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Content

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DOES MODERN MONETARY POLICY STABILIZE COMMODITY PRICES? THE PARADIGM DURING COVID-19

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Abstract

The recovery of the global economy from the COVID-recession accompanied by expanding liquidity, monetary loosening, and fiscal expansion led has led to rising commodities prices across the world including Ghana. Using VEC model, we examined the effect of monetary policy expansion in Ghana on commodity prices (including cocoa, gold and crude oil). The empirical evidence suggests a short run and long run relationship between Ghana's monetary policy and commodity prices. The long run and short-run relationship shows that Ghana's monetary policy shock leads to an immediate rise in cocoa and gold prices index but negative impact crude oil price index which possibly reflect high production cost and an aggregate bias. In addition, whiles the analysis found that the aggregate commodity price index is positively related to monetary policy, the period characterized by COVID-19 mirrored exactly opposite the relationship found during the 2008 financial crisis. We recommend that policy makers should recognize the source of inflation before engaging in expansionary monetary policy. Also, the design of core inflation targeting is essential to inflation targeting.

Keywords: *Monetary policy; Commodity price; VEC; COVID-19; Exchange rate.*

INTRODUCTION

Though periods of changes in interest rate affect many different sectors of the economy such investment, savings, export, capital flow, exchange rate and other developments. The importance and impact of monetary policy on sectorial commodity prices cannot be overemphasized. Most research trace the impact of monetary policy on commodity prices through exchange rate transmission mechanism with emphasis on agricultural commodities. Whiles demand and supply factors can explain the fluctuations in commodity prices, other factors such as monetary and fiscal policy variables play important roles (Hamilton, 2009). Alquist and Kilian (2010) showed that precautionary demand shocks increase demand and thus causes commodity prices to increase as the future become more uncertain.

The recovery of the global economy from the pandemic accompanied by policies of expanding financial liquidity, monetary loosening and expansionary fiscal policy has led to rising commodity prices. In the first two quarter of this year, Blomberg's general commodity price index increased more than 20%. This is largely driven by a 44.5% spike in energy prices followed by an increase in agricultural good price index by 20.5% and another 17.5% rise in industrial metal prices (Beatriz Villafranca, 2021). Supply chain problems, labor supply shocks, and demand shocks has led to increasing volatility in producer prices index, import, and export prices and has impacted commodity prices across the world. Notwithstanding that, the monetary policy continues to play major roles in inflation determination.

The prices of Oil, gasoline, copper, and corn more than doubled over the past 20 years and continued to increase through the pandemic. According to Ghana commodity exchange index (2021), gold price and cocoa price index has more than doubled since the start of the pandemic whiles crude oil price has seen similar hikes in prices. Other locally produced commodities such as maize, soyabean, have seen similar hikes in price. During the same period monetary policy rate decrease from 16% to 12.5%. Whiles M2 representing broad money supply has increase from $137,548.40 million dollars to 13,542.85 million dollars in the first ten months of 2020. Monetary tools have been employed to diagnose the problem whiles fiscal expansion continues.

This paper deals with the impact of monetary policy of sectorial commodity prices. By discretion, most central banks usually use interest rate changes as a monetary tool to stabilize inflation and maintain low level of unemployment. Inflation targeting rules that use interest rate changes as tool to regulate employment affect commodity prices adversely. For example, during the 2020 economic lockdown due to the pandemic, most central banks reduced interest rate in order to induce borrowing and stimulate investment. This led to some transitory changes in the general price level resulting in more than proportionate increases in many commodities prices.

The goal of this paper is to find the time path of monetary policy shock on the aggregate commodity prices index and also the three major commodities in Ghana's export composition. The paper adopted a Vector Error Correction Model (VECM) and bounds testing technique to determine the impact of monetary policy on commodity prices in the long-run and the short-run (separate the effect for periods of crisis and no-crisis). The paper hypothesizes that expansionary monetary policy have structural implications for commodity prices.

LITERATURE REVIEW

The short-term interest rate is an important tool in promoting economic growth and price stability. The theoretical foundation of interest rate changes and changes in the general price level is rooted in interest rate parity (Hammoudeh et al., 2015). According to Frankel (1986), the relationship between interest rate and commodity prices is ingrained in the no-arbitrage condition which posit that the expected rate of change in commodity prices minus its storage cost is equal to the short-term interest rate. Another empirical perspective on monetary shock and commodity price relationship posits that, the general rise in price level due to interest rate shock is proportional to the changes seen in commodity prices (Franke & Hardouvelis, 1985).

Also, Frankel (1984) show that an expansion in money supply increases the real prices of the commodities because prices of many other goods display rigidity in the short term. Again, Frankel & Rose (2010) investigated the monetary policy interest rate nexus, and concluded that, interest rate does not fully show the impact of monetary shock on commodity prices. Another empirical work by Azuini et al., (2012) shows that monetary policy affect commodity prices through demand and supply forces as such interest rate were the main driving force of commodity prices. Demand forces from low interest rate reduces the opportunity cost of holding money, increase money demand and thereby leading to an increase in commodity prices. Conversely, supply forces from low interest rate affect inventory negatively, reduce supply level and raise market price.

A number of previous works used standard VAR and Bayesian framework to assess the impact of monetary policy on commodity prices. Christiano et al., (2005) used monetary policy shock in the US and found large and negative effect of monetary policy contractions on the aggregate commodity price index. They argued that including commodity price index in the system of endogenous variables help solve the price obscurity. Sousa (2010) used data from the euro area found substantial effect of monetary policy on commodity price index after accounting for household composition wealth effect. Malik and Sousa (2012) investigated the effect of monetary policy on commodity prices using data from the BRICS. They reported that contractionary monetary policy results in an immediate fall in aggregate commodity prices. Carolina et al., (2014) showed that commodity prices overshoot their long run equilibrium in response to a contractionary shock using that from the US. and, in contrast to literature, they found that the response of the individual commodity prices is stronger than what has been found in the aggregate commodity prices. Furthermore, they found that the monetary policy explains a major share of the fluctuations in prices.

Anzuini et al., (2008) performed a structural VAR estimation (SVAR) which allows identifying monetary policy shocks by assuming structural restrictions on their contemporaneous impact on the system. The results posits that the monetary effects on aggregate commodity prices are statistically significant and that the short-run response usually has an overshooting during the first year after the shock. The paper also finds the shock on inflation and growth expectations as the main transmission channel.

Hammoudeh et al., (2015) reported that monetary contraction leads to immediate increase in broad commodity prices index, however the shock disappears after some time as the interest rate increase and liquidity drainage take a grip. Akram (2013) suggest that an explanation for the possible weakness in the relationship between monetary policy and commodity prices may be due to the possible weakness in controlling for macroeconomic variables like the real exchange rate and economic activities. There exists endogeneity between commodity prices and interest rate, low interest rate implies high commodity prices and high commodity prices can lead an increase in aggregate price indices and subsequently a contractionary monetary policy.

From the literature, it could be noted that empirical relationship between monetary policy and commodity prices does not always result in a consensus. More importantly, the use of aggregate measures for commodity prices enshrouds important price reactions of different sectors of the economy. This analysis tries to bridge the gap in existing literature by using the case of small open economy Ghana whiles controlling for the impact of real exchange rate, GDP, and other macroeconomic variables.

METHODOLOGY

Data

The scope of this study is to find out the effects of Ghana-monetary policy on commodity prices. The study uses a time series data on the Ghana from 2000: 1 to 2021: 3. Data for empirical analysis will be extracted from the Word development Indicators and the Bank of Ghana. The macroeconomic variables used in the estimation include GDP, GDP deflator, private consumption and investment, Monetary policy rates (MPR), M2, as money supply measure instrument for the analysis. The MPR and M2 data is extracted from the Bank of Ghana and growth rate of M2 calculated. Aggregate commodity price index is an aggregation of sectorial activity price level change and therefore these different commodity categories will be explored. The commodity price index data cover the monthly commodity prices on cocoa (COC), gold (GLD) and crude oil (CRU) was obtained from the Bank of Ghana. and food (Maize, soyabean) index from Ghana commodity exchange database. These commodities are the major export commodities of Ghana.

Econometric Model

The variables are non-stationary and co-integrated hence, the study uses the Vector Error Correction (VEC) model to make the most of the information on long-run stochastic relations while preserving the properties of the time series data. The model is explained below:

If two non-stationary variables y_t and x_t are integrated of order 1: $y_t \sim I(1)$ and $x_t \sim I(1)$ and proved to be cointegrated, so that:

$$y_t = \beta_0 + \beta_1 x_t + e_t \tag{1}$$

The VEC model is a special form of the VAR for I (1) variables that are cointegrated. The model can be specified as:

$$\Delta y_t = \alpha_{10} + \alpha_{11} + (y_{t-1} - \beta_0 - \beta_1 x_t) + v_t^y \tag{2}$$

$$\Delta x_t = \alpha_{20} + \alpha_{21} + (y_{t-1} - \beta_0 - \beta_1 x_{t-1}) + v_t^x \tag{3}$$

Equation (2) and (3) can be expanded as

$$y_t = \alpha_{10} + (\alpha_{11}+1)\, y_{t-1} - \alpha_{11}\beta_0 - \alpha_{11}\beta_1 x_{t-1} + v_t^y \tag{4}$$

$$x_t = \alpha_{20} + (\alpha_{21}+1)\, y_{t-1} - \alpha_{21}\beta_0 - (\alpha_{21}\beta_1 - 1)\, x_{t-1} + v_t^x \tag{5}$$

The coefficients α_{11}, α_{21} are error correction co-efficient and they show how much and respond to the cointegrating error $y_{t-1} - \beta_0 - \beta_1 x_{t-1} = e_{t-1}$. The model allows to examine how much dependent variable will change in response to a change in the explanatory variable (the cointegration part, $y_t = \beta_0 + \beta_1 x_t + e_t$, as well as the speed of the change (the error correction part, $\Delta y_t = \alpha_{10} + \alpha_{11}(e_{t-1}) + v_t^y$ where e_{t-1} is the co-integrating error.

This estimates a unique and stable long-run cointegrating vector between monthly data and the long-term interest rate. The Johansen–Juselius (1990) methodology was used to estimate the long-run cointegrating vector from a VEC of the form:

$$\Delta x_t = (L)\, \Delta x_t + DZ_t + \alpha\beta[x_{t-1}] \tag{6}$$

where x_t is a vector of endogenous variables (MPR, COC, GLD CRU), $\Gamma(L)$ is a matrix of parameters for a fourth-order lag process, Z_t is a vector of stationary exogenous variables, and D is the matrix of parameters associated with the exogenous variables. The parameters measure the speed at which the variables in the system adjust to restore a long-run equilibrium, and the vectors are estimates of the long-run cointegrating relationships between the variables in the model.

Long run relation

$$ECM = \beta_0 \ln MPR + \beta_1 \ln CRU + \beta_2 \ln COC + \beta_3 \ln GLD + C \tag{7}$$

Short run relation

$$\Delta \ln MPR_t = \alpha_0 ECM_t + \alpha_1 \Delta \ln MPR_{t-1} + \alpha_2 \Delta \ln MPR_{t-2} + \alpha_3 \Delta \ln CRU_{t-1} + \alpha_4 \Delta CRU_{t-2} + \alpha_5 \Delta \ln COC_{t-1} + \alpha_6 \Delta \ln COC_{t-2} + \alpha_7 \Delta \ln GLD_{t-1} + \alpha_8 \Delta \ln GLD_{t-2} + k \tag{8}$$

The monetary policy is characterized by

$$I_t = f(\Omega_t) + \varepsilon^{i}_{t} \tag{9}$$

i_t represent the central banks target interest rate, f is the linear function, Ω_t is the information set and ε^{i}_{t} is the shock to monetary policy rate(MPR).

here ECM is the error correction term for both the long and the short run relationship, MPR, CRU, COC and GLD. The framework above followed the work of Hammoudeh et al., (2015), Hendry & Adam (2002), Boateng et al., (2020) among others in estimate the model with all the variables.

RESULTS AND DISCUSSION

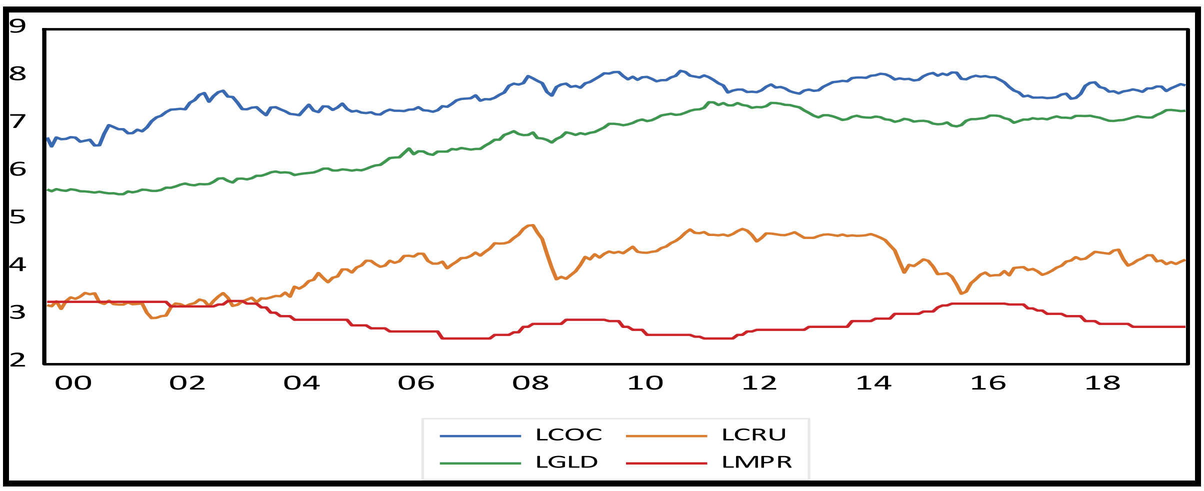

FIG 1. TREND ANALYSIS AND SUMMARY STATISTICS

The time series plot of Monetary policy rate shows a downward trend in monetary policy rate from 2000-2008. During same time, the selected commodities prices gold, crude oil and cocoa showed an upward trend in price. From 2008-2010, Monetary policy rate saw an upward revision. This was accompanied by a mix reaction from commodity prices. Initial upward adjustment in 2008 in monetary policy rate led to drop in crude oil prices sharply. Cocoa price and oil gold price index dropped but less proportionately. The period between 2010 through 2012 experienced another decreasing trend in monetary policy rate. During the same time, cocoa price index decreased whiles crude oil price and gold price experienced an increase in price. The increase in crude oil price could be attributed to a demand shock after the economic recovery from the prior global financial crises. From 2012-2016 saw another upward in monetary policy rates and began decreasing again prior to the 2019 Covid pandemic. Around the same period, the series plot for cocoa and gold showed an upward trend before dipping at the end to 2016 through 2019. The trend in crude oil price was exactly opposite the other commodities. Overall, the price of gold and cocoa fairly showed upward trend for the from 2000 through 2019. Gold prices trend keenly followed business cycles adjustments.

TABLE 1. MODEL RESULTS

Results For LR and SR model			
Variables	Short Run Model		Long Run Model
MPR	Δ(1)	Δ(2)	LR
lnMPR	0.987**(0.066)	-0.0235(0.0684)	1
lnCOC	0.0663*(0.0327)	-0.0512(0.0326)	0.077*(0.0269)
lnCRU	0.0164(0.0263)	0.0039(0.0255)	0.0423(0.0362)
lnGLD	-0.1356*(0.0598)	0.122*(0.061)	-0.028*(0.0408)
lnEXCH			- 0.0856*(0.0122)
lnGDP			-0.0140866
lnallcom			0.808(0.0522)
lnGDPI			0.223*(0.0108)
lnGDPC			0.0327*(0.0122)
lnGDPDEF			0.223*(0.0108)
Constant/ECM	0.5967*(0.1561)	-0.00511(0.0303)	4.310**(0.0192)
Observation	36	32	238
R-squared	0.971	0.916	0.984

Standard errors are in parentheses* $p < 0.1$**, $p < 0.05$*** $p < 0.01$

From the long-run model, the VECM shows that monetary policy rate is positively related to the exchange rate, and gold price index. This positive relationship is insignificant at 5% for gold and significant for the exchange rates. A 1% increase in exchange rates, and gold price index leads to 0.085% and 0.028% decrease in monetary policy rates respectively. Also, Monetary policy rate is negatively corelated with crude oil prices and cocoa prices. A percentage increase in crude oil price index by 1% cause monetary policy rates to increase by 0.042%. The model again predicts a positive impact of cocoa price on monetary policy rates. MPR increase by 0.077% when cocoa price increase by 1%. It's worth mentioning that Ghana is the second largest exporter of cocoa beans and thus not surprising to see cocoa price index have the largest impact on monetary policy rates. The lag of monetary policy is positively correlated with itself. This implies that today's monetary policy rates depend on yesterday's monetary policy rates. About 0.98% of monetary policy rate today is determined by yesterday's monetary policy rates.

The short run model revealed different dynamics. The first lag of monetary policy rate is positively related to itself whiles the second lag negatively correlated with monetary policy rate. However only the first lag is significant. The first and second lag of crude oil price index is positively influence monetary policy rate in Ghana though not statistically significant. The first lag of cocoa price index is significant and positively impact monetary policy rate. The second lag is negatively monetary policy rate but rather insignificant. The first and second lag of gold price index are jointly significant and positively correlated with monetary policy rate in Ghana.

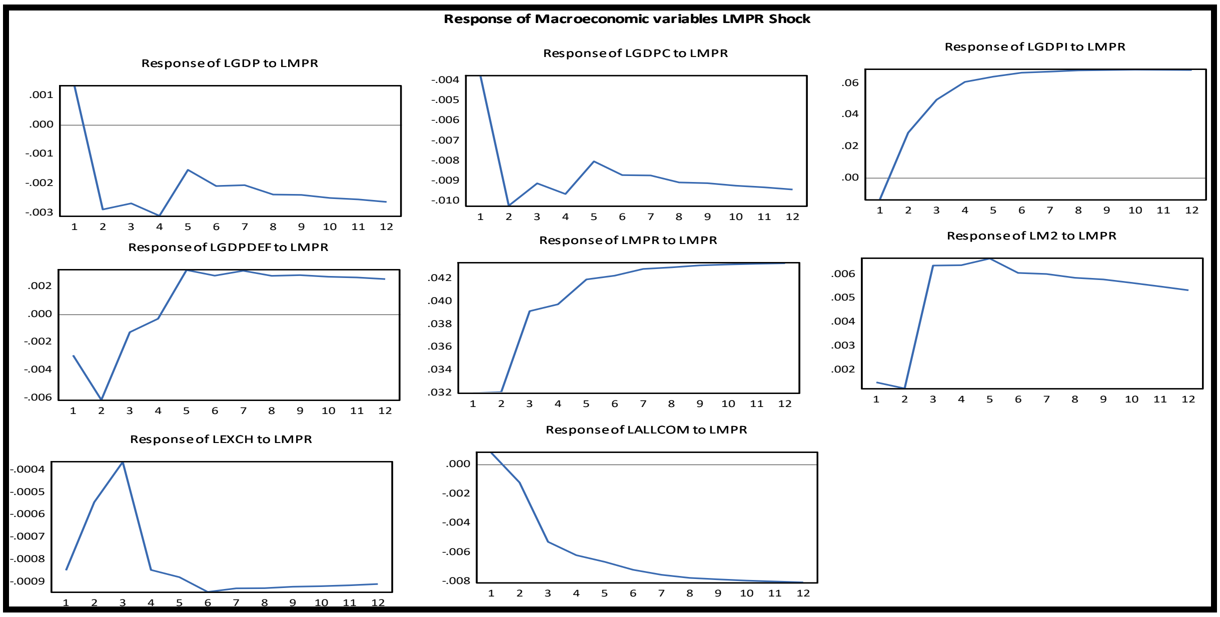

FIG 2. RESPONSE OF MACROECONOMIC VARIABLES

The empirical analysis shows that Monetary policy in Ghana leads to an immediate increase in broad commodity price index which reflect aggregate bias, high production cost and greater expected inflation or overshooting due to overreaction. The response of GDP and consumption due to contractionary monetary policy is negative but the response of GDP comes with a lag. The initial response of Investment (GDPI) and GDP deflator to monetary policy shock is negative. GDP deflator response turn upward but negative until month 4 and positive from month 4 to 12. The response of both monetary policy rate and growth rate of broad money(M2) is persistently positive with the lag. Thus, following an expansionary monetary, the aggregate price level increase, M2 growth increase reflecting an increase in liquidity. The exchange rate response is negative but increasing until month 3 and turned persistently negative.

TABLE 2. COINTEGRATION RANK TEST (TRACE)

Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	0.05 Critical Value	Prob.**
None	0.158285	69.16740	69.81889	0.0463
At most 1	0.071106	30.22442	47.85613	0.7075
At most 2	0.030188	13.55451	29.79707	0.8646
At most 3	0.019316	6.626881	15.49471	0.6214
At most 4	0.009769	2.218644	3.841465	0.1364

The Granger cointegration test popularized in 1981 was done to provide statistical basis on which an error correction model can be run, and this help to establish the long-run equilibrium relationship between the variables and the short-term disequilibrium of the generation of dynamic process. After this test, the short-term model was estimated with variables Monetary policy rate, gold, crude oil and cocoa. The lag of 2 was chosen for VEC model based on the results of the AIC and SC selection criterion. The AIC suggested an optimal lag of 3 whiles the SC suggested and optimal lag of 2. The final decision on lag of two was based on how significant these lags impact our VEC model.

Test Of Stationarity

TABLE 3. ADF UNIT ROOT TEST

Variable	Level t-value	P-value	Difference-Statistic	Prob.
MPR	-1.648606	0.4561	-8.518025	0.0000
GLD	-1.406506	0.5789	-13.61952	0.0000
CRU	-2.095438	0.2468	-12.06211	0.0000
COC	-2.938734	0.0425.	-13.96599	0.0000

TABLE 4. PP UNIT ROOT TEST

Variable	Level t-value	Level Value	Difference t-Statistic	Difference P-Value
MPR	-1.744034	0.4078	-16.23657	0.0000
GLD	-1.36905	0.5972	-13.59957	0.0000
CRU	-1.953588	0.3073	-12.04478	0.0000
COC	-2.356681	0.15535.	-13.99936	0.0000

Non-stationary time series contains unit roots or structural breaks. A time series is non-stationary, if it has a time varying mean and variance (Gujarati & Porter, 2009). The Augmented Dicker-Fuller test and Philips-Pearson unit roots test was carried out.

The p-values of the level variables were greater than 0.05 thus we failed to reject the null hypothesis that there the series are stationary. The first-difference p-values of both the ADF and PP showed that the variables are not stationary since their p-values is less than 0.05% level of significance.

TABLE 5. GRANGER CAUSALITY

Null Hypothesis:	Obs	F-Statistic	Prob.
LEXCH does not Granger Cause LMPR	226	10.7047	4.E-05
LMPR does not Granger Cause LEXCH		1.14768	0.3193
LCRU does not Granger Cause LMPR	238	2.29517	0.1030
LMPR does not Granger Cause LCRU		7.27243	0.0009
LCOC does not Granger Cause LMPR	238	2.26658	0.1059
LMPR does not Granger Cause LCOC		3.75033	0.0249
LGLD does not Granger Cause LMPR	238	2.72888	0.0674
LMPR does not Granger Cause LGLD		5.18298	0.0063
LCRU does not Granger Cause LEXCH	226	1.60129	0.2040
LEXCH does not Granger Cause LCRU		0.63094	0.5330
LCOC does not Granger Cause LEXCH	226	0.25315	0.7766
LEXCH does not Granger Cause LCOC		1.63422	0.1975
LGLD does not Granger Cause LEXCH	226	2.22532	0.1104
LEXCH does not Granger Cause LGLD		1.61175	0.2019
LCOC does not Granger Cause LCRU	238	0.17099	0.8429
LCRU does not Granger Cause LCOC		1.08238	0.3405
LGLD does not Granger Cause LCRU	238	2.90541	0.0567
LCRU does not Granger Cause LGLD		0.18427	0.8318
LGLD does not Granger Cause LCOC	238	1.62345	0.1994
LCOC does not Granger Cause LGLD		0.77340	0.4626

The results presented in table shows monetary policy rates granger cause gold price and crude oil prices. However, there is bi-directional causality between exchange rates and monetary policy rates as expected. The F-statistic of 2.91 and p-value of 0.05 implies that gold price also granger cause Crude oil price. There is also bi-directional granger causality between monetary policy rates and gold at 10% level of significance. From empirical observations, there granger causality between monetary policy rate and gold price, and exchange rate is expected.

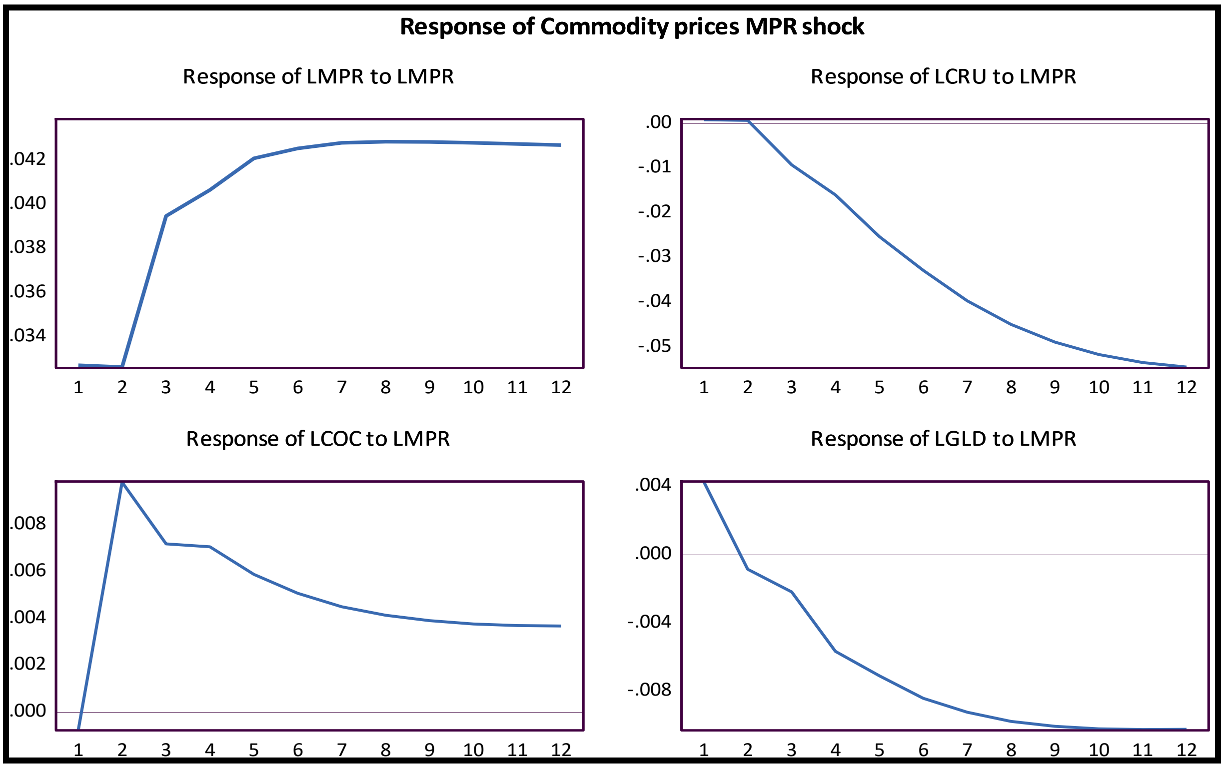

FIG 3. IMPULSE RESPONSE ANALYSIS

The impulse response analysis indicates that monetary policy rates have positive and persistent impact on itself. Today's MPR is dependent on yesterday's monetary policy rate. Also, the positive shock of monetary policy rate on exchange rate initially decreases and the turn positive after 12 periods and continued to be positive but quasi-convex. The positive shock of monetary policy rate on gold prices, crude oil prices is negative. The shock has persistently greater and positive effect on cocoa price.

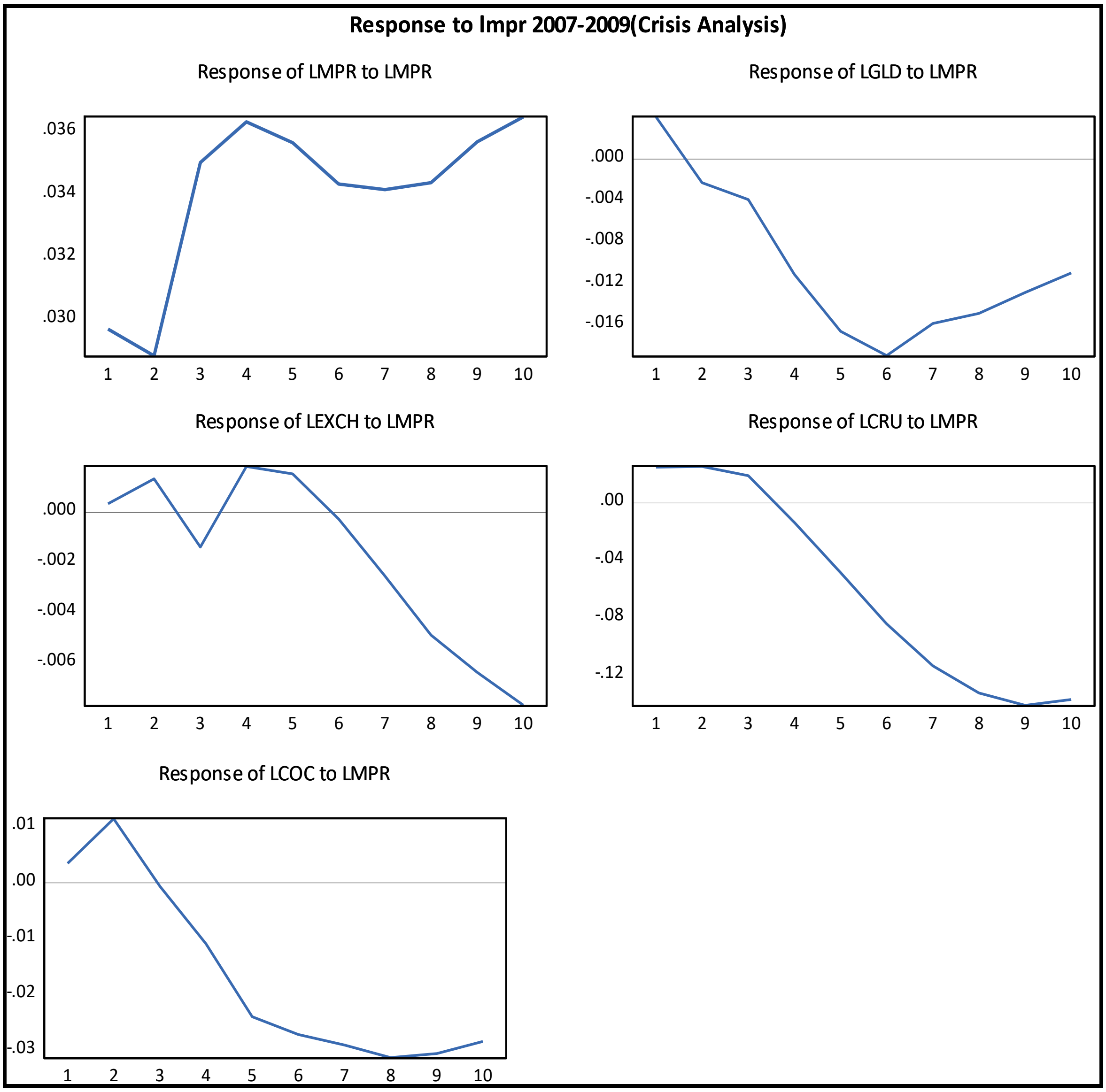

FIG 4. RESPONSE COMMODITY PRICES DURING 2007-2009 FINANCIAL CRISIS TO LMPR.

Between 2007 to 2009, Monetary policy responded positively to itself initially, dropped small by period 2 and begun to increase. Throughout the crisis monetary policy rate response was persistently positive. The initial response of exchange rate was near zero but begun to decrease to period 3 and, increased back positive in period 4 before finally decreasing. The initial response of all three commodity prices were positive but decrease to negative by period 2 for gold and between period 3 and 4 for crude oil and cocoa.

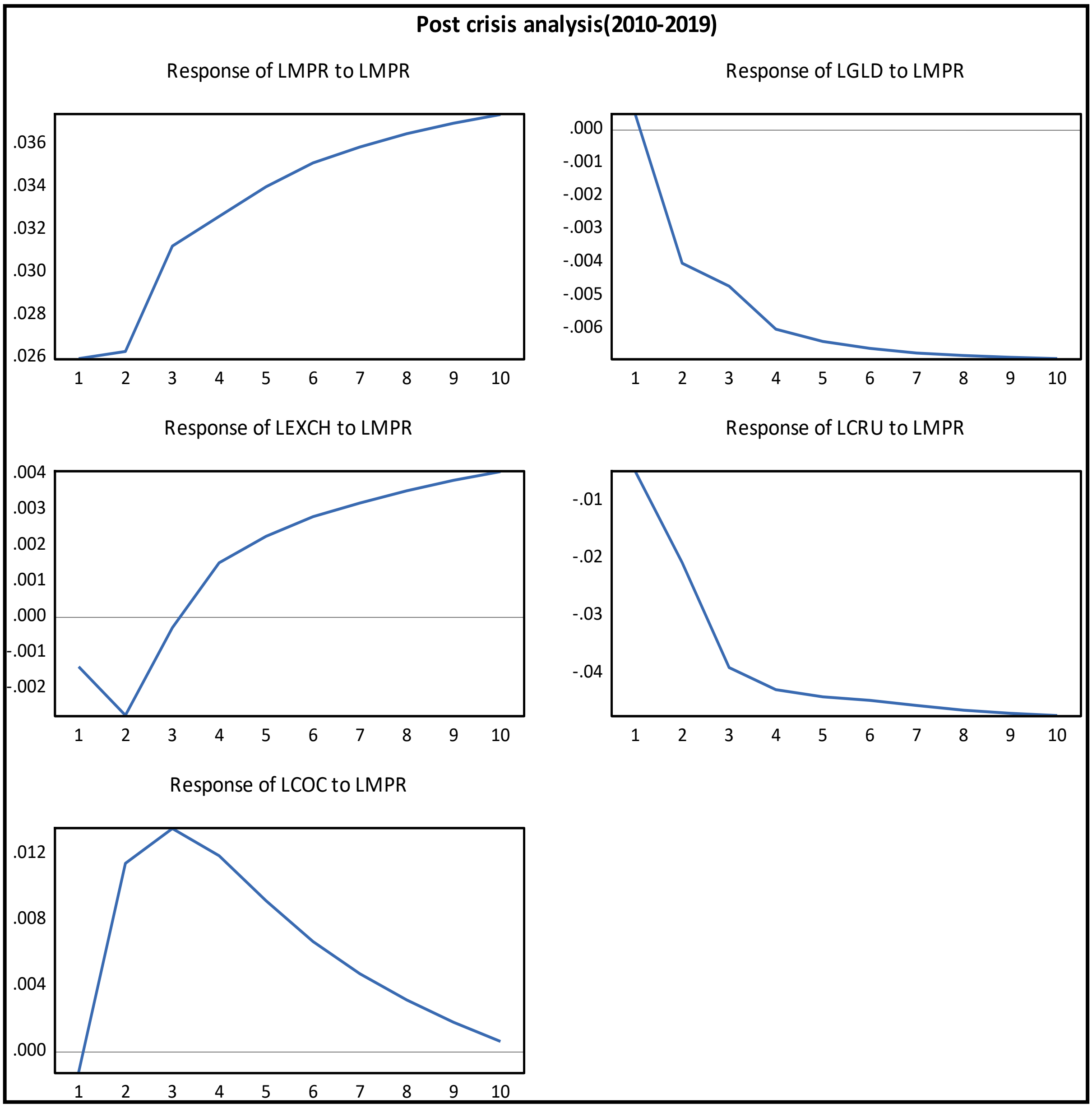

FIG 5. RESPONSE COMMODITY PRICES FROM 2010-2019 TO LMPR.

During the more stable period of 2010 to 2019, monetary policy rate responded the lag of lmpr positively. The response of exchange rate was initially negative but become positive by period 3. Cocoa price index response was persistently positive. The initial response of gold price and crude oil prices were positive but become negative by period 2.

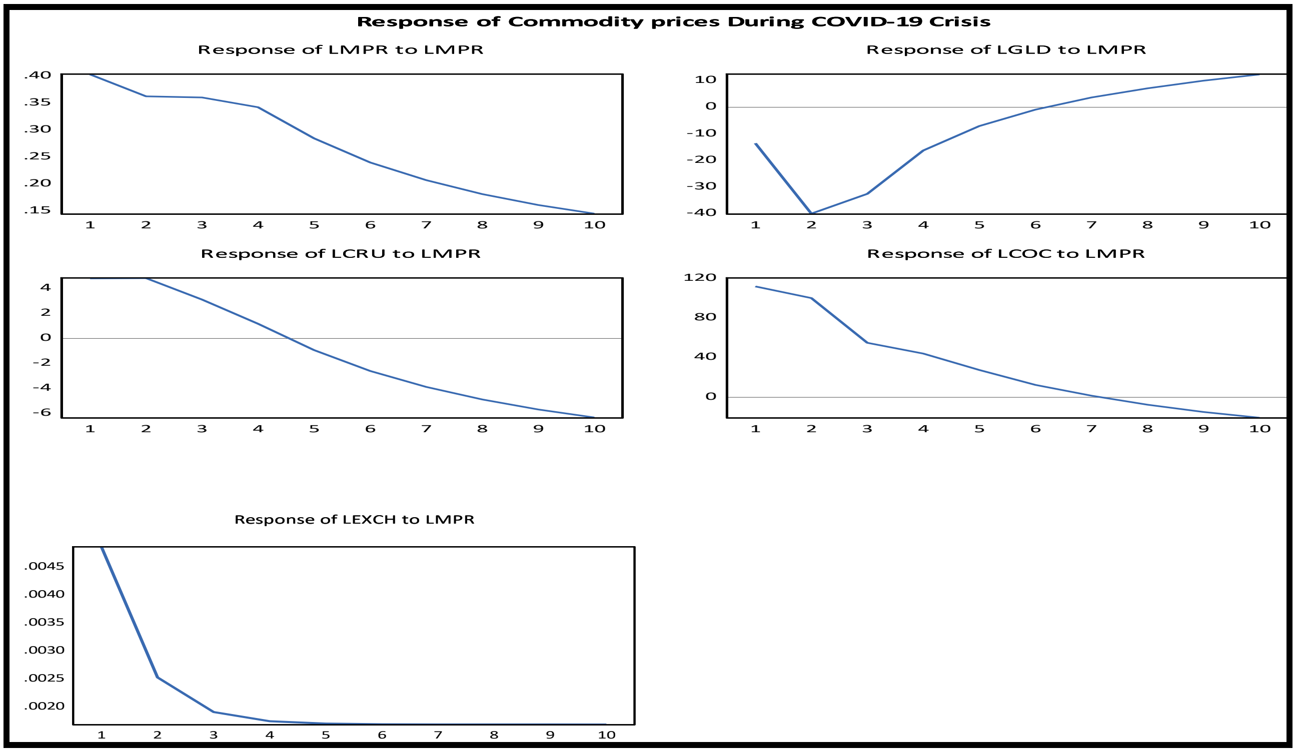

FIG 6. RESPONSE OF COMMODITY PRICES TO MPR DURING COVID-19 CRISIS

The response of commodity prices during the COVID-19 crisis is different compared to the 2008 financial crisis. The response of MPR to the lag of MPR is positive but persistently decreasing. The impact of monetary policy rates on gold price index and cocoa price index mirror exactly opposite the findings of the 2008 financial crisis. Cocoa price index initially responded positively to monetary policy rate but disappeared over time while gold price index responded negatively initial but upward overtime before diminishing to zero. Crude oil price index responded positively to monetary policy rates but turn negative by the 5th period. Though both the period of 2008 financial crisis and the COVID pandemic saw expansionary monetary policy, the responses are different. It should be noted that one major challenge that characterized the period of the pandemic is supply chain issues. The different dynamics is similar to the findings of Hamilton (2010) when demand supply scenarios are taken into consideration.

Variance Decomposition

We analyze variance decomposition of our set of commodity prices over the 200 months forecasting horizon. It shows the percentages contribution of variance to the prediction error made in forecasting a variable at a given horizon due to structural shocks. The tables 4.7.1 shows the variance decomposition for monetary policy rates contribution to all commodity prices. Gold, cocoa, and crude oil contributed about 3.41%, 5.36% and 8.07% by the end of the first year respectively. This increased to 10%, 4.63% and 14.37% by the

200th months of the considered period. That's MPR variance contribution to cocoa price decreased overtime. The MPR variance contribution to exchange rates were highest. That's 6.62% by the 12th month and increased to about 42% in the 200th month. The impact of MPR variance on itself decreased overtime.

It's evident from the appendix that the variance contribution of exchange rates to gold price and crude oil price is high. The exchange rates contribute about 26% to gold price by the 12th period and about 12% to crude oil prices. However, this contribution just by a point when the period is extended to cover over 200 months period. The variance contribution of all commodities to itself are often much higher but decreases overtime. It could be noted from the above analysis that structural monetary policy shocks as well as the exchange rates are very important in determining commodity price fluctuations.

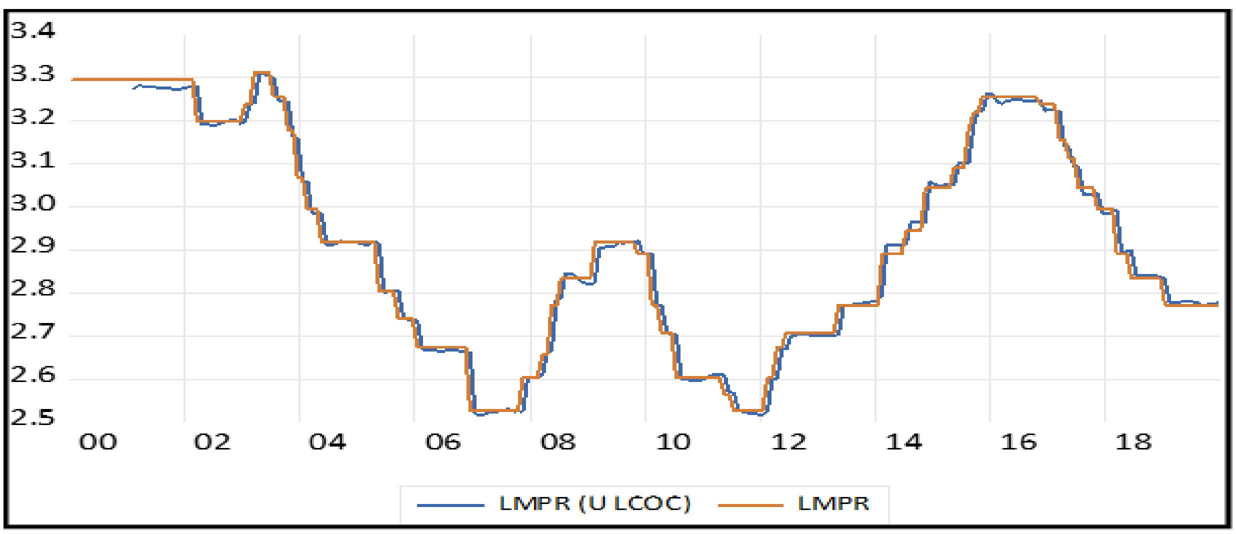

FIG 7. FORECASTED MONETARY POLICY RATE VS ACTUAL MONETARY POLICY RATES.

The graph above shows predicted monetary policy rate against the actual monetary policy rates. It could be noted that, when MPR is decreasing the predicted policy rates is higher than the actual and when MPR is increasing the predicted is lower the actual policy rates.

However, the predicted policy rates and the actual policy rates closely moved together overtime. This implies that commodity prices is a good and close measure of monetary policy rate in Ghana under the assumptions of this analysis.

TABLE 8. DIAGNOSTIC TEST

Test	Hypothesis	Test statistics	P-value	Decision
Hetroskedasticity	Ho: Homoskedasticity	Chisq =14.026	0.9721	Homoskedastic
Autocorrelation	Ho: No serial correlation	Chisq =2.258	0.132	No serial correlation
Model stability	Ho: Model is dynamically stable	The CUSUM plot lie within the 5% level of significance		

The analysis used the White's test of hetroskedasticity and the Breush-Godfrey test for autocorrelation and the CUSUM test of stability was used to test for the validity of the results. The CUSUM plot test for the stability of the VEC model and do not require prior determination of where the break occurs (Ozturk and Acaracvi 2010). The results of the CUSUM plot are based on the cointegration test and recursive residuals and does not show evidence of statistically significant breaks and therefore the model is dynamically stable. The results showed that there is no autocorrelation in the errors and the error variances are homoskedastic.

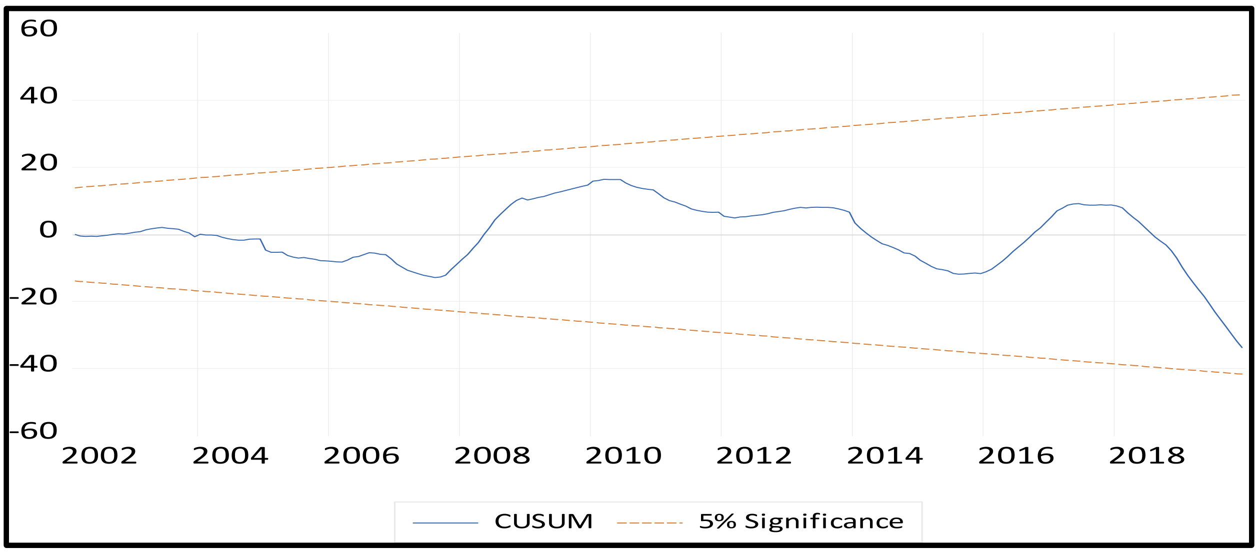

FIG 8. CUSUM TEST OF STABILITY

CONCLUSION

The study used the Vector Error Correction (VEC) model to analyze the impact of monetary policy rate on commodity prices in Ghana. The empirical results indicates that there is a long-term equilibrium relationship among MPR, cocoa, crude oil, and gold prices. Monetary policy rate responds to previous policy rates positively for most part of the period under consideration. Cocoa price index has positive and persistent response to positive monetary policy shock. The positive persistent shock of LMPR to cocoa price is not surprising as cocoa production form a major part of Ghana's export. Gold price index has positive response to monetary policy rates. crude oil price index negatively responds to monetary policy rate. Exchange rate is important to commodity price index in Ghana. There is a negative correlation between exchange rate and monetary policy. The response of commodity price indices to monetary policy mirrored exactly opposite relationships. Here, we argue that different in dynamics though similar policy response for the two periods could be attribute the supply shock that is associated with the COVID crisis.

The short run model revealed different dynamics. The first lag of monetary policy rate is positively related to itself whiles the second lag negatively correlated with monetary policy rate. However only the first lag is significant. The first and second lag of crude oil price index is positively influence monetary policy rate in Ghana though not statistically significant. The first lag of cocoa price index is significant and positively impact monetary policy rate. The second lag is negatively monetary policy rate but rather insignificant. The first and second lag of gold price index are jointly significant and positively correlated with monetary policy rate in Ghana. It is evident from the variance decomposition and the impulse response that the shock to gold, cocoa and crude oil is primarily caused by changes in the variable themselves and the monetary policy rate has the greatest impact on crude oil price index.

The dynamic relationship of the macroeconomic variables considered in the VEC model established a long run relationship with monetary policy. Due to the inability of the VEC model to deal with many variables, only the exchange rate was keenly considered throughout the analysis, though the identification process considered a wider range of macroeconomic variables as shown in the first impulse response graphs. The exchange rate plays a major in analyzing commodity prices in Ghana and therefore was closed analyzed with the commodity price indices. The monetary policy rate variance contribution to exchange rates is about 41%, the highest for the long-run model.

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APPENDIX

Variance Decomposition

Variance Decomposition of LMPR:

Period	S.E.	LMPR	LEXCH	LCRU	LCOC	LGLD
1	0.032014	100.0000	0.000000	0.000000	0.000000	0.000000
2	0.044803	99.41785	0.119806	0.222116	0.157503	0.082723
3	0.054461	98.18825	0.386680	0.682750	0.483613	0.258706
4	0.062564	96.45194	0.783771	1.321652	0.933864	0.508773
5	0.069724	94.34016	1.292600	2.084983	1.467695	0.814565
6	0.076245	91.96848	1.894705	2.927076	2.050204	1.159536
7	0.082300	89.43414	2.572744	3.810873	2.652784	1.529456
8	0.087992	86.81587	3.311120	4.707458	3.253009	1.912544
9	0.093389	84.17522	4.096253	5.595114	3.834053	2.299359
10	0.098533	81.55878	4.916603	6.458169	4.383891	2.682556
11	0.103455	79.00057	5.762546	7.285838	4.894455	3.056588
12	0.108173	76.52446	6.626166	8.071163	5.360821	3.417394
199	0.230747	29.36584	41.65489	14.36785	4.631871	9.979549
200	0.230803	29.35808	41.63458	14.37758	4.630206	9.999559

Variance Decomposition of LEXCH:

Period	S.E.	LMPR	LEXCH	LCRU	LCOC	LGLD
1	0.023969	0.015030	99.98497	0.000000	0.000000	0.000000
2	0.033643	0.030199	99.93212	0.003997	0.025127	0.008561
3	0.040905	0.048536	99.83383	0.011548	0.077624	0.028466
4	0.046897	0.068826	99.69887	0.021078	0.151602	0.059627
5	0.052068	0.090080	99.53459	0.031377	0.242038	0.101918
6	0.056648	0.111502	99.34709	0.041544	0.344681	0.155188
7	0.060775	0.132466	99.14138	0.050934	0.455956	0.219264
8	0.064540	0.152491	98.92156	0.059112	0.572875	0.293957
9	0.068004	0.171212	98.69094	0.065817	0.692965	0.379068
10	0.071215	0.188370	98.45213	0.070925	0.814189	0.474385
11	0.074207	0.203789	98.20721	0.074423	0.934889	0.579693
12	0.077008	0.217364	97.95775	0.076388	1.053729	0.694767
197	0.169227	3.981798	55.79171	11.55120	1.688737	26.98655
198	0.169280	3.988979	55.76114	11.56604	1.689511	26.99433
199	0.169331	3.995977	55.73151	11.58047	1.690281	27.00177
200	0.169381	4.002797	55.70279	11.59449	1.691048	27.00888

Variance Decomposition of LCRU:

Period	S.E.	LMPR	LEXCH	LCRU	LCOC	LGLD
1	0.079806	0.083088	0.150900	99.76601	0.000000	0.000000
2	0.105334	0.415599	0.094160	99.42290	0.000145	0.067200
3	0.120854	0.992005	0.080717	98.68967	0.000234	0.237379
4	0.131284	1.822135	0.124984	97.52728	0.000213	0.525389
5	0.138728	2.903342	0.240914	95.91386	0.000244	0.941643
6	0.144354	4.218409	0.440548	93.85014	0.000662	1.490239

7	0.148887	5.735167	0.732538	91.36275	0.001903	2.167637
8	0.152808	7.408222	1.120959	88.50414	0.004420	2.962257
9	0.156440	9.182738	1.604672	85.34878	0.008599	3.855207
10	0.159999	10.99964	2.177414	81.98619	0.014683	4.822068
11	0.163625	12.80124	2.828585	78.51205	0.022736	5.835388
12	0.167404	14.53624	3.544546	75.01921	0.032631	6.867378
199	0.381297	17.99552	36.49251	29.30554	0.822591	15.38385
200	0.381363	17.99315	36.48087	29.30609	0.822470	15.39743

Variance Decomposition of LCOC:

Period	S.E.	LMPR	LEXCH	LCRU	LCOC	LGLD
1	0.062437	0.029493	0.960022	4.594390	94.41609	0.000000
2	0.085966	0.086417	1.061400	4.151476	94.69824	0.002463
3	0.102555	0.167561	1.164862	3.758915	94.90017	0.008494
4	0.115402	0.269776	1.269767	3.413013	95.02901	0.018435
5	0.125797	0.390167	1.375497	3.110310	95.09142	0.032610
6	0.134423	0.526070	1.481463	2.847574	95.09357	0.051323
7	0.141701	0.675043	1.587098	2.621782	95.04122	0.074856
8	0.147916	0.834851	1.691869	2.430112	94.93971	0.103463
9	0.153269	1.003450	1.795276	2.269921	94.79398	0.137370
10	0.157913	1.178979	1.896852	2.138739	94.60866	0.176769
11	0.161964	1.359747	1.996167	2.034252	94.38802	0.221817
12	0.165517	1.544220	2.092830	1.954291	94.13602	0.272636
199	0.216120	7.386400	3.332179	9.147970	70.14639	9.987064
200	0.216125	7.386676	3.334206	9.148706	70.14321	9.987199

Variance Decomposition of LGLD:

Period	S.E.	LMPR	LEXCH	LCRU	LCOC	LGLD
1	0.036084	0.714031	0.669351	0.620838	2.446520	95.54926
2	0.050925	0.393027	0.654244	0.311706	3.067902	95.57312
3	0.062420	0.285120	0.634007	0.376968	3.675146	95.02876
4	0.072294	0.349864	0.609996	0.740472	4.247013	94.05266
5	0.081203	0.549123	0.583409	1.331808	4.770065	92.76560
6	0.089471	0.849126	0.555247	2.089601	5.237133	91.26889
7	0.097275	1.221297	0.526319	2.962651	5.645734	89.64400
8	0.104723	1.642297	0.497261	3.909700	5.996646	87.95410
9	0.111880	2.093597	0.468556	4.898436	6.292760	86.24665
10	0.118789	2.560838	0.440567	5.904179	6.538207	84.55621
11	0.125477	3.033137	0.413559	6.908527	6.737731	82.90705
12	0.131964	3.502426	0.387724	7.898096	6.896263	81.31549
199	0.351159	12.98144	3.740331	28.52827	4.707446	50.04251
200	0.351173	12.98099	3.746025	28.52682	4.707569	50.03860

cholesky ordering: lmpr lexch lcru lcoc lgld

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OPEN ACCESS ARTICLE

ESTIMATING THE SIZE OF CASH REWARDS IN HEALTH INTERVENTIONS: THE *EX-ANTE* WILLINGNESS TO EXERT EFFORT

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Abstract

This paper proposes a method to estimate the optimal size of cash rewards in health interventions. We adapt a theoretical model in which an individual chooses effort to maximize utility. Effort is costly but it provides intrinsic satisfaction that adds to the external cash reward. We considered alternative functional forms for the cost function and tested the model using data from hypothetical reward schemes to motivate individuals with diabetes to exert effort to lose weight. The value of intrinsic motivation, the curvature of the cost of effort, and the value elasticity of effort are estimated using a Nonlinear Least Squares procedure as well as a Minimum Distance approach. Results indicate that effort is rather inelastic to the size of the reward and that a high curvature of the cost of effort prevents individuals from engaging in healthy behavior.

Keywords: Intrinsic motivation; Diabetes; Stated willingness to accept; Stated willingness to deposit.

INTRODUCTION

A common practical problem in designing health interventions that rely on cash rewards is to estimate the optimal size of the cash reward. Program designers may be inclined to use the level of cash rewards implemented in other social interventions or to use arbitrary reference points such as the minimum wage. In the context of the field of Development Economics, cash rewards are usually called conditional cash transfers when goals are linked to the rewards. In this paper, we will use the term cash rewards, financial incentives or extrinsic motivation interchangeably.

Some researchers conduct exploratory qualitative research to define the size of the reward in an intervention, but no attention is given to the individual's elasticity in the level of response. This paper proposes an alternative method to elicit preferences toward effort given different cash rewards so that one can estimate the elasticity of effort to different cash rewards before conducting a randomized controlled trial (RCT). We illustrate this approach in the context of a health intervention where cash rewards are used to motivate individuals with diabetes to exert effort to lose weight. Since we start with reasonable assumptions about the individual's cost of engaging in an activity that involves effort, our method could be used in other policy areas where it is important to gauge the size of the cash reward to influence behavioral changes before conducting the intervention.

A literature review of cash rewards in health suggests different aspects of the architecture of cash incentives that could be beneficial in designing health interventions (Kane et al., 2004; Volpp et al., 2011; Sigmon & Patrick, 2012). It is well accepted that programs that incorporate positive rather than negative rewards, frequent and small cash amounts, and an element of uncertainty in the scheme tend to be more effective to motivate change in health behavior (Kane et al., 2004; Volpp et al., 2009; Blumenthal et al., 2013). Yet, less is known about the link between the size of the cash reward and the response in effort (Kane et al., 2004; Sigmon & Patrick, 2012). It is expected that the dose-response curve with respect to cash rewards follows a rank ordering shape, in which the greater the size of the reward leads to greater responses in effort. Yet, little evidence is available about this curvature or what we call in this paper the value elasticity of effort (i.e., the response in effort to different levels of cash rewards) (Kane et al., 2004; Sutherland et al., 2008).

On one hand, cash incentives could be too small and overshadow intrinsic motivation contributing to less effort exerted than would have occurred in the absence of the cash program (Gneezy & Rustichini, 2000; Deci, 1971). Offering too little could have the opposite effect to what was intended and reduce the motivation of an individual to perform a task (Frey & Jegen, 1999; Lacetera & Macis, 2010). The idea of paying may produce a negative reaction and displeasure on the individual to execute the task freely (Rabin, 1998; Benabou & Tirole, 2003). Low levels of cash rewards may also be detrimental when the payer cannot distinguish effort from outcomes. Contracts based on payments conditional on outcomes rather than effort may create disincentives for people to engage in healthy behavior as individuals who allocate larger effort may not receive the larger changes in outcomes (Edmans & Gabaix, 2016). Lastly, the benefit of low levels of cash payment and positive intrinsic motivation may not be sufficient to overcome the individual's marginal costs of engaging in the activity.

On the other hand, the cash rewards-response curve may exhibit a non-linear shape. In addition, for some programs offering large cash amounts may not be fiscally feasible. Even though results from experimental settings with high rewards may lead to cost savings in the long term, the cash amount involved may not be financially sustainable for a public insurance payer. For instance, a recent randomized controlled trial (RCT) suggests that an annual reward of 500-750 promotes reduction in smoking (Volpp et al., 2009). This amount is 33 times higher than what is used in a program at the state level in Florida Blumenthal et al., (2013). Public support for an intervention may decline as healthy individuals perceive the size of the cash reward as excessive and unfair (Lagarde et al., 2007; Blumenthal et al., 2013).

It is important to note that even in RCTs with multiple arms, the results of trials are not sufficient to plot a set of responses to different sizes of cash rewards. Traditional RCTs offer little or no guidance on how elastic an individual's effort is in response to the size of the cash reward. The results from these types of trials suggest that larger cash rewards produce larger effort or behavioral responses; yet one cannot infer if the magnitude of the value elasticity remains constant over the relevant distribution of effort or if it is variable. It is possible that at a low level of cash rewards the value elasticity is positive and elastic while after a certain level of cash rewards is reached, the value elasticity becomes inelastic. Lastly, randomizing individuals to various cash reward amounts and powering the experiment to detect effect may be too costly. Therefore, it is common for project designers in the health field to narrow their attention to one or two amounts of cash rewards based on a reference point such as minimum wage or amounts offered in other social programs.

Our review of 16 recent highly cited RCT studies of health interventions using cash rewards indicates that only three explain how the researchers determined the size of the cash reward. One used the minimum wage as a reference while the other two studies used reference values from previous studies. None used rigorous formative research to define the initial size of the reward. The majority used one or two cash rewards schemes. From these readings, policy makers may consequently ask if they can achieve similar behavioral changes in magnitude with less or more cash. Furthermore, from these studies policy makers cannot be sure if the rewards are sufficiently large to cover the marginal cost of effort associated with the health behavior, or if the health programs designed to motivate healthy behaviors were cost-effective (Blumenthal et al., 2013).

Our model is in the spirit of the behavioral economics framework presented by DellaVigna and Pope (2017) to study how monetary and non-monetary interventions motivate individuals to complete computer tasks that require a costly effort. Starting from the first principles, we assume that an individual will make effort to maximize her/his utility. Effort provides utility to the individual from intrinsic motivation and from a monetary reward that the individual receives from her/his effort. Monetary rewards motivate an individual to exert effort as the return of effort increases linearly with changes in the magnitude of the cash reward. However, exerting effort is costly. Therefore, given some level of reward, an individual would exert effort until the marginal benefit of effort equals its marginal cost.

We considered two standard cost functions to model effort: the power cost function and the exponential cost function. Both functions fit the cost of effort involved in most health behaviors. For instance, the cost of effort according to these functions is always positive, monotonic, and convex while the derived elasticity of value of effort would be constant at all levels of effort (power cost function) or decreasing (exponential cost function). Another advantage associated with these cost functions is that they are mathematically tractable in empirical work.

We fit the model using data from individuals with diabetes attending a large public hospital in Peru who were asked about their ex-ante preferences to exert effort to lose weight under different hypothetical reward scenarios. Our data comes from patients with diabetes who met the inclusion criteria (e.g., older than 18 years of age; diagnostic with diabetes type II, uncontrolled sugar level, not using insulin) to be in a feasibility RCT to explore how individual and group cash rewards motivate individuals with diabetes to lose weight (www.clinicaltrials.gov NCT02891382, 2014). Using this information, we computed three fundamental parameters using a Nonlinear Least Squares procedure: the elasticity of losing weight to reward, the curvature of the cost of losing weight, and the intrinsic value associated to losing weight.

This approach has several advantages. First, it will allow researchers and policy makers to estimate how elastic effort is to reward, which in turn allows the computation of net benefits associated with different levels of rewards. Second, the approach will determine the magnitude of how costly individuals perceive the effort involved. Third, our methods will inform the question of whether individuals are willing to exert effort in the absence of a cash reward.

MODEL

We start with a simple economic model of an individual's decision to exert effort in preventive behavior. For a representative individual, the net utility from preventive effort E depends on the internal satisfaction it provides m plus any monetary reward received and, on the other hand, the cost of exerting a given level of effort $C(E)$. The presence of intrinsic motivation allows for the possibility that an individual may engage in preventive effort even in the absence of cash incentives. An individual also receives utility from effort if the effort is compensated with a monetary reward r. If we assume that the individual's marginal utility from internal motivation is constant and equal to m while the marginal utility of the rewards is also constant and equal to r, the utility from exerting a level of preventive effort for a representative individual is equal to:

$$u(E) = (m + r)E \quad C(E) \tag{1}$$

We assume that preventive effort is non-negative E 0 and that the cost function of effort is convex (i.e., both the first and second derivatives of the cost function are positive), so that more effort is always costlier, and this happens at an increasing rate. Following DellaVigna and Pope (2017), we first consider the following cost power function:

$$C(E) = \frac{\kappa E^{1+\gamma}}{1+\gamma} \tag{2}$$

where k *is* a cost adjustment scalar and is a parameter that describes the curvature of the power cost function. As a result, the problem of the individual is to choose E to maximize utility:

$$\max_E (m+r)E \quad \frac{\kappa E^{1+\gamma}}{1+\gamma} \tag{3}$$

The first order condition for an optimal level of effort implies that an individual will exert effort until the marginal benefit of effort equals marginal cost:

$$(m + r) \quad k^*E \ = 0 \tag{4}$$

which leads to the optimal level of preventive effort for the individual:

$$E^* = \left[\frac{(m+r)}{\kappa}\right]^{\frac{1}{\gamma}} \tag{5}$$

Notice that, for a given level of cash reward, the optimal solution is a function of three parameters *m*, *k* , *gamma*, which values can be estimated using non-linear least squares.

Fundamental Results from the Power Cost Function

To estimate the structural parameters of the model, we will empirically test a series of additional theoretical results that are implied from the model.

- An increase in total reward (m + r) given a positive level of intrinsic motivation m will produce an increase in the optimal amount of preventive behavior if 1. We can see this result by looking at the partial derivatives of E⇤ with respect to (m + r):

$$\frac{\partial E^*}{\partial(m+r)} = \left(\frac{1}{\kappa\gamma}\right)\left(\frac{m+r}{\kappa}\right)^{1/(\gamma \quad 1)} > 0 \tag{6}$$

- A negative k implies a negative optimal effort. We truncate effort to be positive or equal to zero.

- In this model, optimal effort will be zero in the case of no reward and negative intrinsic motivation *m*, which would be the case when preventive effort produces displeasure. If *m* ⊚ 0 effort will be positive only if *r* is big enough. As a result, at low level of cash rewards may not be enough to compensate the negative internal displeasure of the activity.
- Effort could be zero if the marginal cost of the activity is larger than marginal benefit ($m + r$) at all levels of effort. This could happen even in cases where intrinsic motivation plus a low level of cash reward is positive.

Extending the framework to the Exponential Cost Function

In the case of the power cost function, it is straightforward to derive that the elasticity of preventive effort with respect to the total benefit ($m + r$) is constant at 1 (DellaVigna et al., 2016). This may seem too restrictive, considering that higher levels of self-management activities (e.g., weight management, exercise, etc.) provide lower value for larger efforts. Alternatively, one may assume that the cost of preventive effort follows an exponential cost function form.

To see a full derivation of these results, please see DellaVigna and Pope (2017). Fortunately, the general results discussed above also follow when one assumes an exponential cost function.

EMPIRICAL STRATEGY

In the previous section we presented a model for a representative individual where more effort is always costlier (and at an increasing rate), the reward to effort is constant (at best) or decreasing, and there are both an intrinsic motivation as well as extrinsic monetary incentive to exercise effort. To empirically estimate this basic model, we are going to introduce heterogeneity across individuals so that, in addition to the cognitive level, the preventive behavior cost function depends on the observed characteristics of the individuals.

Thus, the first order condition for optimal effort in the case of power cost function for individual *i* becomes:

$$\log(E_i^*) = \frac{1}{\gamma}[\log(m+r) \quad \log(\kappa)] + \beta x_i + \epsilon_i \tag{9}$$

where x_i is a set of the individual's observed characteristics (such as age, gender, marital status, household size, and education level), gamma is a vector of coefficients associated with each variable, and error is an unobserved *i.i.d.* random error, normally distributed with zero mean and finite variance.

Our empirical aim was to estimate the value of intrinsic motivation (*m*), the curvature of cost function and the scalar of the cost function using data from our sample. Having these parameters, we would estimate the elasticity of effort with respect to value. As the parameters in the model are nonlinear, we used a Nonlinear Lest Squares (NLS) procedure to estimate these parameters given the available data (Fox & Weisberg n.d.; Ratkowsky, 1993) for a detailed description of the method). We first estimate the model ignoring the individual's observed characteristics, we then include age and gender, and finally we estimate the model including all the individual's observed characteristics x.

In the case of exponential cost function, the equation to be estimated using NLS was:

$$E_i^* = \frac{1}{\gamma}[\log(m + r) \quad \log(\kappa)] + \beta \log x_i + \epsilon_i \tag{10}$$

Note that these equations could be estimated using a Minimum Distance Estimator approach; yet this approach ignores the possibility of including individual heterogeneity in the cost of effort function. Our approach incorporates differences in cost of effort due to individual observable variables. However, as it is standard in this literature, we assume that the effect of the reward of preventive effort as well as the intrinsic motivation is homogenous across individuals.

Data

Before starting our feasibility randomized trial, we conducted a survey with 100 patients with diabetes who met our inclusion criteria for a trial to be conducted in a later phase. We asked demographic, socio-economic, and health-related questions as well as gathered information on diagnostics, time since diagnosis of diabetes, and knowledge regarding diabetes.

Table 1 summarizes characteristics of the individuals enrolled in the experiment before conducting our trial. These patients did not participate in the feasibility randomized trial. On average our respondents were 55 years of age; 67% were female; and 89% had completed high school or a higher level of education.

TABLE 1. SUMMARY STATISTICS FOR ALL RESPONDENTS

Variables	N	Mean	St. dev.
Panel A			
Age	100	55.17	11.79
Female	100	0.67	0.47
Married	100	0.33	0.47
Household Size	100	4.04	1.84
Education Level (N=100) Less than high school	11	0.11	0.00
High school	46	0.46	0.00
More than high school	43	0.43	0.00
Employed	100	0.55	0.50
Monthly Income Level (N=100) 0-2000 soles	39	0.39	0.00
2001+ soles	35	0.35	0.00

Unknown	26	0.26	0.00
Insured	100	0.66	0.00
Panel B			
Self-reported Health Status (N=100)			
Poor	11	0.11	0.00
Good	52	0.52	0.00
Very Good	37	0.37	0.00
Weight (kg)	100	68.47	8.45
Height (cm)	100	161.61	8.18
BMI	100	26.32	3.56
Percentage Who Desire to Lose Weight	100	0.55	0.00
Years with Diabetes	100	6.92	5.07
Glycosylated Hemoglobin	59	8.93	1.64
Percentage Taking Diabetic Medication	100	0.92	0.00
Percentage Who Received Diabetes Education	97	0.24	0.00
Percentage Who Exercised to Lose Weight	98	0.53	0.00
Percentage Who Tried to Reduce Sugar Intake	98	0.75	0.00

Notes: We included all respondents to compute summary statistics. Married refers to being legally married; non-married includes single, living together, divorced, separated, widowed, and those who did not respond. Questions with three or more choices were collapsed to three choices. For most variables we did not impute values for missing. There were 14 missing values for weight, for which we imputed the mean of the other values of 68.47 kg, and 1 missing value for height, for which we imputed the mean value of 161.21 cm. Exchange rate is 3.37 Peruvian Nuevo Soles to 1 US Dollar (2016).

55% were employed, and 66% had health insurance. Most people with diabetes in our sample reported good or very good health (89%), and on average the time since diagnosis of diabetes was seven years. Additionally, 55% of patients expressed a current desire to lose weight; and 75% indicated that they had tried to reduce sugar intake.

To elicit an individual's ex ante willingness to exert effort to lose weight, we draw lessons from the public goods literature where individuals are questioned about their willingness to accept certain financial reward as compensation for approving an undesired social project, a situation known in the economic literature as a "not in my backyard" problem (Frey & Oberholzer-Gee, 1997). Specifically, we posed patients with one of two hypothetical reward schemes: the stated willingness to accept (WTA), where rewards are strictly nonnegative, and the stated willingness to deposit (WTD), where there is a chance of losing money.

In the first scheme, the stated willingness to accept (WTA), the patient is posed with a hypothetical scenario where she is invited to enroll in a three-month weight loss program aimed at losing one kilogram (i.e., 2.2 pounds) every other week in exchange of a fixed monetary compensation. Specifically, the patient has to state her willingness to participate if the biweekly reward were: (a) 50 Soles, (b) 100 Soles, (c) 150 Soles, (d) 200 Soles, (e) 250 Soles, (f) 500 Soles, or (g) nil (no monetary reward at all). In 2016, the exchange rate was 3.37 Peruvian Soles to 1 US Dollar.

In the second scheme, the stated willingness to deposit (WTD), the patient is posed with a hypothetical scenario where she is invited to enroll in a three-month weight loss program aimed at losing one kilogram every other week in exchange of a monetary compensation that is a function of achieving the weight lost goal and be willing to risk her own money. Thus, the patient would have to consider a hypothetical scheme where, every other week, she would be asked to make a deposit upfront. If the weight lost goal is achieved (one kilogram in two weeks) she receives double the amount deposited, but if the goal is not accomplished, the patient loses the amount deposited and a new deposit has to be made for the next round. Specifically, the patient has to state her willingness to deposit (a) 25 Soles for a chance of winning 50 Soles if she loses one kilogram in two weeks, (b) 50 Soles, (c) 75 Soles, (d) 100 Soles, (e) 200 Soles, (f) 250 Soles or (f) nil (no deposit at all).

Table 2 shows differences in WTA by group of respondents.

TABLE 2. SUMMARY STATISTICS FOR ALL RESPONDENTS

Variables	N	Mean	St. dev.	Min	Max	Median	Mode
Panel A. WTA Full sample	92	96.96	58.51	50	500	100	100
Female	66	84.39	35.91	50	150	100	50
Male	26	128.85	87.38	50	500	100	100
Age (years) 32 – 50	35	98.86	36.68	50	200	100	100
51 – 62	28	98.57	45.76	50	200	100	50
63 – 81	29	93.10	86.32	50	500	50	50
Education Level Less than high school	10	65.00	24.15	50	100	50	50
High school	45	96.67	40.45	50	200	100	100
More than high school	37	105.95	78.37	50	500	100	100
Panel B: WTD Full Sample	98	21.78	14.34	0	50	20	20
Female	67	23.73	14.10	0	50	20	20
Male	31	17.58	14.19	0	50	10	20
Age (years) 32 – 50	35	25.71	13.57	0	50	20	20
51 – 62	31	22.58	16.07	0	50	20	20
63 – 81	32	16.72	12.16	0	50	10	10
Education Level Less than high school	11	13.64	8.97	0	30	10	20
High School	45	24.56	14.33	0	50	20	20
More than high school	42	20.95	14.83	0	50	20	20

Notes: Eight individuals did not answer the questions on WTA. Two individuals did not answer the questions on WTD. Seven respondents reported a WTD value of 0. WTD values of 0 were changed to equal 0.02 prior to running the log transformation regression. Married refers to being legally married; non-married includes single, living together, divorced, separated, widowed, and those who did not respond. Questions with three or more choices were collapsed to three choices. For most variables we did not impute values for missing, though there were 14 missing values for weight, for which we imputed the mean of the other values of 68.47 kg, and 1 missing value for height, for which we imputed the mean value of 161.21 cm. Exchange rate is 3.37 Peruvian Nuevo Soles to 1 US Dollar (2016).

TABLE 3. SUMMARY STATISTICS FOR ALL RESPONDENTS TO WTA QUESTIONS

Variables	N	Mean	St. dev.
Demographics Characteristics Age	552	54.64	(11.94)
Female	552	0.72	(0.45)
Married	552	0.29	(0.46)
Household Size	552	4.04	(1.79)
Socio-Economic Characteristics			
Education Level			
Less than high school	552	0.11	(0.31)
High school	552	0.49	(0.50)
More than high school	552	0.40	(0.49)
Employed	552	0.54	(0.50)
Have insurance	552	1.33	(0.47)
Health Characteristics Weight (kg)	552	68.45	(8.52)
Height (cm)	552	161.30	(8.13)
Years with Diabetes	552	6.62	(4.71)
Education of diabetes	546	1.76	(0.43)
Have exercise	552	1.45	(0.50)

Notes: We included all respondents who responded to the Willingness to Accept questions to compute summary statistics. Married refers to being legally married; non-married includes single, living together, divorced, separated, widowed, and those who did not respond. Questions with three or more choices were collapsed to three choices. For most variables we did not impute values for missing, though there were 14 missing values for weight, for which we imputed the mean of the other values of 68.47 kg, and 1 missing value for height, for which we imputed the mean value of 161.21 cm. Exchange rate is 3.37 Peruvian Nuevo Soles to 1 US Dollar (2016).

Table 3 shows the descriptive statistics of the respondents. In the case of WTA, the modal response as well as the median is 100 Soles. This is consistent with other conditional cash transfer programs in Peru. For instance, Juntos a Peruvian social inclusion cash transfer program provides 200 Soles every two months to women with children under 5 years of age. The minimum value to accept participation was 50 Soles every other week which represents around 12% of the official minimum wage in Peru in 2016, being 850 Soles a month (e.g., 212.50 Soles a week). This is consistent with figures provided in the literature to estimate optimal size of cash reward from formative research (Rawlings, 2006). The average value reported for participation in the program was around 100 Soles (by weekly) with 59 Soles as a standard deviation. This represents 200 Soles a month which is approximately 24% of monthly minimum wage. Interestingly, none of the respondents reported a WTA value of zero. From the sample, eight did not respond to these questions. The WTA is higher for males and for individuals with higher education. This may be consistent with higher earned wages and cost of time for this group. It is important to mention that interviewers need some patience to engage participants given that, perhaps for cultural reasons, they usually stated up-front that just improving their health would be enough incentive to exert effort, but when they considered the monetary payments, they indeed provided answers.

The responses to the WTD questions are presented in Table 2. As expected, the amounts to participate are consistently lower than the amount reflected in the WTA questions. Seven individuals refused participation in an uncertain contract scheme to lose weight. Individuals would allocate on average 21 Soles every other week with a maximum of 50 Soles. Older, and more educated male participants were less likely to allocate their own money to assert effort to lose weight. This may reflect that these individuals were more realistic about their capacity to change behavior.

Finally, in our empirical section effort is measured as a dummy variable that equals 1 if the respondent takes the offer or is willing to deposit the money. For everyone, we construct one response for each level of cash reward.

In the next section, we explore how elastic to losing weight individuals are in relation to cash reward size assuming two different cost functions of losing weight. We will present the results using all responses from the WTA section. This implies that the sample size for the estimation of optimal effort compromises 552 responses (e.g., 92 individuals with six complete WTA answers). In the robustness checks section, we will discuss the results using the WTD responses.

RESULTS

We started by running a naïve linear probability model to explore the role of cash rewards in the probability of losing weight. As shown in Table 4, using WTA responses, the value elasticity of effort is positive and inelastic (0.129 power cost function; and 0.189 in the exponential cost function). In both cases, the results were statistically significant at $p < 0.01$. Although results from these regressions may suggest that policy makers should not expect a big individual response in effort by increasing the size of the reward, these results are difficult to interpret as they are not based on a conceptual framework. In fact, these results do not provide full information on how cost of effort increases with effort; or how important is intrinsic motivation and external reward to move individuals to exert effort to lose weight. Both elements will impact the individual's optimal level of effort.

TABLE 4. OLS ESTIMATES OF THE DETERMINANTS OF EFFORT TO LOSE WEIGHT AMONG PEOPLE WITH DIABETES

	Constant Cost Function Coeff./ St. Err.	Exponential Cost Function Coeff./ St. Err.
ln (Received Reward)	0.129***	0.186***
	(0.005)	(0.007)
Individual Characteristics Age	0.001	0.041
	(0.001)	(0.083)
Female	0.087***	0.180***
	(0.021)	(0.044)
Married	0.0147	0.039
	(0.023)	(0.047)

Household Size	0.005	0.005
	(0.005)	(0.026)
Education (Ref: less than high school)		
High School	-0.0643**	-0.129*
	(0.033)	(0.067)
More than High School	-0.058	-0.129*
	(0.036)	(0.074)
Years w/Diabetes	-0.002	0.001
	(0.002)	(0.014)
Constant	-0.1380*	(0.259)
	(0.080)	(0.343)
R-sqr	0.586	0.585
N	552	552

Notes: Robust Standard Error in Parentheses,(***) Significant at 1%, (**) at 5%, (*) at 10%. All control variables in the constant cost function are included in their scale while in the exponential cost function are included in log form. In the constant cost function, before taking the log, the dependent variable was transformed to a value 0.02 when the values were zero. Married refers to being legally married; non-married includes single, living together, divorced, separated, widowed, and those who did not respond. Questions with three or more choices were collapsed to three choices. We did not impute values for missing, though there were 14 missing values for weight, for which we imputed the mean of the other values of 68.47 kg, and 1 missing value for height, for which we imputed the mean value of 161.21 cm. Exchange rate is 3.37 Peruvian Nuevo Soles to 1 US Dollar (2016).

The additional analysis driven by economic theory is more informative in terms of the whole picture to motivate changes in health behavior using monetary rewards. Table 5 shows the results from a Nonlinear Least Squares procedure for both cost functions for three different models. In this section, we discussed the results from the model where we included all the control variables (Panel C).

TABLE 5. NON-LINEAR ESTIMATES OF THE DETERMINANTS OF EFFORT TO LOSE WEIGHT AMONG PEOPLE WITH DIABETES (N=552)

	Constant Cost Function Coeff./ St. Err.	Exponential Cost Function Coeff./ St. Err.
Panel A: Model 1		
Curvature of the cost function (1/gamma)	0.124***	0.491***
	(0.025)	(0.078)
Intrinsic motivation value (*m*)	22.532***	27.231***
	(4.734)	(7.009)
Scalar of the cost function (k)	31.443***	41.3562*
	(10.913)	(25.329)
Controls Demographic	No	No
Control Education	No	No
Control Health (years with diabetes)	No	No
Panel B: Model 2		
Curvature of the cost function (1/ gamma)	0.271***	0.467***
	(0.029)	(0.051)
Intrinsic motivation value (*m*)	24.734***	27.391***

	(5.119)	(6.993)
Scalar of the cost function (k)	33.993***	43.4365*
	(10.781)	(24.976)
Controls Demographic	Yes	Yes
Control Education	No	No
Control Health (years with diabetes)	No	No
Panel C: Model 3		
Curvature of the cost function (1/)	0.329***	0.475***
	(0.037)	(0.054)
Intrinsic motivation value (*m*)	26.897***	26.897***
	(7.768)	(7.782)
Scalar of the cost function ( )	37.653***	42.72282*
	(11.674)	(26.985)
Controls Demographic	Yes	Yes
Control Education	Yes	Yes
Control Health (years with diabetes)	Yes	Yes

Notes: Robust Standard Error in Parentheses, (***) Significant at 1%, (**) at 5%, (*) at 10%. All control variables in the constant cost function are included in their scale while in the exponential cost function are included in log form. In the constant cost function, before taking the log, the dependent variable was transformed to a value 0.02 when the values were zero. Married refers to being legally married; non-married includes single, living together, divorced, separated, widowed, and those who did not respond. Questions with three or more choices were collapsed to three choices. We did not impute values for missing, though there were 14 missing values for weight, for which we imputed the mean of the other values of 68.47 kg, and 1 missing value for height, for which we imputed the mean value of 161.21 cm. Exchange rate is 3.37 Peruvian Nuevo Soles to 1 US Dollar (2016).

In the case of the Power Cost Function, the value elasticity of effort is positive and inelastic (0.329); but the parameter is greater than the one obtained using the naïve Ordinary Least Squares (OLS) approach. It is still statistically significant at $p < 0.01$. The estimation indicates that an individual receives positive satisfaction from the effort ($m = 26.897$, $p < 0.01$). However, the coefficient of the scalar of cost function indicates a steep change in cost (37.653, $p < 0.01$). Interpreting these results together suggests that an individual will exert effort at zero cash reward as the FOC for maximizing utility would imply a low positive level of effort. Figure 1 displays the level of optimal effort (level where marginal benefit equals marginal cost) under the assumption of power cost function at different level of rewards. Assuming internal satisfaction and a certain level of rewards, one could see that optimal level increases with reward size.

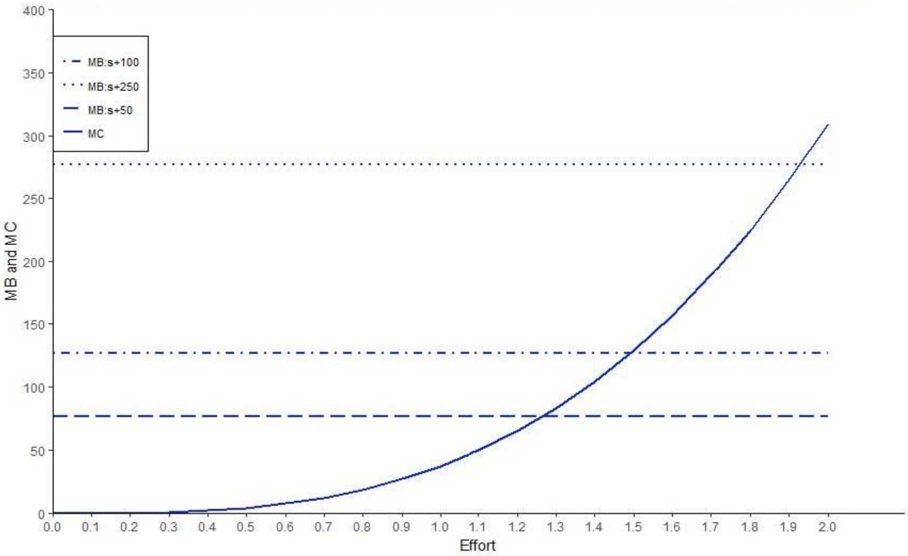

FIG 1. LEVELS OF OPTIMAL EFFORT, POWER COST FUNCTION

Fitting the data to an Exponential Cost Function highlights similar findings. Individuals show a similar curvature of the cost function (0.475, $p < 0.01$). Notice, however, as shown in the previous section, in this case, the value elasticity of effort will depend on the level of reward and (✈). An individual receives positive satisfaction (*m*); and the estimate in this case is like the one estimated using a power cost function. The scalar of the cost function (42.723, $p < 0.10$) is positive and higher than in the case of the power cost function. These results suggest that an individual would need at least up to 16 Soles every other week to exert positive effort. Figure 2 shows optimal level of assuming an exponential cost function. As was mentioned before, at a low level of reward an individual would prefer not to exert effort. After a certain level of reward (around 16 soles every other week), it is optimal for an individual to exert positive effort. Notice that optimal level increases with the level of cash reward.

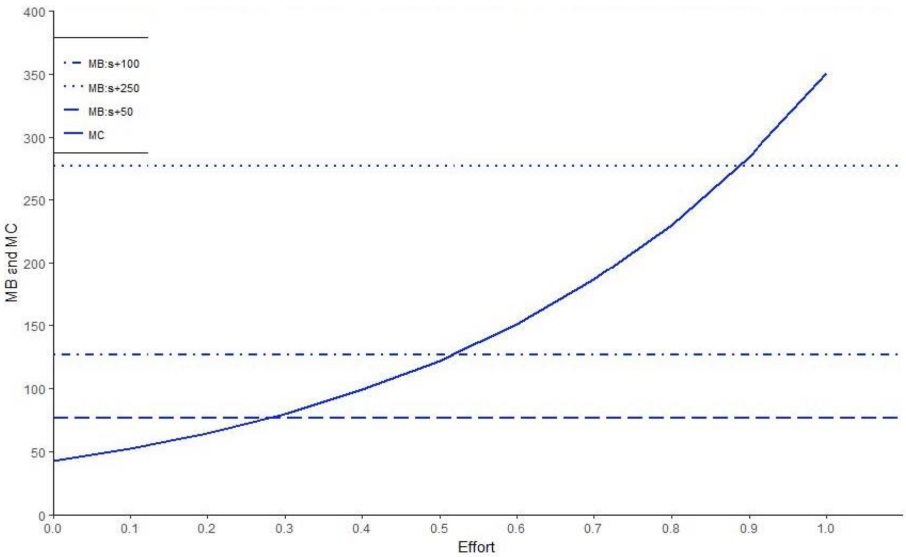

FIG 2. LEVELS OF OPTIMAL EFFORT, EXPONENTIAL COST FUNCTION

Turning our attention to the value elasticity of effort, given the estimated parameters ✈ and *m*, one could report different levels of elasticities (one should recall that in the case of exponential function the value elasticity of effort is not constant). The first implication from this analysis is that above the minimum required to exert positive effort (e.g., 16 Soles every other week), the value elasticity of effort is positive. Now, for a reward level of approximately 60 Soles every other week, the value elasticity of effort is around 3 which represents a very elastic response. At 200 Soles every other week, the value elasticity of effort is still positive and around 1.37. If one assumes a reward of 500 Soles every other week would reduce the elasticity to 0.91. However, this would imply a level of reward bigger than the monthly minimum wage (around 850 Soles a month). In short, the results suggest that individuals have a very elastic response to a lower level of rewards above 16 Soles every other week; however, the value elasticity of effort becomes inelastic at a high level of rewards (around 500 Soles bi-weekly).

These results suggest that, under both types of cost functions, individuals with diabetes receive internal satisfaction from exerting effort to lose weight. The curvature of the cost function and the scalar imply that preventive effort is costly. Therefore, a low level of reward is not enough to outweigh the marginal cost of effort. The value elasticity of effort is positive in both estimations. Yet, the value may oscillate 0.32-1.3 for reasonable sizes of the cash rewards (between 80-200 Soles every other week). For higher values of rewards, the analysis indicates a low level of value elasticity of effort. This means that researchers or policy makers may achieve low pay out from offering extremely high reward amounts.

These results are inconsistent with previous findings in the literature of smoking cessation and substance abuse. For instance, (Lussier et al. 2006) reports that larger sizes of the cash rewards create a larger response in reduction of substance abuse than smaller cash rewards; yet their results are based on two magnitudes of cash rewards. As we pointed out, the value elasticity of effort may differ between the size of the reward and the cost of effort. Positive effects of cash reward size and effort in the case of smoking cessation abuse have been reported by Hughes (2003), Correia & Benson (2006), Sindelar (2008), Volpp et al., (2009).

ROBUSTNESS CHECKS

In this section, we present three different robustness checks that we conducted. First, we estimated the NLQR parameters starting from a reduced-form model where only age and gender were included. We then ran models where marital status and household size (two possible choice variables) were included. In our last model specification, we included the variables for education level as well as years since diagnosis of diabetes. Overall, the main findings reported in the previous sections do not change significantly for both the power cost function and exponential cost function. Broadly speaking, in all estimations an individual receives intrinsic benefits from preventive care. However, given the curvature of the cost function, low levels of rewards are not enough to motivate individuals to exert preventive effort and the value elasticity of rewards in most cases is inelastic (See panel A and panel B in Table 5).

TABLE 6. NON-LINEAR ESTIMATES OF THE DETERMINANTS OF EFFORT TO LOSE WEIGHT AMONG PEOPLE WITH DIABETES (WTD)

	Constant Cost Function Coeff./ St. Err.	Exponential Cost Function Coeff./ St. Err.
Individual Characteristics Age	0.001	0.041
	(0.001)	(0.078)
Female	0.087***	0.180***
	(0.019)	(0.041)
Married	0.015	0.039
	(0.021)	(0.044)
Household Size	0.004	0.005
	(0.005)	(0.024)
Education (Ref: less than high school) High School	-0.064*	-0.1290*
	(0.030)	(0.062)
More than High School	-0.058*	-0.1290*
	(0.033)	(0.074)
Years w/Diabetes	(0.002)	0.001
	(0.002)	(0.013)
R-sqr	0.642	0.585
N	552	552
Curvature of the cost function (1/gamma)	0.329***	0.475***
	(0.037)	(0.054)
Intrinsic motivation value (*m*)	26.897***	26.897***
	(7.768)	(7.782)
Scalar of the cost function (k)	37.653***	42.72282*
	(11.674)	(26.985)

Notes: Robust Standard Error in Parentheses, (***) Significant at 1%, (**) at 5%, (*) at 10%. All control variables in the constant cost function are included in their scale while in the exponential cost function are included in log form. In the constant cost function, before taking the log, the dependent variable was transformed to a value 0.02 when the values were zero. Married refers to being legally married; non-married includes single, living together, divorced, separated, widowed, and those who did not respond. Questions with three or more choices were collapsed to three choices. We did not impute values for missing, though there were 14 missing values for weight, for which we imputed the mean of the other values of 68.47 kg, and 1 missing value for height, for which we imputed the mean value of 161.21 cm. Exchange rate is 3.37 Peruvian Nuevo Soles to 1 US Dollar (2016).

Second, we investigated whether using the WTD data leads to different conclusions. In WTD, the value of exerting effort to lose weight is driven by an individual's willingness to participate in a contingent contract (See Table 6). As we pointed out in the previous section, the WTD figures are smaller than WTA for a similar level of effort. Interestingly, the results from this analysis led us to reach similar conclusions regarding the value of intrinsic motivation, the curvature of the cost function, and the value elasticity of effort. However, in this case, the value elasticity of effort is smaller than the estimate using WTA data while the curvature of the cost function is more pronounced.

Third, we estimated the parameters of interest (*k*,*m*) using a Minimum-Distance approach under the assumption of the power cost function as well as the exponential cost function. Essentially, under this method, we did not include any possible heterogeneity in the cost functions that may come from individual differences such as age, gender, marital status, and other observable covariates. We derived confidence intervals using standard bootstrap methods.

TABLE 7. MINIMUM DISTANCE ESTIMATOR OF THE DETERMINANTS OF EFFORT TO LOSE WEIGHT AMONG PEOPLE WITH DIABETES

	Constant Cost Function Coeff./ St. Err.	Exponential Cost Function Coeff./ St. Err.
Curvature of the cost function (1/gamma)	0.215***	0.187*
	(0.083)	(0.124)
Intrinsic motivation value (*m*)	4.2E-09	1.604
	(0.001)	(2.415)
Scalar of the cost function (*k*)	313.158***	1.565
	(5.615)	(2.395)

Notes: Robust Standard Error in Parentheses, (***) Significant at 1%, (**) at 5%, (*) at 10%. Both models do not include control variables. In the constant cost function, before taking the log, the dependent variable was transformed to a value 0.02 when the values were zero. We use as moments the average efforts for the following rewards 0, 50 and 250. Exchange rate is 3.37 Peruvian Nuevo Soles to 1 US Dollar (2016).

Table 7 shows the main results using WTA responses. The results are like those obtained using the NLQR approach. However, the value elasticity of effort is less inelastic under both cost specifications and the intrinsic motivation parameters are smaller than previous estimates. The scalar of the cost function is still positive under both estimation methods. All this suggests that, although effort increases with reward, the internal motivation value of the activity is such that low level of rewards may not be sufficient to motivate an individual to exert preventive effort.

CONCLUSION

This paper proposes a method to estimate the size of cash rewards in health interventions using information about individuals' ex ante preferences to exert effort to lose weight. The approach uses a questionnaire regarding a hypothetical scheme and probe individuals about their willingness to exert effort to lose weight at different levels of financial reward. We test two hypothetical schemes: the stated willingness to accept (WTA), where rewards are strictly nonnegative, and the stated willingness to deposit (WTD), where there is a chance of actually losing money.

Making reasonable assumptions about the cost associated to lose weight among individuals with diabetes, we can compute three relevant parameters: the curvature of the cost of effort, the intrinsic value of exerting effort, and the value elasticity of effort. We argued that these parameters are valuable for researchers to define more feasible experimental interventions. For instance, using this information, one could model the possible dose-response effort curve with respect to different levels of cash rewards before implementing a trial where the range of the interventions must be determined in advance. We also argued that knowing these parameters provide relevant information to policy makers who would like to motivate changes in health behavior using cash rewards. Our methodology could be used in a larger set of social contexts where policy makers look for the use of cash rewards to influence changes in social behavior.

Our approach is a first attempt to determine the optimal amount of cash reward assuming this amount is fixed for each level of effort. This implies that we only focus on one of the many dimensions of the reward scheme. Certainly, the architecture of a reward schemes may consider other elements such as group versus individual, frequency, what do we reward among other elements. Here the variation considered is very specific. However, defining the size of the cash reward is usually the salient aspect of the scheme in most health interventions. Future research should consider other aspects as they estimate size of the cash reward. One starting point for future researchers may be to consider incentive schemes that are convex (to map the convexity of effort cost). We hope our paper motivates this type of empirical work in the future.

The results suggest that an individual receives intrinsic satisfaction from the effort to lose weight. Yet, at low levels of cash rewards (e.g., 16-40 Soles every other week), the marginal benefit of effort is not enough to cover the marginal cost of effort. We find that the elasticity of effort with respect to the cash reward is inelastic. In the case of an exponential cost function of effort, the results suggest that the response in effort to size of the reward is very elastic at low level of rewards. Yet, at higher levels of rewards, the response becomes inelastic (in our case this happens around 200 Soles every-every-another week). Lastly, the curvature of the cost of effort to lose weight among the people with diabetes in our sample is steep.

The aim of this method was not to investigate the channels through which cash rewards motivate individuals to change health behavior. It could be that cash rewards change an individual's perception of the internal value of effort; or it could be that cash rewards may have an income effect that reduces the cost of effort (e.g., increased intake of more expensive and nutritious food). As we described earlier, in our economic model we assumed that the marginal value of effort was constant so that intrinsic motivation did not depend on the size of the reward. Our model also assumed that a cash reward does not impact the cost of effort. Lastly, we assumed that the intrinsic value of effort was constant across individuals. Future research could consider expanding the economic model to incorporate these assumptions.

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ARTICLE

THE DETERMINANTS OF INTEREST RATES IN THE KINGDOM OF SAUDI ARABIA: AN ARDL APPROACH (1985-2020)

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Abstract

This paper investigates the key factors influencing interest rates in the Kingdom of Saudi Arabia (KSA) over the period 1985-2020. The study utilises an Autoregressive Distributed Lag (ARDL) model, which is best suited for capturing both short-run and long-run impacts of independent variables. The study explores the impact of multiple factors including money supply (M3), exchange rate index (Exc), oil prices (Oilp), stock market index (SMI), consumer price index (CPI), and the London interbank offered rate (LIBOR), and U.S. interest rate indexes (LIBOR) on the dependent variable, i.e., the interest rate on deposits in SAR. Our findings demonstrate a significant influence of the dollar exchange rate and the US interest rate (LIBOR) on the deposit interest rate in KSA in the long term. In the short term, the results reveal an insignificant negative impact of the change in the deposit interest rate of the money supply. These results reflect the realities of the Saudi Arabian economy, which is heavily influenced by external variables due to its open nature. This study provides valuable insights for policymakers, financial institutions, and investors in understanding and predicting interest rate movements in the KSA.

INTRODUCTION

Monetary policy is a set of measures that is carried out by the Central Bank through controlling money to achieve political and economic goals. Monetary policy uses a set of tools, namely, the interest rate and reserve ratio. Therefore, the interest rate is one of the most important monetary policy tools in the contemporary economy. It is called the interest rate if we are talking about the borrowing rate of society members and institutions from commercial banks. The Central Bank (the Saudi Arabian Monetary Agency) can adjust the interest rate. As for some Gulf countries, where the currency is pegged to the dollar, the monetary policy and the interest rate are determined by the US

Central Bank to suit the American economy, and this policy may conflict at times with the objectives. The economic policy of the Kingdom of Saudi Arabia and given the linkage of the Saudi riyal exchange rate to the US dollar, the options for those who set Saudi monetary policies are limited, because local interest rates are significantly affected by the interest rates set by the US Federal Reserve. Therefore, interest rates rose in parallel with the interest rate of the US Reserve Bank between 1998-2001, and also during 2004-2007, when interest rates rose to reach 5.5%, and this measure was taken by the Central Bank Because of inflation (Saudi Arabian Monetary Agency, 2015), Saudi domestic interest rates (represented by the Saudi interbank rate SIBOR) are affected by the US Federal Reserve interest rate in addition to the domestic demand for credit (and the London interbank rate LIBOR). So, through what we previously found that the interest rate is one of the most important tools that maintain the stability of the economy and help in economic growth. This importance constitutes a motive for studying interest rates and their determinants and the most important theories that came in (Al-Qahtani, 2015).

RESEARCH QUESTIONS

What factors determine the interest rate in Saudi Arabia?

What are the size and type of factors that determine the rate of interest?

DATA AND METHODOLOGY

This paper is trying to identify the most important factors that affect interest rates in the Kingdom of Saudi Arabia during the period 1985-2020 using annual data. Data is collected from the Saudi Arabian Monetary Agency, the Annual Statistic 2020, and the Federal Reserve Bank of St. Louis. The dependent variable is interest rate (Ir) on deposits in SAR. The independent variables are money supply (M3), Exchange rate index (Exc), oil prices (Oilp), Stock market index (SMI), consumer price index (CPI) and LIBOR, US interest rate indexes (LIBOR).

The study applied the autoregressive distributed lag (ARDL) approach. The ARDL model is considered the best econometric method compared to others. Since the ARDL approach allows the variable to be stationary at I (0) or integrated of order I (1) from Dickey Fuller (ADF) test, which is a unit root test. Therefore, based on the study objective, ARDL is a better model than others to catch the short-run and long-run impact of independent variables.

LITERATURE REVIEW

Andrea, B. & David, F. (2014): "The rise in interest rates will be limited with the global economy heading to its natural course." In this study, several aspects were discussed, and the most important was the current interest rate situation and future expectations for it in the global economy. The study mentioned several factors that affect real interest rates and led to their decline, which led to a decline in interest rates, as follows: Saving rates increased between the years 2007-2010, which in addition to it increased the demand for assets (portfolios) and bonds in exchange for shares. As for investment, it has declined since the outbreak of the global financial crisis, and therefore interest rates around the world decreased from the early eighties from 5.5% until it reached 0.33% between the years 2008-2012. It was concluded that the two most important reasons that led to the decline in interest rates are as follows: the glut of savings arising from the emerging market economies, especially China, and the shift of investors to assets with all fixed incomes such as bonds instead of stocks.

Omar, et al., (2013): "Determinants of Interest Rates in the State of Kuwait". This study explains the most important variables that affect interest rates and the direction of this effect, as it aims to clarify how to use the response function to suit the needs of monetary policy in the State of Kuwait. As for the standard aspect, the co-integration method was used, and the causal crimes were selected. The study reached several results, the most important of which is knowing the behavior of interest rates in both the short and long term. There is a large part of inflation that cannot be controlled in the State of Kuwait, so it was concluded that money supply, exchange rate, oil prices, real estate asset prices, and financial asset prices are among the main determinants of the interest rate.

Abayomi and Adebayo (2010): "Determinants of Interest Rates in Nigeria". This study touched on clarification of the most important domestic and foreign factors that determine the interest rate in Nigeria. This study elaborates the impact and relative importance of various domestic and external factors that determine domestic interest rates. This was done through the use of quarterly data during the period 2000-2008, by following a standard approach using the co-integration method, Johansson and the error correction vector in addition to VAR 4. The model was estimated using the following variables: average market interest rates, Nigeria's real GDP, money supply M2, the consumer price index, and the exchange rate. The study reached several results, the most important of which is that there are two mutual integration relationships, and there is a significant relationship with the money supply and the exchange rate, and that the increase in the money supply causes an increase in interest rates.

Al-Omar, (2006): "Determinants of Interest Rates Behavior in the State of Kuwait". This study clarifies the most important local factors that affect the behavior of local interest rates, which are the interest rate on dinar deposits, the interest rate on dollar deposits, the discount rate to be the main tool for monetary policy, bank balances with the Central

Bank to reflect banks' liquidity, the exchange rate of the dinar against the dollar. This study uses quarterly data from 1993-2006, and five local variables, by following the autoregressive method VAR. It reached several results, and the most important is that local factors contribute between 49-65% in the behavior of local interest rates on dollar and dinar deposits, respectively, and that the discount rate comes at the forefront of these factors, then bank balances with the Central Bank. Finally, the exchange rate of the dinar against the dollar, in addition to the fact that local interest rates are directly affected by the discount rate and inversely by both bank balances with the Central Bank and the dinar exchange rate. This indicates that there is a room for monetary policy to influence local variables despite the openness of the Kuwaiti economy.

Al-Farhan, (2002): "Determinants of interest rates in the Jordanian economy". The study covers the period 1990-2000 and derives its theoretical framework mainly from the ideas of the Keynesian school. It uses the descriptive statistical analysis method in data presentation and standard analysis, represented by the ordinary least squares method. The study used the following economic variables: nominal money supply, nominal government spending, international interest rate, foreign currency exchange rate. The study achieved a number of results, and the most important are: the interest rate is negatively affected by changes in the money supply, either in the financial aspect. Interest rates on facilities, in relation to external variables, the domestic interest rate is affected by the economic variables external represented by the international interest rate, the foreign exchange rate, which reflects the reality of the Jordanian economy, which is considered an open economy.

The previous studies can be summarized. We find that the measurement methods used in the studies varied between co-integration tests, autoregressive tests, and ordinary least squares. We also note that there is a diversity in the variables used in the studies, and it is noticeable that there is a repetition of some variables due to their great impact on interest rates, such as the exchange rate variable and the money supply variable. While two studies focused on the determinants of interest rates in the State of Kuwait, and a study that spoke on the determinants of interest rates in Jordan, in this study the focus will be on the determinants of interest rates, but in the Kingdom of Saudi Arabia in addition to using data for a different period and different variables.

EMPIRICAL ANALYSIS

This section aims to analyze the variables that were used in the study, and to reach the most important factors that determine the interest rate, using certain indicators such as the exchange rate, oil prices, the general index, money supply index and the stock market index, based on some of the studies that used some of those indicators in measuring the relationship. These variables will be characterized and analyzed in the Kingdom of Saudi

Arabia. Table 1 shows the correlation coefficients between the interest rate on bank deposits and the factors affecting it.

TABLE 1. SIMPLE CORRELATION COEFFICIENTS BETWEEN THE INTEREST RATE ON BANK DEPOSITS AND THE INDEPENDENT VARIABLES

	IR	EXC	M3	OILP	CPI	SMI	LIBOR
IR	1.000000	0.157866	-0.82551	-0.63462	-0.81366	-0.75548	0.780447
EXC	0.157866	1.000000	0.089658	-0.074584	0.021201	-0.100179	-0.022318
M3	-0.82551	0.089658	1.000000	0.553625	0.959372	0.689500	-0.84074
OILP	-0.63462	-0.074584	0.553625	1.000000	0.605791	0.596029	-0.60878
CPI	-0.81366	0.021201	0.959372	0.605791	1.000000	0.596157	-0.84164
SMI	-0.75548	-0.100179	0.6895	0.596029	0.596157	1.000000	-0.587967
LIBOR	0.780447	-0.022318	-0.84074	-0.60878	-0.84164	-0.587967	1.000000

It is noticed from the correlation matrix that the inverse relationship between the deposit interest rate (1) with the money supply (M3), oil prices (OILP), the consumer price index index (CPI) and the stock market index (SMI), while the relationship is positive between the deposit interest rate and the real exchange rate (EXC) and the US LIBOR interest rate (LIBOR).

As mentioned earlier, it is also noted that the other independent variables have negative and positive relationships with each other. Based on the coefficients of the correlation matrix between variables, it is noted that there is a close correlation between the broad concept of money supply index (M3) and the consumer price index (CPI), so that the linear correlation coefficient is close to 1, where we note that the linear correlation coefficient between them is 0.95, which is the ratio large is close to 1.

After conducting the time series Stability Diagnostics tests, we use ARDL model. One of the most important features of this test is that the time series of variables are not required to be of the same degree, so we can apply it if the time series are a mixture of degrees of integration. It is stationary in the first or integral differences of the first degree (1) I and stationary at the level (0) I. The test method depends on the estimation of the equation of the ARDL model as follows:

$$\begin{aligned}\Delta lnI_t = {} & \delta + \beta_1 lnI_{t-1} + \beta_2 \, lnM3_{t-1} + \beta_3 lnOilP_{t-1} + \beta_4 lnER_{t-1} \\ & + \beta_5 lnLIBOR_{t-1} + \beta_6 lnSMI_{t-1} + \sum_{i=1}^{n} \gamma_{1i} \, \Delta lnI_{t-i} \\ & + \sum_{t=0}^{n} \gamma_{2i} \, \Delta lnM3_{t-i} + \sum_{t=0}^{n} \gamma_{3i} \, \Delta lnOilP_{t-i} \\ & + \sum_{t=0}^{n} \gamma_{4i} \, \Delta lnER_{t-i} + \sum_{t=0}^{n} \gamma_{5i} \, \Delta lnLIBOR_{t-i} \\ & + \sum_{t=0}^{n} \gamma_{6i} \, \Delta lnSMI_{t-i} + u_t\end{aligned}$$

From the previous equation, where the symbol Δ indicates the first differences of the variable, and $\boldsymbol{\delta}$ indicates the secant, and $\boldsymbol{u_t}$ indicates the random error. The ARDL model shows that the interest rate on bank deposits can be explained by the lagging value of the dependent variable that was introduced to measure the adaptation of interest rates to changes that occur in the independent variables, and the lagging values of the independent variables, and therefore the ARDL model helps us to know the effects of short and long term. The ARDL test depends on two stages: testing the existence of a long-term relationship between the variables, then we move to the second step through which you can estimate the parameters of the long-term equilibrium and the short-term parameters of the error correction model.

To test the existence of the long-term equilibrium relationship between the variables. It is important to calculate two statistics, the first (f) test and the null hypothesis that the parameters of the lagging levels are all equal to zero, meaning that there is no long-term relationship, and the alternative hypothesis says that there is a long-term equilibrium relationship, and this means that the parameters do not equal Zero.

This test is based on critical values of the integration test, then we consider that if the calculated value of (F) is greater than the upper limit of the critical values. We reject the null hypothesis that there is no long-term equilibrium relationship. But if the calculated (F) value is less than the minimum critical values, we accept the null hypothesis. As for the second test, it is a statistic calculation (t), which is based on testing the null hypothesis that the parameter of the decelerated dependent variable is zero, that is, there is no long-term equilibrium relationship. The test results are illustrated by Table 2.

TABLE 2. F-BOUNDS TEST

F-statistic		t-Statistic
4.666241		7.014815
critical values 5% Level		
upper limit	lower limit	
3.28	2.27	

From the previous table the calculated statistical value (F) (4.666241) is greater than the upper limit values (3.28) at a significant level of 5%, so it rejects the null hypothesis that says that there is no long-term equilibrium relationship. The t-test is significant, and this confirms the existence of a long-term equilibrium relationship. Then, to obtain the estimations of the long-term parameters of the ARDL model, with lag times equal to 2 were selected according to the Schwartz criterion.

TABLE 3. ARDL LONG RUN FORM AND BOUNDS TEST (LONG-TERM PARAMETERS)

VARIABLE	COEFFICIENT	STD. ERROR	T-STATISTIC	PROB.
LOG(EXC)	4.421065	2.745617	1.610226	0.1216
LOG(LIBOR)	0.824979	0.433026	1.905149	0.0699

It is concluded from the Table 3 that the most important variables that affect interest rates in the Kingdom of Saudi Arabia in the long term, and the results can be interpreted as follows:

There is a positive effect of change in the interest rate on deposits from the dollar exchange rate in the long term, where the partial flexibility of the dollar exchange rate in relation to the interest rate on deposits reached 4.421 in the long term. This means that the increase in the dollar exchange rate by 4.4% will lead to an increase in the interest rate on deposits by 1% in the long term, which indicates that the rise in the dollar exchange rate contributes positively to the increase in the interest rate on deposits. Since the exchange rate is one of the external variables, it becomes clear that the domestic interest rate is affected by external economic variables, which reflects the reality of the Saudi economy, which is considered an open economy. Also, this result agrees with the study of Al-Farhan (2002).

There is a positive effect of change in the interest rate on deposits from the US interest rate LIBOR in the long term, where the partial flexibility of the interest rate of LIBOR in relation to the interest rate on deposits reached 0.824 in the long term. This means that the increase in the interest rate of LIBOR by 0.82% will lead to an increase in the interest rate on deposits by 1% in the long term, which indicates that the rise in interest rates for LIBOR contributes positively to the increase in the interest rate on deposits. Since the US interest rate is one of the external variables, it becomes clear that the domestic interest rate is affected by external economic variables, which reflects the reality of the Saudi economy, which is considered an open economy.

ARDL Long Run equation:

$$LnIr_t = 12.9211 + 4.4211Ln\ EXC_t + 0.8798Ln\ M3\_\$_t + 0.5058LnOILP_t$$
$$- 4.2604LnCPI_t - 0.2399LnSMI_t - 0.8250LnLIBOR_t$$

TABLE 4. ARDL ERROR CORRECTION REGRESSION (SHORT-TERM PARAMETERS)

VARIABLE	COEFFICIENT	STD. ERROR	T-STATISTIC	PROB.
DLOG(IR(-1))	0.420435	0.108742	3.866347	0.0008
DLOG(EXC)	-1.068419	0.711978	-1.50064	0.1477
DLOG(M3_$)	-4.715892	0.838635	-5.6233	0.0000
DLOG(LIBOR)	-0.09624	0.120573	-0.79819	0.4333
COINTEQ(-1)*	-0.494414	0.070481	-7.01482	0.0000

It is concluded from Table 4 that the most important variables that affect interest rates in the Kingdom of Saudi Arabia in the short term, and the results can be interpreted as follows:

> We note that the error correction term or adjustment coefficient (1-) ECM has appeared with a negative sign and less than or significant. There is an insignificant negative impact of the change in the interest rate on deposits from the money supply in its expanded concept in the short term, as the partial flexibility of money supply in its expanded concept in relation to the interest rate on deposits reached (-4.71) in the short term. This means that the increase in money supply in its concept an expanded 0.5% will lead to a 1% decrease in the deposit rate in the short term. It is a convergent result between the long and short term.

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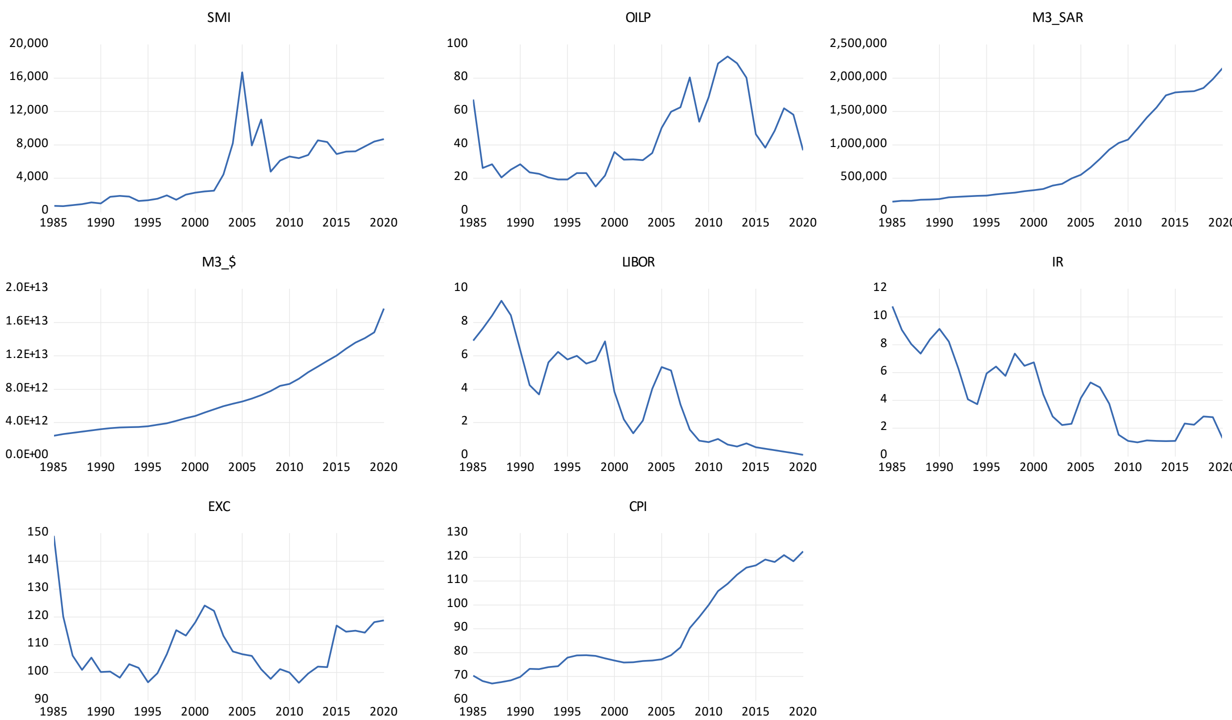
APPENDIX 1



Null Hypothesis: D(LCPI) has a unit root
Exogenous: Constant
Lag Length: 1 (Automatic - based on SIC, maxlag=9)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-2.405005	0.1481
Test critical values:	1% level	-3.646342	
	5% level	-2.954021	
	10% level	-2.615817	

Null Hypothesis: D(LEXC) has a unit root
Exogenous: Constant
Lag Length: 1 (Fixed)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-4.883717	0.0004
Test critical values:	1% level	-3.646342	
	5% level	-2.954021	
	10% level	-2.615817	

Null Hypothesis: D(LIR) has a unit root
Exogenous: Constant
Lag Length: 1 (Fixed)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-3.533472	0.0132
Test critical values:	1% level	-3.646342	
	5% level	-2.954021	
	10% level	-2.615817	

Null Hypothesis: D(LLIBOR) has a unit root
Exogenous: Constant
Lag Length: 1 (Fixed)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-3.958642	0.0045
Test critical values:	1% level	-3.646342	
	5% level	-2.954021	
	10% level	-2.615817	

Null Hypothesis: D(LM3_$) has a unit root
Exogenous: Constant
Lag Length: 1 (Fixed)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-1.892148	0.3318
Test critical values:	1% level	-3.646342	
	5% level	-2.954021	
	10% level	-2.615817	

Null Hypothesis: D(LOILP) has a unit root
Exogenous: Constant
Lag Length: 1 (Fixed)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-4.356956	0.0016
Test critical values:	1% level	-3.646342	
	5% level	-2.954021	
	10% level	-2.615817	

Null Hypothesis: D(LSMI) has a unit root
Exogenous: Constant
Lag Length: 1 (Fixed)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-3.552403	0.0126
Test critical values:	1% level	-3.646342	
	5% level	-2.954021	
	10% level	-2.615817	

Covariance Analysis: Ordinary
Date: 12/05/21 Time: 16:48
Sample: 1985 2020
Included observations: 36

Covariance Correlation	LIR	LEXC	LM3_$	LOILP	LCPI	LSMI	LLIBOR
LIR	0.552822						
	1						
LEXC	0.01076	0.008403					
	0.157866	1					
LM3_$	-0.350259	0.00138	0.325646				
	-0.825511	0.026382	1				
LOILP	-0.244698	-0.00017	0.199428	0.268938			
	-0.634615	-0.00362	0.673888	1			
LCPI	-0.122699	0.00027	0.109097	0.067492	0.041135		
	-0.813662	0.014508	0.942622	0.641685	1		
LSMI	-0.515361	-0.01056	0.465828	0.330006	0.138505	0.84177	
	-0.755478	-0.1256	0.889725	0.693584	0.744327	1	
LLIBOR	0.736594	-0.0169	-0.67131	-0.38239	-0.24017	-0.82002	1.611329
	0.780447	-0.14521	-0.92674	-0.58089	-0.93287	-0.7041	1

ARDL Long Run Form and Bounds Test
Dependent Variable: DLOG(IR)
Selected Model: ARDL(2, 1, 1, 0, 0, 0, 1)
Case 2: Restricted Constant and No Trend
Date: 12/05/21 Time: 20:38
Sample: 1985 2020
Included observations: 34
Conditional Error Correction Regression

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-6.388365	15.53622	-0.411192	0.6849
LOG(IR(-1))*	-0.494414	0.153263	-3.225913	0.0039
LOG(EXC(-1))	2.185838	1.096452	1.993556	0.0587
LOG(M3_$(-1))	-0.435003	0.845240	-0.514650	0.6119
LOG(OILP)**	-0.250091	0.173366	-1.442559	0.1632
LOG(CPI)**	2.106384	1.548500	1.360274	0.1875

LOG(SMI)**	0.118609	0.209578	0.565943	0.5772
LOG(LIBOR(-1))	0.407881	0.144407	2.824533	0.0099
DLOG(IR(-1))	0.420435	0.172910	2.431533	0.0236
DLOG(EXC)	-1.068419	1.077518	-0.991555	0.3322
DLOG(M3_$)	-4.715892	1.737490	-2.714198	0.0127
DLOG(LIBOR)	-0.096240	0.195264	-0.492872	0.6270

* p-value incompatible with t-Bounds distribution.
** Variable interpreted as Z = Z(-1) + D(Z).

Levels Equation
Case 2: Restricted Constant and No Trend

Variable	Coefficient	Std. Error	t-Statistic	Prob.
LOG(EXC)	4.421065	2.745617	1.610226	0.1216
LOG(M3_$)	-0.879835	1.755614	-0.501155	0.6212
LOG(OILP)	-0.505832	0.347064	-1.457464	0.1591
LOG(CPI)	4.260362	3.897532	1.093092	0.2862
LOG(SMI)	0.239898	0.445140	0.538927	0.5953
LOG(LIBOR)	0.824979	0.433026	1.905149	0.0699
C	-12.92107	32.21627	-0.401073	0.6922

EC = LOG(IR) - (4.4211*LOG(EXC) -0.8798*LOG(M3_$) -0.5058*LOG(OILP) + 4.2604*LOG(CPI) + 0.2399*LOG(SMI) + 0.8250*LOG(LIBOR) -12.9211)

F-Bounds Test		Null Hypothesis: No levels relationship		
Test Statistic	Value	Signif.	I(0)	I(1)
			Asymptotic: n=1000	
F-statistic	4.666241	10%	1.99	2.94
k	6	5%	2.27	3.28
		2.5%	2.55	3.61
		1%	2.88	3.99
Actual Sample Size	34		Finite Sample: n=35	
		10%	2.254	3.388
		5%	2.685	3.96
		1%	3.713	5.326
			Finite Sample: n=30	
		10%	2.334	3.515
		5%	2.794	4.148
		1%	3.976	5.691

ARDL Error Correction Regression
Dependent Variable: DLOG(IR)
Selected Model: ARDL(2, 1, 1, 0, 0, 0, 1)
Case 2: Restricted Constant and No Trend
Date: 12/05/21 Time: 21:12
Sample: 1985 2020
Included observations: 34
ECM Regression
Case 2: Restricted Constant and No Trend

Variable	Coefficient	Std. Error	t-Statistic	Prob.
DLOG(IR(-1))	0.420435	0.108742	3.866347	0.0008
DLOG(EXC)	-1.068419	0.711978	-1.500636	0.1477
DLOG(M3_$)	-4.715892	0.838635	-5.623295	0.0000
DLOG(LIBOR)	-0.096240	0.120573	-0.798188	0.4333
CointEq(-1)*	-0.494414	0.070481	-7.014815	0.0000
R-squared	0.715779	Mean dependent var		-0.057716
Adjusted R-squared	0.676576	S.D. dependent var		0.333323
S.E. of regression	0.189562	Akaike info criterion		-0.353144
Sum squared resid	1.042083	Schwarz criterion		-0.128679
Log likelihood	11.00345	Hannan-Quinn criter.		-0.276595
Durbin-Watson stat	2.170785			

* p-value incompatible with t-Bounds distribution.

F-Bounds Test		Null Hypothesis: No levels relationship		
Test Statistic	Value	Signif.	I(0)	I(1)
F-statistic	4.666241	10%	1.99	2.94
k	6	5%	2.27	3.28
		2.5%	2.55	3.61
		1%	2.88	3.99