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An Empirical Analysis of The Trilemma: Inflation, Interest Rate and Exchange Rate Dynamics in Singapore

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Abstract. *This study considers the correlation among the Consumer Price Index (CPI), the Singapore / US dollar exchange rate, and the Singapore overnight rate average from 2012 to 2023 in Singapore. This small and open economy effectively manages its monetary policy to maintain a healthy inflation rate but has experienced high inflation rates and slow economic growth, raising questions about the effectiveness of the floating exchange rate system adopted by the Monetary Authority of Singapore in recent years. This study employs unit root and cointegration tests, impulse response functions, and variance decomposition. According to the vector error correction model specification, the production function primarily facilitated short-term adjustments toward long-term equilibrium; however, these adjustments were gradual, and it took more than two years to respond to system shocks. Analyses of the impulse response functions and variance decomposition indicate that changes in the variables resulted in analogous behavior patterns, with notable effects that primarily differ in their response to shocks. The empirical evidence supports the view that inflation controls are more sensitive to interest rate adjustment in Singapore. The findings of the present research provide valuable insights and have numerous important implications for the macroeconomic evaluation of Singapore. The study acknowledges that economies are subject to unforeseen events like global crises or pandemics, which can impact exchange rates and inflation beyond the scope of policy measures, and these might not be fully captured in the study.*

Keywords: *Consumer price index, Singapore overnight rate average (sora), monetary authority of Singapore, free economy, monetary policy, foreign exchange policy*

1. Introduction

Singapore is a small and open country that is largely reliant on trade. Exchange rate and inflation targeting are important macroeconomic policy tools used by central banks to preserve price stability and stimulate economic growth (Adler et al., 2019). Instead of tracking to a single currency, the Monetary Authority of Singapore (MAS) maintains a stable and competitive rate of exchange between the Singapore dollar and the currencies of its major trading partners. Additionally, the MAS employs inflation targeting to sustain a stable and low inflation rate. (MAS, 2023). Despite the efforts of the MAS to maintain price stability and promote economic growth, Singapore has experienced high inflation rates and slow economic growth in recent years, raising questions about the effectiveness of monetary policies in achieving its objectives. According to Statistics Singapore, in the first quarter of 2023, Singapore's GDP improved 0.4% year on year; in 2022, the economy grew 3.6%, which is well below the 7.6% achieved in 2021. There is also a lack of understanding of the factors that influence inflation and exchange rates and their relationship among the two in Singapore.

In the United States (US), the central bank frequently increases interest rates to combat inflation, which can lower the demand for goods and services and control the rate of

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inflation. By contrast, consumers will increase their borrowing and spending habits when the interest rate is low, which may boost demand for goods and services and, in turn, impact the inflation rate. Based on its evaluation of the state of the economy, inflationary pressures, and the intended pace of economic development and stability, the US Federal Reserve modifies interest rates (Campos, 2019).

The literature focuses on the correlation between market interest rates and monetary policy (Valente, 2009). The job of the central bank is to maintain a certain level of consistency in the country's financial system by monitoring the production and circulation of money in the economy, publicizing statistics and data, and promoting growth in jobs and the economy through adjustment of the discount rate. The central bank's capacity to change the discount rate is the most important tool in its arsenal (Heakal, 2021).

If the economy grows at a scale that threatens hyperinflation, interest rates might be boosted by the central bank. Consumer spending and investment habits will be affected when interest rates increase, causing savings to be more attractive (Egilsson, 2020). Lending becomes less desirable to banks and consumers when the discount rate rises, but customers are more likely to earn higher interest on low-risk savings instruments (Kenton, 2023).

Currency is a particularly sensitive instrument that fluctuates relative to other currencies. The exchange rate's indirect effects and their variations affect various significant areas of our economic lives. Exchange rates have intermediate and long-lasting impacts on the economy and have a particularly significant impact on stock prices (Gokmenoglu, 2021).

In contrast to a fixed rate system, in which the exchange rate is pegged to a particular value or a basket of currencies, a floating rate system allows for flexibility and modifications based on market circumstances (Hussein & Muslim, 2020).

Inflation means rising prices, which, over time, means decreased purchasing power. Over time, the pace of reduction in purchasing power is seen in average price increases for a selected basket of goods and services (Fernando, 2023). The cost of such goods and services and their proportion in household spending influence consumers' cost of living. Government agencies compute the cost of living for a typical consumer by surveying households to select a basket of regularly purchased goods and then tracking the cost of purchasing this over time (Banton, 2021).

The Consumer Price Index (CPI) measures the average change in prices paid by urban consumers in the US over time for a market basket of consumer goods and services, including transportation, food, and medical treatment. The CPI is calculated by averaging the price changes for each item in a predetermined basket of products based on their relative weight in the overall basket. The costs taken into account are the retail costs per item as offered for sale to private citizens (Fernando, 2023).

Inflation in Singapore has increased from 2% to 6% as of the first quarter of 2023. The speed of this increase has been especially rapid in recent years (Tradingeconomics, 2023). A high inflation rate will affect economic growth because of higher debt rates. A downstream effect of higher inflation is a slowing of the economy, as companies often sell fewer products. Although MAS does not have a specific target, a rate of 2% is ideal, according to NASDAQ (Rosenberg, 2023).

Singapore achieved fair growth in 2022 (3.6% year on year), aided by increased global trade and healthy local consumption. However, the economy's momentum is definitely diminishing, with the first-quarter GDP down from the prior quarter. GDP decreased (−0.7%) in the first quarter, resulting in a year-on-year expansion of 0.1%, falling far short of market estimates (Mapa, 2023).

There is little research on the variables that affect Singapore's inflation and exchange rates and their interaction. Understanding these factors and their relationship is vital for appropriately influencing policy choices and guaranteeing the long-term stability and growth of the Singaporean economy. The MAS uses an inflation targeting strategy to keep inflation low and stable, with reference to two measures of inflation: headline CPI and core inflation (MAS, 2018).

The goal of this study is to determine how well the MAS inflation targeting and exchange rate policies support economic growth and price stability. The study focuses on the following in the case of Singapore:

1. The correlation between the exchange rate and the inflation rate
2. The correlation between the interest rate and the inflation rate
3. The correlation between the exchange rate and interest rate

As a small and open economy, Singapore faces special difficulties in controlling its exchange rate. The Singapore dollar nominal effective exchange rate (S$NEER) is a strategy used by the MAS to control the movement of exchange rates (MAS, 2020). Understanding this policy and its effects allows policymakers and academics to assess the success of Singapore's exchange rate system and make any necessary adjustments.

2. Literature Review / Hypothesis Development

Interest Rates and Inflation Relationship

There is conflicting evidence from empirical studies on the Fisher effect and the connection between interest rates and inflation. In their study of the connection between interest rates and inflation in the US, Mishkin and Simon (1995) found empirical evidence in favor of the Fisher effect, concluding that a one percentage point increase in nominal interest rates was correlated with a 1 percentage point rise in projected inflation.

Researchers have studied the idea of a non-linear link between interest rates and inflation. Hamilton (1983) found that interest rates will be more sensitive to inflation after they surpass a certain threshold. The author offered proof of a non-linear correlation between inflation and interest rates, recommending that the US central banks respond differently to high and low levels of inflation.

There is empirical research into the connection between interest rates and inflation in Singapore. For example, Lim & Ng (2008) examined how monetary policy was communicated in Singapore and determined that changes in interest rates had a substantial effect on inflation. Their study highlighted the effectiveness of Singapore's monetary policy framework in monitoring inflation dynamics.

Exchange Rates and Inflation Relationship

The purchasing power parity hypothesis is that exchange rate changes ought to result in proportional changes in relative price levels, thus influencing the inflation rate (Balassa, 1964). Depreciation of the home currency will lead to an increase in costs of imports and further increasing inflation and vice versa. Engel & Rogers (1996) examined the connection between consumer inflation and exchange rates in a sample of industrialized economies; they found inflation rates were significantly affected by changes in long-term exchange rates. Campa & Goldberg (2005) considered this same connection but came to a different conclusion. They suggested that changes in the exchange rate did not affect consumer prices completely and did not fully impact inflation.

Hodrick (1987) noted that the presence of nominal rigidities, such as wage rigidities and sticky prices, can mitigate the impact of exchange rate changes on inflation. The openness of capital markets and exchange rate regimes can impact the correlation between inflation and exchange rates (Levy-Yeyati & Sturzenegger, 2003). In Singapore, Siregar & Rajaguru (2012) used vector autoregression (VAR) models to inspect the pass-through

consequences of exchange rates for the CPI in Singapore. There is only a minimal effect on inflation when there are exchange rate changes in Singapore.

The Relationship between Interest Rates, Exchange Rates, and Inflation

Chen, Khoo, & Chan (2018) used a panel dataset of developing and developed economies to assess the effect of US quantitative easing on exchange rates and found variations in countries' rates of monetary policy transmission through exchange rates. This raises the prospect that country-specific characteristics and policy measures influence the link between interest and exchange rates.

Various empirical studies have explored the correlation between interest rates, exchange rates, and inflation. Engel & West (2005) assessed the correlations between interest rates, exchange rates, and inflation in a number of developed countries. They revealed evidence of a positive correlation among these factors, indicating channels for monetary policy transmission.

Researchers have also looked into the function of exchange rates as a mechanism to export monetary policy. The Keynesian open economy model (Clarida, Gali & Gertler, 2002) takes into account how monetary policy, exchange rates, and inflation relate. The model emphasizes how alterations in interest rates impact the value of the dollar and, in turn, impact inflation dynamics. This theory revealed the complexity of these connections, especially in open economies.

3. Methodology

Data and Methodology

This study relied on monthly data from January 2012 to October 2023 from the Singapore Department of Statistics. The variables are the CPI (*CPI*), exchange rate (*SGD*, *SGD/USD*), and interest rate (*SORA*; Singapore Overnight Rate Average). CPI is taken to represent inflation. A natural logarithm was applied to the data before performing the analysis. The notional model assumes that CPI is a function of the exchange rate and the interest rate:

$$Y=f(SGDt,SORAt), \quad (1)$$

where *Y* represents the CPI, *SGD* represents the rate at which Singapore dollars are bought and US dollars are sold, and *SORA* represents the monthly interest rate.

Unit Root and Cointegration Test

The reliability of the econometric models was ensured by employing diagnostic tests such as the Augmented Dickey-Fuller (ADF) test for stationarity and the Johansen cointegration test for long-term relationships. These tests are crucial for validating the assumptions underlying the models and ensuring the robustness of the results. First, the ADF unit root test was implemented to check the data properties, and each variable was tested for stationarity. The null hypothesis of the presence of a unit root establishes a series as non-stationary, and the opposite case will establish stationarity. Ng and Perron (2011) adopted the modified Akaike information criterion to determine the appropriate lag length. The variables were tested for cointegrating relationships. The significance levels of trace statistics, the levels of eigenvalues were examined. The rank of cointegration was determined via likelihood-based tests proposed by Johansen (1991). The Johansen–Juselius VAR of order p is stated below:

$$yt = \mu + A1yt-1 + \cdots + Apyt-p + \varepsilon t, \quad (2)$$

where yt is the n x 1 vector of variables that are integrated of order one I (1), εt is the n x 1 vector of innovations. VAR can also be articulated as follows:

$$\Delta yt = \mu + nyt-1 + i=1p-1iyt-i + t, \quad (3)$$

where n=i=1pAi-I, and i = j=i+1pAj. When r < n, this denotes that the lower rank of ɪɪ (coefficient matrix), rank r, occurred with matrices α and β, each of n x r; α is the modification constraint of the vector error

correction model (VECM), β is the cointegrating vector; and r is the number of cointegrating relationships.

Johansen proposes two statistical tests for integration: the trace test and the maximum eigenvalue test.

Trace test:

$$Jtrace(r)=-Ti=r+1nln(1-xi) \quad (4)$$

Maximum eigenvalue test:

$$Jtrace(r, r+1)=-Tln(1-xr+1), \quad (5)$$

with sample size, T and the i^{th} largest canonical correlation = x.

In the first test, the null hypothesis of cointegrating vectors (r) and the complementary assumption of cointegrating vectors (n) is assessed. The maximum eigenvalue test contrasts the alternative assumption of *r*+1 cointegrating vectors with the null hypothesis of *r* cointegrating vectors (Johansen, 2000). Because it produces findings of accurately r cointegrating vectors, the maximum eigenvalue test is more favored. Osterwald-Lenum (1992) tallied the critical values for both tests, and MacKinnon-Haug-Michelis (1999) sourced the p-values.

Pairwise Granger Causality Test

The pairwise Granger causality test (Granger, 1969) is a numerical assessment of forecasting accuracy from one time series to another and includes consideration of causal interrelationships (bidirectional or unidirectional). If two or more time series are cointegrated, the pairwise Granger causality must occur in either one or both directions but not in both directions. If it is determined that a time series, X, gives statistically meaningful data about prospective values of Y—often via a series of F-tests and t-tests on lagged values of X (together with lagged values of Y) —then that time series is assumed to Granger cause Y. Granger causality was originally a bivariate theory of the sequential arrangement of two time series. This test was selected to explore the causality relationship between the variables, for example, whether changes in exchange rates precede changes in inflation. The statistical validation of chronological causation assures that it does not reference actual causality. Bivariate regressions are often structured as follows:

$$yt=a0+i=1niyt-i+i=1nixt-i+t \quad (6)$$

$$yt=a0+i=1nixt-i+i=1niyt-i+t, \quad (7)$$

where *t* represents the time stage aspect for all probable pairs of (x, y) series in the cluster. In the joint hypothesis, Wald statistics also reflect as F-statistics when the following holds:

$$B1=2=3=\ldots=i=0$$

Granger (1969) states the null hypothesis for each equation as follows:
H1: x does not Granger cause y
H2: y does not Granger cause x

Impulse Response Function

In the philosophy of signal administering and mechanism, the impulse response, or impulse response function (IRF), is the output in response to a transient input signal recognized as an impulse (t). An impulse response is the reaction of any dynamic system to an outside alteration. The system's response is defined as a function of time (or, alternatively, as a function of an independent variable that parameterizes the system's dynamic behavior) in both cases. The IRF records the development of the variable of interest over a defined period as it interacts following an exogenous impulse (shock) in a specified instant, affecting further dependent variables in the current method via the vigorous structure. (Enders, 2014). A shock to *εj*, is usually caused by an impulse response function, *yi*, where the time horizon, *t*, represents the variable *i's* reaction to shock.

The vector moving average (VMA) is expressed as follows:

yt=+t + E1t-1+E2t-2+ (8)

yt=i=0Eit-i+ (9)

The impulse response *yi* after a shock in *εj* could be articulated by exercising this VMA,

yt+n=i=0Eit+n-i (10)

{En}i,j=∂yi,t+n∂ϵj,t, ∀*j≥0* (11)

The equations are produced by changing the VMA representation from the VAR model. It is a useful technique in empirical causal analysis and policy usefulness analysis, particularly when looking at specific economic problems (Lütkepohl, 2008). Structural information is required to identify meaningful shocks because IRF is formed by assuming the remaining shocks are constant. In order to detect the shock, the Cholesky decomposition was proposed (Hatemi, 2014).

Variance Decompositions

Variance decompositions, also known as forecast error variance decompositions, are used to analyze the relative role of different variables in clarifying the estimated inaccuracy variance of a precise variable in a VAR model. The decomposition provides insight into the dynamic interactions and comparative importance of the variables over time. The variance decomposition thus method reveals the comparative significance of each arbitrary shock that influences the variables. To orthogonalize the impulses, Cholesky employs the contrary of the Cholesky component in the remaining covariance matrix. As a result, the variables in the system are forced into a certain sequence, and the variable that appears first in the system is given full credit for any common component's effects. Cholesky factorization is a decomposition method under Cholesky. This is a Hermitian decomposition in which matrix A ε $L^{n \times n}$ in a positive definite form is factored into the outcome of L, a rare minor matrix in triangle form with positive transverse components, and its conjugate transposition L^T.

$$A = LL^T \quad (12)$$

where A's Cholesky factor is L. Partitions A and L are as follows:

$$\begin{bmatrix} a_{11} & a_{12} & \cdots & a_{1n} \\ a_{21} & a_{22} & \cdots & a_{2n} \\ a_{31} & a_{32} & \cdots & a_{3n} \\ \vdots & \vdots & \ddots & \vdots \\ a_{n1} & a_{n2} & \cdots & a_{nn} \end{bmatrix} = \begin{bmatrix} l_{11} & 0 & \cdots & 0 \\ l_{21} & l_{22} & \cdots & 0 \\ \vdots & \vdots & \ddots & \vdots \\ l_{n1} & l_{n2} & \cdots & l_{nn} \end{bmatrix} \begin{bmatrix} l_{11} & l_{21} & \cdots & l_{n1} \\ 0 & l_{22} & \cdots & l_{n2} \\ \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & \cdots & l_{nn} \end{bmatrix}$$

Put simply, after being post-multiplied by its transpose, the n product of the n triangular matrix was formed by any n x n positive definite covariance matrix via Cholesky decomposition.

4. Findings and Discussion

This study applied an ordinary macroeconomic model to evaluate Singapore's economic performance from January 2012 to October 2023 using the following key indicators: the CPI, SGD/USD exchange rate, and the SORA. Figure 1 illustrates the recent patterns and shifts in these macroeconomic indicators. The CPI shows a consistent upward trajectory, indicating a prolonged increase in the average prices of goods and services consumed by urban consumers. Simultaneously, the SORA values fluctuate, suggesting variation in the overnight interbank lending rates over time. The exchange rate (*LSGD*) appears to have experienced fluctuations, with periods of depreciation and appreciation against the USD.

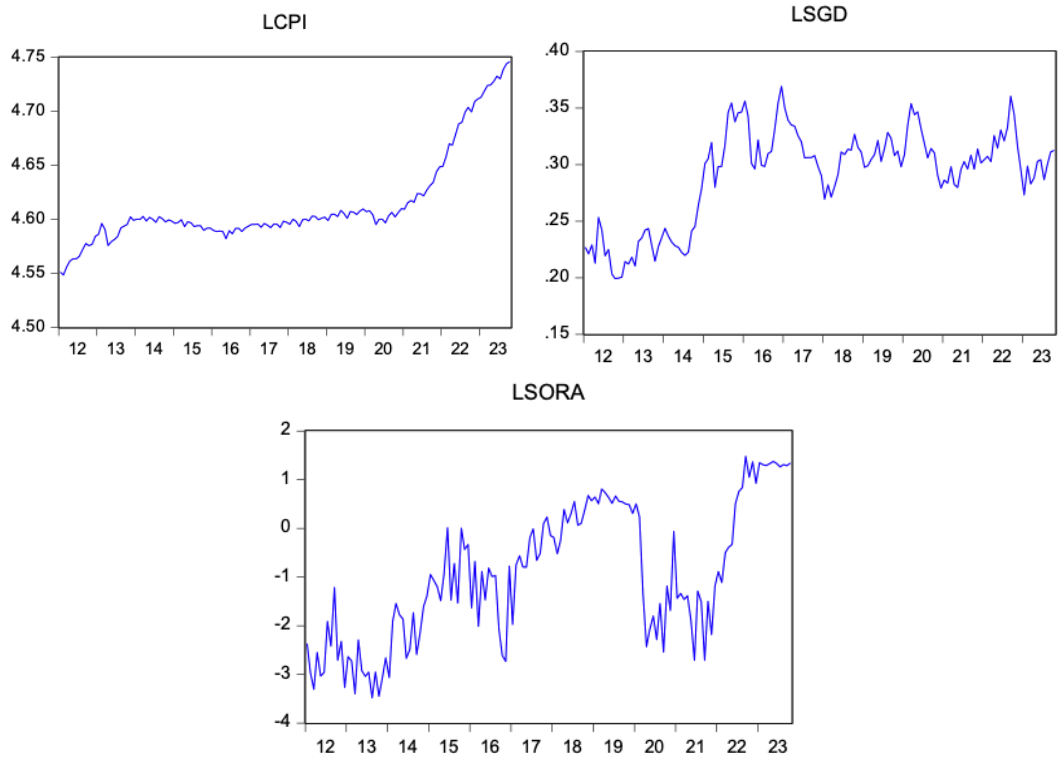

Figure 1
Consumer Price Index, Exchange Rate, Interest Rate, 2012 – 2023
Source: Singapore Department of Statistics
Notes: LCPI = natural logarithm of CPI, LSGD = natural logarithm of SGD/USD, LSORA= natural logarithm of SORA

Table 1
Data Properties

	Descriptive Statistics								Unit Root Test: ADF t-stat			
	N	**Mean**	**Median**	**Max**	**Min**	**Std Dev**	**Skewness**	**Kurtosis**	**Level**	**Lag**	**1st Diff**	**Lag**
LCPI	142	4.61	4.60	4.75	4.55	0.04	1.69	4.97	2.03	3	-3.91*	2
LSGD	142	0.29	0.30	0.37	0.20	0.04	-0.59	2.40	-2.28	0	-12.24*	0
LSORA	142	-0.96	-0.98	1.47	-3.48	1.39	0.03	1.88	-1.59	1	-12.22*	0

Note: * 95% confidence interval levels proposed by MacKinnon (1996)

The ADF assessment is implemented to assess the information characteristics of each variable with a distinctive divert. The proper lag lengths are resolute using the Akaike information criterion (AIC). As depicted in Table 1, the variables (*LCPI, LSGD, LSORA*) cannot be rejected by the null hypothesis at the level, indicating that these variables have unit roots and are non-stationary in their initial form. The variables will become stationary after the first differencing; at the 5% significance level, the null hypothesis can be rejected for the unit root. In short, all variables can be integrated of order one, I (1), meeting the criteria for conducting a test of cointegration.

Cointegration Test and Long-Run Estimation

This section discusses the outcomes of the cointegration test proposed by Johansen and Juselius (1990). The reported trace test statistics stand at 29.85231, surpassing the 95% critical value of 29.79707 set out in Table 2 below. Therefore, the null hypothesis of no cointegrating vector can be rejected based on the results shown. In statistical terms, at lag length 1, there is a presence of at least one cointegrating vector. This implies that the

three variables (LCPI, LSGD, LSORA) exhibit an equilibrium and a common long-run relationship.

Table 2
Cointegration Tests

Hypothesized No. of CE(s)	Test Statistics		Critical Value	
	Trace	**Max-Eigen**	**Trace**	**Max-Eigen**
None*	38.59044	24.66337	29.79707*	21.13162
At most 1	13.92706	11.52209	15.49471	14.26460
At most 2	2.404975	2.404975	3.841465	3.841465

Notes: * According to MacKinnon-Haug-Michelis's (1999) p-values, the null hypothesis can be rejected at a 95% confidence interval. The trace and Max-Eigenvalue tests indicate one cointegrating relationship

The standardized cointegrating equation is derived by using the relation of each cointegrating vector to the undesirable cointegrating vector, Y. The product excludes the null hypothesis that the coefficients of the associated variables are equivalent to zero; this is denoted by the t-statistics in parenthesis. There is thus a substantial, durable relationship among *CPI*, *SGD*, and *SORA*, and the durable estimation with corresponding constants is stated below:

$$Y=-0.005SGD+0.02SORA$$
$$(0.172) \qquad (0.005)$$

The stabilized cointegrating equation shows that the long-run impact of the exchange rate (*SDG*) on Singapore's inflation is negative and insignificant. The effect is larger (coefficient = 0.05) than that of the interest rate. At the same time, the interest rate contributed positively to inflation. This indicates that monetary policy that targets interest rates contributes significantly to controlling inflation. The MAS can use the SORA rate to control the inflation rate.

Vector Error Correction Model and Causality

VECM shows that none of the error correction terms in the VAR model are significant and negative. Changes to the industrial production equation address approximately 4.0% of the uncertainty on a monthly basis. A straightforward calculation indicates that these adjustments are gradual, requiring 25 months (or more than two years) to fully reconcile following a system shock.

Table 3
Vector Error Correction Model

Error Correction:	D(LCPI)	D(LSGD)	D(LSORA)
CointEq1	**0.040099**	0.040822	2.730254
	(0.01283)	(0.004986)	(2.10242)
	[3.12524]	[0.81881]	[1.29862]
D(LCPI(−1))	−0.111374	−0.131437	−3.540389
	(0.09264)	(0.35996)	(15.1795)
	[−1.20225]	[−0.36515]	[−0.23324]

Table 3 (Continued)

Error Correction:	D(LCPI)	D(LSGD)	D(LSORA)
D(LCPI(−2))	−0.149491	−0.504955	9.587654
	(0.08659)	(0.33647)	(14.1889)
	[−1.72637]	[−1.50077]	[0.67572]
D(LCPI(−3))	0.397933	0.215264	4.540980
	(0.08378)	(0.32555)	(13.7285)
	[4.74956]	[0.66123]	[0.33077]
D(LCPI(−4))	−0.138672	−0.319271	4.497235
	(0.08954)	(0.34794)	(14.6726)
	[−1.54864]	[−0.91761]	[0.30651]
D(LSGD(−1))	−0.024243	0.011150	−0.182663
	(0.02230)	(0.08664)	(3.65350)
	[−1.08730]	[0.12870]	[−0.05000]
D(LSGD(−2))	−0.013515	−0.010153	−1.401956
	(0.02227)	(0.08654)	(3.64924)
	[−0.60686]	[−0.11733]	[−0.38418]
D(LSGD(−3))	−0.007519	−0.078331	4.852155
	(0.02230)	(0.08665)	(3.65417)
	[−0.33717]	[−0.90396]	[1.32784]
D(LSGD(−4))	−0.019209	−0.072903	2.122232
	(0.02257)	(0.08770)	(3.69833)
	[0.85106]	[−0.83128]	[0.57384]
D(LSORA(−1))	−0.024243	−0.001576	−0.463376
	(0.02230)	(0.00225)	(0.09475)
	[−1.08730]	[0.70134]	[−4.89059]
D(LSORA(−2))	−0.000783	−0.000338	−0.028344
	(0.00063)	(0.00244)	(0.10279)
	[1.24823]	[−0.13885]	[−0.27574]
D(LSORA(−3))	0.00000145	0.002803	−0.089007
	(0.00062)	(0.00242)	(0.10209)
	[0.02326]	[1.15794]	[−0.87181]
D(LSORA(−4))	0.000156	0.002130	−0.054960
	(0.00055)	(0.00212)	(0.08947)
	[0.28628]	[1.00417]	[−0.61430]
C	0.001288	0.001318	0.027393
	(0.00040)	(0.00156)	(0.06596)
	[3.20013]	[0.84265]	[0.41533]

The adjustment to the last period deviation from the long-term equilibrium occurs at a rate of 0.040099% and happens in the current period. A 1% movement in the exchange rate corresponds to a drop in inflation in the short run. In addition, a 1% change in the interest rate will result in a 0.000156% increase in the short run. The presence of error corrections and cointegration among all variables removes the potential of fictitious random correlations and the likelihood of Granger non-causality. This indicates, at a minimum, the presence of a single channel of Granger causality, whether unidirectional or bidirectional. At the 95% confidence interval, the null hypothesis can be rejected. The direction of the causal relationship is not specified by the cointegrating vector between the two variables. According to economic theory, pairwise Granger causality happens in a minimum of one direction throughout; the test can be carried out to check whether any

endogenous variables in the present VAR model can be deemed exogenous in the Granger sense.

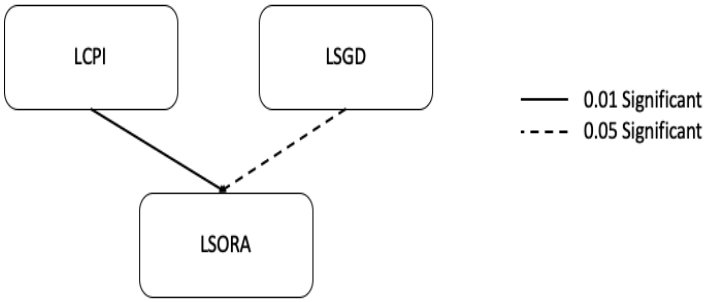

Figure 2
Causal Effects Within the VECM

Figure 2 depicts the results from the pairwise Granger causality tests within the VECM at a lag length of one. Inflation (*LCPI*) Granger caused the interest rate (*LSORA*) at the 99% confidence level. The exchange rate (*LSGD*) Granger caused the interest rate (LSORA) at the 95% confidence level. Both are considered to be a unidirectional causal effect. There is no causality between inflation (*LCPI*) and the exchange rate (*LSGD*). In short, changes in interest rates were disturbed by the inflation rate and the rate of exchange between the Singapore and US dollars.

IRF

While the pairwise Granger causality test shows a causal correlation between variables, it does not provide information on the relationship's direction or the extent of its effects. The IRF addresses this by illustrating how a specific variable responds to shocks from systemic variables. In circumstances where two variables have a consistent correlation and a stable relationship, a shock to one variable is expected to affect the other. IRFs efficiently capture this shock, known as impulse or innovation. Importantly, IRFs have the benefit of not relying on the arrangement of functions in the VAR model, allowing observation of a variable's dynamic response to unexpected changes or shocks in other variables.

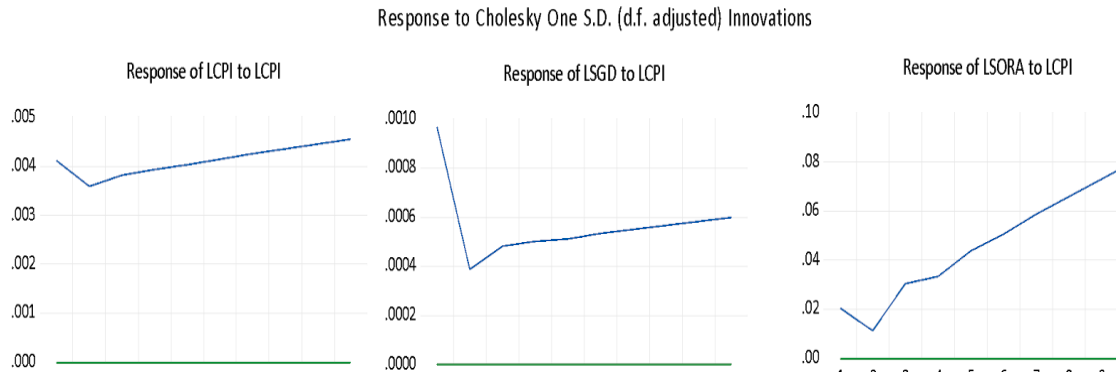

Figure 3
Impulse Responses

Figure 3 (Continued)

Figure 3 depicts the response of the model's variables to a one-standard-deviation change in the inflation rate, currency rate, and interest rate. A change in *LCPI* (*Y*) leads it to move to a lesser level and increase over the period. A similar trend is seen in the relationship between the exchange rate (*LSGD*) and interest rate (*LSORA*). Where there is a shock to *LSGD* (*Y*), the inflation rate (*LCPI*) and the interest rate (*LSORA*) have a negative and strong response, while the exchange rate (*LSGD*) has a positive and weak response.

The response of inflation (*LCPI*) to a change in *LSORA* (*Y*) is strong and negative, while the exchange rate (*LSGD*) and the interest rate (*LSORA*) have a strong positive response.

Variance Decompositions

In addition to exploring impulse response patterns, variance decomposition is used to improve the analysis. Variance decomposition is a method of dissecting fluctuations in an endogenous variable by attributing the variation to shocks arising from other endogenous variables in the VAR model. The purpose of variance decomposition is to quantify the proportion of variance explained by a variable's own shock vs. the variance explained by shocks from other variables during the sample period.

Table 4
Variance Decomposition Analysis

Period	S.E.	LCPI	LSGD	LSORA
1	0.004112	**100.0000**	0.000000	0.000000
6	0.009898	**95.10401**	0.480108	4.415883
12	0.015975	**84.13628**	0.199063	15.66466

Table 4. Continued

Period	S.E.	LCPI	LSGD	LSORA
18	0.022326	**73.66670**	0.145059	26.18824
24	0.028954	**65.45014**	0.184683	34.36518
1	0.014380	0.451453	**99.54855**	0.000000
6	0.034478	0.177904	**99.63309**	0.189008
12	0.048736	0.176841	**99.70258**	0.120581
18	0.059731	0.194510	**99.72351**	0.081983
24	0.069036	0.216177	**99.72033**	0.063488
1	0.578804	0.124286	1.453974	**98.42174**
6	0.896088	0.871900	1.243460	**97.88464**
12	1.041584	3.944818	1.078626	**94.97656**
18	1.105423	10.06805	0.966148	**88.96580**
24	1.165613	18.78535	0.950857	**80.26380**

Table 4 shows the variance decomposition for the empirical prototypical. The study shows that most changes in inflation (*LCPI*), up to 100%, can be explained by its own inventions. This significant influence is reduced over the sample period to approximately 65.5%, indicating that the inflation rate begins to respond more cautiously to shocks from other macroeconomic variables, particularly the interest rate, at a quick pace. Variance explained by interest rates (*LSORA*) increases from 0% to 34.37%, and variance explained by the exchange rate (*LSGD*) reaches 0.18%.

The strong contribution of exchange rates increased from 99.55% at the beginning to 99.72% in the 24th period. As for interest rates (*LSORA*), the own contribution drops from 98.42% to 80.26% at the end of the sample period. The major contribution came from inflation (*LCPI*), which is aligned with the VECM results.

Discussion

This comprehensive study on the macroeconomic variables of exchange rates, inflation, and interest rates in Singapore provides a nuanced picture of the sophisticated relationship in a nation's economic framework. The analysis, which extends from 2012 to 2023, sheds light on the policies of the MAS, particularly its monetary policy of the exchange rate against a basket of currencies and its strategy of inflation targeting. The research employs a robust methodology and employs unit root and cointegration tests, IRF, and variance decomposition to unravel the short- and long-term connections among these vital economic indicators.

A significant finding is the time it takes for the economy to adjust to shocks; the study suggests a gradual response that extends beyond two years. This gradual adjustment emphasizes the complexity and resilience of Singapore's economic system. The study highlights the sensitivity of inflation to exchange and interest rates. The negative short-term impact of exchange rate movements on inflation aligns with economic theory, emphasizing the role of currency fluctuation in prices. The Granger causality tests reveal a temporal order of causation, indicating that inflation Granger causes interest rates, and exchange rates Granger cause interest rate adjustments. This temporal causality offers insight into the dynamic interplay of these variables. The IRF depicts how variables react to shocks. This dynamic

perspective is crucial for anticipating and understanding the evolving nature of the economic system and offers valuable information for policymakers in crafting timely and effective interventions. Variance decomposition further dissects the sources of variation in each variable, highlighting the dominance of own shocks in initially explaining inflation variability. However, the study suggests that over time, inflation becomes more responsive to shocks from other macroeconomic variables, notably interest rates.

The study's practical implications extend beyond Singapore to the Asia region via monetary policy coordination. Coordinating exchange rates could mitigate the effects of external shocks, promote regional trade, and enhance economic stability.

The paper's findings highlight the nuanced strategies employed by Singapore, such as its managed floating exchange rate system and the use of exchange rate targeting as a monetary policy tool. The study contributes to the academic discourse on monetary policy by showcasing an alternative to the traditional focus on interest rate targeting, which is prevalent in larger economies.

The paper provides empirical evidence of the effectiveness of Singapore's monetary policy in maintaining macroeconomic stability, offering a case study for comparative analysis of similar economies. The study adds to the existing literature by broadening the understanding of how different monetary policy frameworks can be tailored to specific economic and institutional contexts of smaller, more open economies.

5. Conclusions

Economic conditions can be influenced by unforeseen events, such as global economic crises or pandemics. These events can introduce unanticipated factors that may affect exchange rates and inflation independently of policy measures. However, any change in US monetary policy can influence Singapore's economic conditions. These external influences might not be fully accounted for in the study.

In conclusion, the interconnectedness of exchange rates, inflation, and interest rates underscores the importance of a holistic approach to policy formulation. In this study, the results show the short-term impact of exchange rate movements on inflation and that interest rates are more effective in controlling inflation over time. The findings provide actionable insights for the MAS, offering guidance on fine-tuning policies for sustained economic stability, growth, and effective inflation management in the unique context of Singapore's small and open economy.

Declarations

Author contribution

All authors contributed equally as the main contributors of this paper. All authors read and approved the final paper.

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Competing interest

The authors declare that they have no conflicts of interest to report regarding the present study.

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