Granger-causes of the Ringgit-US dollar exchange rate after 2005

Article *in* Journal of Financial Economic Policy · June 2019

DOI: 10.1108/JFEP-01-2019-0026

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Journal of Financial Economic Policy

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Received 28 January 2019
Revised 28 January 2019
Accepted 5 April 2019

Abstract

Purpose – This study aims to investigate Granger-causal relations between the Ringgit-USD exchange rate and selected domestic and international economic variables after the flotation of the Ringgit beginning with 25 July 2005.

Design/methodology/approach – The study uses lag-augmented vector autoregression (LA-VAR) developed by Toda and Yamamoto (1995) to test for Granger-causality. To visualize short-run dynamics in the Malaysian Ringgit (RM)-USD exchange rate to shocks in predictor variables, generalized impulse-response functions (Pesaran and Shin, 1998) are derived from the estimated LA-VAR models.

Findings – Results based on LA-VAR generalized impulse responses and data measured in daily frequency indicate strong Granger-causal relationships with the Dow Jones Industrial Average and oil prices. Evidence is also indicative for a causal relationship with the Shanghai Composite Index. Positive shocks in these three variables lead an appreciation of the Ringgit.

Practical implications – These results provide insights for policymakers in East Asia in their attempt to manage the floating of their currency.

Originality/value – The paper adds to existing empirical literature in three ways. First, it investigates the RM-USD exchange rate after its managed flotation beginning with 25 July 2005. Second, the study provides results for exchange rates measured in two frequencies, namely, daily and monthly. Third, the empirical LA-VAR model applied includes variables capturing economic and financial conditions in China. Prior literature puts a focus on macroeconomic conditions in the USA. Yet, since 2009, China has been the largest trading partner of Malaysia.

Keywords Foreign exchange, Exchange rate, Granger-causality, Malaysia, Ringgit, Generalized impulse response

Paper type Research paper

1. Introduction

The Malaysian Ringgit (RM) exchange rate with the US Dollar (USD) has been depreciating since January 2011. From its record high of RM2.94/USD on 8 January 2011, the Ringgit has shown a depreciating trend reaching a low of RM4.50/USD on 4 January 2017. Media reports claim that the Ringgit is the worst performing currency in Asia in 2015 (The Straits Times, 2016). Various factors causing this development are reported in media and literature. Among these causes are sizeable capital outflows, weak export markets, drops in oil and commodity prices, the normalization of US interest rates, spillovers from China and the concerns over the financial and political scandal of 1Malaysia Development Berhad (International Monetary Fund, 2016; The Straits Times, 2016; The World Bank, 2016). However, little research has been conducted to econometrically investigate the drivers behind the RM-USD exchange rate dynamics over Malaysia's recent past.

JEL classification – F31 Foreign exchange, F41 Open economy macroeconomics C50 General econometric modelling

Journal of Financial Economic Policy

1757-6385
DOI 10.1108/JFEP-01-2019-0026

Having a thorough understanding of variables, which Granger-cause the development of the Ringgit exchange rate is a vital input to effective economic policymaking as exchange rates impact, for instance, purchasing power, sourcing and marketing decisions and trade and capital flows (Chen, 2014). The present study, therefore, aims to bridge this gap between perceptions of and facts about main leading indicators of the RM-USD exchange rate. It investigates Granger-causal relations between the RM-USD exchange rate and selected domestic and international economic variables. The study uses lag-augmented vector autoregression (LA-VAR) developed by Toda and Yamamoto (1995) to test for Granger-causality. To visualize short-run dynamics in the RM-USD exchange rate to shocks in predictor variables, generalized impulse response functions (IRFs) (Pesaran and Shin, 1998) are derived from the estimated LA-VAR models.

The paper adds to existing empirical literature in three ways. First, it investigates the RM-USD exchange rate after its managed flotation beginning with 25 July 2005[1]. Earlier literature puts a focus on the years prior to and including the Asian financial crisis (AFC). Therefore the study is also indicative for a change in Granger-causal relationships between certain variables and the RM-USD exchange rate after the adoption of the new exchange rate regime by Bank Negara Malaysia (BNM). Second, the study provides results for exchange rates measured in two frequencies, namely, daily and monthly. Related literature mainly focusses on exchange rate data measured in one frequency. However, the variables, which Granger-cause exchange rates likely vary across data frequencies (Chen, 2014). For instance, as stressed by Granger *et al.* (2000), monthly data likely are too coarse for describing the effects capital in- and outflows have on exchange rates. Put differently, as stressed by Zhang *et al.* (2016), Granger-causality testing is not invariant to data aggregation and findings based on lower frequency data may be spurious. Third, the empirical LA-VAR model applied includes variables capturing economic and financial conditions in China. Prior literature puts a focus on macroeconomic conditions in the USA. Yet, since 2009 China has been the largest trading partner of Malaysia. It contributes about 16.2 per cent of total external trade in 2016, while the share of the USA is 8.9 per cent (Bank Negara Malaysia, 2017; Ministry of Finance Malaysia, 2017).

The remainder of the paper is structured as follows: Section 2 outlines the theoretical foundations of exchange rate determination and it reviews empirical research on the determinants of the RM-USD exchange rate. Section 3 outlines the research methodology and data used in the study. Empirical findings are presented in Section 4. Section 5 concludes the paper.

2. Literature review

Important determinants of freely-floating exchange rates are normally grouped along three – interlinked – strands of reasoning[2]: parity theories; the asset market approach; and the balance of payment approach (Officer, 1981; Chen, 2014). Table I briefly summarizes these three theories of exchange rate determination.

Table I implies that monetary policy influences exchange rates under a flexible exchange rate policy. In countries, which adopt a managed float exchange rate policy direct intervention of central banks in foreign exchange markets, too, plays a crucial role. Under a managed float system central banks intervene to keep the exchange rate from deviating too far from a target value.

In addition to the drivers of exchange rates outlined in Table I, world commodity prices may matter in exchange rate determination, at least for "commodity currencies", that is for currencies of major commodity-exporting countries (Chen, 2014), such as Malaysia (Cashin *et al.*, 2004). Indeed, according to Chen (2014), the "commodity currency" phenomenon is one of the few robust empirical regularities in exchange rate determination.

Approach	Variables of interest	Relationship and implications
Parity theory Purchasing power parity (PPP) and interest rate parity (IRP)	Inflation rates; real interest rates; and Forward exchange rate	According to the absolute form of PPP, the exchange rate of two currencies is determined by the relative price level of the two countries Relative PPP theory postulates a direct relationship between differences in inflation rates and the exchange rate. An increase (decrease) in the domestic price level in comparison to that abroad is accompanied by a proportionate depreciation (appreciation) of the home currency The IRP relationship suggest that if foreign interest rate is larger (smaller) than the home interest rate, the forward rate should exhibit a premium (discount)
Asset market approach (portfolio balance approach)	Nominal interest rates; economic growth prospects; and liquidity/ money supply	Exchange rates are determined by stock equilibrium conditions. The exchange rate is determined by total demand for and total supply of financial assets. It is determined via equilibrating supply and demand for financial assets
Trade balance approach (traditional approach)	Exports of goods and services; and imports of goods and services	Exchange rates are determined by the flow of goods and services across borders. They are determined via equilibrating flows of goods and services across border

Table I. Main theories and determinants of exchange rates

Turning to this empirical evidence on exchange rate determination, it becomes evident that exchange rate movements are affected by many factors simultaneously. The impact of different variables is episodic, varies from country to country and is dependent on the economic conditions within a country. Results not only depend on the sample under study but also on research methodologies applied and the frequency of data used (Auboin and Ruta, 2012; Edwards, 2011).

Relatively few papers deal with the determinants of the RM-USD exchange rate. Table II provides a summary of previous studies, which focus on or include this exchange rate in their analysis.

Table II shows that the selected variables, sample periods, methodologies and the frequency of data vary across different studies. Several studies use data up to and including the AFC, others use data up to the great financial crisis starting in 2007/2008. Some studies indicate that long-run, cointegration-relationships exist between the RM-USD exchange rate and economic fundamentals. As cointegration implies Granger-causality, these studies, thus, are in favour of Granger-causal relations between the RM-USD exchange rate and selected macroeconomic variables.

In the short-run, the RM-USD exchange rate is linked to both, Malaysian (stock market indices, money supply, trade balance and currency reserves) and foreign economic variables. However, the foreign variables considered predominately capture the economic situation in the USA while economic conditions in Malaysia's main trading partner, China, are not considered. In addition, despite the well-known fact that the variables shaping the dynamics of exchange rates measured at lower frequencies (e.g. years) tend to have little or no relevance in explaining daily exchange rate dynamics and vice versa (Chen, 2014), studies only use data measured in one frequency. The present article adds to this literature by analysing more recent exchange rate data, data in different frequencies and by investigating the impact of economic conditions in China on the RM-USD exchange rate.

Table II.
Empirical studies on the Ringgit exchange rate

Study	Variables of main interest	Sample period	Methodology	Findings
Lee *et al.* (2011)	Stock price, exchange rate (USD per domestic currency unit) in six Asian countries, including Malaysia	2000-2008 (weekly data)	Generalized autoregressive conditional heteroscedasticity model	Significant price spill-over effects from the stock market to the foreign exchange market in Malaysia. Correlation between stock and foreign exchange markets becomes higher when stock market volatility increases
Baharumshah *et al.* (2009)	Exchange rate (RM/USD rate), broad money supply, industrial production indices, and interest rates	1971-2006 (quarterly data)	Johansen cointegration test	Evidence of a long-run relationship between the exchange rate and economic fundamentals (money supply, income and inflation)
Chin *et al.* (2007)	Exchange rate (RM/USD), broad money supply, industrial production indices, interest rates and inflation rate	1981Q1-2003Q1 (quarterly data)	Johansen cointegration test	A long-run relationship exists between board money supply, industrial production, interest rate, expected inflation rate and the RM-USD exchange rate
Chong and Tan (2007)	Exchange rate volatility (RM-USD), money supply, trade balance and stock market indices in four ASEAN economies (including Malaysia)	1980M1 to 1998M9 (monthly data)	E-GARCH model, Johansen cointegration test and Granger causality test	Exchange rate volatility and relative macroeconomic factors are moving together in the long-run in Malaysia Money supply, trade balance and stock market indices influence the volatility of the RM-USD exchange rate in the short-run
Hussain and Liew (2005)	Exchange rates (RM/USD and THB/USD), Kuala Lumpur Composite Index (KLCI), Stock Exchange of Thailand Index (SETI)	2 July 1997-31 August 1998 (daily data)	Granger-causality tests	Bi-directional Granger-causal relationship between the foreign exchange and stock markets in Malaysia. The fall of Thai Baht is transmitted to the Ringgit
Ibrahim (2003)	Exchange rate (RM/USD), real output, price levels, money supply and interest rate in Malaysia; US real output, price level and Federal fund rate	1977M1-1998M8 (monthly data)	VAR model, Johansen cointegration tests, variance decompositions and IRFs	Presence of cointegration; Shocks in US price level and US real economic activity influence the RM-USD exchange rate
Ibrahim (2000)	Various measures for the RM-USD exchange rate, stock prices (*KLCI*), M2 money supply and currency reserves of Malaysia	1979M1-1996M6 (monthly data)	Bivariate and multivariate cointegration, Granger-causality tests	No long-run relationship between the RM-USD exchange rate and stock prices (*KLCI*) in bivariate models; Cointegration is found when the model includes M2 money supply and international currency reserves Granger-causality tests show a bi-directional causality between the *KLCI* and the RM/USD exchange rate rate. Money supply and currency reserves Granger-cause the RM-USD exchange rate

(*continued*)

Study	Variables of main interest	Sample period	Methodology	Findings
Granger *et al.* (2000)	Exchange rates, stock prices in nine Asian countries, including Malaysia; KLCI is used asa proxy for the stock price in Malaysia	3 January 1986 to 16 June 1998 (daily data)	Bivariate VAR model and Granger-causality tests	No cointegration exists between exchange rates and stock prices; Feedback relations are reported for Malaysia where the change in exchange rate leads changes in stock prices and vice versa

Table II.

3. Variables, data and econometric approach

3.1 Variables and data

Choice of variables is guided by the various approaches to exchange rate determination outlined in Section 1 and by findings from related literature. Variables capturing both, Malaysian and foreign financial and macroeconomic developments are included in the empirical model. The crude oil price is considered for the Ringgit being a "commodity-currency". A dummy variable (global financial crisis [GFC]) controls for effects of the global financial crisis on the RM-USD exchange rate.

Data in daily and monthly frequencies are used to obtain short-term perspectives on RM-USD exchange rate movements. Due to the short time span of 11 years, quarterly and yearly exchange rate data are not used in the analysis. Variables measured in monthly frequencies are computed as average of daily data unless monthly data is directly provided by databases. Due to missing data on the Chinese short-term interest rate the sample starts with 9 October 2006. It ends with 29 December 2017. Variables with non-negative values are used in natural logarithm.

Data for Malaysia were collected from BNM's database and from annual reports of BNM (Bank Negara Malaysia, 2005/2016). These data are supplemented by information from the IMF Statistics Database, Federal Reserve Economic Data, US Bureau of Economic Analysis, National Bureau of Statistics of China, US Energy Information Administration and Thompson Reuters Eikon. Information on the variables used in the analysis is given in Table III. Figures 1 and 2 display time paths of variables of main interest.

Table III. Overview of variables and data

Variables	Description	Frequency of data	Data source
EX	Exchange rate in USD per unit of RM; increase in value means appreciation of RM	Daily and monthly	Federal reserve (FRED) economic data
DJIA	DJIA	Daily and monthly	Thomson Reuters Eikon
GFC	Dummy variable for GFC. Value of 1 is assigned to the period of February 2007-2009	Daily and monthly	Own classification
INFCH	The year-on-year inflation rate of China in percentage	Monthly	FRED economic data
INFM	The year-on-year inflation rate of Malaysia in percentage	Monthly	BNM
INFUS	The year-on-year inflation rate of the USA in percentage	Monthly	FRED economic data
INTCH	Shanghai Interbank Offer rate SHIBOR (% per annum)	Daily and monthly	Thomson Reuters Eikon
INTM	Overnight conventional interest rate Malaysia (% per annum)	Daily and monthly	BNM
INTUS	US Effective federal fund rate (% per annum)	Daily and monthly	FRED economic data
KLCI	FTSE Bursa Malaysia Kuala Lumpur Composite index	Daily and monthly	Thomson Reuters Eikon
MS	Broad money supply, M3 (RM million)	Monthly	BNM
OILPRICE	Crude oil price, Europe brent spot price (dollar per barrel)	Daily and monthly	US Energy Information Administration
RES	Malaysia's international currency reserves (USD million)	Monthly	International Monetary Fund
SCI	SCI	Daily and monthly	Thomson Reuters Eikon

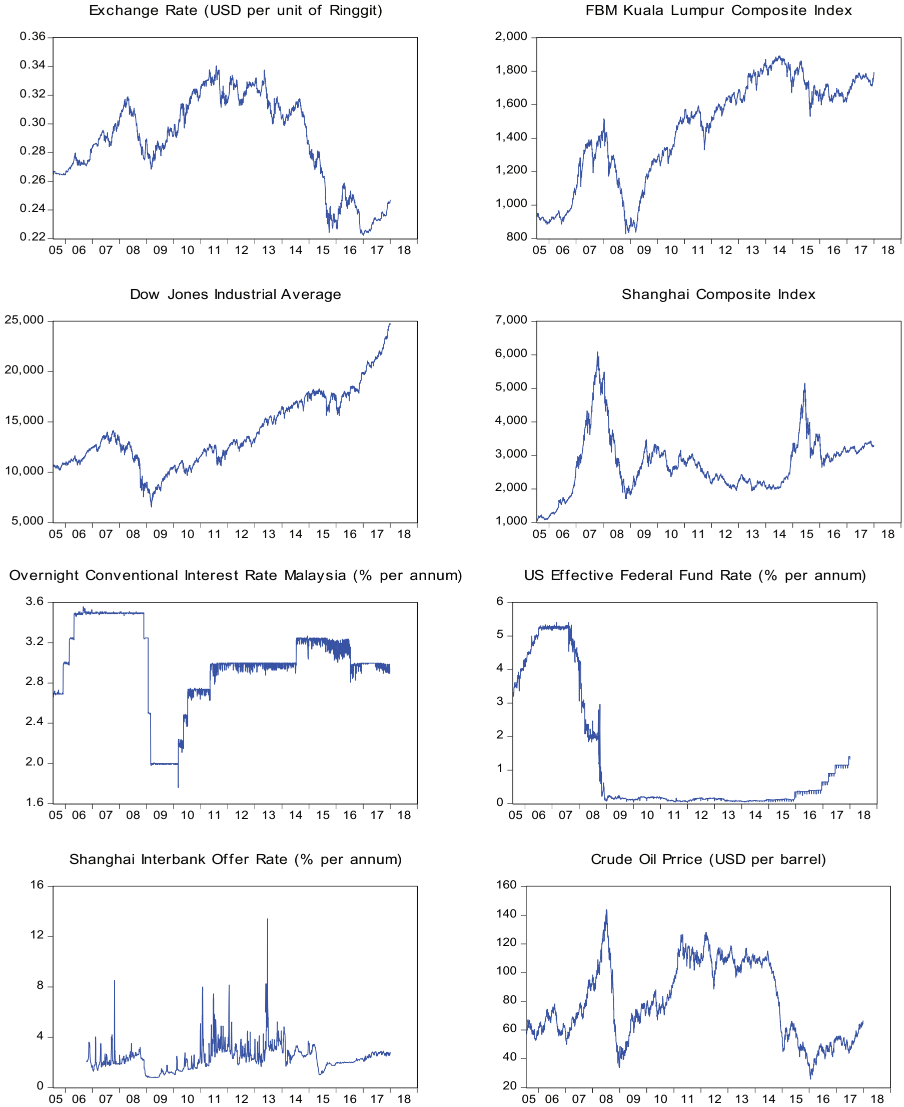


Figure 1.
Variables in daily frequency

3.2 Econometric approach

Granger-causality testing in an unrestricted VAR framework is conditional on variables being stationary. To overcome this restriction of conventional Granger-causality testing, this study applies the Toda and Yamamoto approach (TY) to Granger-causality testing (Toda and Yamamoto, 1995). The TY procedure involves the estimation of a LA-VAR ($p + d$ max) model, where p is the optimal lag length in the underlying VAR model and d max is the highest order of integration of the variables in the VAR system. The TY method can be used irrespective of the order of integration of the variables and whether the variables are

Figure 2.
Variables in monthly frequency

cointegrated (Toda and Yamamoto, 1995). This is of importance for this application as related empirical studies establish cointegration between the RM-USD exchange rate and several economic variables (Table II). Thus, differencing of all I(1) variables would likely lead to misspecification bias (Granger *et al.*, 2000). Yet, as the power of cointegration tests depends on the span of the time series rather than its frequency (Hakkio and Rush, 1991; Chen and Chou, 2015), our time series is too short in years to meaningfully test for and to model long-run, cointegration relationships. TY allows us to be agnostic regarding any long-run relationships between the RM-USD exchange rate and potentially leading variables.

The TY procedure is executed in the following four steps: First, the Augmented Dickey–Fuller, the Phillips–Perron Unit Root and the Zivot–Andrews test, which accounts for one endogenously determined structural break in the series tested, are applied to isolate *d* max. The choice of deterministic terms included in and the types of structural breaks considered in the tests is based on inspection of the time paths of individual variables (Figures 1 and 2). The unit root *H0* is rejected in case all tests signal rejection at least at the 5 per cent significance level. Selection of lag-length for the Augmented Dickey–Fuller and the Zivot–Andrews test is based on Bayesian information criterion (BIC) (Dickey and Fuller, 1981; Zivot and Andrews, 2001).

Second, an unrestricted VAR model with all variables measured in levels is estimated. The general VAR model can be expressed as:

$$Z_t = \alpha + \sum_{i=1}^{p} \beta_i Z_{t-i} + D_t + \varepsilon_t \tag{1}$$

Z is an $(n \times 1)$ vector of endogenous variables, α is $(n \times 1)$ vector of constants, β is an $(n \times n)$ matrix of coefficients and D is a dummy variable to control for the global financial crisis. The error term, ε, is independently and identically distributed. The optimal lag length is represented by p. For example, the equation for the exchange rate with variables measured in daily frequency is:

$$\begin{aligned}\log(EX_t) = \beta_0 &+ \sum_{i=1}^{p} \beta_{1i}\log(EX_{t-i}) + \sum_{i=1}^{p} \beta_{2i}\log(KLCI_{t-i}) + \sum_{i=1}^{p} \beta_{3i}\log(DJIA_{t-i}) \\ &+ \sum_{i=1}^{p} \beta_{4i}\log(SCI_{t-i}) + \sum_{i=1}^{p} \beta_{5i}\log(INTM_{t-i}) + \sum_{i=1}^{p} \beta_{6i}\log(INTUS_{t-i}) \\ &+ \sum_{i=1}^{p} \beta_{7i}\log(INTCH_{t-i}) + \sum_{i=1}^{p} \beta_{8i}\log(OILPRICE_{t-i}) + GFC_t + \varepsilon_t \end{aligned} \tag{2}$$

The optimum lag length p of the unrestricted VAR is determined according to five selection criteria, namely, sequential modified LR test statistic, final prediction error, Akaike information criterion and BIC and the Hannan–Quinn IC. In addition, residuals are examined for remaining serial correlation using the autocorrelation lagrange multiplier test.

Third, the LA-VAR ($p + d$ max) model is estimated in levels. The equation for the exchange rate with variables in daily frequency is:

$$\begin{aligned}\log(EX_t) = \beta_0 &+ \sum_{i=1}^{p+dmax} \beta_{1i}\log(EX_{t-i}) + \sum_{i=1}^{p+dmax} \beta_{2i}\log(KLCI_{t-i}) \\ &+ \sum_{i=1}^{p+dmax} \beta_{3i}\log(DJIA_{t-i}) + \sum_{i=1}^{p+dmax} \beta_{4i}\log(SCI_{t-i}) + \sum_{i=1}^{p+dmax} \beta_{5i}\log(INTM_{t-i}) \\ &+ \sum_{i=1}^{P+dmax} \beta_{6i}\log(INTUS_{t-i}) + \sum_{i=1}^{p+dmax} \beta_{7i}\log(INTCH_{t-i}) \\ &+ \sum_{i=1}^{p+dmax} \beta_{8i}\log(OILPRICE_{t-i}) + GFC_t + \varepsilon_t \end{aligned} \tag{3}$$

Fourth, Granger-causality is established using a Wald test based on the LA-VAR model. The test has an asymptotic (chi-square) distribution with p degrees of freedom (Toda and Yamamoto, 1995; Dolado and Lutkepohl, 1996).

Granger-causality analysis does not provide the signs of interrelationships between variables (Granger *et al.*, 2000). IRFs can be used to visualize and investigate short-run dynamic patterns of the RM-USD exchange rate. Generalized IRFs, which are independent to the ordering of variables in the underlying VAR system (Pesaran and Shin, 1998) are derived from the estimated LA-VAR model (Kawakami and Doi, 2004). Sims *et al.* (1990) show that the estimated coefficients of a VAR including I(1) variables are consistent and that the parameters that can be written as coefficients on mean zero, stationary variables follow an asymptotic normal distribution. Toda and Yamamoto (1995) extent this work to Granger-causality testing. Phillips (1998) shows that IRFs derived from a VAR including I(1) variables are inconsistent for long forecast horizons. However, this study is interested in short-run responses. The IRFs derived from a VAR in levels containing I(1) variables are consistent estimators of the true IRFs in this case (Basher *et al.*, 2012).

4. Results and discussion

4.1 Unit root tests

Table IV displays results from unit root tests. Most of the variables measured in daily frequencies are I(1). An exception is a log(*INTCH*), which captures the interest rate in China (i.e. SHIBOR). This variable is I(0). All but two variables measured in monthly frequencies are I(1). The exceptions are log(*INTCH*) and INFM, which are I(0). Thus, the maximum order of integration, *d* max, is 1.

4.2 Granger-causality tests

The optimal lag length in the unrestricted VAR is five for the model in daily frequency. It is three for the "monthly model[3]". Thus, the LA-VAR models the Granger-causality tests are based upon, have lags 6 and 4.

4.2.1 Data in daily frequency. Table V shows that there are Granger-causal effects running from *log*(*DJIA*) and *log*(*OILPRICE*) to the RM-USD exchange rate. These variables contain useful information for predicting the value of the daily RM-USD exchange rate. The results indicate that international economic developments exert significant influence on the Ringgit exchange rate, which is consistent with the findings of Ibrahim (2003). Moreover, the Shanghai Composite Index (SCI) (*log*(*SCI*)) also Granger-causes the RM-USD exchange

	Daily data			Monthly data		
Variables	ADF test	PP test	ZA test	ADF test	PP test	ZA test
log(*EX*)	I(1)	I(1)	I(1)	I(1)	I(1)	I(1)
log(*KLCI*)	I(1)	I(1)	I(1)	I(1)	I(1)	I(1)
log(*DJIA*)	I(1)	I(1)	I(0)	I(1)	I(1)	I(0)
log(*SCI*)	I(1)	I(1)	I(1)	I(1)	I(1)	I(1)
log(*INTM*)	I(1)	I(1)	I(1)	I(1)	I(1)	I(1)
log(*INTUS*)	I(1)	I(1)	I(1)	I(1)	I(1)	I(1)
log(*INTCH*)	I(0)	I(0)	I(0)	I(0)	I(0)	I(0)
log(*OILPRICE*)	I(1)	I(1)	I(1)	I(1)	I(1)	I(1)
INFM	NA	NA	NA	I(0)	I(0)	I(0)
INFUS	NA	NA	NA	I(0)	I(1)	I(1)
INFCH	NA	NA	NA	I(0)	I(1)	I(1)
log(*MS*)	NA	NA	NA	I(1)	I(1)	I(1)
log(*RES*)	NA	NA	NA	I(1)	I(1)	I(1)

Notes: NA = Not applied; ADF-test = Augmented Dickey–Fuller test; PP-test = Phillips–Perron test; ZA = Zivot–Andrews test; decisions are based on 5% level of significance; I(0) means test implies variable is integrated of order 0; and choice of deterministic terms and types of structural breaks is based on inspection of Figures 1 and 2 and is detailed in Table AI

Table IV.
Unit root tests

rate. However, for the latter case, the statistical evidence (p-value of 0.05) must be considered as being rather weak given the large sample size of N = 2,390. From a statistical viewpoint, economic conditions in Malaysia's main trading partner China matter less for the RM-USD exchange rate than those in the USA. The influence of the oil price on the RM exchange rate can be derived from the contribution of the oil and gas sector to Malaysia's GDP. Malaysia produces 648,000 barrels of crude oil per day in 2016 (Ministry of Finance Malaysia, 2017). Oil and gas related commodities account for about 10 per cent of exports of Malaysia (International Monetary Fund, 2016).

Turning to the reverse relationships, Table V indicates that changes in the RM-USD exchange rate precede changes in the stock market index of Malaysia (*KLCI*). This result is in favour of the traditional approach to the relationship between exchange rates and stock market prices (Granger *et al.*, 2000; Noman *et al.*, 2012). The traditional approach postulates that an appreciation of the exchange rate leads to a fall in stock prices for export-oriented firms and to an increase in stock prices of importers (Noman *et al.*, 2012; Ho and Lyke, 2017).

Furthermore, according to Table V, the RM-USD exchange rate may also precede changes in Malaysia's interest rate, which would be consistent with the view that BNM' interest policy reacts to dynamics in foreign exchange markets. Yet, with p-values of 0.04 and 0.05, respectively, the statistical evidence in favour of these two Granger-causal relationships should be considered as rather weak.

4.2.2 Data in monthly frequency. Do we see these Granger-causal relationships also in monthly data? Table VI shows that this is not the case. The results do not reveal any

X does not Granger-cause *log*(*EX*)	Chi-square	p-value	*Log*(*EX*) does not Granger-cause X	Chi-square	p-value
X = *log*(*KLCI*)	6.18	0.29	X = *log*(*KLCI*)	11.51	0.04
X = *log*(*DJIA*)	100.32	0.00	X = *log* (*DJIA*)	10.55	0.06
X = *log*(*SCI*)	10.90	0.05	X = *log* (*SCI*)	1.79	0.88
X = *log*(*INTM*)	4.82	0.44	X = *log* (*INTM*)	10.95	0.05
X = *log*(*INTUS*)	9.10	0.11	X = *log* (*INTUS*)	1.93	0.86
X = *log*(*INTCH*)	6.75	0.24	X = *log* (INTCH)	9.32	0.10
X = *log*(*OILPRICE*)	33.00	0.00	X = *log* (*OILPRICE*)	3.04	0.69

Table V. Granger-causality tests for daily data

X does not Granger-cause *log*(*EX*)	Chi-square	p-value	*Log*(*EX*) does not Granger-cause X	Chi-square	p-value
X = *log* (*KLCI*)	0.88	0.83	X = *log* (*KLCI*)	1.42	0.70
X = *log* (*DJIA*)	2.90	0.41	X = *log* (*DJIA*)	6.96	0.07
X = *log* (*SCI*)	0.22	0.97	X = *log* (*SCI*)	1.26	0.74
X = *log* (*INTM*)	3.33	0.34	X = *log* (*INTM*)	6.29	0.10
X = *log* (*INTUS*)	1.94	0.59	X = *log* (*INTUS*)	1.55	0.67
X = *log* (*INTCH*)	3.32	0.34	X = *log* (*INTCH*)	12.73	0.01
X = *log* (*OILPRICE*)	4.08	0.25	X = *log* (*OILPRICE*)	3.83	0.27
X = *INFM*	1.58	0.66	X = *INFM*	1.26	0.74
X = *INFUS*	6.12	0.11	X = *INFUS*	2.11	0.55
X = *INFCH*	0.42	0.94	X = *INFCH*	1.12	0.77
X = *log* (MS)	2.54	0.47	X = *log* (MS)	2.12	0.55
X = *log* (RES)	0.52	0.91	X = *log* (RES)	3.58	0.31

Table VI. Granger-causality tests for monthly data significant Granger-causality running from predictor variables to the RM-USD exchange rate. This result should be interpreted in light of the fact that exchange rates are generated at very high frequency on highly active financial markets. Movements on these markets are fast and often short-lived. Low-frequency data, such as monthly data, thus, may fail to isolate Granger-causal relationships (Zhang *et al.*, 2016).

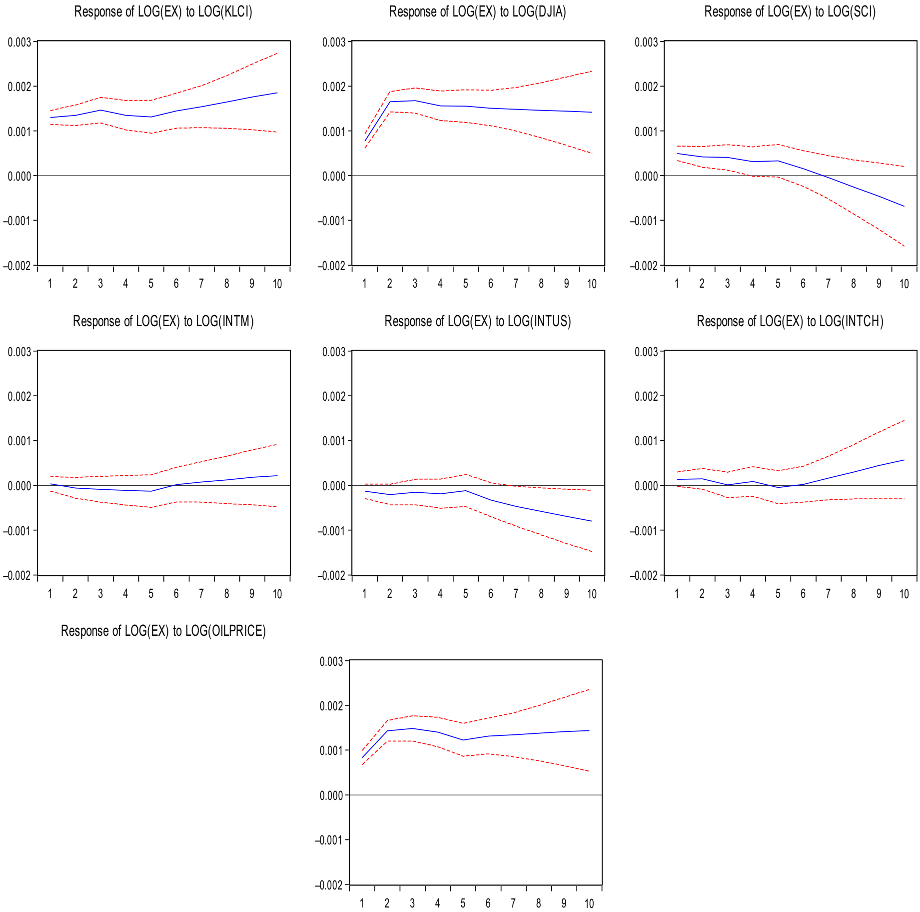
Compared to the years up to and including the AFC (Hussain and Liew, 2005; Ibrahim, 2000), money supply, stock market indices and macroeconomic conditions in the USA, when measured on monthly basis, do not lead the RM-USD exchange rate from 2006 onwards. This is consistent with an improvement in market efficiency on foreign exchange markets in East Asia over the past two decades, which can be attributed to improved information sets of investors, a more rapid dissemination of information among investors, generally more experienced market participants and a generally better developed market system (Zalewska-Mitura and Hall, 1999; Fifield and Jetty, 2008). Ahmad *et al.* (2012) compare efficiencies on several Asia-Pacific foreign exchange markets, including Malaysia, during the AFC and the GFC. Their results are consistent with an increase in market efficiency over time. These improvements in market efficiency will increase speed of movements on foreign exchange markets, which, in turn, makes analyses based on daily data increasingly important.

Table VI reveals that the RM-USD exchange rate Granger-causes the interest rate in China. One explanation for this somewhat unexpected result is that the change in the RM-USD exchange rate is indicative for a general strengthening or weakening of the USD. While the People's Bank of China (PBOC) switches to a managed-floating exchange rate regime in 2005, it still maintains tight exchange rate control to avoid hot money flows that may threaten exchange rate stability (MacKinnon and Schnabl, 2014). In particular, PBOC might react to the strengthening or weakening of the USD via altering short-run interest rates. Indeed, sterilization efforts by POBC to stabilize the Renminbi use not only liquidity but also interest rates (Wu, 2015). However, Figure A2, which shows the generalized IRF of *log*(*INTCH*) to one standard deviation sized innovation in *log*(*EX*), implies that the negative response of *log*(*INTCH*) is only very short-lived. The detected Granger-causality may be spurious, a possibility, which is well-known to occur with low-frequency data (Zhang *et al.*, 2016)[4].

4.3 Generalized impulse responses

Figures 3 and 4 display generalized IRFs for *log*(*EX*) to a one standard deviation shock in predictor variables. Figure 3 shows that the daily effect of a positive shock in *log*(*DJIA*) and in *log*(*OILPRICE*) on a *log*(*EX*) is positive. The response is visible over the entire forecast horizon of 10 trading days. In contrast, the positive effect of a shock in *log*(*SCI*) lasts only for a few days. With one exception shocks in the remaining predictor variables do not lead to future changes in *log*(*EX*), which is consistent with the results from Granger-causality tests[5]. The exception is KLCI.

A one-time shock in *log*(*KLCI*) exerts positive effects on future values of *log*(*EX*). A positive shock in *KLCI* is paired with an appreciation of the Ringgit over the USD in the near future. This result is in line with the portfolio balance approach to the relationship between the stock market and exchange rates. The portfolio approach postulates that a decrease (increase) in stock prices gives rise to a depreciation (appreciation) of the exchange rate due to a decrease (increase) in domestic wealth, which leads to a corresponding change in interest rates. Lower (higher) interest rates, eventually, impact on the supply of and demand for the domestic currency on foreign exchange markets (Noman *et al.*, 2012; Granger *et al.*, 2000). However, Figure A1 shows that *KLCI* also significantly reacts to positive shocks in the exchange rate. Thus, an appreciation of the Ringgit is paired with an increase in Malaysian stock prices in the near future. Put



Notes: Shows the response to a one standard deviation change in predictor variable. Trading days are displayed on the x-axis 95% confidence bands are included

Figure 3.
Generalized IRFs for daily data

differently, in contrast to Granger-causality tests, impulse response analysis indicates strong feedback relations between the RM-USD exchange rate and the stock market index in Malaysia. This result is in line with the finding of Granger *et al.* (2000) for the years up to and including the AFC.

Figure 4 contains IRFs for variables measured in monthly frequency. The figure implies that the RM-USD exchange rate responses positively to shocks in *log*(*KLCI*) and *log*(*OILPRICE*), which reinforces the results derived based on daily data. In addition, increases in *log*(*RES*) have a positive impact on the values of *log*(*EX*) in the near future. This latter result is consistent with a floating exchange rate regime where increases in the supply of foreign exchange lead an appreciation of the local currency. Market forces are also the primary means to determine the exchange rate of the Ringgit. Intervention by BNM on foreign exchange markets is confined to combat excessive movements (cf. Footnote 1).

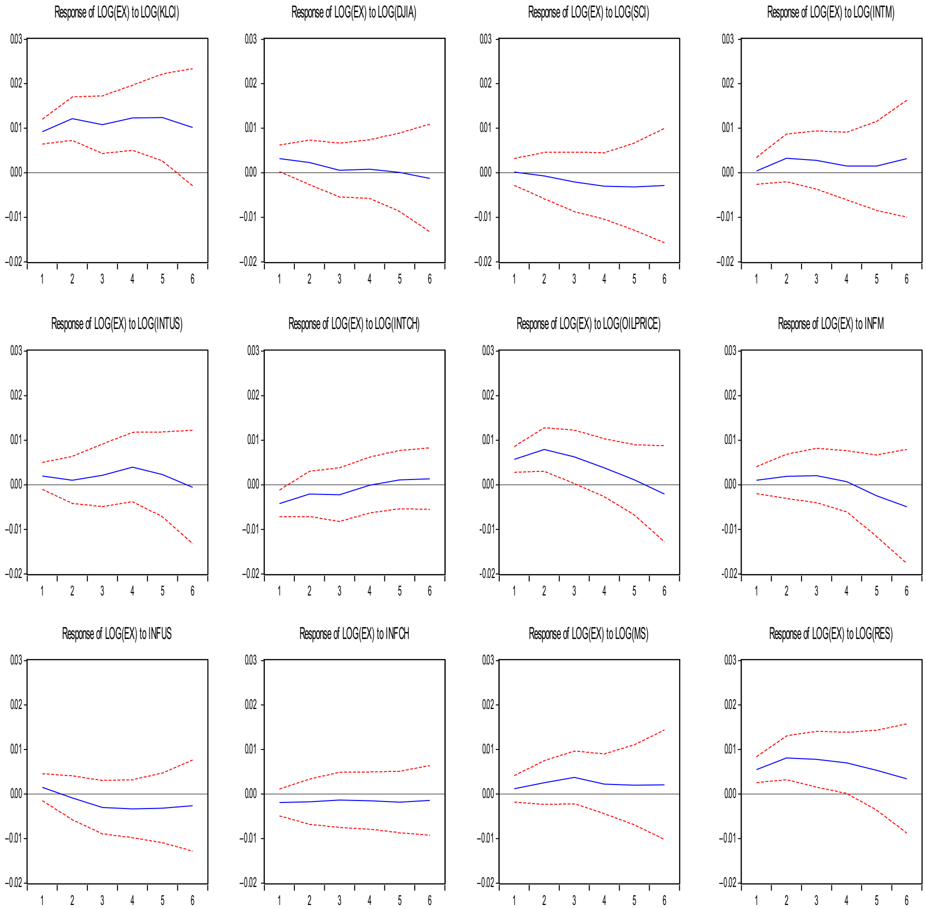


Figure 4.
Generalized IRFs for monthly data

Notes: Shows the response to a one standard deviation change in predictor variable. Weeks are displayed on the x-axis. 95% confidence bands are included

5. Conclusion

This article uses (LA-VAR) developed by Toda and Yamamoto (1995) to test for Granger-causality and it uses generalized IRFs to visualize short-run dynamics in the RM-USD exchange rate to shocks in predictor variables.

The paper attempts to add to existing empirical literature in three ways, namely, By investigating the RM-USD exchange rate after its flotation beginning with 25 July 2005; by using data in two different frequencies (daily and monthly) and by including variables capturing economic and financial conditions in China, Malaysia's largest trading partner.

Strongest predictor variables for the RM-USD exchange rate are the Dow Jones Industrial Average (DJIA) and oil prices. Positive shocks in these variables lead to an appreciation of the Ringgit. The positive impact of DJIA signifies positive spill-over effects of changes in US macroeconomic conditions to the demand for Ringgit on foreign exchange markets. The oil price effect is expected given that the Ringgit is a "commodity-currency". The study also finds some evidence of a positive effect of increases in the SCI on the RM-USD exchange rate. Thus, also Chinese macroeconomic conditions may matter for the foreign exchange value of the Ringgit.

The study is not able to unveil significant Granger-causal relationships based on data measured in monthly frequency. Thus, it appears that in contrast to the years up to and including the AFC, US inflation rates and money supply in Malaysia no longer are Granger-causally related to the RM-USD exchange rate. However, monthly data may be too coarse to detect significant predictors of exchange rates given increases in efficiency on many Asian financial markets over the past two decades. Finally, based on generalized IFRs, the study detects significant feedback relations between the RM-USD exchange rate and the stock market index in Malaysia.

Fluctuations in exchange rates impact in manifold ways on an economy. The findings of this study should prove useful to BNM in its attempt to manage the foreign exchange value of the Ringgit. However, this study leaves out latent factors such as market sentiments as predictors of the RM-USD exchange rate. Future research could apply an event study design to isolate the impact of the political and financial firm related scandals on the Ringgit exchange rate.

Notes

1. In the aftermath of the AFC BNM pegs the Ringgit to the USD. On July 21, 2005, BNM removes the peg and announces the adoption of a managed float system, whereby the exchange rate of the Ringgit is monitored against an undisclosed trade-weighted basket of currencies (International Monetary Fund, 2010). According to the governor of BNM market forces are the primary means to determine the exchange rate of the Ringgit. Interventions are confined to containing excessive movements (The Straits Times, 2016).
2. Chen (2014) divides the drivers of exchange rate movements into two categories, namely, fundamentals, which are observable in the data and latent factors such as market sentiments. The following discussion and analysis focus on fundamentals.
3. Detailed results of the lag-length selection are not shown for brevity, but are available upon request.
4. Spurious Granger-causality may be induced in case intervals in decisions of economic agents are finer than those between sample observations (Zhang *et al.*, 2016).
5. While Granger-causality and impulse responses have a clear equivalence relationship in bi-variate VARs, this is no longer the case in multivariate settings (Dufour and Tessier, 1993).

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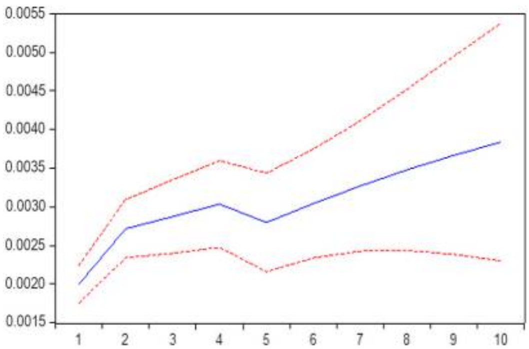
Appendix

Variables	Daily data ADF-test	Daily data PP-test	Daily data ZA-test	Monthly data ADF-test	Monthly data PP-test	Monthly data ZA-test
log(*EX*)	Intercept	Intercept	Trend and intercept	Intercept	Intercept	Intercept
log(*KLCI*)	Trend and intercept	Trend and intercept	Intercept	Trend and intercept	Trend and intercept	Trend and intercept
log(*DJIA*)	Trend and intercept	Trend and intercept	Intercept	Trend and intercept	Trend and intercept	Trend and intercept
log(*SCI*)	Intercept	Intercept	Trend and intercept	Intercept	Intercept	Intercept
log(*INTM*)	Intercept	Intercept	Intercept	Intercept	Intercept	Intercept
log(*INTUS*)	Intercept	Intercept	Trend and intercept	Intercept	Intercept	Intercept
log(*INTCH*)	Intercept	Intercept	Intercept	Intercept	Intercept	Intercept
log(*OILPRICE*)	Intercept	Intercept	Trend and intercept	Intercept	Intercept	Intercept
INFM	NA	NA	NA	Intercept	Intercept	Trend and intercept
INFUS	NA	NA	NA	Intercept	Intercept	Trend and intercept
INFCH	NA	NA	NA	Intercept	Intercept	Trend and intercept
log(*MS*)	NA	NA	NA	Trend and intercept	Trend and intercept	Intercept
log(*RES*)	NA	NA	NA	Intercept	Intercept	Trend and intercept

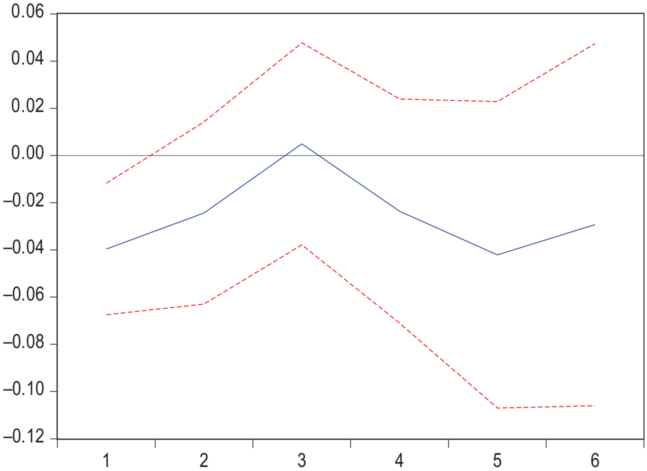
Notes: NA = Not applied; ADF-test = Augmented Dickey–Fuller test; PP-test = Phillips–Perron test; ZA = Zivot–Andrews test

Table AI. Deterministic trends (ADF and PP) and structural breaks (ZA) considered



Notes: Shows the response to a one standard deviation change in the predictor variable. 95% confidence bands are included

Figure A1. Generalized IRF of *log*(*KLCI*) to *log*(*EX*) for daily data



Notes: Shows the response to a one standard deviation change in the predictor variable. 95% confidence bands are included

Figure A2.
Generalized IRF of *log*(*INTCH*) to *log*(*EX*) for monthly data

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