as suggested by the money supply theory. The elasticity of a long-run interest rate in relation to real money is negatively affected in all four models with the lowest to be presented in the semi-logarithmic models. The interest semi-elasticity is 0.170 and 0.181 for models A and C, respectively, whereas the elasticity of interest rate is 0.681 and 0.710 for models B and D, respectively. This implies that high interest rates in Korea reduce the demand for narrow and broad money. Moreover, in absolute value, the interest rate has a larger effect on the demand for real M3 than real M1.

6.3.1. Structural Break Test

The estimation period of this paper covers time periods of economic development, innovation and reforms in the Republic of Korea. The same period covers the Asian and Global financial crises, facts that affected the country's fiscal and monetary policies. Consequently, it is important to test for a cointegrated relationship and structural breaks (Gregory & Hansen, 1996). Gregory and Hansen suggested a number of tests based on residuals creating cointegrated models with a potential of an endogenous structural break. The three Gregory and Hansen models with possible endogenous structural breaks with two variables can be expressed as follows:

Model C: Level shift

$$Y_t = \mu_1 + \mu_2 D_t(r) + \alpha_1 X_t + e_t \tag{14}$$

Model C/T: Level shift with trend

$$Y_t = \mu_1 + \mu_2 D_t(r) + \beta_1 t + \alpha_1 X_t + e_t \tag{15}$$

Model C/S: Regime shift (that allows the slope vector to shift)

$$Y_t = \mu_1 + \mu_2 D_t(r) + \alpha_1 X_t + \alpha_2 X_t D_t(r) + e_t \tag{16}$$

The break date in the above models is defined endogenously with a dummy as follows (see Gregory & Hansen (1996)):

$$D_t = \begin{cases} 0 & if \quad t \le [n,r] \\ 1 & if \quad t > [n,r] \end{cases}$$

where $r \in (0,1)$ is an unknown parameter that denotes the timing change of the point and the brackets denote an integer. Dummy D_t allows us to test one structural change or a regime shift. In the above equations, parameter μ_1 is the constant before a shift, and parameter μ_2 is the change in the constant due to a shift.

For cointegration testing of the above models with one structural break (residuals' stationarity e_t), Gregory & Hansen (1996) suggested the use of three tests. These tests are modifications of the Z_α and Z_t statistics suggested by Phillips (1987) as well as ADF statistics. These statistics are specified as follows:

$$Z_\alpha^* = \inf_{r \in T} Z_\alpha(r)$$

$$Z_t^* = \inf_{r \in T} Z_t(r)$$

$$ADF^* = \inf_{r \in T} ADF(r)$$

where $Z_{\alpha}(r)$, $Z_t(r)$ and $ADF(r)$ correspond to the choice of structural break r. The T values obtained are a subtotal from interval $(0,1)$. Gregory and Hansen suggested that T is in the interval $[0.15 \le T \le 0.85]$. According to Monte Carlo repetitions, Gregory and Hansen created critical values modifying MacKinnon (2010). The null hypothesis of the Gregory–Hansen test is that a unit root exists on models' residuals [the variables are integrated of order one I(1)] thus there is no cointegration with a structural break, whereas the alternative hypothesis is that there is no unit root on residuals, therefore a cointegration with one structural break exists. The null hypothesis is rejected if Z_{α}^*, Z_t^* and ADF^* statistics are smaller than the corresponding Gregory–Hansen critical values.

Table 5 presents the results of the Gregory and Hansen test for the examined models.

Table 5. Gregory and Hansen test results for regime shifts.

Model	M1				M3			
	Test statistics	Breakpoint	Test statistic	Breakpoint	Test statistic	Breakpoint	Test statistic	Breakpoint
ADF^*								
C	-5.92**	1988 M04	-5.61**	1981 M05	-5.76**	2014 M05	-5.60**	2009 M07
C/T	-4.87	2008 M03	-6.17**	1999 M04	-5.92**	1982 M02	-6.12**	1998 M08
C/S	-6.95**	1999 M01	-6.74**	1990 M03	-6.59**	1998 M07	-5.92	1981 M05
Z_t^*								
C	-5.64**	2011 M09	-5.59**	2011 M10	-5.57**	2020 M03	-5.08	1987 M04
C/T	-5.91**	2001 M08	-6.03**	2000 M02	-5.12	1981 M04	-6.23**	2013 M01
C/S	-6.47**	2020 M03	-5.43	1993 M10	-6.47**	2010 M09	-6.92**	2010 M05
Z_{α}^*								
C	-21.785	1993 M09	-27.819	1998 M01	-30.284	1984 M03	-29.216	1981 M05
C/T	-28.536	2001 M06	-32.561	2008 M02	-37.892	2008 M12	-39.453	2011 M03
C/S	-34.317	2019 M08	-40.713	2020 M01	-45.671	2011 M01	-48.962	2020 M05

Note: ** Significant at the 5% level. The critical values are from Table 1 of Gregory & Hansen (1996).
The 5% critical values for ADF (and Z t) are -5.56, -5.83 and -6.41 for equations C, C/T and C/S, respectively, while the Z_a for the same equations are -59.40, -65.44 and -78.52, respectively (see Table 1 of Gregory & Hansen (1996)).

The money demand functions for narrow money (M1) and broad money (M3) reveal structural breaks in the ADF^*, Z_t^* and Z_{α}^* statistics. The tests indicate that structural breaks in the cointegrated vectors are significant and should be taken into account in the specification of the money demand function. Therefore, the specification of the money demand function, including a varying economic and financial incident, raises some questions as far as the long-run relationship among the time series is concerned.

According to the ADF^* and Z_t^* statistics, the demand function of narrow money (M1), the years of structural breaks estimated by the three models are 1988 and 1990, 1999 and 2000 and also 2020. The depression of the economy of South Korea in 1989, due to the sharp decline of exports, caused deep nervousness in the industrial sector. Analysts reported that inefficiency of exports was due to structural problems of country's economy, including a highly powerful profit, increased wages, high labor cost, strikes and high interest rates. The result was an increase of inventories and drastic cuts in production in various sectors, such as construction, electronics, automobiles and textiles.

During 1999–2000, the economic problems of the country derived from debt exchange from international creditors. A large part of South Korea's recovery from the Asian financial crisis in 1997 can be attributed to labor adjustments, in other words to a dynamic and productive labor with flexible wages, and also to alternative financial sources. After recovery from the crisis at the end of 1999, the economy continued to increase in 2000 with the GDP reaching almost 9%.

The economy of South Korea withdrew during the first quarter of 2020, recording the worst performance after the global financial crisis, and the GDP decreased significantly in relation to the previous quarter.

For the demand function of broad money (M3), the years with structural breaks based on the three models are at the beginning of 1980. In order to test the inflation in Korea, a conservative monetary policy and strict fiscal measures were adopted. The governmental intervention in the economy reduced significantly and the policies concerning imports and foreign investments were liberalized in order to promote competitiveness.

In 2010, Korea recorded a strong economic recovery with a growth rate 6.1% signifying high levels economic growth in the economy before the crisis. Exports recorded a high increase in exports in the first eleven months in 2010.

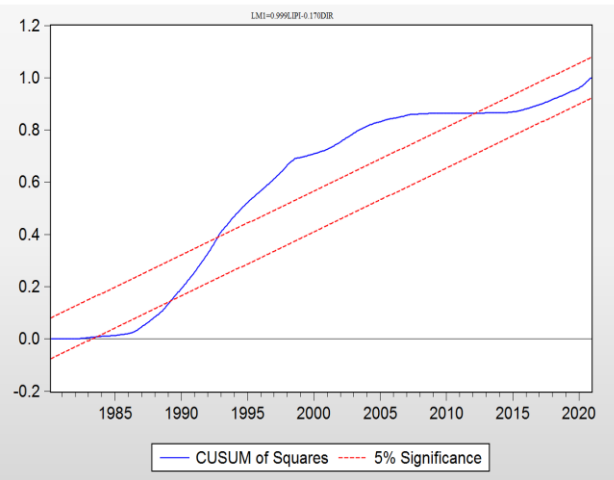
The Korean government signed the agreement of free trade between Korea and Australia in December 2013. The Australian government tried to benefit from numerous industries including automobile, services and energy industries and place them next to competitors such as the USA and Asia.

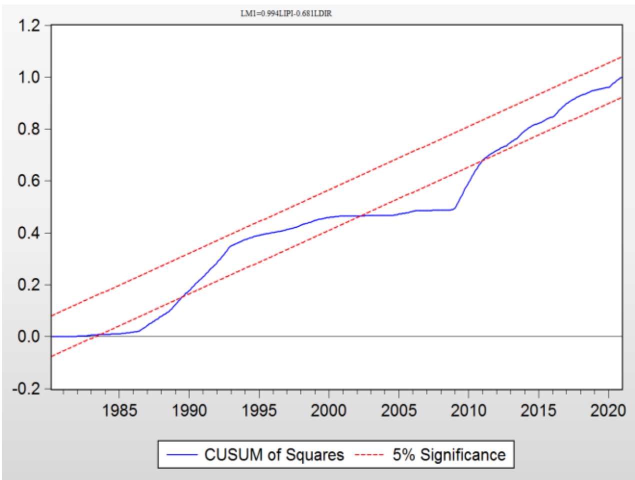
After the 2020 pandemic, the economic activity of South Korea decreased sharply and was characterized as the worst activity since the global financial crisis. The Korean authorities reacted immediately by supporting the economy. However, GDP shrank considerably.

These tests show that the structural breaks in the cointegrated vectors are important and should be taken into account in the specifications of the money demand function in Korea. The results are crucial, given the fact the endogenous estimation process generates structural breaks that correspond to recognizable financial and economic events. Thus, the specification of the money demand function that encompasses changes from economic events and fiscal deregulations raises some significant queries related to the long-run relationship between money, industrial production and interest rate.

6.3.2. Stability Test

If there are indications of cointegration with structural breaks, we estimate an error correction model. Also, coefficients' stability in the models is examined using Brown, Durbin, & Evans (1975) tests based on the intertemporal behavior of the recursive residuals of all equations. The cumulative sum of squares (CUSUMSQ) introduced by Brown et al. (1975) tests the stability of all equations, and the results are presented in Figure 3.





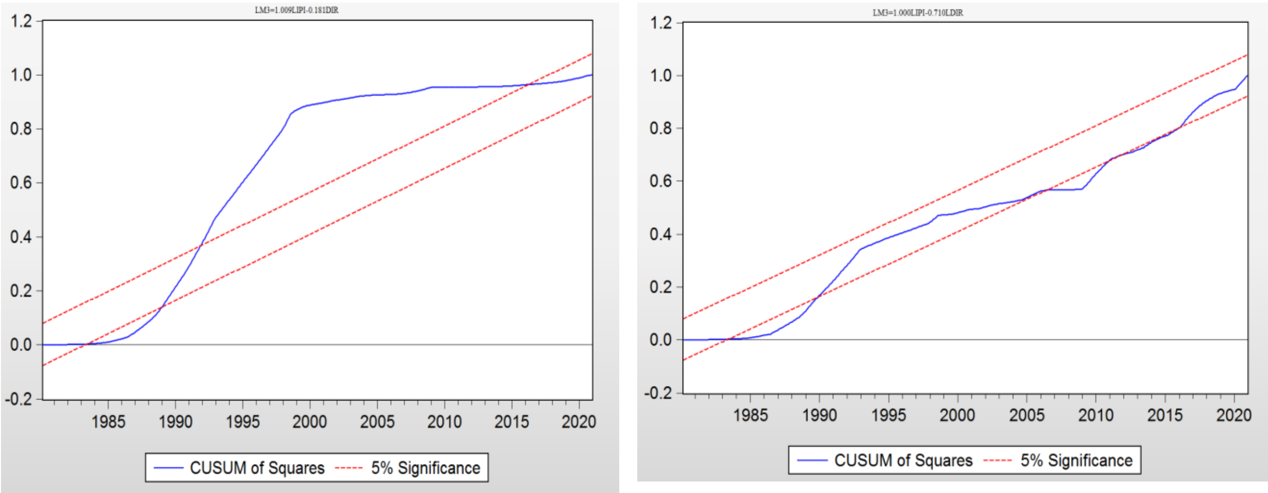


Figure 3. Cumulative sum of squares of recursive residuals (*CUSUMSQ*) stability tests.

The results of the stability tests and error correction model provide evidence in favor of instability on the money demand function during the period from 1980 to 2020. The CUSUMSQ statistics remain outside the critical bounds at the 5% level of significance, thus there is evidence of instability on the long run models' estimation examined for Korea.

6.4. Exogeneity and Causality Tests

In order to test for a long-run causal relationship between cointegrating relationships, we test for weak exogeneity (see Johansen & Juselius (1990)). Arestis, Demetriades, & Luintel (2001) interpreted the weak exogeneity of a system which has the concept of long-run causality. The null hypothesis is the existence of weak exogeneity $H_0 : \beta_{ij} = 0$ for $j = 1,\ldots,r$, where β is the impetus of the adjustment parameters, so that error equilibrium coefficients in a dynamic equation for real money and i only contain zero. If the test results are not able to reject the null hypothesis, then this proves a weak exogenous variable. Conversely, if the null hypothesis is rejected, then a bi-directional causality exists between the variable and other weak exogenous variables.

Table 6. Test for weak exogeneity of the demand function.

H_0: weak exogenous variable	Chi-square statistics	Probability
Model A: (LM1, LIPI, DIR)		
LM1	427(7)	0.00
LIPI	7.98(7)	0.33
DIR	27.2(7)	0.00
Model B: (LM1, LIPI, LDIR)		
LM1	392(7)	0.00
LIPI	8.01(7)	0.33
LDIR	20.8(7)	0.00
Model C: (LM3, LIPI, DIR)		
LM3	226(7)	0.00
LIPI	8.27(7)	0.31
DIR	4.53(7)	0.72
Model D:(LM3, LIPI, LDIR)		
LM3	154(7)	0.00
LIPI	9.81(7)	0.19
LDIR	1.13(7)	0.99

Table 6 shows that weak exogeneity is rejected both for narrow money (M1) and broad money (M3) as well as for the interest rate in both models for M1 at the 1% level of significance. This indicates that there is a long-run unidirectional causality from industrial production to M1 and bi-directional causality between M1 and interest rate in both models (semi-logarithmic and logarithmic). For M3, there is a long-run unidirectional causal relationship from industrial production and interest rate to M3 in both models. Based on the result of the weak exogeneity test, the short-run model can be designed using one equation system, both for broad and narrow money, taking into account that industrial production and interest rate (in broad money) are exogenously weak. The dynamic adjustment to disequilibrium occurs through changes in real money.

For further analysis of the causal relationship between the equation variables, we perform the Granger Causality/Block Exogeneity Wald tests based on the VEC model. This procedure assesses the significance of each joint lagged endogenous variable in every VAR equation through chi-square statistics and at the same time the significance of the joint contribution of all offset endogenous variables presenting in the equation using F-statistics. In Table 7, the Wald test is shown for every equation of the estimated VAR models regarding the joint significance of the other endogenous variables based on the selected offsets defined by the Akaike and Schwarz information criteria.

Table 7. Block causality tests.

VEC Granger Causality/Block Exogeneity Wald Tests Sample: 1980:01–2020:12 Included observations: 484							
Dependent Variable D(LM1)				Dependent Variable D(LM1)			
Excluded	Chi-sq	df	Prob.	Excluded	Chi-sq	df	Prob.
D(LIPI)	7.98	7	0.33	D(LIPI)	8.00	7	0.33
D(DIR)	27.27	7	0.00	D(LDIR)	20.87	7	0.00
ALL	37.41	14	0.00	ALL	31.67	14	0.00
Dependent Variable D(LIPI)				Dependent Variable D(LIPI)			
Excluded	Chi-sq	df	Prob.	Excluded	Chi-sq	df	Prob.
D(LM1)	12.36	7	0.08	D(LM1)	12.52	7	0.08
D(DIR)	8.13	7	0.32	D(LDIR)	20.11	7	0.00
ALL	22.52	14	0.06	ALL	29.99	14	0.00
Dependent Variable D(DIR)				Dependent Variable D(LDIR)			
Excluded	Chi-sq	df	Prob.	Excluded	Chi-sq	df	Prob.
D(LM1)	14.88	7	0.03	D(LM1)	16.23	7	0.02
D(LIPI)	9.01	7	0.25	D(LIPI)	26.68	7	0.00
ALL	24.78	14	0.03	ALL	39.07	14	0.00

VEC Granger Causality/Block Exogeneity Wald Tests Sample: 1980:01–2020:12 Included observations: 484							
Dependent Variable D(LM3)				Dependent Variable D(LM3)			
Excluded	Chi-sq	df	Prob.	Excluded	Chi-sq	df	Prob.
D(LIPI)	8.27	7	0.30	D(LIPI)	9.81	7	0.19
D(DIR)	4.53	7	0.71	D(LDIR)	1.12	7	0.99
ALL	13.08	14	0.52	ALL	11.36	14	0.65
Dependent Variable D(LIPI)				Dependent Variable D(LIPI)			
Excluded	Chi-sq	df	Prob.	Excluded	Chi-sq	df	Prob.
D(LM3)	5.84	7	0.55	D(LM3)	4.67	7	0.69
D(DIR)	8.56	7	0.28	D(LDIR)	19.08	7	0.00
ALL	14.74	14	0.39	ALL	22.59	14	0.06
Dependent Variable D(DIR)				Dependent Variable D(LDIR)			
Excluded	Chi-sq	df	Prob.	Excluded	Chi-sq	df	Prob.
D(LM3)	23.83	7	0.00	D(LM3)	5.35	7	0.61
D(LIPI)	12.90	7	0.07	D(LIPI)	22.53	7	0.00
ALL	39.46	14	0.00	ALL	28.09	14	0.01

Notes: The VECM is used to estimate the speed of the adjustment toward equilibrium.

According to the results in Table 7, there is a bi-directional causal relationship between narrow money (M1) and interest rate in the semi-logarithmic function, whereas in the logarithmic function there is a bi-directional causal relationship between industrial production and interest rate and a unidirectional causal relationship from interest rate to M1. For broad money functions, there is a unidirectional, short-run, causal relationship from interest rate to M3 in the semi-logarithmic function and a bi-directional, short-run, causal relationship between industrial production and interest rate in the logarithmic function.

7. CONCLUSION AND POLICY IMPLICATIONS

Over the past few years, especially after the economic crisis and the pandemic, developments in the world economy have shaken many of the certainties or supposed certainties related to monetary policy and its long-run stabilization. According to Benati, Lucas, Nicolini, & Weber (2021), central banks in developed countries review their political frames in order to adjust to very low real interest rates. None is seriously considering examining the rules behind money, while money demand models do not exist for the first time. They also argue that even narrow money, the most rudimental monetary element, is considered to be the anchor of monetary policy, has been heavily criticized.

The money demand function should be determined correctly for the monetary policies employed by central banks. Identifying the most appropriate specification of the money demand function has a considerable impact on the population welfare cost and the exercise of monetary policy. Nevertheless, in the regression analyses of the money demand function, there is no consensus with regard to whether nominal interest rates should be used in their linear or logarithmic form as an independent variable. More specifically, Ireland (2009) has shown that the semi-log specification performs better than the log-log specification, which is contrary to the results found by Lucas (2000).

The stability of money demand is essential in order to overcome the effects of production and interest rates through the mechanism of monetary policy. Many central banks have moved to expressing money demand through multiple indices with M3 (broad money) capital share as an index for price movements in the future. However, the use of indices does not exempt money demand stability as a prerequisite because the main aim of every monetary policy is to ensure the stability of prices in the long run.

The current paper examined whether economic and financial reforms which took place in Korea have destabilized the money demand function during the period from 1980 to 2020. Some previous studies that have employed the cointegration technique in the estimation of money demand in Korea have interpreted the cointegration between variables as a sign of a stable money demand function. However, the advances in literature have shown that cointegration between a set of variables does not necessarily imply that the estimated vector is stable. The empirical findings are based on a rather elaborate methodology which first determines the full system of the money demand model, later reduces it to a simple equation, and finally to a structural variation with an unknown timing test. The latter, which allows regime shifts, seems to indicate a lack of stability of money demand in the case of all datasets examined (1980–2020) with its model specifications. This evidence seems to agree with the findings of Mohsen & Sungwon (2002), who showed that the stability of money demand in the case of Korea is unstable. These inconsistent findings in previous studies are due to the different model specifications applied, the econometric methods used and the time span of the data. This finding is reassuring from the endogenous estimation process point of view, which produced variations that correspond to recognizable economic and financial events.

In general, the current paper presents the following empirical results:

- Based on the results from the Zivot-Andrews and Bai-Perron tests, we found several structural fluctuations and critical economic and financial incidents reflected in these fluctuations.
- The long-run elasticity of industrial production to real money is positive and very close to one, as suggested by the theory of money supply.

- The elasticity of long-run interest rate to real money is negative. Furthermore, in absolute terms, interest rates have a greater effect on the demand for broad money (M3) in comparison to narrow money (M1).
- The weak exogeneity is rejected in the cases of M1 and M3 as well as the interest rates in both models for M1 at the 1% significance level. This suggests a one-way causality from industrial production toward M1 in the long-run. In the case of M3, there is a long-run, one-way, causal relationship from industrial production and interest rates toward M3 in both models.
- The estimated structural variations are particularly evident for 1989, 1997 and 2007, which could be linked to respective critical financial and economic events. As a result, when the money demand is analyzed in the case of Korea, a structural variation should definitely be considered.

A fact of considerable interest is that the elasticity of industrial production to the demand of M3 is bigger than that of M1 and even greater than the elasticity of interest rates. Assuming that the aim of monetary policy is broad money (M3), then the efforts of the central bank toward M3 supply should not occur through interest rate but through industrial policy. Since the elasticity of industrial production is greater that the elasticity of interest rates, in order to set a monetary policy and be more efficient, the central bank should interrupt money supply through industrial production and not through changing interest rates.

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Authors' Contributions: Both authors contributed equally to the conception and design of the study.

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Appendix A. Data descriptions.

Variables	Periods	Database	Explanation
m = M/P (real money)	1980:1–2020:11	OECD	M - Broad Money (M3) Index (2015 = 100), seasonally adjusted
P = CPI	1960:1–2020:11	Federal Reserve Bank of St. Louis	P - Consumer Price Index (2015 = 100), seasonally adjusted
y (output)	1989:1–2020:12	Federal Reserve Bank of St. Louis	Industrial Production Index (2015 = 100), seasonally adjusted
r (interest rate)	1964:1–2020:10	Federal Reserve Bank of St. Louis	Discount Rate for Republic of Korea, percent per month, seasonally adjusted