CAUSALITY AND BEHAVIORAL FINANCE STUDIES

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Scientific and Business World

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Contents

PREFACE

This book has been compiled with five academic papers. We do not have any copyright issues in our book. This book includes Chapter 1, Causality Relationship between Money, Income, Price, and Exchange Rates in a Small Open Economy; Chapter 2, The Effect of Global Oil Price and Macroeconomic Variables on the stock market returns for ASEAN Countries; Chapter 3, Is it Worthwhile to Study Competitiveness Indices? Evidence from the Causal Relationship between Global Competitiveness Index and Economic Growth Rate; Chapter 4, Structural Time Series Analysis of Data from Interwar European Hyperinflations of Germany, Hungary and Poland; Chapter 5, Review of Behavioral Finance and Behavioral Econometrics: Theories and Applications. The co-authors are eager to get this book published and intend to maintain strong friendships. We are working closely together and are more united than ever.

Chapter 1
Causality Relationship between Money, Income, Price, and Exchange Rates in a Small Open Economy

Raymond Wai-man Yeung
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Abstract

We extend Hon's (2015) paper to investigate the direction of causation among income, price, exchange rates, and money supply in Hong Kong. We use the Granger causality concept to assess the existence of such relationships. The chapter presents the results of two separate bivariate analyses: one involving money and income, and the other involving money and exchange rates. A notable result from the chapter is that there is no causal relationship between them.

1.Introduction

Causality is a fundamental concept that helps us understand how events and phenomena are interconnected. It involves discovering the relationships between variables and determining how one variable influences the behavior of another. Clive W. J. Granger, a prominent scholar in this field, published the concept of "Granger Causality" in Econometrica in 1969, which has since been widely used in testing temporal causation and analyzing economic time series with common trends (Granger, 1980 and 1988). He defines causality as depending on the variance of the best least squares prediction using all information at some point in the past. The tests have been conducted using the concepts known in the literature as 'Granger-causation'. In 1987, Granger and Engle worked on the concept of cointegration, for which they were jointly awarded the Nobel Memorial Prize in Economic Sciences in 2003. In doing so, we hope to extend Hon's paper and contribute to the study of monetary policy, causality, and hedging. This chapter's tables and appendix are referred to in Hon (2015) for Tables 1-4 and Appendix 1.

Researchers still rely heavily on causality to uncover meaningful causal relationships in economic studies. For instance, Gbenga and Daniel (2024) aimed to explain the relationship between money supply and inflation rate in Nigeria's economy. To deepen our understanding of the crucial economic relationship between money supply and inflation rate in the country, the study attempted to elucidate the impact of these fluctuations. The data used for this analysis consisted of annual time series data ranging from 1990 to 2022, sourced from the CBN Statistical Bulletin. The empirical findings revealed that the various components of the money supply collectively contribute to the inflation rate, while the individual indicators of the money supply exhibit distinct consequences. Broad money supply and exchange rate exhibit a negative relationship,

albeit with weak significance in determining the inflation rate in Nigeria.

Conversely, the interest rate has a positive effect on the inflation rate. Based on these results, several policy implications can be derived. It is crucial for the government, while formulating monetary policy, to recognize that an increase in the money supply tends to have a positive response from the inflation rate. Additionally, the government must be mindful of the relationship between the interest and inflation rates. Therefore, this study recommends that the Central Bank of Nigeria understand the role of money supply in enhancing inflation rate adjustments and devise monetary policies that would facilitate the proper functioning of the economy, ultimately leading to a stable price level.

Paul, Inore, and Kimat (2023) conducted a study in Papua New Guinea using long-term annual data from 1977 to 2020. Their research revealed a long-term cointegrating relationship between consumer price inflation, the money supply, the Kina-USD exchange rates, and real GDP. Their error-correcting model found that consumer price inflation is Granger-caused by the money supply, the Kina-dollar exchange rates, and real GDP. As per the theory, the money supply has a positive sign, the Kina-USD depreciation has a positive sign, and the real GDP has a negative sign.

The variance decomposition results showed that high-magnitude shocks in the natural logarithm of exchange rates were generated by one-standard-deviation shocks in consumer prices, corroborating the Purchasing Power Parity theory. This theory asserts that increases in consumer prices lead to the depreciation of the currency. In addition, a one-standard-deviation shock to the money supply produced significant shocks to the natural logarithms of the consumer price index and exchange rates, supporting the monetarist hypothesis that the money supply is an important policy variable driving inflation and exchange rate depreciation. Finally, the nominal exchange rate depreciation explains inflation in an open economy such as Papua New Guinea.

Moreover, Shi, Stan and Phillips (2020) conducted a study to re-examine the changes in the causal relationship between money and income in the United States from 1959 to 2014. They proposed three methods to discover changing points in causal relationships, all of which could be implemented without detrending the data. These methods include a forward-recursive algorithm, a rolling-window algorithm, and a recursive-evolving algorithm. They utilized subsample tests of Granger causality within a lag-augmented vector autoregressive framework. The study also provided the limit distributions for these subsample Wald tests. They developed bootstrap methods to control the family-wise error rate when implementing recursive testing algorithms.

The suite of simulation experiments has shown that the recursive evolving window algorithm provides the most reliable results, followed by the rolling window method. On the other hand, the forward-expanding window procedure is found to perform the worst. During the Volcker period in the 1980s, both the rolling-window and recursive-

evolving approaches indicated the presence of Granger causality from money to income. However, the forward algorithm fails to find any evidence of causality over the entire sample period.

2.Framework

Cointegration theory is first used to test whether a long-run equilibrium relation exists between the two variables. After cointegration has been established, causality measures are constructed to quantify various types of feedback between the variables. The theory of cointegration was developed by Granger and others in a series of papers, such as Engle and Granger (1987). Cointegration of a pair of variables may be defined as follows. A series, x_t which has a stationary, invertible, non-deterministic ARMA (autoregressive- moving average) representation after differencing **d** times, is integrated of order **d**, denoted $x_t \approx I(d)$. Thus a series which is integrated of order zero (**I(0)**) is itself stationary, whilst the simplest example of an **I(1)** series is a random walk. For a pair of variables to be cointegrated, a necessary (but not sufficient) condition is that they be integrated of the same order. If both x_t and y_t are **I(d),** then the linear combination $z_t = x_t - \alpha y_t$ will generally also be **I(d)**. However, if there exists a constant scalar α such that $z_t \approx I(d-b)$, b > 0, x_t and y_t are said to be cointegrated of order **d**, **b** denoted $(x_t, y_t) \approx CI(d, b)$.

The cointegration model aims to explain the economic relationship between the dependent and independent variables using an econometric framework grounded in equilibrium theory. In simpler terms, as the independent variable changes, the dependent variable will show a related movement. This type of causal relationship represents a long-term and stable equilibrium state. Short-term effects, such as seasonal or random interference factors, should not constitute long-term severe interference, and other factors apart from independent variables should not affect the establishment of a stable equilibrium relationship between the dependent variable and the independent variable. To establish an econometric model representing a long-term equilibrium relationship, it is essential to ensure that the residual portion of the dependent variable that the independent variable cannot explain does not impede the establishment of a stable equilibrium relationship between the two variables, and that the residual sequence is stationary. In summary, the cointegration model is based on the economic concept of modelling "long-term equilibrium" and verifies whether the linear combination of the cointegration model is stationary by stabilizing the model residual sequence.

In this chapter, we are most concerned that x_t and y_t are both **I(1)** and $z_t \approx I(0)$. While x_t and y_t may each have infinite variance, the linear combination z_t is stationary. We mainly use tests based on the work of Fuller (1976) and Dickey and Fuller (1979, 1981) to test for unit roots and cointegration. First, we test for integration to find the order of integration **d**.

$$\Delta x_t = \alpha_0 + \alpha_1 x_{t-1} + \varepsilon_t$$

If x_t is random walk, it implies $\alpha_1 = 0$ ($\alpha_0 = 0$); or, if x_t is random variable, it implies $\alpha_1 < 0$. We set the hypothesis as follows.

$$H_0: x_t \approx I(1)$$
$$H_1: x_t \approx I(0)$$

We run the regression by OLS:

$$\Delta X_t = \alpha_0 + \alpha_1 X_{t-1} + \sum_{i=1}^{k} \beta_i \Delta X_{t-i} + \varepsilon_t$$

So, we can find **t** – statistic for $\hat{\alpha}_1$ and compare with Augmented Dickey-Fuller (ADF) table. If the value of **t** – statistic for $\hat{\alpha}_1$ is statistically insignificant, we accept the null hypothesis [$x_t \approx I(1)$]. On the other hand, if $\hat{\alpha}_1$ is significant, then, we reject the null hypothesis [x_t is **I(0)** and not **I(1)**].

Suppose we get all the results to accept the null hypothesis for the above equation, then, we can run the regression for the twice differenced variable as follows.

$$\Delta^2 X_t = \alpha_0 + \alpha_1 \Delta X_{t-1} + \sum_{i=1}^{k} \beta_i \, \Delta^2 X_{t-i} + \varepsilon_t$$

Similarly, we may compute the **t** – statistic and compare with ADF table. If the **t** – statistic value for $\hat{\alpha}_1$ is statistically insignificant, we conclude that $\Delta x_t \approx I(1)$ [or $x_t \approx I(2)$]. Alternatively, if the **t** – statistic for $\hat{\alpha}_1$ is significant, we propose that $\Delta x_t \approx I(0)$ [or $x_t \approx I(1)$]. Also, the present paper concentrates on two tests: Sargan – Bhargava (1983) Durbin-Watson (DW) test and the Augmented Dickey Fuller (ADF) test of residuals from the cointegration regression. The cointegrating regression for the present model has the following form:

$$X_t = INT + \alpha Y_t + \varepsilon_t$$

Note that this equation is simply the stochastic version with an intercept term (INT).

Engle and Granger (1987) report tables of critical values generated by Monte Carlo simulation for the DW statistic from the cointegrating regression; these are 0.511, 0.386 and 0.322 for test sizes of one, five and ten per cent, and 100 observations. Augmented Dickey – Fuller (ADF) test is computed by first running the cointegrating regression

and find the residuals $e = x - \hat{x}$ the, we run the following regression:

$$\Delta e_t = \emptyset_0 + \emptyset_1 e_{t-1} + \sum_{i=1}^{k} \theta_i \Delta e_{t-i} + U_t$$

The test statistic is computed as the ratio of $\emptyset_1$ to its estimated standard error. The estimated residual series, U_t, is white noise. The **t** ratio is known as the ADF statistic. If it is necessary to add one or more lagged first differences into the auxiliary regression in order to induce an approximately white noise disturbance, then the '**t** – ratio' of the lagged level ('Augmented Dicky – Fuller statistic') has approximate critical values of -3.77, -3.17 and -2.84 for nominal test sizes of one, five and ten per cent and a sample size of 100 observations. Granger (1987), and Engle and Granger (1987) have proved a theorem showing that the existence of an error-correction form (ECF) between two variables is necessary and sufficient for them to be cointegrated. The definition of causality proposed by Granger (1969) essentially states that **X** causes **Y** if the history of **X** can be utilized to more accurately predict **Y** than only the history of **Y**. This view of causality gives rise to a one-sided distributed lag approach. The test consists of estimating the following two equations:

$$Y_t = a_0 + \sum_{i=1}^{m1} \alpha_i Y_{t-i} + \sum_{i=1}^{n1} \beta_i X_{t-i} + e_{1t}\,; \qquad (1)$$

$$X_t = b_0 + \sum_{i=1}^{m2} \gamma_i X_{t-i} + \sum_{i=1}^{n2} \delta_i Y_{t-i} + e_{2t}\,. \qquad (2)$$

In running two equations, it is assumed that **X** and **Y** are stationary time series and that e_{1t} and e_{2t} are uncorrelated. Decisions regarding the lag length of the variables and the appropriate filter to achieve stationary must be made when employing this test procedure.

Unidirectional causality from **X** to **Y** is said to exist if the estimated coefficients on the lagged values of **X** in Equation (1) are significantly different from zero as a group, while the set of δ_i is statistically zero. Similarly, unidirectional causality from **Y** to **X** is said to exist if, as a group, δ_i is statistically different from zero but β_i is not. For bidirectional causality to happen, both the sets of β_i and δ_i are statistically non-zero. It is noted that, when X_t and Y_t are cointegrated, either unidirectional or bidirectional causality will be found.

The error correction model (ECM) and the cointegration model are two econometric models used for stationary time series analysis based on the concept of "long-term equilibrium." However, the error correction model differs from the cointegration model

in that it focuses on the short-term "disequilibrium process" rather than the long-term equilibrium properties and the stationarity of the model residuals. While the error correction model is a logical deduction of the "long-term equilibrium" relationship between two variables, economic operations in the real world are driven by a "non-equilibrium process." This non-equilibrium process generates economic and financial data, so it's necessary to use the dynamic non-equilibrium process to approximate the long-term equilibrium state of economic theory. Therefore, the autoregressive distributed lag model (ADL) is the most common modelling method.

This study provides a theoretical overview of Wald tests for Granger causality in levels vector autoregressions (VARs) and Johansen-type error correction models (ECMs). The theory is based on results in Toda and Phillips (1991) and allows for stochastic and deterministic trends as well as arbitrary degrees of cointegration. We recommend operational procedures for conducting Granger causality tests based on Gaussian maximum-likelihood estimation of ECMs. These procedures are applicable in the important practical case of testing the causal effects of one variable on another group of variables and vice versa. This study also investigates the sampling properties of these testing procedures through simulation exercises. Three sequential causality tests in ECMs are compared with conventional causality tests in levels and differences VARs.

3.Data

All data were taken from Data Stream and the Hong Kong Monthly Digest of Statistics. The Tiananmen Square protests of 1989, commonly known as the June Fourth Incident or '89 Democracy Movement in Chinese, were student-led popular demonstrations in Beijing which took place in the spring of 1989 and received broad support from city residents, exposing deep splits within China's political leadership. To avoid the influence of the June Fourth Incident in 1989, the analysis covers the period from the first quarter of 1981 to the fourth quarter of 1988. Quarterly data were used as this was thought more appropriate. The definition of money supply is:

Money Supply Definition 1. (Total)-
Notes and coins in public, plus customers' demand deposits with licensed banks.

Money Supply Definition 2. (Total)-
M1 plus customers' savings and time deposits with licensed banks, plus negotiable certificates of deposit issued by licensed banks and held outside the monetary sector.

Money Supply Definition 3. (Total)-
M2 plus customers' deposits with licensed and registered deposit-taking companies plus negotiable certificates of deposits issued by deposit-taking companies held outside the monetary sector.

HK$M1, HK$M2 and HK$M3 are the Hong Kong dollar components of these definitions.

Gross domestic product (GDP) is an aggregate measure of the value of goods and services produced by residents within the domestic boundary of a country or a territory, net of their import content before provision for depreciation (or capital consumption). The two consumer price index series were derived from the household expenditure survey conducted in 1984-1985. They are defined in terms of the percentage distribution of households by expenditure as follows.

	Approximate percent of households covered	**Monthly expenditure range in 1984/85**
INDEX		
CPI(A)	50	HK$2,000-HK$6,499
CPI(B)	30	HK$6,500-HK$9,999

The effective exchange rate indexes (EERI) measures movements in weighted-average of nominal exchange rates of HK Dollar against the currencies of 15 principal trading partners. Since quarterly data on GDP are not available from the first quarter 1981 to fourth quarter 1988, we have derived them indirectly. We use the total domestic export data to estimate the quarterly GDP. One plausible method is that GDP as annual data (GDP_A) is regressed on total domestic export as annual data (DX_A). We find the intercept term (INT_A) and the slope (S_A), then the whole equation is divided by four to give the estimate of GDP as quarterly data (GDP_Q) as follows.

$$GDP_A = INT_A + S_A DX_A$$

$$\frac{GDP_A}{4} = \frac{INT_A}{4} + S_A \frac{DX_A}{4}$$

$$GDP_Q = INT_Q + S_A DX_Q$$

4.Results

Cointegration techniques for examining long-run equilibrium relationships form the basis of our study. Quarterly data on M1, M2, M3, GDP, CPIA, CPIB, and effective exchange rate indices (EX) for Hong Kong were obtained for the period from the first quarter of 1981 to the fourth quarter of 1988. First, we tested these macroeconomic variables for unit roots. The results, reported in Table 1, present the unit root tests for the M1, M2, M3, GDP, CPIA, CPIB, and EX series.

Table 1 Test for a unit root in M1, M2 M3, GDP, CPIA, CPIB and EX series

	$\hat{T}_{\mu}$		$\hat{T}_{\mu}$
$\Delta(LM\ 1)$	1.5147	$\Delta^2(LM\ 1)$	-4.2591
$\Delta(LM\ 2)$	-2.2058	$\Delta^2(LM\ 2)$	-3.1581
$\Delta(LM\ 3)$	-1.9659	$\Delta^2(LM\ 3)$	-3.3597
$\Delta(LGDP)$	-0.9689	$\Delta^2(LGDP)$	-6.4374
$\Delta(LCPIA)$	-0.6387	$\Delta^2(LCPIA)$	-2.2867
$\Delta(LCPIB)$	-0.6658	$\Delta^2(LCPIB)$	-2.2169
$\Delta(LEX)$	-2.1046	$\Delta^2(LEX)$	-3.5625

Where:
LM1 is the money supply definition 1 (Total) in logarithms;
LM2 is the money supply definition 2 (Total) in logarithms;
LM3 is the money supply definition 3 (Total) in logarithms;
LGDP is the gross domestic product in logarithms;
LCPIA is consumer price index (A) in logarithms;
LCPIB is consumer price index (B) in logarithms;
LEX is the effective exchange rate indexes in logarithms.

Critical values for the $\hat{T}_{\mu}$ statistic are -2.93 and -2.60 for 5% and 10% level of significance, respectively (critical values are taken from Fuller, 1976). In all seven cases, we are unable to reject the null hypothesis of a unit root in the framework of the equation**.**

$$\left[\Delta x_t = \alpha_0 + \alpha_1 x_{t-1} + \sum_{i=1}^{2or\,4} \beta_i \Delta x_{t-i} + \varepsilon_t\right].$$

Moreover when the data series are twice differenced the hypothesis is accepted that **LM1** (the money supply definition 1 (Total) in logarithms), **LM2** (the money supply definition 2 (Total) in logarithms), **LM3** (the money supply definition 3 (Total) in logarithms), **LGDP** (the gross domestic product in logarithms), **LEX** (the effective exchange rate indexes in logarithms) may be integrated of the order **I(1)** with rejection region $\{\theta : \theta < -2.93\}$; **LCPIA** (consumer price index (A) in logarithms) and **LCPIB** (consumer price index (B) in logarithms) may be integrated of order **I(2)** with rejection region $\{\theta : \theta < -2.93\}$. We ran the cointegrating regressions for each of the possible combinations, normalizing alternately on the **LM1**, **LM2**, **LM3**, **LGDP,** and **LEX**. These regressions are reported in Table 2: cointegrating regressions (1981-1988).

Table 2 Cointegrating regressions (1981-1988)

(1)	M1-GDP	LM1=-12.1554+2.1204 LGDP	DW=1.2154
		LGDP=6.6037+0.3869 LM1	DW=1.3319
(2)	M1-EX	LM1=27.9125-3.6631 LEX	DW=0.1859
		LEX=6.1524-0.1348 LM1	DW=0.2802
(3)	M2-GDP	LM2=-20.9363+3.1256LGDP	DW=0.9488
		LGDP=7.3037+0.272 LM2	DW=1.0967
(4)	M2-EX	LM2=40.9633-6.0007 LEX	DW=0.2423
		LEX=6.0426-0.1046 LM2	DW=0.3679
(5)	M3-GDP	LM3=-15.8753-2.6727 LGDP	DW=1.1085
		LGDP=6.5321+0.328 LM3	DW=1.2585
(6)	M3-EX	LM3=36.3688-4.9858 LEX	DW=0.2143
		LEX=6.2935-0.1226 LM3	DW=0.3422

Asymptotic critical value for **DW** statistic at 5% level is 0.386, with rejection region $\{DW | DW > 0.386\}$; the result is largely invariant to the choice of normalizing variable. Only for the M1-EX, M2-EX and M3-EX regressions do the Durbin-Watson statistics fall below the 5% critical level for the test of **I(1)** residuals. For all other regressions (M1-GDP, M2-GDP, M3-GDP), the Durbin-Watson statistic is large enough to reject the null of I(1) residuals at 5% test size. This impression is confirmed by examining the Dickey-Fuller test statistics for a unit root in the residuals from the cointegrating regression, which are reported in Table 3: Augmented Dickey-Fuller test statistic for residuals from cointegrating regressions.

Table 3: Augmented Dickey-Fuller test statistic for residuals from cointegrating regressions

Normalized on	LM1	LM2	LM3	LGDP	LEX
(1)M1-GDP	-2.3741			-3.3502	
(2)M1-EX	-1.4423				-2.8429
(3)M2-GDP		-6.5804		-6.9287	
(4)M2-EX		-2.3317			-2.8652
(5)M3-GDP			-4.8429	-6.3616	
(6)M3-EX			-2.1172		-2.9077

The approximate critical value for the Augmented Dickey-Fuller (ADF) statistic at the 5% level is -3.17, with a rejection region. Except for the M1-EX, M2-EX, and M3-EX combinations, the null hypothesis of a unit root in the residuals is rejected for all variable combinations (M1-GDP, M2-GDP, M3-GDP) at or below the 5% significance level. We can in some cases reject the null hypothesis of **I(1)** residuals using Augmented Dickey-Fuller statistics or the Durbin-Watson statistic; i.e., we find cointegration between M1-GDP, M2-GDP and M3-GDP. If co-integration exists, then causality tests may be performed concerning the levels of the variables concerned **(X** causes **Y** or vice versa). If cointegration does not exist, one way may still take differences in the data and perform causality tests on the differenced (i.e. stationary) series (ΔY causes ΔX; ΔX causes ΔY).

We examine M1-GDP, M2-GDP, M3-GDP, M1-EX, M2-EX, M3-EX, GDP-M1, GDP-M2, GDP-M3, EX-M1, EX-M2 and EX-M3 to find error-correction forms which are reported in Appendix 1, estimated error-correction forms. The period of estimation is 1981 quarter 2 – 1988 quarter 4. Figures in parentheses are heteroscedastic-consistent standard errors; figures in brackets are critical values. **DW** is the Durbin-Watson statistic. **LM** is a Lagrange multiplier test statistic for up to fourth order serial correlation [Breusch and Pagan (1980)]; **Q** is the Ljung-Box statistic; **ARCH** is a test statistic for autoregressive conditional heteroscedasticity [Engle (1982)]; **WH** is White's (1980) test statistic for general heteroscedasticity and functional misspecification; **N** is a test statistic for normally of the residuals based on the coefficient of skewness and excess kurtosis; **CHOW** is Chow's (1960) test statistics for post sample predictive failure, obtained by estimating up to 1987 quarter 4 and forecasting twelve months out of sample. **Q**, **ARCH** and **N** are central chi-square under the appropriate null; all other statistics (except R^2 and **DW**) are central **F**.

The estimated error-correction forms for (1) to (12) are quite impressive. Error-correction forms re-estimated up to 1987 quarter 4 forecast well for twelve months out of sample. For models (7) to (12), the **Q** statistic are too large to accept the hypothesis of no autocorrelation, and we can reject the models, since the probability that the residuals are not white notice is at least 95 percent; thus, we need not accept the hypothesis that the residuals are nonwhite, and for (1) to (6) models, would be acceptable. To determine the "best" specification, we might want to specify and estimate some models to see whether a low chi-square statistic can be obtained.

For models (1) to (12), since the value of the **CHOW** statistics is smaller than the critical value of the **F** distribution at the 5 percent level, we accept the null hypothesis. It is plausible to assume equal coefficients (no structure change). Except model (4), for models (1) to (12), since the value of the White's **F** statistic is smaller than the critical value of the **F** distribution at the 5 percent level, there is no evidence of heteroscedasticity; but, if we consider the **LM** version of the statistic for normality test, for model (1) to (4), the value of the $\chi^2 N(2)$ statistic are greater than the critical value of the χ^2 distribution at 95 percent level, there is evidence of heteroscedasticity for them. For models (1) to (12), an **ARCH** test, since the value of the chi-square statistic are smaller than critical value of the χ^2 distribution at 95 percent level, there is no evidence of heteroscedasticity; but, if we consider the Lagrange Multiplier (**LM**) test statistic for up to fourth order serial correlation, in models (1), (7), (8) and (9), since the value of the **F** version statistic are greater than the value of the **F** distribution at the 5 percent level, there is evidence of autocorrelation. The **R**-squares are quite small for each model. It means that they are not quite representative. However, these results concur with our cointegration analysis for models (1) to (6). Long-run relationships go through for M1-GDP, M2-GDP, M3-GDP, M1-EX, M2-EX and M3-EX. We report next

the results of 'Granger' causality testing between the above variables. There is strong evidence of no causal relationship between them.

Table 4: Granger's technique

Hypothesis	**F-stat.**	**d.f.**
GDP $\rightarrow$ M1	1.366	4, 19
M1 $\rightarrow$ GDP	0.833	4, 19
GDP $\rightarrow$ M2	0.5677	4, 19
M2 $\rightarrow$ GDP	1.482	4, 19
GDP $\rightarrow$ M3	0.446	4, 19
M3 $\rightarrow$ GDP	1.135	4, 19
$\Delta EX \rightarrow \Delta M1$	0.464	4, 18
$\Delta M1 \rightarrow \Delta EX$	0.357	4, 18
$\Delta EX \rightarrow \Delta M2$	1.186	4, 18
$\Delta M2 \rightarrow \Delta EX$	2.35	4, 18
$\Delta EX \rightarrow \Delta M3$	1.059	4, 18
$\Delta M3 \rightarrow \Delta EX$	1.347	4, 18

As seen in Table 4, Granger's technique. Critical values for the **F(4, 19)** and **F(4, 18)** are 2.9 and 2.93 for the 5 percent level of significance, respectively. This suggests neither variable in each of these pairs causes the other in the Granger sense. Taken with the cointegration results, this may suggest other factors 'cause' both variables.

5.Conclusions

In our analysis, there is no evidence of a causality relationship between money supply, income, prices, and exchange rates in Hong Kong. All data covered the period from the first quarter of 1981 to the third quarter of 1983 under the floating exchange rate system, and from the fourth quarter of 1983 to the fourth quarter of 1988 under the linked exchange rate system. The Sino-British Joint Declaration, formally known as the Joint Declaration of the Government of the United Kingdom of Great Britain and Northern Ireland and the Government of the People's Republic of China on the Question of Hong Kong, was signed by Prime Ministers Zhao Ziyang of the People's Republic of China and Margaret Thatcher of the United Kingdom on behalf of their respective governments on 19 December 1984 in Beijing. The period covers a structural break in the fourth quarter of 1983.

When the linked exchange rate system was adopted. This may be a source of criticism of our findings. However, if we consider the linked exchange rate system, we can obtain only 21 observations, which may jeopardize the validity of our tests. Hence, we must

extend our data coverage. GDP is annually published before 1989. Since we use quarterly GDP data, we use total domestic export data to estimate quarterly GDP. However, in Hong Kong, GDP is sometimes propelled by exports, sometimes by domestic demand. Typically, in an upswing, growth is first propelled by exports, and then by domestic demand. It is not a perfect cyclical consideration. This is a serious data limitation and may invalidate our results.

The Granger approach relies on heuristic justification, i.e., 'post hoc ergo propter hoc'. Thus, they give the wrong result if an event occurs before the event that causes it. This is equivalent to the 'Christmas card' and 'Travel agent' example – people go to travel agents and book their holidays; subsequently they take their holidays. This does not mean that the act of booking causes the holiday. For instance, if it is announced that wage increases in the next pay round will be very high, leading the market to expect large future price increases, the exchange rate may depreciate immediately. These tests would suggest that exchange rate changes caused the subsequent price changes. Instantaneous causality (i.e., where one variable has an effect on another variable within the same period) may not be discovered by the tests. Moreover, when this test is extended to form 'triangular' causality, it may give misleading results. If A causes B and B causes C within the same period, the effect of A on C may appear in the next period. Thus, it will appear that the only causality between the variables is from **A** to **C**. The test cannot distinguish the actions of the authorities from those of other market participants: for instance, if it is found that exchange rate movements, unexplained by past price movements, lead to price movements, the implication for policy will be different, depending on whether the exchange rate movements are caused by the authorities or by private speculators. 'Causality' may be a misleading term in these tests since both variables may in fact respond to another variable.

In Hong Kong, the money supply cannot be treated as an exogenous variable with respect to change in aggregate economic activity. The linked exchange rate system provides sufficient current capital to the economy. It will not be excessive or inadequate because money is determined by the balance of payments. But first, because of the depreciation of the US dollar, the depreciation of the HK dollar leads to 'imported inflation', which will raise the prices of raw materials and production costs and ultimately lower the competitiveness of Hong Kong export goods. However, 'imported inflation' was, in fact, lower than expected from 1985 to 1987. This is because Japan has cut down its export prices to maintain its market share in Hong Kong. So many speculators want to profit from the revaluation of the official rate. So, there was so much 'hot money' that flowed into Hong Kong's money market to press the government to revalue. For this reason, the government considered introducing a negative interest rate policy to curb capital inflows. Also, if the HK dollar were forced to revalue, the public holding US-dollar-denominated assets would suffer significant losses immediately, causing the public to lose confidence in the government and potentially triggering political repercussions.

Furthermore, speculators would disrupt the monetary system repeatedly to profit from successive revaluations. Interest rates do not reflect the actual needs of the Hong Kong economy but are only a tool for maintaining the official rate. It fluctuated rapidly and frequently. And the Hong Kong economy will be directly affected by the US economy; Hong Kong will suffer economic recession whenever the US economy contracts. The linked exchange rate system remains practical and feasible because it can stabilize public confidence, and its automatic adjustment mechanism is satisfactory to a certain extent, as it can control the money supply in line with the balance of payments.

It is hoped that the present work can stimulate and arouse future research to use causality tests. In this paper, we propose an advanced technique to test the assumption of endogeneity of the money supply in Hong Kong. It is highly recommended to use a vector autoregressive (VAR) test (Toda and Phillips, 1994). This study provides a theoretical overview of Wald tests for Granger causality in vector autoregressions (VARs) and Johansen-type error correction models (ECMs). The theory is based on results in Toda and Phillips (1991) and allows for stochastic and deterministic trends as well as arbitrary degrees of cointegration. We recommend operational procedures for conducting Granger causality tests based on Gaussian maximum-likelihood estimation of ECMs. These procedures are applicable in the important practical case of testing the causal effects of one variable on another group of variables and vice versa. This study also investigates the sampling properties of these testing procedures through simulation exercises. Three sequential causality tests in ECMs are compared with conventional causality tests in levels and differences VARs.

This view can be put to rigorous empirical test. One relevant test would be the causality between the money supply and factors that might have caused it or been caused by it. Bivariate causality tests based on Granger's (1969) conception have been widely used by econometricians, and various versions have been developed. However, they suffer from the limitation that only two variables can be considered, despite Granger's original multivariate formulation. The vector autoregression (VAR) technique popularized by Sims (1980, 1982) and Toda and Phillips (1991, 1994) overcomes this drawback. Therefore, we recommend using the VAR test to determine the direction of causality between the money supply and other relevant variables in Hong Kong.

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Appendix 1: Estimated Error Correction Forms

(1) M1-GDP

$$\Delta LM1_t = 0.0515 - 0.4248\Delta LGDP_t + 0.0123\left(LM1 - LGDP\right)_{t-1}$$

(0.0179) (0.2145) (0.0584)

$R^2 = 0.1256$ DW=2.948 LM(4,24)=4.0557 [2.78]

N(2)=64.6271 [5.99] WH(1,29)=1.2776 [4.17] Q(10)=13.3706 [18.31]

ARCH(12)=11.5602 [21.03] CHOW(3,25)=0.1916 [2.99]

(2) M1-EX

$$\Delta LM1_t = -0.0352 - 0.3003\Delta LEX_t + 0.0126\left(LM1 - LEX\right)_{t-1}$$

(0.2) (0.5254) (0.0339)

$R^2 = 0.0154$ DW=2.7635 LM(2,24)=2.5631 [2.78]

N(2)=24.5252 [5.99] WH(1,29)=0.000124 [4.17] Q(10)=10.3977 [18.31]

ARCH(12)=12.4071 [21.03] CHOW(3,25)=0.384 [2.99]

(3) M2-GDP

$$\Delta LM2_t = 0.1062 - 0.0983\Delta GDP_t - 0.0197\left(LM2 - LGDP\right)_{t-1}$$

(0.0321) (0.1046) (0.0168)

$R^2 = 0.0854$ DW=1.0025 LM(4,24)=2.6914 [2.78]

N(2)= 28.4925 [5.99] WH(1,29)=1.1702 [4.17] Q(10)=18.2935 [18.31]

ARCH(12)=18.6475 [21.03] CHOW(3,25)=0.0262 [2.99]

(4) M2-EX

$$\Delta LM2_t = 0.1986 + 0.0741\Delta LEX_t - 0.0166\left(LM2 - LEX\right)_{t-1}$$

(0.0891) (0.2487) (0.0112)

$R^2 = 0.074$ DW=0.9869 LM(4,24)=2.5877 [2.78]

N(2)=11.2233 WH(1,29)=12.3122 Q(10)=17.4107
[5.99] [4.17] [18.31]
ARCH(12)=18.0208 CHOW(3,25)=0.1994
[21.03] [2.99]

(5) M3-GDP

$$\Delta LM3_t = 0.0928 - 0.0167\Delta GDP_t - 0.0167\left(LM3 - LGDP\right)_{t-1}$$
(0.0236) (0.0548) (0.0113)

$R^2 = 0.0813$ DW=1.637 LM(4,24)=0.8951
[2.78]
N(2)=1.7875 WH(1,29)=2.8958 Q(10)=10.8333
[5.99] [4.17] [18.31]
ARCH(12)=15.2786 CHOW(3,25)=0.1524
[21.03] [2.99]

(6) M3-EX

$$\Delta LM3_t = 0.1431 - 0.001788\Delta LEX_t - 0.0106\left(LM3 - LEX\right)_{t-1}$$
(0.0558) (0.1298) (0.0068768)

$R^2 = 0.0783$ DW=1.6335 LM(4,24)=0.8755
[2.78]
N(2)=1.4655 WH(1,29)=3.9336 Q(10)=10.1015
[5.99] [4.17] [18.31]
ARCH(12)=15.0926 CHOW(3,25)=0.6945
[21.03] [2.99]

(7) GDP-M1

$$\Delta LGDP_t = 0.0415 - 0.2893\Delta LM1_t - 0.0653\left(LGDP - LM1\right)_{t-1}$$
(0.0149) (0.146) (0.0466)

$R^2 = 0.1815$ DW=2.3639 LM(4,24)=9.0454
[2.78]
N(2)=0.6078 WH(1,29)=0.2662 Q(10)=42.4173
[5.99] [4.17] [18.31]
ARCH(12)=15.5253 CHOW(3,25)=1.8773
[21.03] [2.99]

(8) GDP-M2

$$\Delta LGDP_t = 0.0135 - 0.3112\Delta LM2_t - 0.0151\left(LGDP - LM2\right)_{t-1}$$
(0.0673) (0.3311) (0.0304)

$R^2 = 0.0487$ DW=2.1075 LM(4,24)=19.0017
[2.78]
N(2)=2.7929 WH(1,29)=0.038 Q(10)=70.5774
[5.99] [4.17] [18.31]
ARCH(12)=16.5572 CHOW(3,25)=1.8398
[21.03] [2.99]

(9) GDP-M3

$$\Delta LGDP_t = 0.0855 - 0.2003\Delta LM3_t - 0.02\left(LGDP - LM3\right)_{t-1}$$
(0.0881) (0.6541) (0.0342)

$R^2 = 0.0209$ DW=2.0803 LM(4,24)=16.8168
[2.78]
N(2)=3.1524 WH(1,29)=1.4128 Q(10)=71.5513
[5.99] [4.17] [18.31]
ARCH(12)=17.0743 CHOW(3,25)=1.9752
[21.03] [2.99]

(10) EX-M1

$$\Delta LEX_t = -0.0346 - 0.0384\Delta LM1_t - 0.0048198\left(LEX - LM1\right)_{t-1}$$
(0.0713) (0.0672) (0.0121)

$R^2 = 0.0161$ DW=1.2365 LM(4,24)=1.192
[2.99]
N(2)=0.1324 WH(1,29)=0.7047 Q(10)=21.7623
[5.99] [4.17] [18.31]
ARCH(12)=16.2709 CHOW(3,25)=0.0272
[21.03] [2.99]

(11) GDP-M2

$$\Delta LEX_t = -0.0307 + 0.0426\Delta LM2_t - 0.0025365\left(LEX - LM2\right)_{t-1}$$
(0.0731) (0.1432) (0.008845)

$R^2 = 0.0047984$ DW=1.2158 LM(4,24)=1.2038
[2.78]
N(2)=0.2025 WH(1,29)=0.7696 Q(10)=22.3458
[5.99] [4.17] [18.31]
ARCH(12)=13.9485 CHOW(3,25)=0.37
[21.03] [2.99]

(12) EX-M3

$$\Delta LEX_t = -0.0237 + 0.0067243\,\Delta LM3_t - 0.0046128\left(LEX - LM3\right)_{t-1}$$

(0.0393) (0.2753) (0.0092964)

$R^2 = 0.0092543$ DW=1.2333 LM(4,24)=1.1774
[2.78]

N(2)=0.2612 WH(1,29)=1.5922 Q(10)=22.5568
[5.99] [4.17] [18.31]

ARCH(12)=14.2073 CHOW(3,25)=0.3889
[21.03] [2.99]

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Chapter 2
The Effect of Global Oil Price and Macroeconomic Variables on the Stock Market Returns for ASEAN Countries

Jacky Ho-Man Lau
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Abstract

This research examines the interrelationships among macroeconomic variables in Thailand and the Philippines. Using VAR analysis, we find that the relationships differ substantially between the two countries. In Thailand, changes in global oil futures prices have a significantly positive effect on stock prices, while lagged stock returns and the inflation rate exert significantly positive effects on the policy interest rate. In contrast, such relationships are not observed in the Philippines. These findings are further confirmed through various robustness checks.

1. Introduction

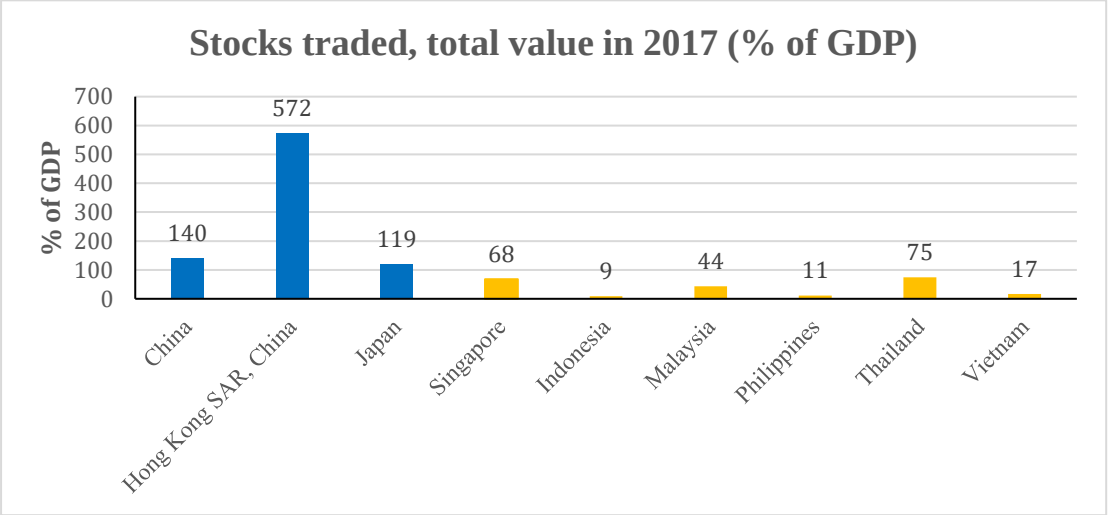
In the past decade, Asian countries have developed rapidly, including the development in science, technology, trading, production, and other aspects. The average living standard of the countries in Asia and the per capita income have increased significantly. Among all the countries located in Asia, ASEAN is a new impetus for business development affecting the whole world. ASEAN is an association of Southeast Asian nations formed in 1967, which currently includes 10 countries in Southeast Asia: Brunei, Cambodia, Indonesia, Laos, Malaysia, Myanmar, the Philippines, Singapore, Thailand, and Vietnam. It aims to solve various economic, security, political, and social problems. According to HKTDC Research, ASEAN has over 640 million people, and its aggregate economic size (GDP) rose from US$1.63 trillion in 2008 to already exceed US$2.7 trillion in 2017. Some experts even predict that ASEAN would become the fourth-largest economy in the world by 2030. All this information and these statistics show the importance of understanding the economic and financial characteristics of the ASEAN countries for the future.

Various factors would affect the performance of the ASEAN countries' capital markets. First, the capital market size of the ASEAN countries is different. On one hand, some national capital markets have a larger capital market size as they started earlier, such as Malaysia, Singapore, Thailand, Vietnam, the Philippines and Indonesia. On the other hand, some national capital markets were relatively smaller, such as Laos, Cambodia and Myanmar. The Lao Securities Exchange and Cambodian Securities Exchange were founded and started to operate in January 2011, and the Yangon Stock Exchange was opened in October 2015. Some of the ASEAN countries have not yet established a

national stock exchange, such as Brunei; this shows the distinction between the ASEAN countries' capital market size.

However, even though the capital markets of Malaysia, Singapore, and Indonesia are relatively larger among ASEAN countries, they are still far behind other countries in Asia, such as China, Hong Kong, and Japan. As shown in Figure 1, there is a great gap between the total values of stocks traded of each Asian country in 2017. The value of stocks traded in China was nearly twice as much as the total values of Singapore, Malaysia and Thailand. In addition, Figure 2 shows that the number of listed domestic companies of ASEAN countries are only one seventh while comparing to China, Hong Kong and Japan. Moreover, as highlighted in Figure 3, the market capitalization of listed domestic companies of China in 2017 was decuple than the companies in each country. These figures show the disparity of stock markets between mature countries in Asia and ASEAN countries.

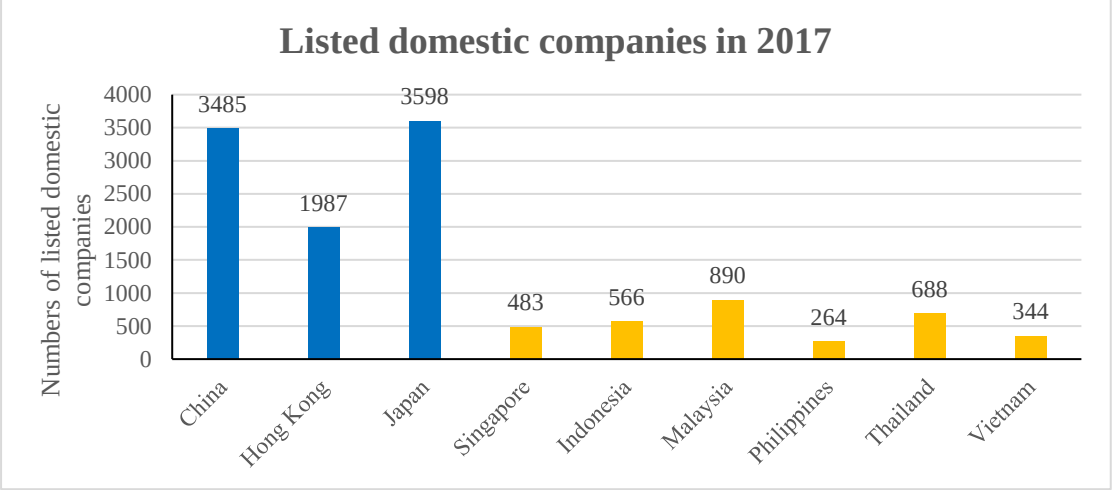
Figure 1 – Total value of stocks traded of Asia countries in 2017 (% of GDP)



Source: World Bank Group

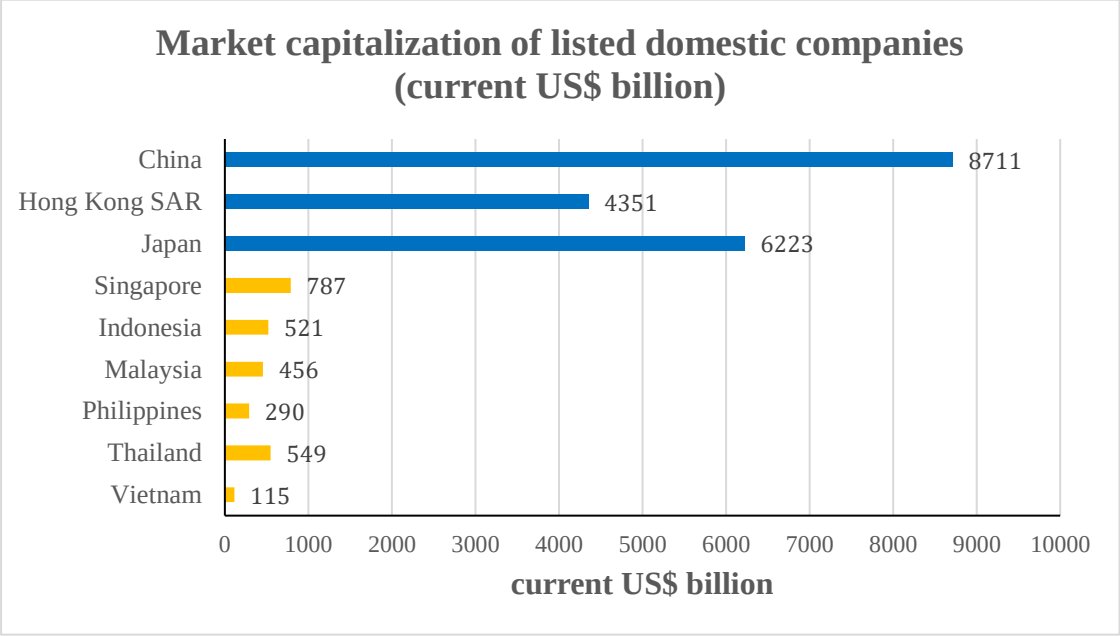
Besides the size of the stock market, the economic structure and policy orientation would also affect the performance of the ASEAN countries' capital markets. For example, the market of Malaysia is relatively open and has a relatively high speed of financial reform. Indonesia and the Philippines ' markets are relatively competitive, as they have implemented strict trade protection and financial regulation for a long period, so that financial reform is relatively lagging.

Figure 2 – Listed domestic companies in 2017



Source: World Bank Group

Figure 3 – Market capitalization of listed domestic companies of Asia countries in 2017 (current US$ billion)

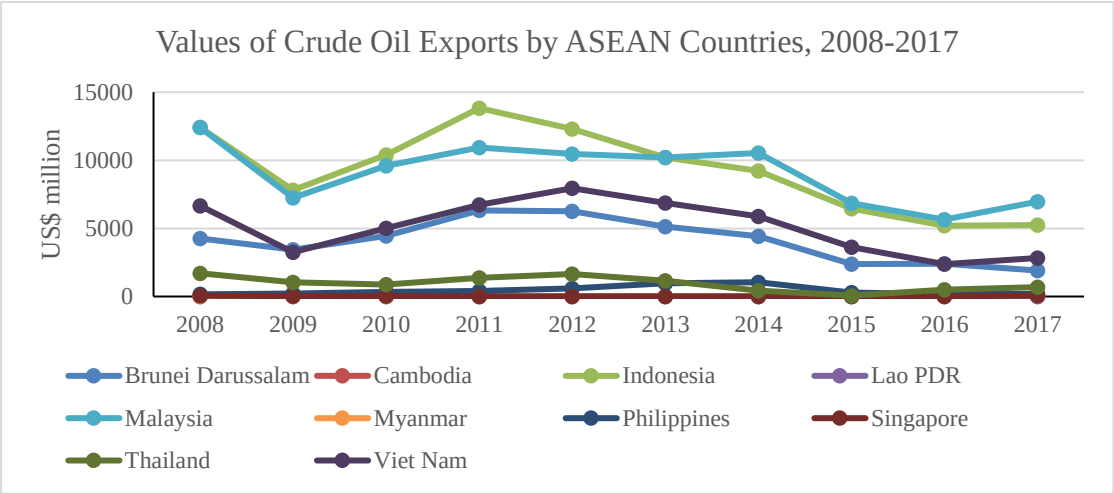


Source: World Bank Group

For a rapid expansion of the economy, besides the capital market structure and size, the price of crude oil should be an important determinant that affects the capital market. Along with the findings of Miller, J. I., & Ratti, R. A. (2009), a clear long-run relationship is found that stock market indices would respond negatively to the rise in the price of oil. Consequently, it is reasonable to say that when the price of crude oil imports rises, the cost of production would be raised eventually, which slows down the growth of the economy and negatively affects the performance of the local stock market. For ASEAN countries, the unsteady price of crude oil is one of the most important factors that affect the cost of production. According to the report announced by ASEAN Centre for Energy (ACE), since 2016, ASEAN has not discovered any new giant oil. This forced most of the ASEAN countries to become net oil importers and vulnerable

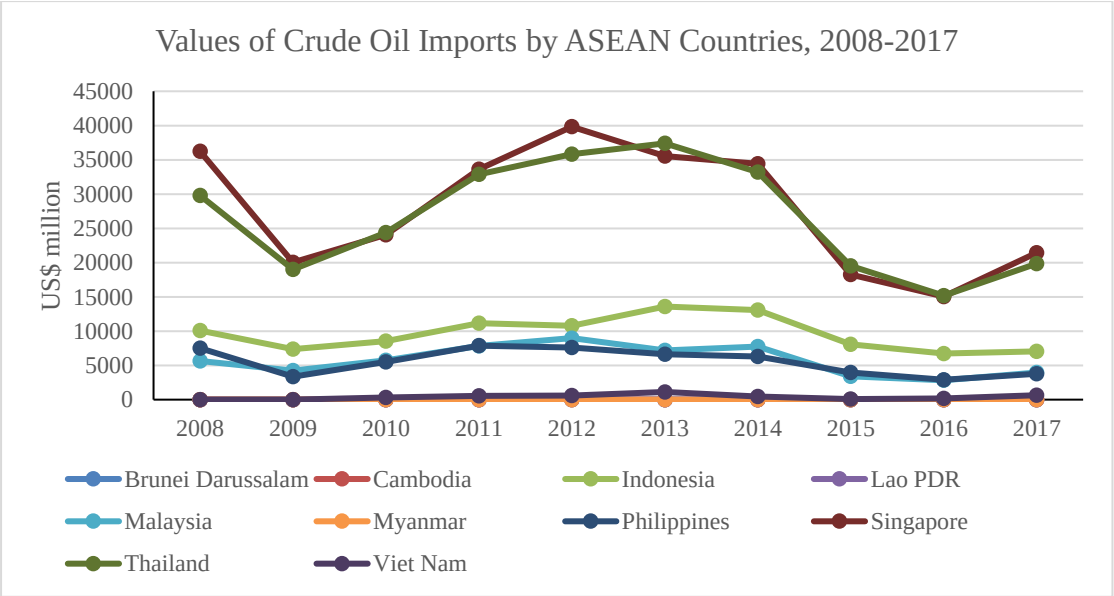
to supply disruption and oil price fluctuation. As shown in Figures 4, 5 and 6, the number of crude oil imports far exceeded the exports by ASEAN countries from 2008 to 2017, especially Thailand. It obviously reflects the fact that ASEAN members are still relying on the importation of crude oil.

Figure 4 – Values of Crude Oil Exports by ASEAN Countries, 2008-2017



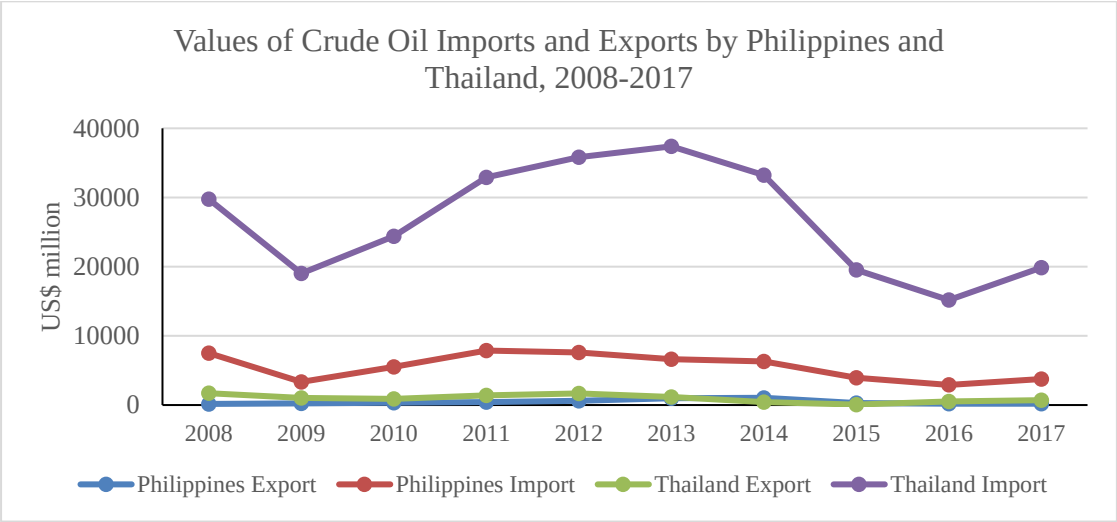
Source: Association Southeast Asian Nations

Figure 5 – Values of Crude Oil Imports by ASEAN Countries, 2008-2017



Source: Association Southeast Asian Nations

Figure 6 – Values of Crude Oil Imports and Exports by Philippines and Thailand, 2008-2017



Source: Association of Southeast Asian Nations

However, according to our observation, even though the oil price rose sharply in the past decade, the development speed of the ASEAN members seems not to have been harmed or slowed significantly. This interesting phenomenon inspired us to analyze how oil price and other local economic variables would affect the stock market of ASEAN countries from 2000 to now.

2. Literature Review

Being in a rapidly developing era, investing in the stock market is always a great way to maintain the purchasing power of money under inflation, and also to enlarge wealth for a better living standard. However, it's not easy to earn money in developed countries' stock markets due to information asymmetry, and most of the markets are lacking room for improvement. But in some developing countries, like ASEAN, the stock markets are still full of expanding potential. Therefore, it would be a great idea to invest in developing countries' stock markets, as in the long run, the stock value of superior listed companies must increase a couple of times during market development.

Most of the members of ASEAN are developing countries, and the stock markets are full of expanding potential. ASEAN is composed of a miscellaneous group of ten fast-growing countries at different stages of economic and financial development. The investment demand is vast as those countries are advancing urbanization, also increasing both hard and soft infrastructure. After the Asian financial crisis, ASEAN has sharply improved its internal and external trade and capital flows. Besides, direct investment has risen, and foreign participation in ASEAN capital markets has increased. (Almekinders, Mourmouras, Zhou & Fukuda, 2015). With a population of more than 600 million in ASEAN, it is considered to be one of the most diverse regions in the world and also the world's fastest-growing region (Bhattacharya, 2009). Although the financial crisis in 1998 generated a profound impact on the ASEAN region, they sustained to grow robustly after the disturbance. Therefore, according to the dynamic

business environment with a stable and high growth rate, ASEAN has become a promising target for international investors (Rao-Nicholson, Salaber & Cao, 2016).

In order to be well-prepared before investing money into the stock market of ASEAN, it's necessary to understand the relationship between stock market returns and multiple macroeconomic variables. First, the price of crude oil should be considered, as the price change of oil might have a great relationship with the stock market return. Alvarez-Ramirez, Soriano, Cisneros& Suarez (2003) pointed out that crude oil has become one of the most important factors in the world economy, as nearly 67% of energy demands in the world are fulfilled by crude oil. Basher and Sadorsky (2006) also found strong evidence that the change of oil prices are most likely to affect the stock market returns of 21 emerging economies; and oil price is a positive and significant variable (10%) to explain the stock market returns for most of the countries studied in the paper. By using a vector autoregressive model, oil price and its volatility play important roles in affecting real stock returns (Sadorsky, 1999). Moreover, Filis, Degiannakis, & Floros (2011) found that the lagged time-varying correlation results show oil prices always exercise a negative effect in all stock markets, no matter what the sources of the oil price shock are. The relationship should be quite important for ASEAN countries as most of them rely on importing crude oil, such as Singapore, the Philippines, and Thailand. Singapore's energy is 100% imported from other countries; for the Philippines, more than half of the energy supply is imported, especially coal and crude oil; Thailand is also relying on imported crude oil (Kanchana & Unesaki, 2014). Therefore, the price of crude oil will be used in the following part of the paper. In particular, we use the data of Brent crude oil and West Texas Intermediate (WTI) crude oil as they are the most famous benchmark prices, which are used widely as the basis of many crude oil price formulae (Yu, Wang & Lai, 2008).

Second, interest rate, inflation rate, and GDP should be included in the following testing as they would bring various effects on the stock market return. For the relationship of interest rate and stock market, Alam & Uddin (2009) pointed out that interest rate should have a significant negative relationship with share price. In some countries, the changes in interest rate would also have a significant negative relationship with changes in share price. In addition, Ahmad, Rehman, & Raoof (2010) pointed out that the change in interest rate would significantly affect stock returns by using Pakistan as an example. Besides the interest rate, the inflation rate would also affect the stock market. The stock market reacts negatively to inflation in the Consumer Price Index, especially for an unexpected change in the inflation rate (Schwert, 1981). Furthermore, Gultekin (1983) said that the increase in inflation raises the tax burden of corporations. In the long-run, inflation may have a very large impact on the composition of the capital stock as it declines in the price of corporate capital and raises the price of its substitute, housing capital. In addition, GDP should not be excluded in the following testing process as it is widely believed that along with great economic growth (Great growth rate of GDP), the business environment would be great for the stockholders. The stock

prices are very high relative to gross domestic product (Diamond, 2000). By analyzing the newspaper stories, Birz and Lott (2011) found that news about GDP does affect stock returns between 1991 and 2004. However, it needs to be remembered that GDP might not affect the stock price positively in all situations; Ritter (2005) raised that the real stock returns have a negative relationship with the per capita GDP growth over 1900–2002, as some of the examined countries with great GDP do not offer good equity investment opportunities.

In the testing process, referencing to the testing method used in "Oil price shocks and stock market activity" wrote by Sadorsky (1999) and "Energy shocks and financial markets" wrote by Huang, Masulis and Stoll (1996), vector autoregressive model (Sims, 1980) would be used to test the relationship between the price change in crude oil, change in interest rate, change in inflation rate, change in GDP and the stock return in ASEAN countries. It's important to find out whether the data are stationary while using the VAR model. Most of the time, the data generated from a financial market is inherently non-stationary, and therefore, we have to force the data to become stationary (Huang, Wu, Qu, Long & Shen, 2003).

3. Methodology

In this research paper, the idea of finding out the relationship between global oil price, national economic factors, and local stock market reaction is based on the paper written by J. Isaac Millera and Ronald A. Rattib in 2009. In that paper, they analyzed the long-run relationship between the world price of crude oil and international stock markets from 1971 to 2008 by using the integrated Vector Error Correction model, and they found that stock market indices would respond negatively to the price rise of oil. However, would it apply to the rapidly developing countries in ASEAN? To find out the answer, this research paper aims to reveal the relationship between the global price of crude oil, local interest rate, local inflation rate, national GDP, and the stock performance in ASEAN countries, particularly Thailand and the Philippines.

3.1 Unit Root Test

For analyzing the data, the Vector Autoregressive (VAR) model will be used to capture the linear interdependencies of a set of endogenous variables (Stock price, Interest rate, Inflation rate, GDP in USD) over the same sample period (t=72). In general, unit root tests should be used before using a VAR model. Spurious relationships may arise when the variables in the dataset contain unit roots, and this analysis result is unreliable, as the variables are not causally related.

Dickey-Fuller Test and Augmented Dickey-Fuller Test are often used for the unit root testing process (Dickey and Fuller, 1979). Both of them are possible and appropriate to

use in this paper, but the Dickey-Fuller Test would be more suitable. First, the equation of the Dickey-Fuller Test is:

$$Y_t = \emptyset Y_{t-1} + u_t$$

where Y_t is the testing variable at time t, $\emptyset$ is a coefficient that demonstrates the relationship between the testing variables at time t-1 and time t. u_t is the error term. By subtracting Y_{t-1} from both sides, the equation was further developed to be:

$$\Delta Y_t = \theta Y_{t-1} + u_t \qquad [where\ \theta = \emptyset - 1]$$

where ΔY_t is equal to is the first difference of the testing variable at time t and the coefficient θ is equal to $(\emptyset - 1)$ and now representing the relationship between the testing variables at time t-1 and the first differenced testing variable at time t. Moreover, if the Dickey-Fuller Test involved drift and deterministic time trend, the equation would be:

$$\Delta Y_t = \propto + \beta t + \theta Y_{t-1} + u_t$$

where $\propto$ represents the drift and βt represents the deterministic time trend. With this equation, hypotheses are set as: Null hypothesis (H_0): $\theta = 0$, and the alternative hypothesis (H_1) is: $\theta \neq 0$. If the result of the Dickey-Fuller Test rejects the null hypothesis, which means the testing variable ΔY_t is stationary and no unit root arises. However, structural effects including autocorrelation are still involved while testing with the Dickey-Fuller Test; therefore, the Augmented Dickey-Fuller Test method emerged by changing the equation into (Dickey and Fuller, 1979):

$$\Delta Y_t = \theta Y_{t-1} + \sum_{i=1}^{r} \propto_i \Delta Y_{t-i} + u_t$$

After all this, the Augmented Dickey-Fuller (ADF) test would be used in this paper for examining the existence of non-stationary variables in our model without any structural effects, and the hypotheses are set as: Null hypothesis (H_0): $\theta = 0$ and the alternative hypothesis(H_1) is: $\theta \neq 0$. It is noteworthy that the standard T-Distribution is not able to provide critical values for the Augmented Dickey-Fuller Test; the T-distribution would be replaced by the Dickey–Fuller Distribution, which is defined as:

$$test\ stat = \frac{\hat{\varphi}}{\widehat{SE(\varphi)}}$$

If the final version of the model does include a deterministic trend, at 5% significance level, the Dickey-Fuller critical value is approximately –3.45. If the t-stat on θ is more

negative than –3.45, we reject the unit root hypothesis and conclude that the series is stationary. Otherwise, we conclude that the series has a unit root at the 5% significance level.

3.2 Vector Autoregressive model

After testing whether the variables are having unit-root or not, the VAR model would find out the linear relationship among multiple time series. All variables within the VAR model would be explained by their lagged values and the lagged values of other variables, and an error term. The equation of a VAR model is:

$$Y_t = \beta_0 + \beta_i Y_{t-1} + u_t$$

where Y_t, β_0, Y_{t-1} *and* u_t are vectors with the format of $m \times 1$, and β_i is a vector representing the format of $m \times m$,which is equal to $\begin{bmatrix} Y_{11} & \cdots & Y_{1m} \\ \vdots & \ddots & \vdots \\ Y_{m1} & \cdots & Y_{mm} \end{bmatrix}$. In this equation, all variables are endogenous, and it enables us to determine the relationship between the lagged values of the variables and the lagged values of other variables, including the error term. However, sometimes the VAR model is affected immediately by other observable variables (Exogenous/independent variables) that are determined outside the system. In this case, the equation would be changed into:

$$Y_t = \beta_0 + \beta_i Y_{t-1} + \alpha_i X_t + u_t$$

where X represents exogenous variables and the α_i is a vector with the format of $m \times 1$, which is equal to $\begin{bmatrix} \alpha_1 \\ \vdots \\ \alpha_m \end{bmatrix}$.

3.3 Robustness Check

In order to confirm the accuracy of the data analysis in this paper, two controlling experiments would be involved in the last part of the analysis. First, the VAR model would change the exogenous variable – the price of oil into the endogenous variables. Second, the VAR model would use another oil price dataset for testing in order to dismiss the possibility of unreliable results generated by only testing one oil price benchmark.

4. Data and Variable Descriptions

This section is going to describe the variables involved in the research model. In this paper, it attempts to find out the effects of global oil prices and national economic factors on the local stock market of ASEAN Countries. According to the literature review, experts pointed out the relationship between various macroeconomic variables and the stock market. As shown in Table 1, within the model, endogenous variables would be included: 1. Price of Stock Market, 2. Local Interest Rate, 3. Local Inflation Rate, and 4. Local Gross Domestic Product. Besides, 5. Price of Global Oil would be the exogenous variable. However, due to data availability, only Thailand and the Philippines are selected for analysis; the details of the stock markets of Thailand and the Philippines are shown in Table 2. All quarterly data cover the period from September 2000 to September 2018.

As shown in Table 3, the price of Thailand's stock market would be represented by the quarterly index price of the Thailand SET Index; and the price of the Philippines' stock market would be represented by the quarterly price of the Philippines PSEi Index. Using the Thailand SET Index as the variable because the SET Index is one of the most significant stock market benchmarks in Thailand, which is currently separated into 6 different series[1] and includes 150 listed companies. About the Philippines PSEI.PS index, which is also a famous benchmark index in the Philippines, and it is composed of the top 30 companies selected by the Philippine Stock Exchange.

[1] *There are Large Cap, Mid Cap, Small Cap, All-Share, Mid/Small Cap, Fledging

Table 1 – Summary table of the Thailand and Philippines data comparison

	Thailand	Philippines
Sampling Period	01/09/2000 to 01/09/2018	
Data Frequency	Quarterly	
National Level Data	Stock price, Interest rate, Inflation rate, GDP in USD	
Global Level Data	Brent Crude Oil Price WIT Oil Price (use for robustness check)	

Table 2 – Stock Market information summary table of the Thailand and Philippines

	Thailand	Philippines
Stock Exchange History	The Bangkok Stock Exchange (SET) was established in 1962, currently located in Bangkok.	The Philippine Stock Exchange (PSE) was established in 1927, currently located in Taguig City.
Number of Stock Listed	317	270
Trading Hours	Conducted on all bank business days, normally Monday through Friday. There are two trading sessions per day, morning and afternoon. (9:30 - 17:00)	Continuous session from 9:30AM to 3:30PM daily with a recess from 12:00PM to 1:30PM.

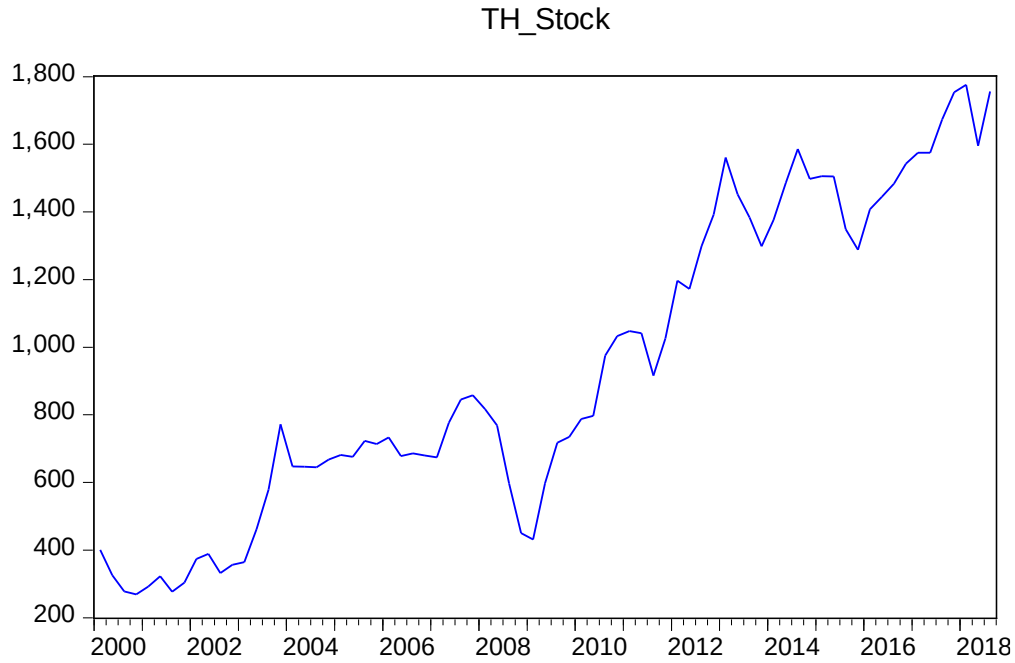
Table 3 – Variables Description

Variables	Abbrev.	Order
Quarterly ending price of Thailand SET Index	TH_STOCK	I(1)
Quarterly Policy interest rate of Thailand	TH_INT	I(1)
Change of Consumer Price Index of Thailand	TH_INF	I(1)
Quarterly GDP of Thailand	TH_USDGDP	I(1)
Quarterly ending price of Philippines PSEi Index	PH_STOCK	I(1)
Quarterly Philippines policy interest rate	PH_INT	I(1)
Change of Consumer Price Index of Philippines	PH_INF	I(1)
Quarterly GDP of Philippines	PH_USDGDP	I(1)
Quarterly Future price of Brent Crude Oil	BRENT_CRUDE_OIL	I(1)
Quarterly Future price of WTI Oil	WTI_OIL	I(1)

Figure 7 shows the trend of the quarterly price of the Thailand SET Index from 2000 to 2018, and Figure 8 shows the trend of the quarterly price of the Philippines PSEi Index. Obviously, both the quarterly prices of the Thailand SET Index and the Philippines PSEi Index are in a rising trend. After the global financial crisis, both indices accelerated significantly. By 2018, the Indexes were two times higher than the historical peak in 2008.

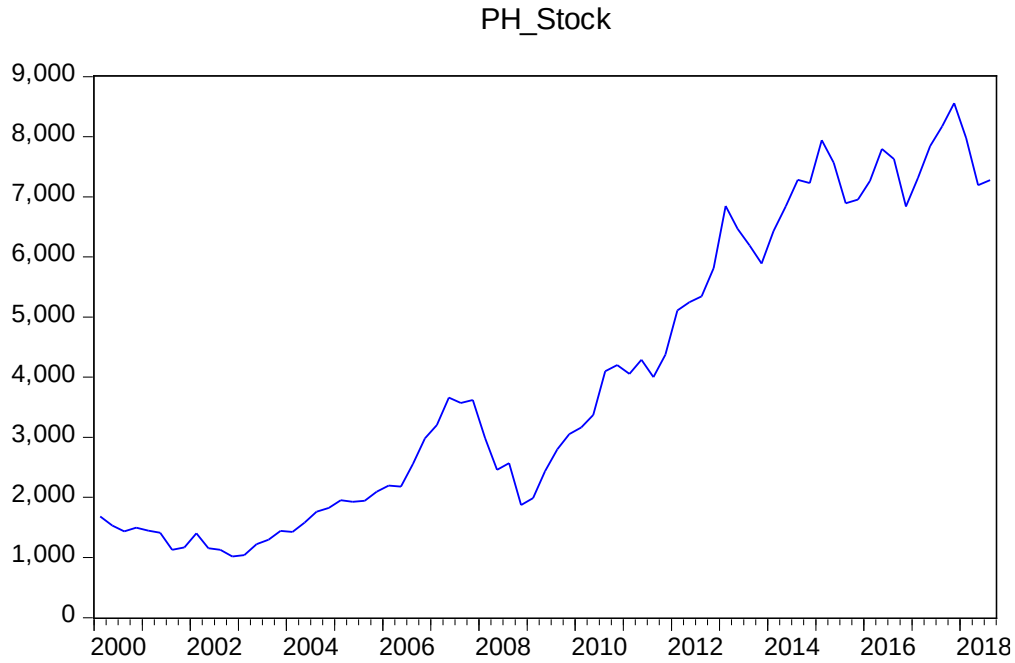
The second variable is the local quarterly policy interest rates, which are decided by the local central banks. Its change will exert an effect on saving and investment decisions. For the third variable, it uses the local inflation rate. It is constructed as the quarterly change in the Consumer Price Index (CPI). In addition, local Gross Domestic Product (GDP) is used to represent the living standards of a nation, as it calculates the market value of all the final goods and services produced by a nation within a period of time.

Figure 7 – Quarterly price of Thailand SET Index



Source: Thomson Reuters Eikon

Figure 8 – Quarterly price of Philippines PSEi Index

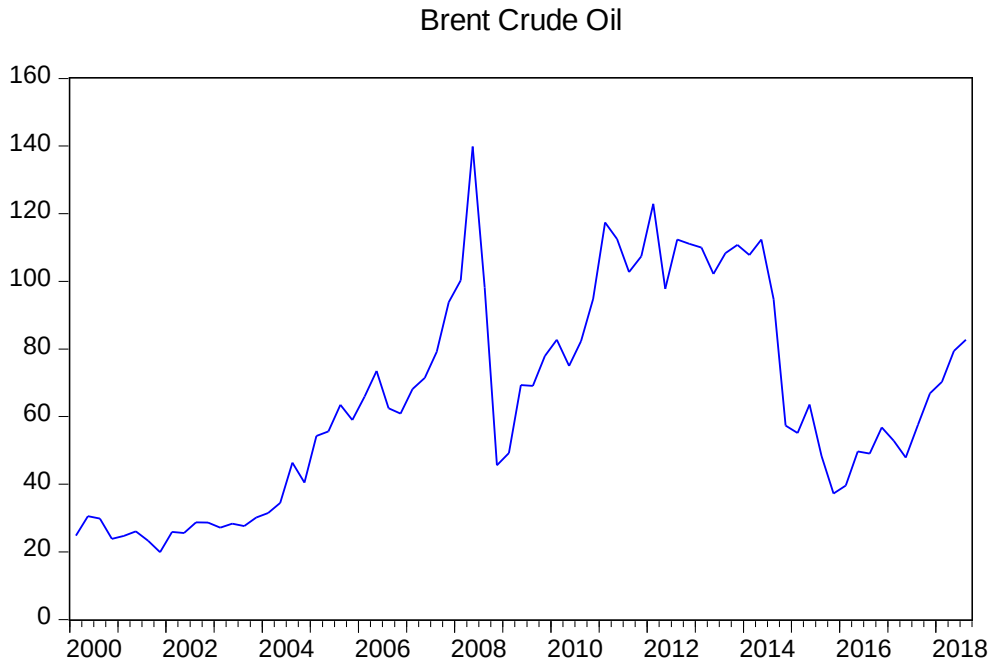


Source: Thomson Reuters Eikon

The final variable is the Price of Global Oil, which would be represented by the quarterly futures price of Brent Crude Oil. It is the most famous and globalized trading sweet light crude oil and it is extracted from the North Sea. The Brent Crude Oil is

largely adopted by the producers in Asia in the early 2000s. Besides, the outstanding crude oil benchmark - WTI Oil would be used as a part of robustness check. Figures 9 and 10 show the trend of quarterly price of Brent Crude Oil futures and the quarterly price of WTI Oil futures. They are moving analogously with glance over the figures. Both of them were having a great upward trend from 2004 to 2008 but turned around during the global financial crisis of 2007–2008. The historical highest level were both between 2006-2008 and it seems that there were a new upward trend after 2017.

Figure 9 – Quarterly price of Brent Crude Oil future



Source: Thomson Reuters Eikon

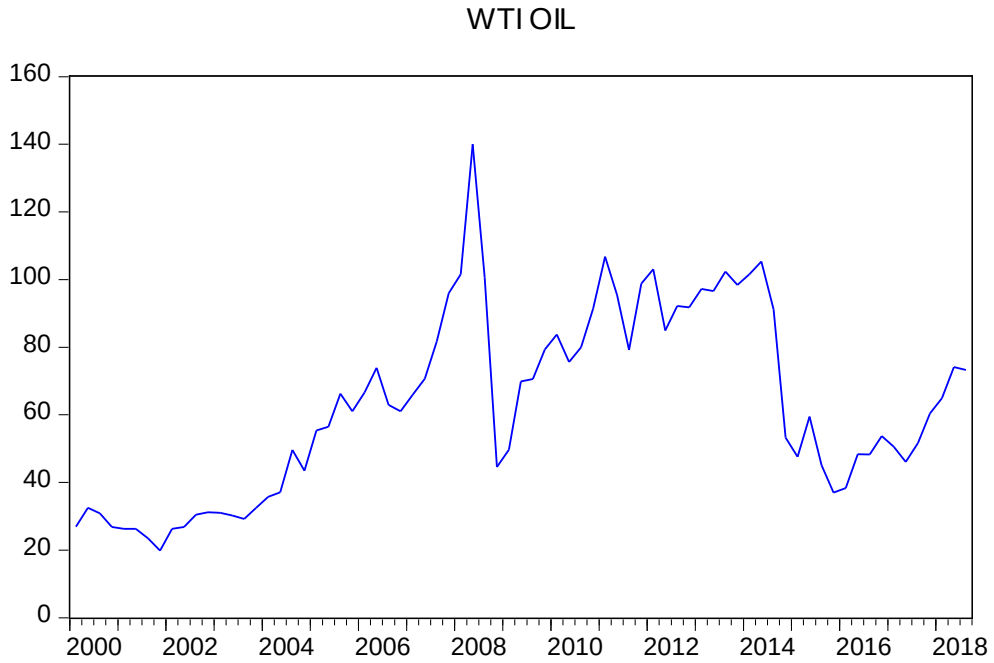
Table 4 – Correlations among selected variables of Thailand

	D(TH_STOCK)	D(TH_INT)	D(TH_INF)	D(TH_USDGDP)
D(TH_STOCK)	1			
D(TH_INT)	-0.1047	1		
D(TH_INF)	-0.2091	0.0726	1	
D(TH_USDGDP)	0.5085	0.0390	-0.2976	1

Table 5 – Correlations among selected variables of Philippines

	D(PH_STOCK)	D(PH_INT)	D(PH_INF)	D(PH_USDGDP)
D(PH_STOCK)	1			
D(PH_INT)	0.0184	1		
D(PH_INF)	-0.1749	0.3437	1	
D(PH_USDGDP)	0.4643	-0.1619	-0.3540	1

Figure 10 – Quarterly price of WTI Oil future



Source: Thomson Reuters Eikon

Before going into the analysis part, stationary test – unit root test must be done in order to avoid the spurious result. It sets Null hypothesis (H_0): $\theta = 0$ and the alternative hypothesis (H_1) is: $\theta \neq 0$. According to Table 6, as all the variable tested t-statistics are larger than the critical t-statistics; thus we do not reject the Null hypothesis and therefore these variables are non-stationary. In this case, we would take a first difference for the non-stationary data and test again. Obviously, all the variables tested t-statistics become smaller than -3.476 and thus reject the Null hypothesis (H_0), meaning that all variables have no unit root and become stationary. Thus, all the data used in the analysis part would be first-differenced variables.

Table 6 – Augmented Dickey-Fuller (ADF) Test Results

Abbrev.	Level (Trend and intercept)	1st difference (Trend and intercept)
TH_STOCK	-2.75953	-7.08182*
TH_INT	-2.66574	-5.07991*
TH_INF	-0.783367	-7.90920*
TH_USDGDP	-2.30744	-8.48307*
PH_STOCK	-2.93586	-6.98995*
PH_INT	-2.77571	-8.09391*
PH_INF	-2.11299	-5.32942*
PH_USDGDP	-3.21717	-7.20974*
BRENT_CRUDE_OIL	-2.14809	-7.51325*
WTI_OIL	-1.81092	-8.15990*

The optimal lag is determined by SIC criteria at a maximum lag of 11 quarters.
* significant at 5% level;

5. Empirical Results

5.1 VAR model

Table 7 – VAR Lag Order Selection Criteria of Thailand

Lag	LR	FPE	AIC	SC	HQ
0	-2156.35	NA	1.51e+21	60.1209	60.3739
1	-2121.62	63.6795*	9.01e+20*	59.6005*	60.3594*
2	-2116.44	8.92219	1.22e+21	59.9011	61.1659
* indicates lag order selected by the criterion					
LR: sequential modified LR test statistic (each test at 5% level)					
FPE: Final prediction error					
AIC: Akaike information criterion					
SC: Schwarz information criterion					

Table 8 – VAR Lag Order Selection Criteria of Philippines

Lag	LR	FPE	AIC	SC	HQ
0	-2222.15	NA	9.42e+21	61.9486	62.0493
1	-2203.23	34.6857*	8.70e+21*	61.8675*	62.1696
2	-2191.015	21.0378	9.72e+21	61.9726	62.4762
* indicates lag order selected by the criterion					
LR: sequential modified LR test statistic (each test at 5% level)					
FPE: Final prediction error					
AIC: Akaike information criterion					
SC: Schwarz information criterion					

According to the result of Table 6, the VAR model in this paper will include first-difference variables. After solving the unit root test problem, the lag length of the VAR model is determined by the following question, as the analysis result would be affected by different lag lengths. From Tables 7 and 8, the test results for Thailand and the Philippines show that the sequential modified LR test statistic (LR), final prediction error (FPE), and Akaike information criterion (AIC) suggest that the optimal lag is one. Therefore, for both the VAR model of Thailand and the Philippines, they should both be constructed as:

$$\mathrm{Y_t} = \beta_0 + \beta_\mathrm{i}\mathrm{Y_{t-1}} + \alpha_i \mathrm{X_t} + \mathrm{u_t}$$

where $\mathrm{Y_t}, \beta_0, \beta_\mathrm{i}, Y_{t-1}, \alpha_i$ and u_t are a vector in 4×1, $\mathrm{X_t}$ is a variable which represents the D(BRENT_CRUDE_OIL) at time t-1. Therefore, the VAR (1) model of Thailand is established as:

$$\begin{bmatrix} D(TH\_STOCK) \\ D(TH\_INT) \\ D(TH\_INF) \\ D(TH\_USDGDP) \end{bmatrix}_t = \begin{bmatrix} C_1 \\ C_2 \\ C_3 \\ C_4 \end{bmatrix} + \begin{pmatrix} \beta_{1,1} & \cdots & \beta_{4,1} \\ \vdots & \ddots & \vdots \\ \beta_{1,4} & \cdots & \beta_{4,4} \end{pmatrix} \begin{bmatrix} D(TH\_STOCK) \\ D(TH\_INT) \\ D(TH\_INF) \\ D(TH\_USDGDP) \end{bmatrix}_{t-1} +$$

$$\begin{bmatrix} \alpha_1 \\ \alpha_2 \\ \alpha_3 \\ \alpha_4 \end{bmatrix} \text{D(BRENT\_CRUDE\_OIL)}_t + \begin{bmatrix} u_1 \\ u_2 \\ u_3 \\ u_4 \end{bmatrix}_t$$

And the VAR(1) model of the Philippines is established as:

$$\begin{bmatrix} D(PH\_STOCK) \\ D(PH\_INT) \\ D(PH\_INF) \\ D(PH\_USDGDP) \end{bmatrix}_t = \begin{bmatrix} C_1 \\ C_2 \\ C_3 \\ C_4 \end{bmatrix} + \begin{pmatrix} \beta_{1,1} & \cdots & \beta_{4,1} \\ \vdots & \ddots & \vdots \\ \beta_{1,4} & \cdots & \beta_{4,4} \end{pmatrix} \begin{bmatrix} D(PH\_STOCK) \\ D(PH\_INT) \\ D(PH\_INF) \\ D(PH\_USDGDP) \end{bmatrix}_{t-1} +$$

$$\begin{bmatrix} \alpha_1 \\ \alpha_2 \\ \alpha_3 \\ \alpha_4 \end{bmatrix} \text{D(BRENT\_CRUDE\_OIL)}_t + \begin{bmatrix} u_1 \\ u_2 \\ u_3 \\ u_4 \end{bmatrix}_t$$

Table 9 – Parameter Estimation for the Thailand VAR (1) Model with Brent Crude Oil

	D(TH_STOCK)	D(TH_INT)	D(TH_INF)	D(TH_USDGDP)
D(TH_STOCK(-1))	0.90419	2.89880**	0.21494	2.56672**
D(TH_INT(-1))	-1.30629	5.40793**	-0.04311	-0.03888
D(TH_INF(-1))	-0.12156	5.06247**	1.25001	-0.16557
D(TH_USDGDP(-1))	-0.21476	-2.46666^^	0.74353	-1.53234
C	1.59593	-2.28515^^	3.94506**	1.93868*
D(BRENT_CRUDE_OIL)	3.36626**	1.78873*	9.26141**	1.39140

** positive significance at 5% level; * positive significance at 10% level;
^^ negative significance at 5% level; ^ negative significance at 10% level

Table 9 shows the results of the VAR(1) model for Thailand's Brent Crude Oil. As a t-test was used in the VAR (1) model, the critical t-statistics would be 1.67 at the 10% significance level and 2.00 at the 5% significance level. The following are the results of the Thailand VAR (1) Model with Brent Crude Oil:

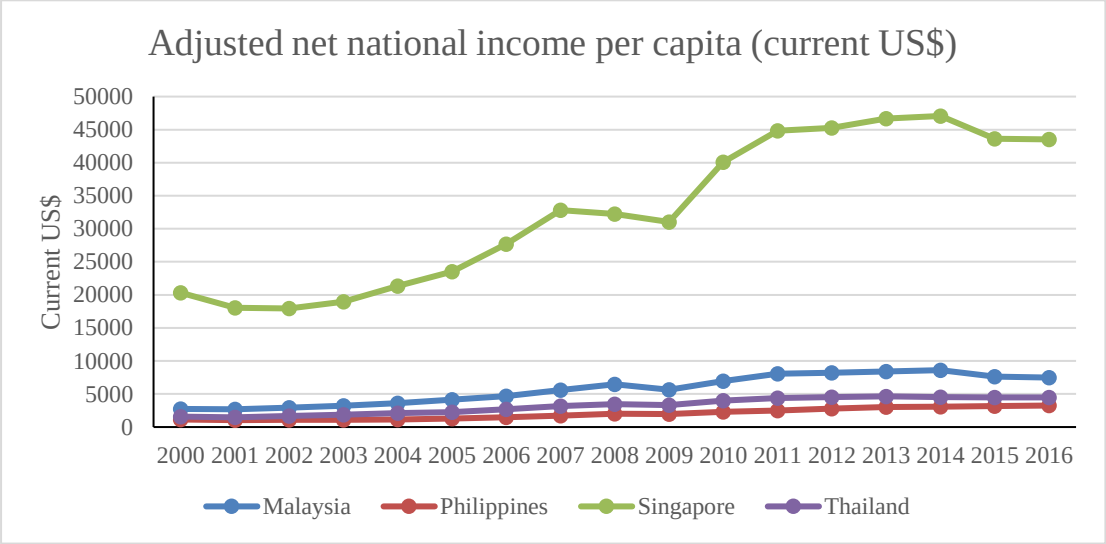
First, D(TH_STOCK (-1)) and D(TH_INF(-1)) are significant variables to explain D(TH_INT) at 5% level. It's well known that while the market is overheated or over-calmed, most of the central banks in the world would change the interest rate to turn

the market into an ideal direction. It is because one of the major duties of each central bank is to mitigate the pressure of over-inflation or over-deflation situations in society, which is generated by local asset and stock price movements. Changing the interest rate is a significant monetary policy to stimulate or cool down the market, as it would change the cost of production and investment. For example, when the interest rate decreases, households and businesses would increase their spending and investment and thus stimulate the financial market and also the inflation rate. Therefore, central banks would raise the interest rate during over-inflation (asset price and stock market boom sharply) or reduce the interest rate during over-deflation (asset price and stock market bust sharply). A paper about Monetary Policy And Asset Price Volatility has been published by Bernanke & Gertle (2000), the paper pointed "Because inflation targeting both helps to provide stable macroeconomic conditions and also implies that interest rates will tend to rise during (inflationary) asset price booms and fall during (deflationary) asset price busts, this approach may reduce the potential for financial panics to arise in the first place." Similarly, for Thailand, when the stock market and inflation rate were rising and going to be higher than the inflation target set by the central bank, the interest rate would therefore react positively under the control of the central bank; vice versa.

Second, according to Table 9, it unexpectedly shows that D(TH_INT(-1)) is not a variable that significantly affects D(TH_STOCK) and even D(TH_INF), which means the change in interest rate does not bring a significant effect on the economy market. A step further, this relationship can also show that controlling interest rate might not be a great method for affecting the financial market and controlling inflation in Thailand. One of the available reasons to explain this rare circumstance is that Thailand is a developing country with low national income per capita and low interest rate pass-through. According to Figure 11, Thailand has low national income per capita compared with Singapore and Malaysia, where the annual national income per capita of Thailand was only USD 6,595. In the paper "Monetary policy and the transmission mechanism in Thailand", it was pointed out that when interest rates fall, the desire by households to raise their spending is limited by their low current earnings (Disyatat & Vongsinsiriku, 2003). This might be a possible reason to explain why the D(TH_INT(-1)) is not a significant

variable affecting the D(TH_STOCK) and the D(TH_INF), as the motivation generated by interest rates cannot affect citizens with low current earnings and wealth.

Figure 11 – Adjusted net national income per capita (current US$)



Source: World Bank Group

Besides the reason for low current income and wealth, the low interest rate pass-through is a reasonable explanation for why the interest rate cannot significantly affect the stock market and inflation rate. Interest rate pass-through means how changes in interest rates would directly affect the retail rates. This factor is important to Thailand as it has limited financial sources and thus the retail rates are equal to the opportunity cost of funds. According to Cottarelli & Kourelis, they tested the degree of pass-through and discovered that the interest rate pass-through of Thailand is smaller and slower than that of the other countries, including Indonesia, Singapore, and the Philippines, in the long run (Cottarelli & Kourelis, 1994). It raised the problem that interest rate movements in Thailand cannot directly affect the opportunity cost of funds and might be a reason why D(TH_INT(-1)) is not a variable that significantly affects D(TH_STOCK) and D(TH_INF). From the insignificant relationship between D(TH_INT(-1)), D(TH_STOCK), and D(TH_INF), we can also say that the monetary policy (especially the part of interest rate control) currently is not the best option for controlling the economy of Thailand, but the channels of credit, exchange rate, or asset price might be better.

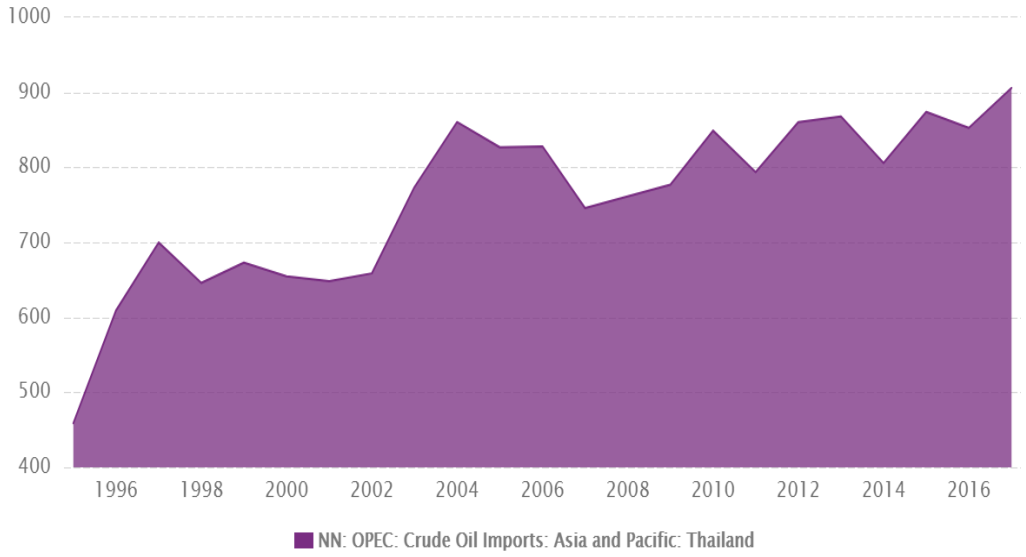
Third, D(TH_INF(-1)) is not a variable that significantly affects D(TH_STOCK); it can be explained as inflation belongs to lagging data, which is usually announced by the government monthly or quarterly. According to Tangjitprom (2011). “Inflation rates are insignificant to determine the stock return. The data about stock return, interest rate,

or exchange rate can be known daily, but inflation rate or unemployment rate need to be waited until the responsible agency reports the calculated number." Therefore, it is commonly believed that the inflation rate is not a significant estimator for explaining the stock market return due to a lag problem.

Fourth, it is not surprising that the D(TH_STOCK(-1)) is the 5% positive significant variable to explain the D(TH_USDGDP). This is because stock market activities are part of investment, and thus the lagged stock market return would most likely have a positive significant effect on the Gross Domestic Product.

More importantly, the D(BRENT_CRUDE_OIL) is a 5% positive significant variable to explain the D(TH_STOCK). Normally, when the global oil price is rising, the cost of production would increase and thus negatively affect the stock market, which means there should be a negative relationship between the change in oil price and the change in stock market return. However, it's not absolutely true for some developing countries, and here are the reasons: First, the composition of Thailand's stock benchmark index would affect the relationship between oil and stock performance. According to the companies listed on the Thailand SET Index, more than 1/5 of companies are directly related to the industry of Energy & Utilities, and most of them are companies for oil generation or power generation with sustainable energy, such as Energy Absolute Plc. (Providing Liquid fuel, Solar and wind power), Glow Group (Electricity Generating via gas, coal-fired and solar power) and Electricity Generating Plc. (Generating electricity using several fuel sources such as natural gas, liquefied natural gas, coal, biomass, hydro, solar, wind, and geothermal) etc. Therefore, when the oil price rose, the revenue and the stock price of these companies would also increase, thus affecting the change of the stock index positively. Moreover, from 2000 to now, Thailand is still classified as a developing country. The oil import numbers might be great evidence to show that even if the price of oil rises, the companies would keep on importing more for production. The oil import numbers of Thailand kept rising from 2000 to now. According to Figure 12, we can easily see that the imports of crude oil by Thailand kept rising, from 458.900 barrel per day in 1995 to 906 barrels per day in 2017.

Figure 12 – Thailand's Crude Oil: Imports from 1995 to 2017



Source: Organization of the Petroleum Exporting Countries

Furthermore, according to Table 9, the D(BRENT_CRUDE_OIL) is a 5% positive significant variable to explain the D(TH_INF) but only 10% positive significant to explain the D(TH_INT). According to the paper written by Cologni & Manera (2008), they raised that in most of the countries, the impact of unexpected oil price movements would bring shocks on interest rates, and also linking with the Fisher effect, the interest rate shocks would finally affect the inflation rate. Therefore, the effect of a change in Brent crude oil price on the change in interest rate should be as significant as the change in inflation rate, but it's not shown in the test's result. In this situation, one of the possible reasons might be that inflation in Thailand is mainly dominated by cost-push factors but not by demand-pull factors. Cost-push inflation means inflation happens mainly due to increases in the cost of wages and raw materials. According to Jongwanich & Park (2009), the empirical analysis result shows that developing Asian countries' current inflation surge is related to external oil and food price shocks, but more related to excess aggregate demand and inflationary expectations. In this case, the change in the price of Brent oil might also give an inflationary expectation to Thai citizens and thus affect inflation more significantly than the interest rate.

Table 10 – Parameter Estimation For the Philippines VAR(1) Model with Brent Crude Oil

	D(PH_STOCK)	D(PH_INT)	D(PH_INF)	D(PH_USDGDP)
D(PH_STOCK(-1))	0.89945	-0.86541	-2.96879^^	1.79780*
D(PH_INT(-1))	0.34351	0.17533	0.74823	-0.27211
D(PH_INF(-1))	-1.50046	0.69875	4.86637**	-0.52552
D(PH_USDGDP(-1))	0.35598	0.16048	2.55873**	-0.01139
C	1.96423*	-0.95443	4.29194**	1.73765*
D(BRENT_CRUDE_OIL)	0.37917	-0.76089	5.90285**	0.77216

** positive significance at 5% level; * positive significance at 10% level;

^^ negative significance at 5% level; ^ negative significance at 10% level

Table 10 shows the results of the VAR(1) Model with Brent Crude Oil of the Philippines. Obviously, the VAR(1) result for the Philippines is different from the Thailand counterpart. As mentioned before, when the stock market and the economic situation are overheated, most of the countries' central banks would control the situation by adjusting the interest rate via monetary policy. However, as shown in Table 10, the D(PH_STOCK(-1)) and the D(PH_INF(-1)) are not significant in explaining the D(PH_INT), which is totally contrary to the result found in Thailand. This circumstance matches the result raised by Bautista (2003), who pointed out that "Except the Philippines, all other countries show significant negative relationship either Interest Rates with Share price or Changes of Interest Rate with Changes of Share Price or both." One of the possible reasons for explaining this insignificant relationship is that the Philippines' monetary policy failed to control the stock market and inflation rate, but only the exchange rate. According to the paper wrote by Yap (1996), it showed that starting from 1970 to 1995, the Philippines government was kept controlling the domestic economy and financial market through tight monetary and fiscal policy; however, according to the viewpoint raised by Gochoco-Bautista and Bautista (2005), Philippines attempted to maintain a stable and strong currency and control the inflation rate at the same time, but given the difficulties of attaining simultaneous monetary and exchange rate targets when capital is internationally mobile, it resulted in a relatively higher and more variable rates of inflation. Therefore, the empirical results in Table 10 support the viewpoint above.

Furthermore, as shown in Table 10, it is shown that D(PH_USDGDP(-1)) and D(BRENT_CRUDE_OIL) are significantly positive variables at 5% to explain D(PH_INF). It means that when the change in crude oil and the lagged change in GDP increased, the change in the inflation rate would follow positively. It might be explained by the viewpoint mentioned by Jongwanich and Park (2009) in the paper "Inflation in developing Asia": the Philippines is a country with limited fuel subsidies, and thus the degree of oil price pass-through to consumer prices is higher. It means that when the oil price shock increased the cost of production, the companies would relatively transfer more of the cost to the consumer and finally push up the inflation rate.

More importantly, the opposite result is found in the Philippines, where the D(BRENT_CRUDE_OIL) is not a significant variable to explain the D(PH_STOCK). For Thailand, there are lots of sustainable energy listed companies in Thailand's stock benchmark index; thus, when the change in Brent Crude Oil rises, the price of the substitute – sustainable energy would rise at the same time and finally lead to a positive effect on the D(TH_STOCK). However, as shown in Table 11, there are only 4 energy-related companies listed on the Philippines PSEi Index; the ratio is far less than that of Thailand and supports the fact that D(BRENT_CRUDE_OIL) is not a significant variable to explain the D(PH_STOCK).

Table 11 – Energy-related companies listed on PSEi Index (2019)

Name	Business
Aboitiz Power Corp (https://aboitizpower.com/)	Generating Run-of-river hydroelectric and large hydroelectric power
First Gen Corporation (https://www.firstgen.com.ph/)	Clean and renewable energy
Manila Electric Company (https://www.meralco.com.ph/#toggle-children)	Electric
Semirara Mining And Power Corporation (http://www.semiraramining.com/)	Coal produce

Furthermore, as shown in Figure 6, although the imports of crude oil exceed the exports of crude oil in the Philippines, the gap is much smaller than Thailand's gap. It reflects the fact that the Philippines' dependency on crude oil is much lower than Thailand's,

and thus the shock of crude oil cannot significantly affect the stock market return in the Philippines.

5.2 Robustness Check Model

As mentioned in the section of Methodology, robustness check would be performed to confirm the accuracy of the VAR(1) model of the Philippines above. First, generate a VAR(1) model with the price of oil as an endogenous variable. As shown in Table 12, the result double confirmed most of the relationships within the VAR(1) model of the Philippines in Table 10. The change in interest rate is still significantly affected by the lagged stock return, the lagged change of local interest rate, and the lagged change of local GDP. The only meaningful difference between Tables 12 and 10 is that the return of Brent crude oil futures is no longer a 5% significant variable to affect the change of local interest rate.

Table 12 – Parameter Estimation for the Philippines *VAR(1)* Model using the price of oil as an endogenous variable

	D(PH_STOCK)	D(PH_INT)	D(PH_INF)	D(PH_USDGDP)	D(BRENT_CRUDE_OIL)
D(PH_STOCK(-1))	0.78862	-0.95907	-3.29201^^	1.70277*	-1.31129
D(PH_INT(-1))	0.41182	0.63545	0.23880	-0.39627	-0.85637
D(PH_INF(-1))	-1.61061	-0.45258	2.04142**	-0.39747	-1.32632
D(PH_USDGDP(-1))	0.31565	-0.32214	2.78705**	0.16232	1.37406
D(BRENT_CRUDE_OIL)	0.61796	1.82460*	1.34720	-0.14230	1.13597
C	2.03890**	0.03148	4.04403**	1.47372	1.10449

** positive significance at 5% level; * positive significance at 10% level;

^^ negative significance at 5% level; ^ negative significance at 10% level

Second, by using another benchmark crude oil futures – WTI crude oil futures, to confirm the accuracy of VAR(1) models of Thailand and Philippines. As shown in Tables 13 and 14, all 5% significant relationships demonstrated in Tables 9 and 10 are confirmed to be correct. Therefore, the relationships between variables shown in Tables 9 and 10 are highly reliable.

Table 13 – Parameter Estimation For the Thailand VAR(1) Model with WTI Crude Oil

	D(TH_STOCK)	D(TH_INT)	D(TH_INF)	D(TH_USDGDP)
D(TH_STOCK(-1))	0.95403	2.92714**	0.35217	2.61081**
D(TH_INT(-1))	-1.10651	5.40790**	0.43313	-0.07422
D(TH_INF(-1))	-0.19249	5.00252**	1.01667	-0.19506
D(TH_USDGDP(-1))	-0.39584	-2.54598^^	0.23627	-1.56936
C	1.69897	-2.21839^^	4.09596**	1.97155*
D(BRENT_CRUDE_OIL)	3.29350**	1.59982	8.67834**	0.72361

** positive significant at 5% level; * positive significant at 10% level;

^^ negative significant at 5% level; ^ negative significant at 10% level

Table 14 – Parameter Estimation For the Philippines VAR(1) Model with WTI Crude Oil

	D(PH_STOCK)	D(PH_INT)	D(PH_INF)	D(PH_USDGDP)
D(PH_STOCK(-1))	0.91246	-0.83482	-3.04761^^	1.73922*
D(PH_INT(-1))	0.37011	0.18109	0.87238	-0.30675
D(PH_INF(-1))	-1.46468	0.68721	5.03967**	-0.53990
D(PH_USDGDP(-1))	0.34050	0.12264	2.63900**	0.06139
C	1.94245*	-0.94975	4.14382**	1.74596*
D(BRENT_CRUDE_OIL)	0.49986	-0.60256	5.83177**	0.41881

** positive significance at 5% level; * positive significance at 10% level;

^^ negative significance at 5% level; ^ negative significance at 10% level

6. Conclusions

This research, it investigates how the benchmark of global oil price and several macroeconomic variables potentially affect the price of the benchmark index in Thailand and Philippines stock markets. VAR model is applied in the research; the result shows that in Thailand, the change in oil future price has a significant effect on the benchmark index return, the change in inflation rate, and the change in interest rate. In the Philippines, the change in oil future price has a significant effect on the change in inflation rate but not on the benchmark index return. It is believed to be related to the index structure and dependency on crude oil.

To conclude, our paper takes the first step to probe the stock market reaction to the global oil price in ASEAN, which is a huge financial market with expanding potential. For future research, it will be meaningful and fascinating to further investigate how the price of energy products would affect ASEAN countries.

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Chapter 3
Is it Worthwhile to Study Competitiveness Indices? Evidence from the Causal Relationship between Global Competitiveness Index and Economic Growth Rate

Chun-Kei Tsang
Sung-Ko Li

Abstract
This paper justifies the use of competitiveness indices in empirical studies by examining the causal relationship between the Global Competitiveness Index (GCI) and economic growth rate. A competitiveness map is introduced to identify outperformers of competitiveness and thus investment opportunities. Adopting a panel Granger-causality test to examine the causal relationship between GCI and economic growth rate in the period 2006-2015, this paper finds evidence of two-way causality between GCI and economic growth rate of most countries in the world. Such a causal relationship breaks down in developing countries. It is explained by the effectiveness of the resource allocation mechanism in generating competitiveness. The paper presents a competitiveness map based on data envelopment analysis to analyze the effectiveness in generating competitiveness. This information is used to identify the best-performing countries based on competitiveness. The study supports the use of GCI to analyze the business environment in different countries for making investment decisions. This approach can be extended to test other existing competitiveness indices. The competitiveness map illustrated in the paper provides an easy and effective screening tool to identify outperformers in terms of competitiveness.

1. Introduction

Porter's (1990) framework of competitiveness and its extensions have been widely applied to the field of business and economics. Researchers believe that there are positive impacts of competitiveness on economic growth and firm performance (see, for example, Cho and Moon, 2013; Martins, 2013; Manzur et al., 1999). Specifically, China and India are two similar countries in that they are large, populous, continental economies that have gone through similar stages of transition and development over the past several decades. Yet China's economy significantly outperformed India's economy, especially in terms of foreign direct investment and economic growth. Schwab (2014, pp. 29 - 31) argued that the competitiveness divide between China and India could explain such differences in economic performance between these two countries. [2]

[2] While China's GDP per capita was lower than India's in 1991, China was four times richer in 2014. India and China ranked 48th and 34th in 2007, respectively. The rank differential has increased from 14 places to 43, with India and China ranked 71 and 28 in the Global Competitiveness Index 2014 - 2015 (Schwab 2014, p. 29), respectively.

The framework of competitiveness has been operationalized by constructing competitiveness indices. Some examples are the global competitiveness index of the World Economic Forum, the world competitiveness ranking of IMD, and the competitiveness index of Southeast Asian countries (Kao et al. 2008). Such indices explore more aspects of a country than a narrow focus on inputs and outputs (Peneder, 2016; Krugman, 1996). At the industry level, competitiveness usually refers to a set of indicators that may lead to the success of an industry in the international market (see, for example, Braddorn and Hartley, 2007; Mitchell and Stewart, 2007). At the national level, although there are different kinds of measurements, competitiveness usually refers to a set of indicators that will create more prosperity for an economy, which results in higher economic growth (Bris et al., 2014, p. 489-491; Frontier Economics Limited, 2013, p. 23; Ni, 2012, p. 21-23).

The positive effects of competitiveness on economic performance are supported by some empirical studies such as Li and Tsang (2018), Farinha et al. (2018a), Waheeduzzaman (2011), Fagerberg et al. (2007), and others. Individual aspects of competitiveness also can influence a country's economic growth. For examples, 'location and timing' could explain the difference of economic development between China and India (Prime, Subrahmanyam, and Lin, 2012); institutional environment is important for firm growth (Hadjikhani, Lee, & Ghauri, 2008); endowment of resources helps to exploit business opportunities (Grosse and Trevino, 2005); quality labor promote the development of innovative ideas (Barro, 1991).

The underlying assumption of the previous applications is: National competitiveness contributes to firm performance in the country, which in return drives economic performance of the whole economy. However, the usefulness of competitiveness indices is still under debate (see, for example, Peneder, 2016; Hay, 2012; Lall, 2001).
A less mentioned but important view is that the relationship between competitiveness and economic performance may go in the reverse direction, in which competitiveness can be a result of economic performance. This has been noted by Bris et al. (2014, p. 493) in the IMD World Competitiveness Yearbook. In the construction of the competitiveness indices, some determinants of economic performance are also included. [3] On the other hand, each competitiveness index also consists of many components not directly related to economic performance.

Whether competitiveness can empirically forecast economic performance or vice versa has not been studied seriously in the literature. This paper uses the Global Competitiveness Index as a proxy of competitiveness to investigate the causality between competitiveness and economic performance. This study is significant because if a competitiveness index is able to forecast long-term economic performance, then it

[3] Appendix I lists examples of such determinants as components in several indices.

provides an effective tool for researchers and practitioners to study and identify business opportunities across countries. Otherwise, the usefulness of constructing competitiveness indices is greatly reduced. Conversely, if better economic performance causes higher competitiveness, then the endogeneity of competitiveness must be considered in empirical studies. This paper further indicates that the causality pattern is different for developing and developed countries. Such a difference can be explained by the different abilities of developing and developed countries in transforming resources into competitiveness in. Finally, the information of studying competitiveness indices is useful to draw a competitiveness map for identifying investment opportunities.

2. Empirical design and Hypotheses

As mentioned previously, our primary objectives are to test whether competitiveness index empirically causes economic performance or vice versa. Thus, our hypotheses are:
Hypothesis 1 (H1): Competitiveness causes economic performance.
Hypothesis 2 (H2): Economic performance causes competitiveness.

If H1 is supported, it means economic performance is an outcome of competitiveness. Then researchers and practitioners may apply the concept of competitiveness to forecast the economic performance of a country and identify valuable business opportunities. On the other hand, if H2 is supported, it means economic performance is a cause of competitiveness. Then this relationship should be noticed in empirical studies when competitiveness indices are involved.

3. Data

This paper uses data from two sources: competitiveness (C) in the analysis is represented by the Global Competitiveness Index (GCI) from the Global Competitiveness Report of the World Economic Forum. The economic performance (g) is reflected by the growth rate of the GDP per capita (constant 2005 US$) adopted from World Development Indicators of the World Bank. For data consistency and availability, the studied period is from 2006 to 2015 [4] and 109 countries in the Global Competitiveness Report are covered.

In addition to testing the causality between economic performance and competitiveness for all countries as a group, we also study such a relationship with respect to development stages. All countries in the data set are partitioned into three different subgroups. The GCI data already predefined three country groups, factor-driven

[4] The values of GCI in the Global Competitiveness Report 2015 - 2016, for example, are treated as data in 2015. Since the methodology of GCI has been revised in recent years and the length of new GCI data is insufficient to carry out the study, only the original version of GCI data is included for data consistency.

economies (S1), efficiency-driven economies (S2), and innovation-driven economies (S3), and two transitional groups between S1 and S2, S2 and S3. [5] Since transitional groups have relatively small samples for conducting group individual tests, we combined them with their "higher" groups. Thus, in the following, group S2 includes countries in transition from S1 to S2 and group S3 includes countries in transition from S2 to S3. The descriptive statistics of the variables are listed in Table 1:

Table 1: Descriptive Statistics

All (n = 1090)	Max	Min	Mean	Std
C	5.80	2.58	4.29	0.66
g	0.3303	-0.1887	0.0232	0.0404
S1 (n = 390)	Max	Min	Mean	Std
C	4.90	2.58	3.72	0.41
g	0.3303	-0.1887	0.0349	0.0416
S2 (n = 320)	Max	Min	Mean	Std
C	5.23	3.48	4.21	0.28
g	0.1292	-0.1386	0.0284	0.0364
S3 (n = 380)	Max	Min	Mean	Std
C	5.80	3.85	4.96	0.48
g	0.2564	-0.1515	0.0068	0.0368

4. Method

The test of causal relationship between two variables in time series data has been well-developed since it was introduced by Granger (1969). Starting in the 2000s, researchers have been testing Granger causality in panel data, see Habibullah and Eng (2006), Hartwig (2010, 2014), among others. To test hypothesis H1 of "Competitiveness (C) causes economic performance (g)", the null hypothesis of the relevant Granger causality test is "C does not Granger cause g". Given that both series are stationary, the null hypothesis can be rejected if the inclusion of lagged values of C significantly reduces the predictive error variance of g (Hamilton, 1994). In this case, competitiveness C is said to Granger-cause economic performance g and hypothesis H1 is supported by the data. The causality from g to C can be studied likewise, and hypothesis H2 can be tested.

Although there are many modified versions of the Granger-causality test, applying Granger-causality test in short panel data still relies on the classical Granger model. This paper adopts the approach proposed by Hartwig (2014), which was initiated by Holtz-Eakin et al. (1988). In the testing model, all regression coefficients of lagged g and C are assumed to be the same across various time periods and across different

[5] We note that the World Economic Forum has changed the methodology of GCI in recent years.

countries. All countries are classified into N different groups to represent their development stages. Also, the catching-up effect is further controlled by the initial output level of each country. [6]

In order to test for pairwise Granger-causality between the two series C and g, they must be stationary. We follow Hartwig's (2014) steps to test for unit root. The results of panel unit root tests are reported in Table 2.

Table 2: Test for unit root

H_0: Unit root in level	C		g	
	Stat.	Prob.	Stat.	Prob.
Levin, Lin & Chu t*	-13.08	0.0000	-24.40	0.0000
Im, Pesaran, and Shin W-stat	-2.94	0.0000	-12.66	0.0000
ADF - Fisher Chi-square	292.28	0.0000	586.90	0.0000
PP - Fisher Chi-square	284.59	0.0000	624.30	0.0000

Table 2 shows that the null hypothesis of non-stationarity for C and g can be rejected. Thus, C and g are stationary time series, and the estimations of Granger causality using C and g are valid.

5. Results

5.1 Initial estimations

Pairwise Granger Causality is then tested for all countries, allowing for group-specific effects for the three groups (S1, S2, and S3), and including one time lag to five time lags in the regression equation. The results are presented in Table 3.

Table 3: Pairwise Granger Causality Tests of all countries with group-specific effects (S1 cross-section=39, S2 cross-section=32, S3 cross-section=38, time: 2006-2015)

$C \nrightarrow g$		$g \nrightarrow C$		Lags	Obs.
9.3728	*	4.6886	*	1	987
6.8246	*	9.1693	*	2	872
7.9903	*	6.4458	*	3	763
2.2806		4.4541	*	4	654
3.8621	*	9.5909	*	5	545

Note: F-Statistic is displayed. * denotes significance at the 5% level.
$A \nrightarrow B$: A not Granger Cause B

The first column of Table 3 is for testing hypothesis H1. The null hypothesis is that "C does not Granger cause g", which is rejected at the 5% level of significance in four out of the five lag structures. This means that the null hypothesis can be rejected and the claim of H1 ("C causes g") is supported by the data. On the other hand, the results of

[6] See Appendix II for the detailed model setting.

testing the converse causal relation are shown in the second column. The null hypothesis that "g does not Granger cause C" is rejected at the 5% level of significance for all lags. Hypothesis H2 that "g causes C" can also be supported by the data. In conclusion, both hypotheses H1 and H2 can be confirmed by the data. There is a two-way causal relationship between competitiveness and economic growth. Thus, forecasting economic performance using the competitiveness index (GCI) is valid. Conversely, it is also valid that better economic performance leads to a higher value of the competitiveness index.

The rationale behind the first causal relationship is simple. If the competitiveness index reflects the potential capability of a country that contributes to firm performance in the country, then a higher economic growth rate is a natural consequence of a higher value of the competitiveness index.

The impacts of economic growth on the competitiveness index are more complicated. A higher economic growth rate can provide additional resources. On the one hand, such new resources can be used to produce more consumption goods. On the other hand, new resources can be devoted to promoting the competitiveness of the country by nurturing a better society and creating new technologies. Whether additional resources brought by economic growth are used to enhance competitiveness is an investment issue. It depends on the mechanism of resource allocation in society. Thus, theoretically, a higher economic growth rate may or may not bring forth higher competitiveness. Such a relationship deserves further investigation.

5.2 Estimations on developing and developed countries

We note that the factor-driven economies (group S1) and efficiency-driven economies (group S2) mainly focus on traditional production of manufactured goods and services. In contrast, implementing new technologies from research and development is emphasized in innovation-driven economies (group S3). This difference in economic structure may be critical for the relationship between economic performance and competitiveness, as mentioned by Farinha et al. (2018b). Accordingly, all countries in the dataset are classified into two broad categories: developing countries (S1 and S2) and developed countries (S3). We believe that the ability to transform additional resources into competitiveness is relatively weak in developing countries. We further test for Pairwise Granger Causality for these two groups, and the results are reported in Table 4.

The upper panel of Table 4 lists test results for developing countries. The null hypothesis of "C does not Granger cause g" in the first column can be rejected at the 5% level of significance for all lag structures. On the other hand, there is no overwhelming evidence to reject the hypothesis of "g does not Granger cause C" in the second column. This hypothesis can be rejected only for the regression equations

with two lags and five lags. We can conclude for developing countries that H1 is supported by the data while H2 is not. In other words, competitiveness Granger-causes economic growth rate in developing countries but not vice versa.

Table 4: Pairwise Granger Causality Tests for Institutions and Economic Growth

Developing Countries[#]					
$C \nrightarrow g$		$g \nrightarrow C$		Lags	Obs.
3.9296	*	2.4865		1	639
3.9669	*	4.0657	*	2	568
5.4814	*	2.4346		3	497
2.4676	*	2.3168		4	426
4.5314	*	4.3564	*	5	355
Developed Countries					
$C \nrightarrow g$		$g \nrightarrow C$		Lags	Obs.
9.4327	*	5.5821	*	1	342
6.4578	*	11.7095	*	2	304
5.1597	*	8.9136	*	3	266
2.7487	*	6.0935	*	4	228
0.9911		8.8381	*	5	190

Note: F-Statistic is displayed. * denote significance at the 5% level.
$A \nrightarrow B$: A not Granger Cause B
#Since two groups are involved, one dummy is included in Pairwise Granger Causality Tests to capture group-specific effects

The lower panel of Table 4 lists test results for developed countries. Both null hypotheses "C does not Granger cause g" and "g does not Granger cause C" can be rejected at the 5% level of significance except for the regression equation with 5 time lags in the first column. The two-way causal relation in the previous section holds for the developed countries.

Therefore, forecasting economic performance using the competitiveness index is valid in both developing countries and developed countries. However, better economic performance only leads to a higher value of the competitiveness index in developed countries but not in developing countries. These results support the use of competitiveness indices in predicting economic performance and identifying business opportunities in both developing countries and developed countries. However, different results for H2 in developing countries and developed countries suggest there is a fundamental difference in economic structure between them. This difference should be noticed when using competitiveness indices. We will further study this difference and its implications in the following section.

5.3 Estimations on sub-indices

In order to have a clear picture of the relationship between the competitiveness index

and economic performance, we further estimate the results for different sub-indices of competitiveness. The GCI is constructed from three sub-indices, namely, "basic requirements", "efficiency enhancers" and "innovation and sophistication factors". [7] It is well-known from Porter (1990) that the needs in development shift as a country develops. That means developing countries should focus more on basic requirements or efficiency enhancers while developed countries should focus more on efficiency enhancers or innovation and sophistication factors. We expect different results could be obtained from different sub-indices of competitiveness in different country groups. Thus, we test for Pairwise Granger Causality for different sub-indices of GCI in developing and developed countries. The results are reported in Table 5:

Table 5: Pairwise Granger Causality Tests for Different Types of Institutions

Developing Countries#												
$C_A \nrightarrow g$		$g \nrightarrow C_A$		$C_B \nrightarrow g$		$g \nrightarrow C_B$		$C_C \nrightarrow g$		$g \nrightarrow C_C$		Lags	Obs.
3.8018		0.5389		1.9525		36.9541	*	0.2046		8.8595	*	1	639
3.4884	*	2.6810		2.2968		27.6713	*	0.6568		4.3568	*	2	568
6.1068	*	1.8835		3.3635	*	13.5865	*	0.7568		4.9293	*	3	497
3.4196	*	3.5049	*	1.1569		9.8461	*	0.4754		3.3658	*	4	426
5.1092	*	5.5012	*	1.5666		7.0209	*	1.1234		0.1748		5	355
Developed Countries													
$C_A \nrightarrow g$		$g \nrightarrow C_A$		$C_B \nrightarrow g$		$g \nrightarrow C_B$		$C_C \nrightarrow g$		$g \nrightarrow C_C$		Lags	Obs.
3.6575		0.0753		10.2608	*	17.2692	*	8.0459	*	14.2350	*	1	342
4.0908	*	8.5807	*	6.7339	*	14.3167	*	5.6987	*	13.7471	*	2	304
6.3519	*	5.1485	*	6.1057	*	10.9371	*	3.3286	*	9.7822	*	3	266
1.1315		2.7317	*	2.6363	*	8.9075	*	3.0509	*	7.0639	*	4	228
0.4209		7.3686	*	1.2457		6.6441	*	0.9655		3.1702	*	5	190

Note: F-Statistic is displayed. * denotes significance at the 5% level.
C_A: Basic Requirements
C_B: Efficiency Enhancers
C_C: Innovation and Sophistication Factors
$A \nrightarrow B$: A not Granger Cause B
#Since two groups are involved, one dummy is included in the Pairwise Granger Causality Tests to capture group-specific effects

The first and second columns in Table 5 show the relationship between basic requirements and economic growth rate in developing countries and developed countries. It shows that "basic requirements cause economic growth" only appears in developing countries, whereas "economic growth causes basic requirements" only appears in developed countries. The third and fourth columns show the relationship between efficiency enhancers and economic growth rate in developing countries and developed countries. Although economic growth Granger-causes efficiency enhancers in both developing and developed countries, efficiency enhancers causing economic

[7] See Appendix III for the details of sub-indices of GCI.

growth only appear in developed countries. The fifth and sixth columns show the relationship between innovation and sophistication factors and economic growth rate in developing countries and developed countries. Similar to the efficiency enhancers, the causality from innovation and sophistication factors to economic growth only appears in developed countries, whereas the causality from economic growth to innovation and sophistication factors appears in both developing and developed countries. Thus, forecasting economic performance by the basic requirements sub-index is only valid in developing countries, while forecasting economic performance by the sub-indices of efficiency enhancers and innovation and sophistication factors is only valid in developed countries. As completely different results are obtained for the three sub-indices, these results provide further information to predict economic performance and identify business opportunities in developing countries and developed countries. For example, in considering investment in a developing country, one could pay special attention to the basic requirements sub-index besides the GCI.

5.4 Searching Investment Opportunities through Data Envelopment Analysis on Competitiveness

In the previous section, GCI and its sub-indices are able to predict economic performance. The converse relation is said to be an empirical issue. The fundamental argument behind the causality from economic growth to competitiveness is that transforming economic growth to competitiveness requires a mechanism to allocate resources efficiently and appropriately. This refers to the effectiveness of the government of a country in enhancing competitiveness. When competitiveness can cause economic growth, as shown by the Granger causality tests in the previous section, enhancing competitiveness by mobilizing additional resources from economic growth can stimulate further growth in the future. Thus, the ability to put resources in the right place to enhance competitiveness is also crucial for long-run sustainable growth. This has two implications: (i) Effective resource allocation is a condition of the causality from economic performance to competitiveness. (ii) Since efficient allocation of resources affects future economic growth, a good mechanism of resource allocation can be used as an additional criterion to supplement investment decisions.

This section investigates the reason behind the causal relation from economic growth to competitiveness in more detail by applying the method of Data Envelopment Analysis (DEA). It also explores further the difference between developing and developed countries from the angle of resource allocation. A new tool is then introduced to supplement investment decisions.

5.5 The mechanism of transforming resources into competitiveness

Given some new resources generated from economic growth, such resources can be allocated in two different ways. On the one hand, new resources can be utilized in

sectors not related to competitiveness. This will have minimal effect on future economic growth. On the other hand, the competitiveness of an economy can be reflected by various dimensions. Each dimension is a sector of the economy. New resources can be devoted to different sectors of the economy. This may increase competitiveness and can generate future economic growth. Whether there is higher competitiveness and growth depends on the efficiency of allocating such resources and the appropriateness of such allocation.

Each pattern of competitiveness dimensions is called an economic structure. Behind each economic structure there is an allocation of resources. As competitiveness causes economic performance, there should exist an optimal economic structure that maximizes competitiveness and thus economic growth. For example, the resource allocation in an economy with a large manufacturing sector and a small service sector is very different from an economy with a small manufacturing sector and a large service sector. Thus, these two economies should have completely different optimal economic structures. Allocating resources according to the optimal economic structure is best for future economic growth. A suboptimal structure indicates that there is room for higher economic growth by improving competitiveness through reallocating resources. Thus, allocating resources towards the optimal economic structure should be a major focus of economic policy (Skoorka, 2000).

Our view of the importance of resource allocation is consistent with conventional views in the literature. For example, Wong (2008) examined provinces of China and concluded that allocation of resources is also an important factor of growth. Another example is the hot debate of the "curse of natural resources" on economic development. Daniele (2011) concluded that the effect of resources on economic growth strictly depends on national institutional characteristics. The economies of some oil-exporting countries are influenced by the fluctuations of the oil market. This reflects their inability to build up competitive industries using their oil money. The mechanism from allocation of resources to economic growth is explained in mainstream studies of economic growth by effective allocation of resources into appropriate sectors. For example, Lucas (1988) and Grossman and Helpman (1994) suggested that some resources should be allocated to physical capital and human capital accumulation, research and development, and innovation, etc. In the framework of this paper and GCI, that is equivalent to directing resources to pillars such as “higher education and training” and “innovation”. This increases the competitiveness of a country and then boosts economic growth.

There are twelve dimensions in the GCI (called pillars in the Global Competitiveness Report) that represent various aspects of a country, such as infrastructure, macroeconomy, goods and labor markets, financial markets, and others. The composition of these dimensions can be a good proxy for the economic structure of a country and can be used to study the effectiveness of resource allocation. By retrieving

the information of subindexes from GCI, we will be able to compare the resource allocation of different countries under the competitiveness aspect.

5.6 Data envelopment analysis for competitiveness index

Based on the results in previous subsections, we suspect that the impacts of economic growth on competitiveness are different for countries under different mechanisms of resource allocation. Specifically, we question the ability of developing countries to direct additional resources to strengthen their competitiveness. To confirm this, we adopt a new approach to study the GCI.

Borrowing the idea of Li and Tsang (2018), Li and Zhao (2015), and Bowen and Moesen (2011), we hypothesize that each country utilizes resources to generate competitiveness. Each dimension of the GCI is treated as an output. Each weight used in the computation of the competitiveness index is regarded as the "price" of each dimension. Accordingly, the competitiveness index is like the "revenue" of a firm and can be evaluated by Data Envelopment Analysis (see, for example, Laureti and Viviani, 2011). To make developing and developed countries comparable, we further modify their model by incorporating a resource constraint, a country's GDP per capita (in natural log form) as an input. Using the variable returns to scale (VRS) frontier, we can compute an index of the *efficiency of overall competitiveness* (O_c), which measures the loss in competitiveness compared to the best performer.

As shown in Li and Tsang (2018) and Li and Zhao (2015), this efficiency of overall competitiveness can be eliminated by expanding all dimensions proportionally or by changing dimension mix. The first component is measured by the *efficiency of proportional competitiveness* (E_p) and the second component is measured by the *efficiency of dimension mix* (E_d). Thus, the potential of improving overall competitiveness as indicated by the efficiency of overall competitiveness (O_c) can be decomposed into the efficiency of proportional competitiveness (E_p) and the efficiency of dimension mix (E_d), i.e. $O_c = E_d E_p$. [8] By definition, O_c, E_d, and E_p are greater than or equal to one, in which a larger value represents higher inefficiency. Given existing resources, $O_c > 1$ means that a country is possible to increase her competitiveness. This can be achieved in two ways: expanding all dimensions proportionally (if $E_p > 1$) or changing the relative proportions among dimensions (if $E_d > 1$). Specifically, E_p represents the efficiency of utilizing resources to achieve competitiveness whereas E_d represents the ability of allocating resources according to the optimal dimension mix. Thus, to generate competitiveness, a high value of E_p means a low efficiency of utilizing resources and a high value of E_d means a low efficiency of allocating resources correctly.

[8] See Appendix IV for the derivation of O_c, E_d, and E_p.

The annual geometric means of the efficiency scores for developing countries and developed countries in the years 2011-2015 are reported in Table 6. [9] The average efficiency of proportional competitiveness in the developing group (around 1.06) is significantly higher than that of the developed group (around 1.02). This means developing countries are farther away from the competitiveness frontier and have more room to catch up to the frontier countries. On the other hand, the average efficiency of the dimension mix of the developing group (around 1.15) is also significantly higher than that of the developed group (around 1.10). This means the developing group also has more room for improvement in adjusting the dimension mix, which means a different economic structure is required for improving competitiveness. If the pattern of competitiveness dimensions reflects economic structure, our results confirm that developing countries are weak in directing additional resources to the right sectors to enhance competitiveness.

Table 6: Efficiency Scores for Two Country Groups

Year	2011	2012	2013	2014	2015
Efficiency of proportional competitiveness (E_p)	*	*	*	*	*
Developing countries	1.06	1.06	1.05	1.05	1.06
Developed countries	1.02	1.02	1.02	1.02	1.02
Efficiency of dimension mix (E_d)		*	*	*	*
Developing countries	1.13	1.14	1.14	1.14	1.17
Developed countries	1.10	1.10	1.10	1.10	1.10

Note: Geometric means are shown.
* denote significance difference between the two groups at the 5% level in an independent samples T-test.

5.7 The competitiveness map

As argued before, the efficiency of dimension mix reflects the ability of allocating resources to the right places. In the presence of economic growth, a country with high efficiency of dimension mix should be able to allocate any additional resources correctly. This implies higher competitiveness and more future economic growth. Therefore, a country with higher efficiency of dimension mix is expected to have a more sustainable economic growth in the long run than another country with low efficiency of dimension mix. Seeking global investment opportunities, a company can add higher efficiency of dimension mix as a complementary criterion.

Based on the decomposition of the GCI by DEA, we further map the two components of different countries for comparison. As the level of development (real GDP per capita) is already controlled in the process of decomposition, the E_p and E_d obtained are directly comparable. For illustration, the values of E_p and E_d are presented as 5-year

[9] Different dimension weights are used in different groups following the GCI report. Since dimension weights of transitional groups in older years are missing, only results for 2011 - 2015 are computed.

averages of 2011-2015 and inverse indices (i.e., ranged from 0 to 1, where 1 is the best). We then map the $1/E_p$ and $1/E_d$ to identify investment opportunities (See Figure 1 and Appendix V). This diagram is called the *competitiveness map*.

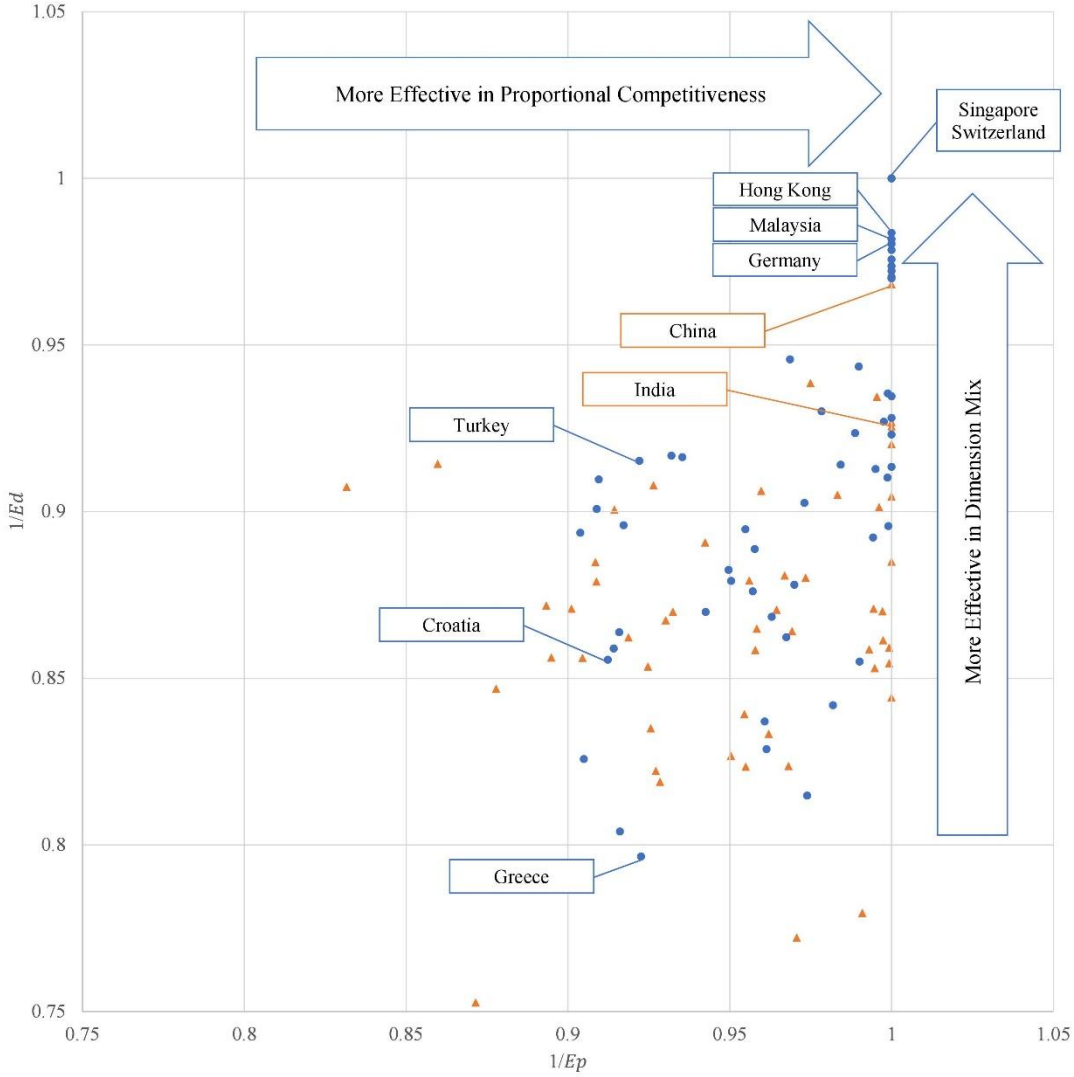
The competitiveness map, which is based on decomposing the competitiveness index, can be used to identify outperformers in terms of proportional competitiveness and dimension mix. In Figure 1, moving rightward means improving the efficiency of proportional competitiveness, whereas moving upward means improving the efficiency of dimension mix. For a country on the map, it is outperformed by any country in its upper-right region. Therefore, the best-performing countries are in the upper-right corner of the competitiveness map, whereas the worst-performing countries are in the lower-left corner. The five best-performing countries in terms of the efficiency of overall competitiveness (O_c) are identified in Figure 1: Singapore, Switzerland, Hong Kong SAR, Malaysia, and Germany. These countries are also identified by other rankings as good business opportunities. For example, Forbes Best Countries for Business 2018 ranked Hong Kong SAR and Singapore as 3rd and 8th out of 161 countries [10], U.S.News & World Report Best Countries Ranking 2019 ranked Switzerland and Germany as 1st and 4th out of 80 countries [11]. Moreover, we further incorporate an adjustment for resource constraints to overcome part of the drawback in which previous competitiveness rankings tend to overrate high-income countries and underrate low-income countries. Thus, our result also identifies Malaysia as a good investment opportunity.

In practical applications, one may use the competitiveness map to compare some selected countries' investment opportunities. For instance, consider Greece, Croatia, and Turkey. They are all located in the Balkan region with a similar value of $1/E_p$ (0.92, 0.91, 0.92). However, for $1/E_d$, we have Greece (0.80) < Croatia (0.86) < Turkey (0.92). Hence, Turkey is a better country to invest in these three countries. Another example is the comparison between China and India. They have the same value of $1/E_p$ (1.00, 1.00) but different $1/E_d$ (0.97, 0.93). It shows that China has a better investment opportunity compared with India. Similarly, one may conduct a comparison using $1/E_p$. The competitiveness map gives us an easy and effective screening tool to identify outperformers in terms of competitiveness for further investigation.

[10] Forbes Best Countries for Business 2018, retrieved on 16/08/2019 from https://www.forbes.com/best-countries-for-business/list/#tab:overall

[11] U.S.News & World Report Best Countries Ranking 2019, retrieved on 16/08/2019 from https://www.usnews.com/news/best-countries/overall-rankings

Figure 1: The Competitiveness Map



Note: ▲: Developing countries; ●: Developed countries; See Appendix V for the data

5.8 Robustness check

Finally, we estimate the effects of E_p and E_d on economic growth as a robustness check. If the value of E_p and E_d truly reflects the performance of a country, E_p and E_d should hurt economic growth. The panel regression results for E_p and E_d on economic growth is shown in Table 7:

Table 7: Panel Regression Results for E_p and E_d

	Dependent variable: g	
	Model A	Model B
E_p	-0.1034*	-0.1132*
	(0.0499)	(0.0492)
E_d	-0.1033*	-0.1260*
	(0.0425)	(0.0422)
Y_{t-1}	-	-7.02E-06*
		(1.82E-06)

Constant	0.2463* (0.0832)	0.4058* (0.0918)
Adj R-squared	0.3856	0.4047
n	545	545

Note: Cross-section and Period fixed effects included. * denotes significance at the 5% level. Numbers in brackets represent standard errors of the coefficient.

In Table 7, Model A estimates the effects of E_p and E_d on economic growth. Model B further controls for the real GDP per capita in the previous year for comparison. As shown in Table 7, all coefficients in both models are significant. In particular, the negative sign of the coefficient of E_p and E_d suggests 1 percentage point increase $(+0.01)$ in inefficient proportional competitiveness and inefficient dimension mix will result in at least a 0.1 percentage point decrease (-0.001) in the economic growth rate. These results confirm our claim that inefficiency in directing additional resources to enhance competitiveness has a negative effect on economic growth. As in previous sections, we have already concluded that the competitiveness index could be used to forecast economic performance. Thus, decomposing the competitiveness index can further facilitate identifying investment opportunities easily.

6. Conclusions

Researchers of competitiveness tend to believe that higher competitiveness will lead to better economic performance in the long run. This paper, using the Global Competitiveness Index as a proxy for competitiveness, provides evidence to support this conjecture. Further, we discuss the relation between using the competitiveness index and investment. Thus, a well-constructed competitiveness index is helpful to forecast the economic performance of a country and can be used to identify investment opportunities for multinational corporations. In fact, when there are sufficient data, testing whether a competitiveness index can Granger-cause economic growth rate can be regarded as a test of the appropriateness of that index to reflect the competitiveness of a country. Since one major purpose of studying competitiveness is to find ways to promote economic growth, failure to Granger-cause economic growth by a competitiveness index can be seen as disqualifying such an index to reflect the competitiveness of a country.

On the other hand, whether better economic performance can enhance the competitiveness of a country is less straightforward. We believe that strong economic growth can provide resources and an environment to nurture a better society and create new technologies, which in turn promote the competitiveness of the country. However, this requires a mechanism to allocate resources efficiently and appropriately.

Developed countries are more advanced in production technologies, market systems, and public management. Thus, they are more efficient in resource allocation. It is not surprising that, as found in this paper, they become more competitive through economic

growth. In contrast, it is found that economic growth does not Granger-cause competitiveness in developing countries. These countries are lagging in social institutions, market mechanisms, and others. Thus, they are less efficient in resource allocation.

The information on efficiency scores of competitiveness is used to draw the competitiveness map, which identifies outperformers in terms of proportional competitiveness and dimension mix. The map is especially useful as a screening tool for studies of competitiveness and international business. This method can be applied to other competitiveness indices, and that deserves further study.

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Appendix I: Growth Determining Factors Included in the Definition of Competitiveness Index

Competitiveness index	**Variables that reflect economic growth**	**Source**
Global Competitiveness Index	GDP (PPP $billions) (Market size)	World Economic Forum
World Competitiveness Yearbook	Real GDP growth per capita (Economic performance)	IMD World Competitiveness Center
EU Regional Competitiveness Index	Potential GDP in PPS (Potential market size expressed in GDP (pps), index EU28 = 100)	European Commission Joint Research Centre Institute for Security and Protection of the Citizens
European competitiveness index	GDP per capita (economic performance)	Centre for International Competitiveness
Overall competitiveness of China's provincial economy	Provincial GDP, GDP growth rate	The Chinese Academy of Social Sciences

Appendix II: The Panel Granger-causality Test

The data involve the value of a competitiveness index and economic growth rate of country i at time t: C_{it} and g_{it}, $i = 1, \dots, I$, $t = 0,1, \dots, T$. Given that both variables are stationary, the competitiveness index C is said to fail to Granger-cause g if the inclusion of lagged values of C does not significantly reduce the predictive error variance of g. That is, the mean squared error (MSE) of a forecast of g_{t+1} based on the information set of $(g_t, g_{t-1}, \dots)$ is the same as the one which uses both $(g_t, g_{t-1}, \dots)$ and $(C_t, C_{t-1}, \dots)$. In particular (Hamilton, 1994),

$$\mathrm{MSE}[\mathrm{E}(g_{t+1}|g_t, g_{t-1}, \dots)] = \mathrm{MSE}[\mathrm{E}(g_{t+1}|g_t, g_{t-1}, \dots; C_t, C_{t-1}, \dots)]. \qquad (A1)$$

Conversely, competitiveness index C Granger-causes economic growth g if the right-hand side of (A1) is larger. The causality from g to C can be studied likewise. The bivariate vector autoregressive (VAR) model with MA(K) describing C and g is:

$$\begin{bmatrix} g_{it} \\ C_{it} \end{bmatrix} = \begin{bmatrix} \alpha_1 \\ \alpha_2 \end{bmatrix} + \sum_{k=1}^{T} \begin{bmatrix} \gamma_{11}^{(k)} & \gamma_{12}^{(k)} \\ \gamma_{21}^{(k)} & \gamma_{22}^{(k)} \end{bmatrix} \begin{bmatrix} g_{i,t-k} \\ C_{i,t-k} \end{bmatrix} + \sum_{n=1}^{N} \begin{bmatrix} \tau_n^{(1)} \\ \tau_n^{(2)} \end{bmatrix} D_{nit} + \begin{bmatrix} y_{i0} \\ y_{i0} \end{bmatrix} + \begin{bmatrix} \varepsilon_{it}^{(1)} \\ \varepsilon_{it}^{(2)} \end{bmatrix}.$$

In the above model, all regression coefficients of lagged g and C are assumed to be the same across various time periods and across different countries. All countries are classified into N different groups to represent their development stages. The group-specific effects are captured by $\tau_n^{(1)}$ and $\tau_n^{(2)}$ (Holtz-Eakin et al. (1988) included country-specific effects in their regression equations). The catching-up effect is further controlled by y_{i0}, the natural logarithm of the initial output level of country i. If country i is in group j, then $D_{jit} = 1$ for all t and $D_{nit} = 0$ for all t which $n \neq j$. C does not Granger-cause g if the coefficient matrices Γ_k are lower triangular for all k, where $\Gamma_k = \begin{bmatrix} \gamma_{11}^{(k)} & \gamma_{12}^{(k)} \\ \gamma_{21}^{(k)} & \gamma_{22}^{(k)} \end{bmatrix}$ (That is, Γ_k is lower triangular if and only if $\gamma_{12}^{(1)} = \gamma_{12}^{(2)} = \cdots = \gamma_{12}^{(T)} = 0$.). If Γ_k are rejected as lower triangular for some k, then C will be said to Granger-cause g, and hypothesis H1 is confirmed by empirical data. Similarly, H2 can be tested.

Appendix III: The Global Competitiveness Index Framework (Schwab, 2014, p.9)

Global Competitiveness Index		
Basic requirements sub-index	Efficiency enhancers sub-index	Innovation and sophistication factor sub-index
Pillar 1. Institutions Pillar 2. Infrastructure Pillar 3. Macroeconomic environment Pillar 4. Health and primary education	Pillar 5. Higher education and training Pillar 6. Goods market efficiency Pillar 7. Labour market efficiency Pillar 8. Financial market development Pillar 9. Technological readiness Pillar 10. Market size	Pillar 11. Business sophistication Pillar 12. Innovation

Appendix IV: Data Envelopment Analysis for Competitiveness Index

Suppose there are K observed countries. Let y_{mk} be the mth dimension and w_{mk} the corresponding weight of that dimension in the competitiveness index for country k, $m = 1, \dots, \mathrm{M}$ and $k = 1, \dots, \mathrm{K}$. Denote the overall competitiveness index by C. Then the observed overall competitiveness index of country j is

$$C^j = \sum_{m=1}^{M} w_{mj} y_{mj}.$$

Previous empirical studies of competitiveness implicitly assume constant tradeoffs among dimensions. Li and Zhao (2015) modeled nonlinear tradeoffs among different dimensions. To make developing and developed countries comparable, we further modify their model by controlling a country's GDP per capita (in natural log form, x) as an input. Using the variable returns to scale (VRS) frontier, the corresponding maximum value of the competitiveness index for country j is

$$C^{j*} = \max_{y,z} \sum_{m=1}^{M} w_{mj} y_{mj}$$

subject to

$$\sum_{k=1}^{K} z_k y_{mk} \geqq \theta y_{mj}, m = 1, \cdots, M$$

$$\sum_{k=1}^{K} z_k x_k \leqq x_j$$

$$\sum_{k=1}^{K} z_k = 1$$

$$z_k \geqq 0, k = 1, \dots \mathrm{K}$$

where the solution y_k^* is an optimal dimension vector. The current loss in competitiveness for country j is indicated by the following measure:

$$O_c{}^j = \left(\sum_{m=1}^{M} w_{mj} y_{mj}^* \right) / \left(\sum_{m=1}^{M} w_{mj} y_{mj}^0 \right).$$

Li and Zhao (2015) called this the *efficiency of overall competitiveness*. The value $(O_c^0 - 1) \times 100\%$ is the percentage of the competitiveness index of y^0 that can be increased.

This efficiency of overall competitiveness can be eliminated through expanding all dimensions proportionally or by changing dimension mix. The first, for country j, is measured by the *efficiency of proportional competitiveness*:

$$E_p^j = \max_{\theta,z} \theta$$

subject to

$$\sum_{k=1}^{K} z_k y_{mk} \geqq \theta y_{mj} \quad m = 1, \cdots, M$$

$$\sum_{k=1}^{K} z_k x_k \leqq x_j$$

$$\sum_{k=1}^{K} z_k = 1$$

$$z_k \geqq 0, k = 1, \ldots \text{K.}$$

The value $\left(E_p - 1\right) \times 100\%$ is the percentage of the competitiveness index that is currently lost if the dimension mix is kept constant. Let $C^p = \sum_{m=1}^{M} w_m \left(E_p y_m^0\right)$ denotes maximum competitiveness attainable when the dimension mix is kept constant. The second component of the efficiency of overall competitiveness is measured by the *efficiency of dimension mix*:

$$E_d = \frac{C^*}{C^p} = \left(\frac{C^*}{C^0}\right) / \left(\frac{C^p}{C^0}\right) = \frac{O_c}{E_p}.$$

The value $(E_d - 1) \times 100\%$ is the percentage of the component of competitiveness lost due to sub-optimal dimension mix. It is easy to see that all O_c, E_p, and E_d are greater than or equal to one. Thus $O_c = E_d E_p$, i.e., thus the potential of improving overall competitiveness as indicated by the efficiency of overall competitiveness (O_c) can be decomposed into the efficiency of proportional competitiveness (E_p) and the efficiency of dimension mix (E_d).

Appendix V: Competitiveness Mapping

Developing Countries					
Country	$1/E_d$	$1/E_p$	Country	$1/E_d$	$1/E_p$
Albania	0.9545	0.8392	Kenya	0.9974	0.8614
Algeria	0.9285	0.8189	Kuwait	0.9910	0.7795
Armenia	0.9424	0.8907	Kyrgyz Republic	0.9682	0.8236
Azerbaijan	0.9931	0.8586	Lesotho	0.9256	0.8349
Bangladesh	0.9948	0.8530	Madagascar	0.9972	0.8701
Bolivia	0.9187	0.8622	Malawi	1.0000	0.9718
Botswana	0.9247	0.8535	Mali	0.9620	0.8333
Bulgaria	0.9645	0.8705	Mongolia	0.9549	0.8234
Burundi	1.0000	0.9241	Morocco	0.9597	0.9062
Cambodia	0.9833	0.9050	Mozambique	0.9504	0.8266
Cameroon	0.9085	0.8848	Namibia	0.8598	0.9143
Chad	0.8715	0.7527	Nepal	0.9944	0.8708
China	1.0000	0.9681	Nicaragua	0.9302	0.8673
Colombia	0.9144	0.9006	Nigeria	0.9707	0.7721
Dominican Republic	0.8316	0.9074	Pakistan	0.9272	0.8221
Egypt	0.9045	0.8561	Paraguay	0.8778	0.8468
El Salvador	0.9088	0.8790	Peru	0.9560	0.8793
Ethiopia	1.0000	0.9268	Philippines	0.9961	0.9013
Gambia, The	1.0000	0.9202	South Africa	0.9993	0.8545
Georgia	0.9734	0.8801	Sri Lanka	1.0000	0.8850
Guatemala	0.9264	0.9078	Tanzania	0.9693	0.8641
Guyana	0.8948	0.8562	Thailand	0.9750	0.9385
Honduras	0.9324	0.8699	Uganda	0.9993	0.8591
India	1.0000	0.9256	Ukraine	1.0000	0.8442
Indonesia	0.9955	0.9344	Vietnam	1.0000	0.9045
Jamaica	0.8933	0.8718	Zambia	0.9579	0.8585
Jordan	0.9669	0.8808	Zimbabwe	0.9011	0.8708
Kazakhstan	0.9584	0.8648			

Appendix V: Competitiveness Mapping (Cont.)

Developed Countries					
Country	$1/E_d$	$1/E_p$	Country	$1/E_d$	$1/E_p$
Argentina	0.9160	0.8040	Lithuania	0.9700	0.8781
Australia	0.9843	0.9141	Luxembourg	0.9990	0.8957
Austria	0.9687	0.9457	Malaysia	1.0000	0.9818
Bahrain	0.9497	0.8826	Malta	0.9819	0.8419
Belgium	0.9976	0.9270	Mauritius	0.9578	0.8888
Brazil	0.9172	0.8959	Mexico	0.9096	0.9097
Canada	0.9988	0.9355	Netherlands	1.0000	0.9700
Chile	0.9784	0.9301	New Zealand	1.0000	0.9232
Costa Rica	0.9505	0.8792	Norway	1.0000	0.9281
Croatia	0.9123	0.8556	Panama	0.9320	0.9168
Cyprus	0.9739	0.8148	Poland	0.9549	0.8947
Czech Republic	0.9354	0.9163	Portugal	0.9675	0.8623
Denmark	0.9899	0.9435	Qatar	1.0000	0.9134
Estonia	0.9943	0.8923	Romania	0.9038	0.8936
Finland	1.0000	0.9785	Russian Federation	0.9426	0.8699
France	0.9887	0.9235	Singapore	1.0000	1.0000
Germany	1.0000	0.9804	Slovak Republic	0.9158	0.8638
Greece	0.9226	0.7966	Slovenia	0.9614	0.8288
Hong Kong SAR	1.0000	0.9836	Spain	0.9630	0.8684
Hungary	0.9089	0.9008	Sweden	1.0000	0.9703
Iceland	0.9902	0.8550	Switzerland	1.0000	1.0000
Ireland	0.9731	0.9026	Trinidad and Tobago	0.9049	0.8258
Israel	0.9987	0.9102	Turkey	0.9221	0.9152
Italy	0.9608	0.8371	United Arab Emirates	0.9951	0.9128
Japan	1.0000	0.9722	United Kingdom	1.0000	0.9737
Korea, Rep.	1.0000	0.9346	United States	1.0000	0.9757
Latvia	0.9571	0.8761	Uruguay	0.9141	0.8590

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Chapter 4
Structural Time Series Analysis of Data from Interwar European Hyperinflations of Germany, Hungary and Poland

Kai-Yin Woo

Abstract

The purpose of this paper is to test for the properties of money supply, prices, and exchange rates using data from the interwar European hyperinflations of Germany, Hungary, and Poland, which are useful for bubble testing in Cagan's (1956) model (Woo, 2004). During that period, these countries experienced hyperinflations. Hence, their data may exhibit unique characteristics that are different from the data during the normal inflationary periods after the Second World War. We adopt the structural time series modeling method for decomposing unobserved components of observed data series for the study.

1. Introduction

In this paper, I will provide a brief description of the data series for the three interwar European hyperinflations of Germany, Hungary, and Poland. It is interesting to investigate the stochastic properties of economic variables during the abnormally high inflationary periods, which are expected to be different from those during the normal inflationary periods. I attempt a structural time series analysis to identify the unobserved stochastic components of the observed data series. From the reduced forms of the trend component, the integration orders of the data series can be found. In addition, some evidence of regime changes in data generation can be detected from the trend component or the slope of the trend. This paper is structured as follows. Section 2 introduces the statistical specifications of the unobserved components in a structural time series model. Section 3 discusses the data sources, sample lengths, and definitions of the variables under study. The statistical and graphical analysis of the unobserved components will also be presented. Section 4 summarizes the findings.

2. Statistical Specifications of Structural Time Series Model

Using the structural time series modeling techniques (Harvey, 1989), I attempt to decompose and analyze the unobserved components of the observed data series in order to examine the stochastic properties of the economic variables under study. A univariate structural time series model is formulated as:

$$(1-\Psi(\boldsymbol{L}))\boldsymbol{y}_{ot} = \mu_t + \gamma_t + \psi_t + \varepsilon_t, \quad \varepsilon_t \sim \text{NID}(0, \ \sigma_\varepsilon^2), \quad t = 1, \ldots, T, \tag{1}$$

where $\boldsymbol{y}_{ot}$ is an observed time series variable, Ψ_i is a parameter of a lagged value of $\boldsymbol{y}_{ot}$, the elements μ_t, γ_t, ψ_t and ε_t represent the unobserved trend, seasonal, cyclical and irregular components respectively.[12]

The trend is the long-run component in the series, which indicates the general moving direction of the observed series under study. There are two parts to the trend specified as:

$$\mu_t = \mu_{t-1} + \beta_{t-1} + \eta_t, \ \eta_t \sim \text{NID}\left(0, \ \sigma_\eta^2\right), \tag{2a}$$

$$\beta_t = \beta_{t-1} + \zeta_t, \ \zeta_t \sim \text{NID}\left(0, \ \sigma_\zeta^2\right), \tag{2b}$$

where μ_t is the level, which is the actual value of the trend, β_t is the slope of the trend. If σ_η^2 and σ_ζ^2 are zero, μ_t and β_t will be fixed respectively.

Different properties of the level, slope, and irregular component would result in different specifications of the trend model. Let's illustrate them briefly.[13] When both σ_ε^2 and σ_η^2 are zero, then the trend specification is given by:

$$\mu_t = \mu_{t-1} + \beta_{t-1}, \tag{3a}$$

$$\beta_t = \beta_{t-1} + \zeta_t, \ \zeta_t \sim \text{NID}\left(0, \ \sigma_\zeta^2\right), \tag{3b}$$

is known as a second differencing model. When σ_ε^2 is not zero, the trend is known as a smooth trend model. Also, in case where both σ_ε^2 and σ_ζ^2 are zero, the trend model is specified as:

$$\mu_t = \mu_{t-1} + \beta_{t-1} + \eta_t, \ \eta_t \sim \text{NID}\left(0, \sigma_\eta^2\right), \tag{4a}$$

[12] A first-order autoregressive component and a vector of exogenous variables are also be included in the univariate structural time series model (1), but they are excluded here for simplicity.

[13] The details of the trend specifications are documented in Koopman et al. (2000).

$$\beta_t = \beta_{t-1}, \tag{4b}$$

is called random walk with a drift, or random walk if $\beta_t = \beta_{t-1} = 0$. While σ_ε^2 is not zero, the trend component is known as the local level with a drift or the local level, dependent upon whether $\beta_t = \beta_{t-1}$ is different from zero.

The seasonal component may be based on the dummy variable form, or the trigonometric formulation. Given that s refers to the number of seasonal frequencies, the seasonal dummy is given by:

$$\gamma_t = \sum_{j=1}^{s-1} -\gamma_{t-j} + \omega_t, \qquad \omega_t \sim \text{NID}(0,\ \sigma_\omega^2). \tag{5}$$

Moreover, the trigonometric seasonal formulation is:

$$\gamma_t = \sum_{j=1}^{s/2} (\cos\lambda_j \gamma_{j,t-1} + \sin\lambda_j \gamma_{j,t-1}^*) + \omega_{j,t}, \quad \text{j} = 1,\ldots,\frac{s}{2}. \quad \omega_{j,t} \sim \text{NID}(0,\ \sigma_{\omega_j}^2). \tag{6}$$

where $\lambda_j = 2j\pi / s$ refers to the frequency in radians, $\gamma_{j,t}^*$ is constructed to estimate γ_t.

The stochastic cycle is specified as follows:

$$\psi_t = \rho(\cos\lambda_c \psi_{t-1} + \sin\lambda_c \psi_{t-1}^* + \kappa_t), \quad \kappa_t \sim \text{NID}\left(0,\ \sigma_\kappa^2\right). \tag{7}$$

where λ_c is the frequency in radians, in the range $0 \le \lambda_c \le \pi$, ρ is a damping factor in the range $0 \le \rho \le 1$ and as in the trigonometric seasonal form (3.6), ψ_{t-1}^* is constructed to generate ψ_t. The period of the cycle is equal to $2\pi / \lambda_c$.

All the disturbance terms of the structural components, and the irregular component, $\{\eta_t, \zeta_t, \omega_t, \omega_{j,t}, \kappa_t, \varepsilon_t\}$ are independent of one another. The inclusion of the disturbance terms produces stochastic properties of the corresponding unobserved components. The q-ratio is the ratio of the standard deviation of each disturbance term to the standard deviation associated with the largest variance. The q-ratio corresponding to a particular component is zero when that component is deterministic or nonexistent.

3. Data Description and Structural Time Series Analysis of Data

The data from Germany, Hungary and Poland include money supply, price index and exchange rate series. The money supply series are month-end data, whereas the other series are monthly averages; I therefore follow Abel *et al.* (1979) in applying the geometric averaging method to make the money supply series conform to the rest of the data. Also, all of the exchange rate series that are originally quoted as the number of US cents per unit of local currency are transformed in terms of the values of domestic currency per US dollar. The German exchange rate series and all the data for Hungary and Poland are taken from Young (1925), while the German money supply and price index are collected from Tinbergen (1934). All series are transformed into natural logarithms.

The statistical treatment of the univariate structural time series model (1) is based on the state space form. The values of the parameters and the unobserved components are estimated using the maximum likelihood (ML) method with the Kalman filter algorithms. Since the unobserved components are in general stochastic, they can only be assessed by examining their behaviours throughout the whole sample, not just at the end. The filtered and smoothed estimates of the components will then be plotted to provide a guide as to whether the model is best decomposed by the estimated components. The model can also be evaluated through goodness-of-fit measures and diagnostic statistics.

For each country under study, the log level and the log difference of money supply ($\boldsymbol{M}_t$ and $\Delta\boldsymbol{M}_t$), price index ($\pi_{1,t}$ and $\Delta\pi_{1,t}$), and exchange rate series ($\pi_{2,t}$ and $\Delta\pi_{2,t}$) as well as the log level of real money balances in terms of both price and exchange rate series ($\boldsymbol{M}_t - \pi_{1,t}$ and $\boldsymbol{M}_t - \pi_{2,t}$) will be decomposed into unobserved components for analysis. The stochastic properties of data are useful for bubble testing in Cagan's (1956) model (Woo, 2004).

3.1 Germany

The German data are collected from January 1920 to December 1923. Money in circulation is employed to represent the money supply series, and the cost-of-living index is used as a price index. The exchange rate figures are transformed from US cents per German mark.

Table 1 reports the empirical results and Figures 1 to 8 show the graphical components of the economic variables under study. From Table 1, all observed series do not contain any lagged dependent variables or irregular components, so that all of the Ψ_i and ε_t are equal to zero. The trend component for the series of $\boldsymbol{M}_t$, $\pi_{1,t}$ and $\pi_{2,t}$ follows a second differencing specification. From the q-ratio and the seasonal test, both $\pi_{1,t}$ and contain significant stochastic dummy seasonal components.

Further, $\boldsymbol{M}_t$ contains a fixed seasonal and $\pi_{1,t}$ contains a nonzero stochastic cycle. Furthermore, the trend component is a random walk with a fixed drift for the series of $\Delta\pi_{1,t}$, $\Delta\pi_{2,t}$, $\boldsymbol{M}_t - \pi_{1,t}$ and $\boldsymbol{M}_t - \pi_{2,t}$ as well as a random walk for the series of $\Delta\boldsymbol{M}_t$. The seasonals in $\boldsymbol{M}_t$, $\pi_{1,t}$ and $\pi_{2,t}$ remain in the structural components of $\Delta\pi_{1,t}$, $\Delta\pi_{2,t}$ $\boldsymbol{M}_t - \pi_{1,t}$ and $\boldsymbol{M}_t - \pi_{2,t}$. In addition, the stochastic cycle contained in $\pi_{1,t}$ is carried forward to $\Delta\pi_{1,t}$.

Table 1 ML Estimation Results of the Structural Time Series Model for Germany

Variables	$\boldsymbol{M}_t$	$\pi_{1,t}$	$\pi_{2,t}$	$\Delta\boldsymbol{M}_t$	$\Delta\pi_{1,t}$	$\Delta\pi_{2,t}$	$\boldsymbol{M}_t - \pi_{1,t}$	$\boldsymbol{M}_t - \pi_{2,t}$
Estimated standard deviation of disturbances [q-ratio]								
σ_η	——	——	——	0.5004 [1.0000]	0.0460 [0.0979]	0.4112 [0.8001]	0.1837 [1.0000]	0.2151 [1.0000]
σ_ζ	0.5024 [1.0000]	0.2895 [0.7189]	0.4506 [1.0000]	——	——	——	——	——
σ_κ	——	0.4026 [1.0000]	——	——	0.4703 [1.0000]	——	0.1139 [0.6198]	——
σ_ω	——	0.0711 [0.1767]	0.2958 [0.6564]	——	0.1557 [0.3311]	0.5139 [1.0000]	0.1328 [0.7228]	0.9401 [0.9401]
Filtered estimates of final state vector at time T with the corresponding root mean square error (RMSE) in the brackets								
μ_T	33.2690* (0.4544)	23.186* (1.0809)	29.373* (0.5543)	2.6041* (0.2694)	1.1880* (0.3342)	3.4429* (0.4157)	6.0249* (0.2683)	4.5411* (0.1974)
β_T	2.5691* (0.5701)	1.7910* (0.5297)	3.5183* (0.6051)	0.0566 (0.0789)	0.0377** (0.0158)	0.0861 (0.0659)	-0.0731** (0.0301)	-0.0691** (0.0343)
φ_T	——	4.0166* (2.7505)	——	——	1.5518 (2.2428)	——	-0.8133 (0.4415)	——
$\gamma_{1,T}$	-0.8713*** (0.4544)	0.6487 (2.6230)	-0.2587 (0.5543)	-0.2419 (0.2694)	-2.0990 (2.2129)	-2.8041* (0.4157)	0.8982** (0.4033)	0.3066 (0.1974)

$\gamma_{2,T}$	-0.8839** (0.4325)	3.4688 (2.6711)	2.6207* (0.4200)	-0.0318 (0.2617)	0.4432 (2.2157)	3.6239* (0.3267)	-0.6341 (0.4062)	-1.6454* (0.1577)
$\gamma_{3,T}$	-0.5708 (0.4245)	4.2237 (2.7078)	-0.8030*** (0.4075)	0.2899 (0.2578)	1.2357 (2.2030)	0.0011 (0.3035)	-0.6560 (0.4047)	0.6287* (0.1505)
$\gamma_{4,T}$	-0.0511 (0.4245)	4.0646 (2.7080)	-0.6008 (0.4127)	0.4926*** (0.2578)	1.2808 (2.2020)	0.1735 (0.3000)	-0.2270 (0.4037)	-0.1109 (0.1502)
$\gamma_{5,T}$	0.6133 (0.4325)	3.3656 (2.6712)	-0.7189 (0.4228)	0.6334** (0.2617)	2.2227 (2.2121)	0.1296 (0.2994)	-0.8710** (0.4064)	-0.3126** (0.1503)
$\gamma_{6,T}$	0.6925 (0.4544)	1.5230 (2.6257)	-0.8964** (0.4307)	0.0442 (0.2694)	2.0706 (2.2224)	-0.2761 (0.2993)	-0.5816 (0.4104)	0.0287 (0.1501)
$\gamma_{7,T}$	0.6790 (0.4557)	-0.7016 (2.6248)	-0.6769 (0.4309)	-0.0350 (0.2773)	1.4104 (2.2268)	-0.3992 (0.3001)	-0.1708 (0.4124)	0.2725*** (0.1507)
$\gamma_{8,T}$	0.5831 (0.4495)	-2.7581 (2.6712)	-0.2818 (0.4260)	-0.1037 (0.2825)	0.4452 (2.2149)	-0.1219 (0.3018)	0.0684 (0.4094)	0.2427 (0.1518)
$\gamma_{9,T}$	0.4370 (0.4443)	-4.1619 (2.7171)	-0.1315 (0.4222)	-0.1403 (0.2850)	-0.7557 (2.1988)	-0.3371 (0.3033)	0.4284 (0.4046)	0.4940* (0.1527)
$\gamma_{10,T}$	0.1600 (0.4443)	-4.4652 (2.7170)	0.2009 (0.4226)	-0.2576 (0.2850)	-1.8780 (2.1988)	-0.6201** (0.3038)	0.6170 (0.4045)	0.3923** (0.1530)
$\gamma_{11,T}$	-0.2185 (0.4495)	-3.4875 (2.6713)	0.7738*** (0.4270)	-0.3456 (0.2825)	-2.1109 (2.2151)	0.1295 (0.3031)	0.5048 (0.4093)	-0.1621 (0.1526)
Estimated parameters of cycle								
Variance	____	18.3227	____	____	8.0315	____	0.5105	____
ρ	____	0.9956	____	____	0.9861	____	0.9872	____
Period (yr.)	____	0.9604	____	____	0.9684	____	0.9218	____
λ_c	____	0.5452	____	____	0.5407	____	0.5680	____
Seasonal test (at time T)								
$\chi^2(11)$	____	21.5743**	421.345*	____	34.9284*	514.924*	95.5476*	361.616*
Goodness-of-fit measures and diagnostic checking								
SE	0.4175	0.7133	0.8542	0.4168	0.6535	0.8706	0.3613	0.3846
R(1)	0.2022	0.1393	-0.0865	0.1710	0.0991	-0.1347	-0.0388	-0.0414
R(6)	-0.0756	-0.0790	-0.0099	-0.0797	-0.0456	-0.0134	-0.0793	0.1283
Q(4)	6.3655	3.8261	1.3000	6.6425	5.3202	1.4800	8.6160	3.5528
Q(7)	6.8320	4.6983	3.1197	7.2309	5.6424	3.2953	9.0970	5.8950
PEV	0.1743	0.5087	0.7297	0.1737	0.4271	0.7579	0.1305	0.1479
R_d^2	0.8634	0.6813	0.5699	0.2581	0.4060	0.5412	0.3166	0.5676
AIC	-1.1281	0.1337	0.3515	-1.1314	-0.0412	0.3894	-1.2267	-1.2443
BIC	-0.5903	0.8370	0.9307	-0.5936	0.6621	0.9687	-0.5233	-0.6651
Max ln L	7.1769	-4.6230	-7.8919	7.8000	-2.4095	-7.8991	16.6318	15.6629

Notes:

A cycle component is not persistent throughout the series; a t-value is therefore not appropriate.
SE is the standard error of the residuals of the estimated equations.
r(k) is the residual autocorrelation coefficient at lags (k).
Q(k) is the Box-Ljung Q statistic with degrees of freedom = k.
PEV is the prediction error variance.
R_d^2 is a modified coefficient of determination based on the first difference of the dependent variable.
AIC and BIC refer to the Akaike information criterion and Bayes information criterion, respectively.
Max ln L is the maximum log-likelihood function.
All computations are produced using the STAMP package written by Koopman *et al.* (2000).
*/**/*** Denotes the significance at the 1%, 5%, and 10% level.

From the figures of the structural components, the slopes of the trend for the level series, M_t, $\pi_{1,t}$ and $\pi_{2,t}$, as well as the trend for $\Delta\pi_{1,t}$, $\Delta\pi_{2,t}$ $M_t - \pi_{1,t}$ and $M_t - \pi_{2,t}$ exhibit changes in moving direction toward the end of 1923. It signifies the possible regime shifts in data generation.

Figure 1. Structural Time Series Components of the German Money Supply Level (M_t)

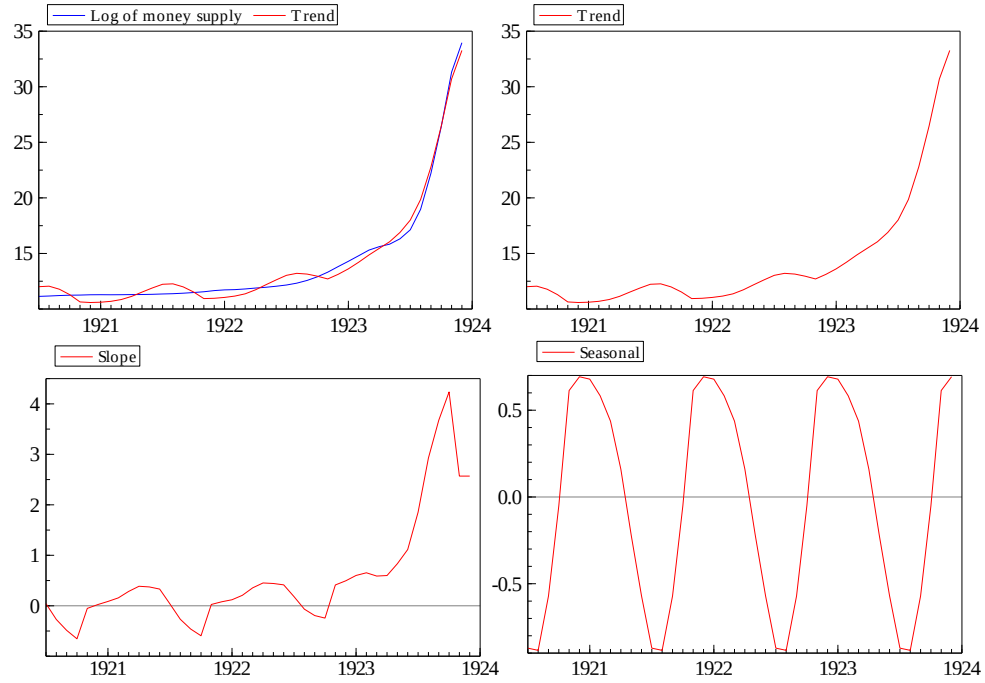


Figure 2. Structural Time Series Components of the German Consumer Price Level (π_{1t})

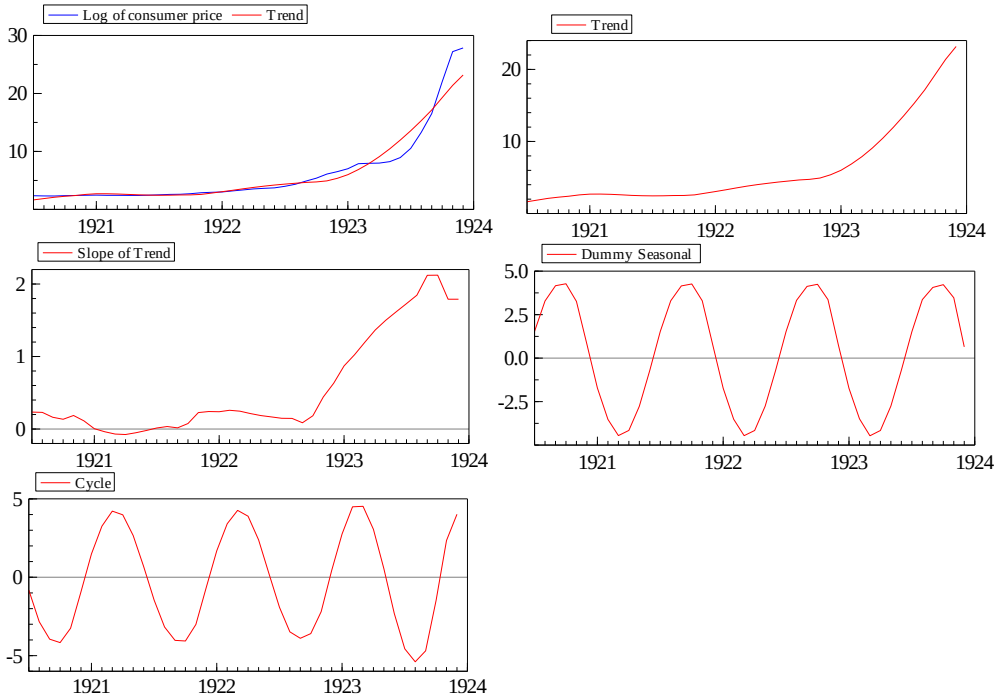


Figure 3. Structural Time Series Components of the German Exchange Rate (π_{2t})

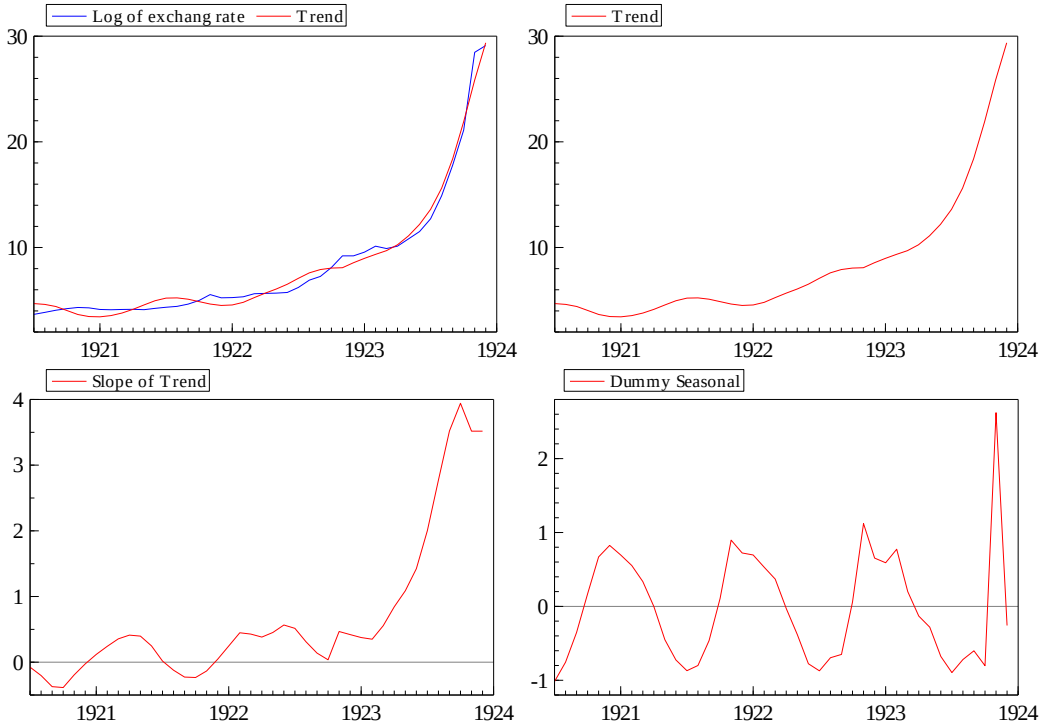


Figure 4. Structural Time Series Components of the Money Supply Growth (ΔM_t) for Germany

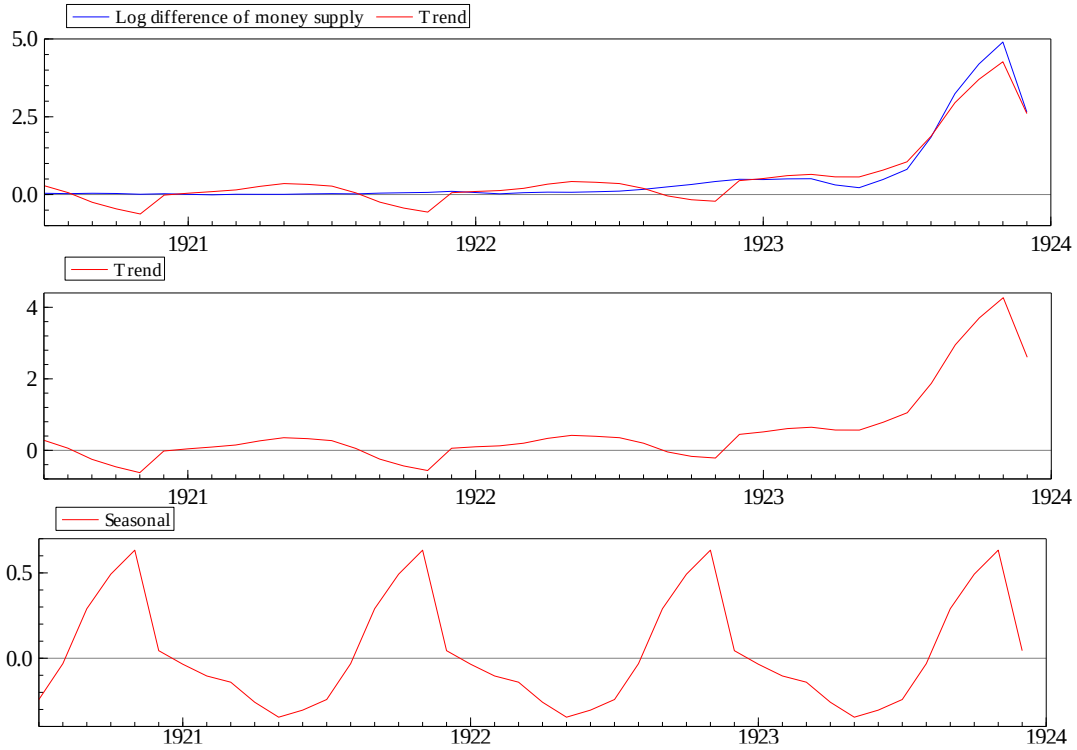


Figure 5. Structural Time Series Components of the Price Change ($\Delta\pi_{1t}$) for Germany

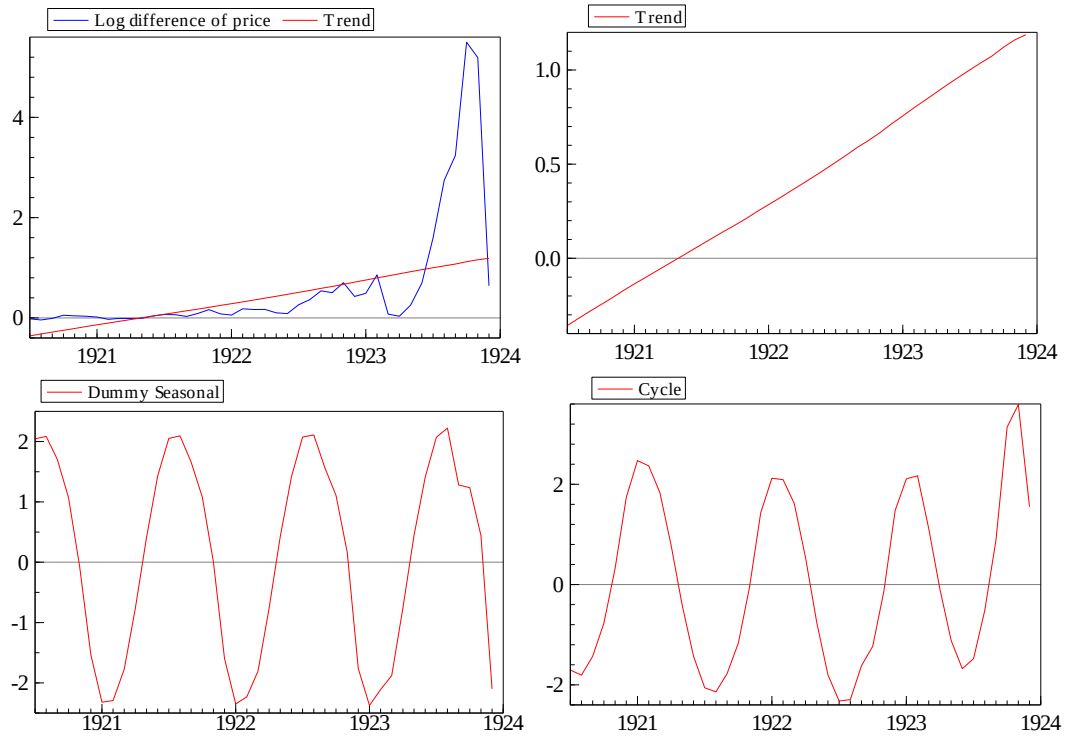


Figure 6. Structural Time Series Components of the Exchange Rate Change ($\Delta\pi_{2t}$) for Germany

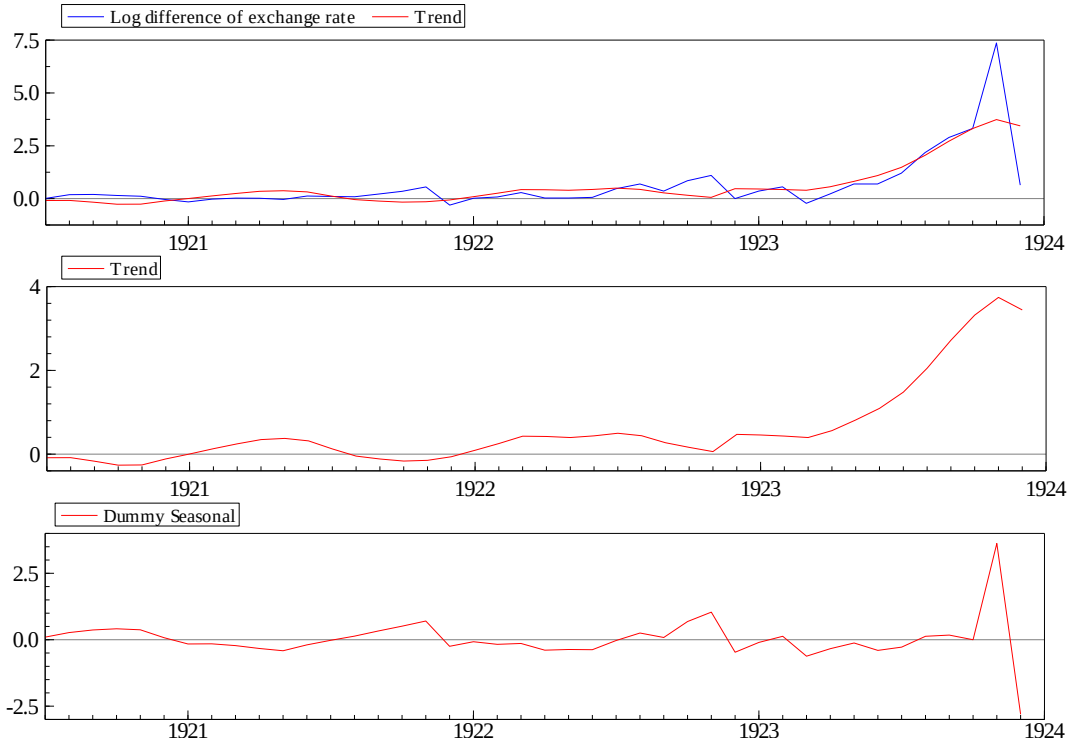


Figure 7. Structural Time Series Components of the Real Money Balance in terms of Consumer Price ($M_t - \pi_{1t}$) for Germany

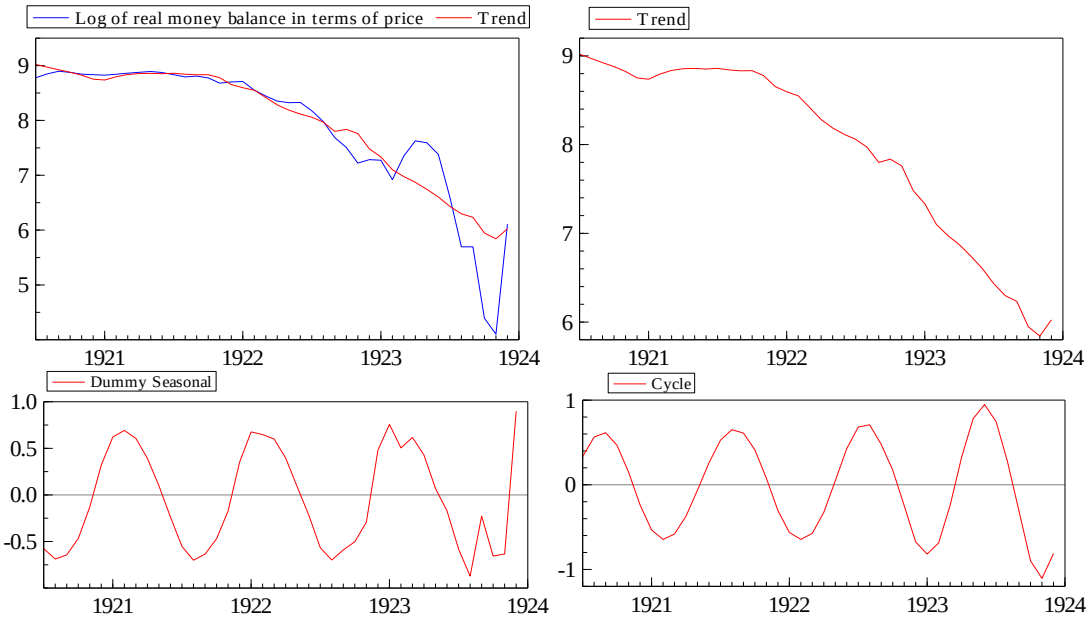
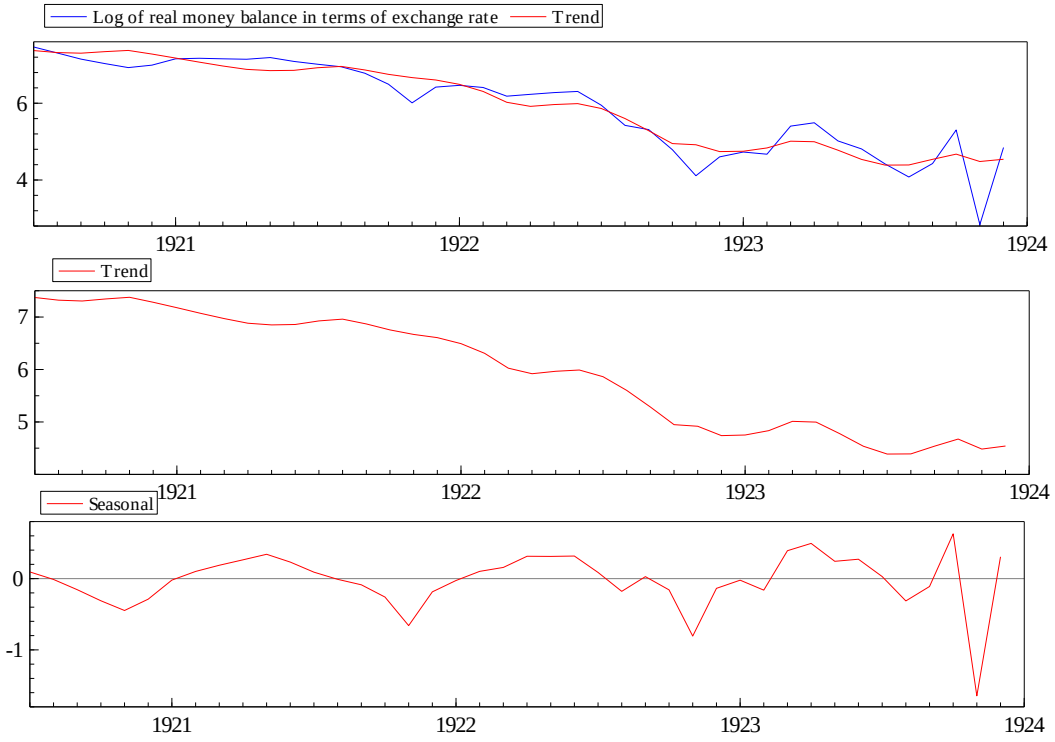


Figure 8. Structural Time Series Components of the Real Money Balance in terms of Exchange Rate ($M_t - \pi_{2t}$) for Germany



3.2. Hungary

The Hungarian data sets start from July 1921 to March 1925. The money supply series includes notes in circulation and deposits. The price index numbers from July 1921 through December 1923 represent retail prices based on 60 commodities. From December 1923 through March 1925, the figures of the price index represent wholesale prices based on 52 commodities. The exchange rate data are originally quoted as US cents per Hungarian crown.

The empirical results of the structural time series models are presented in Table 3.2 with the component graphics plotted from Figures 9 to 16. All series under study do not contain any seasonal components. The trend for $\boldsymbol{M}_t$ and $\pi_{1,t}$ is found to follow a second differencing specification, but given that the irregular component is not zero, the trend for $\pi_{2,t}$ is known as a smooth trend specification. Moreover, there is one cyclical component found in $\boldsymbol{M}_t$, $\pi_{1,t}$ and $\pi_{2,t}$. The model for the series of $\boldsymbol{M}_t$, $\boldsymbol{M}_t - \pi_{1,t}$ and $\boldsymbol{M}_t - \pi_{2,t}$ include lagged values of the corresponding dependent variables.

The trend follows a random walk for the series of $\Delta\boldsymbol{M}_t$, $\Delta\pi_{1,t}$, and $\boldsymbol{M}_t - \pi_{1,t}$. When the irregular components are nonzero, the trend models for the series of $\boldsymbol{M}_t - \pi_{2,t}$ and $\Delta\pi_{2,t}$ are known as the local level and the local level with a fixed slope, respectively, depending upon whether the fixed slope of the trend exists or not. Also, the stochastic cycles are carried forward to the series of $\Delta\boldsymbol{M}_t$, $\Delta\pi_{1,t}$ and $\boldsymbol{M}_t - \pi_{1,t}$ from the series of $\boldsymbol{M}_t$ and $\pi_{1,t}$, but no cycle is found in the series of $\Delta\pi_{2,t}$ and $\boldsymbol{M}_t - \pi_{2,t}$.

Table 2 ML Estimation Results of the Structural Time Series Model for Hungary

Variables	$\boldsymbol{M}_t$	$\pi_{1,t}$	$\pi_{2,t}$	$\Delta\boldsymbol{M}_t$	$\Delta\pi_{1,t}$	$\Delta\pi_{2,t}$	$\boldsymbol{M}_t - \pi_{1,t}$	$\boldsymbol{M}_t - \pi_{2,t}$
Estimated standard deviation of disturbances [q-ratio]								
σ_η	——	——	——	0.0111 [0.7274]	0.0473 [0.4701]	0.0761 [0.4713]	0.0905 [1.0000]	0.1420 [1.0000]
σ_ζ	0.0150 [1.0000]	0.0531 [0.6997]	0.0393 [0.4932]	——	——	——	——	——
$\sigma_{\kappa 1}$	0.0132 [0.8826]	0.0759 [1.0000]	0.0796 [1.0000]	0.1520 [1.0000]	0.1006 [1.0000]	——	0.0716 [0.7917]	——
$\sigma_{\kappa 2}$	——	——	——	0.0109 [0.7142]	——	——	——	——
σ_ε	——	——	0.0667 [0.8372]	——	——	0.1615 [1.0000]	——	0.0813 [0.5724]
Filtered estimates of final state vector at time T and the estimated coefficient of lagged dependent variable with the corresponding RMSE in the brackets								

μ_T	5.5685* (0.9141)	14.571* (0.1138)	6.5584* (0.1476)	-0.0045 (0.0209)	-0.0153 (0.0737)	-0.0197 (0.1007)	0.5336* (0.1604)	5.2435* (1.2454)
β_T	0.0086 (0.0206)	-0.0227 (0.0826)	-0.0424 (0.0726)	____	____	-0.0057 (0.0121)	____	____
φ_{1T}	0.0025 (0.0178)	-0.0049 (0.1138)	0.0133 (0.1379)	0.0005 (0.02106)	-0.0313 (0.0737)	____	0.0254 (0.0868)	____
φ_{2T}	____	____	____	0.0101 (0.0201)	____	____	____	____
Ψ_1	1.4445* (0.0928)	____	____	0.7691* (0.1049)	____	____	0.5512* (0.1249)	0.4283* (0.1361)
Ψ_2	-0.7987* (0.0922)	____	____	____	____	____	____	____
Estimated parameters of the first cycle [second cycle]								
Variance	0.0006	0.0200	0.0411	0.0012 [0.0012]	0.0181	____	0.0130	____
ρ	0.8429	0.8438	0.9195	0.8979 [0.9513]	0.6645	____	0.7783	____
Period (yr.)	0.4424	0.6942	0.8341	0.4674 [0.8786]	0.5405	____	0.6661	____
λ_c	1.1834	0.7542	0.6278	1.1202 [0.5960]	0.9687	____	0.7861	____
Goodness-of-fit measures and diagnostic checking								
SE	0.0321	0.1403	0.1767	0.0325	0.1382	0.1997	0.1322	0.1748
R(1)	0.0203	0.1292	-0.0437	0.1149	0.0300	0.0886	0.0746	-0.0347
R(6)	-0.0389	0.0606	0.0126	-0.0821	0.0500	-0.1706	0.0518	-0.2389
Q(4)	4.5138	3.7516	4.4654	6.3933	2.8203	7.1317	5.2419	7.3353
Q(7)	6.7565	8.4173	6.2431	6.5268	5.6989	7.5821	8.3902	9.2621
PEV	0.0010	0.0197	0.0312	0.0011	0.0191	0.0399	0.0175	0.0306
R_d^2	0.9191	0.3233	0.1630	0.6929	0.2383	0.2479	0.3192	0.0893
AIC	-6.5683	-3.7064	-3.1996	-6.4889	-3.7769	-3.0852	-3.8200	-3.3518
BIC	-6.2873	-3.5057	-2.9587	-6.1645	-3.6147	-2.9636	-3.6173	-3.2302
Max ln L	140.084	83.0573	72.6282	142.888	84.2527	63.6983	83.8088	71.9792

Notes:

$\sigma_{\kappa 1}$ and $\sigma_{\kappa 2}$ are the standard deviations of the disturbance terms of the first and the second cycle, respectively. Also, φ_{1T} and φ_{2T} are the final states of the first and the second cycle, respectively.

Since the money supply level contains a stochastic trend component, the standard statistical inference of Ψ_1 and Ψ_2 is interpreted with care.

The figures for the structural components indicate that the slopes of the trend and the trend of the economic variables start to shift in the second half of 1923. They all display some evidence of regime-switching behaviour in the observed data series.

Figure 9 Structural Time Series Components of the Hungarian Money Supply Level (M_t)

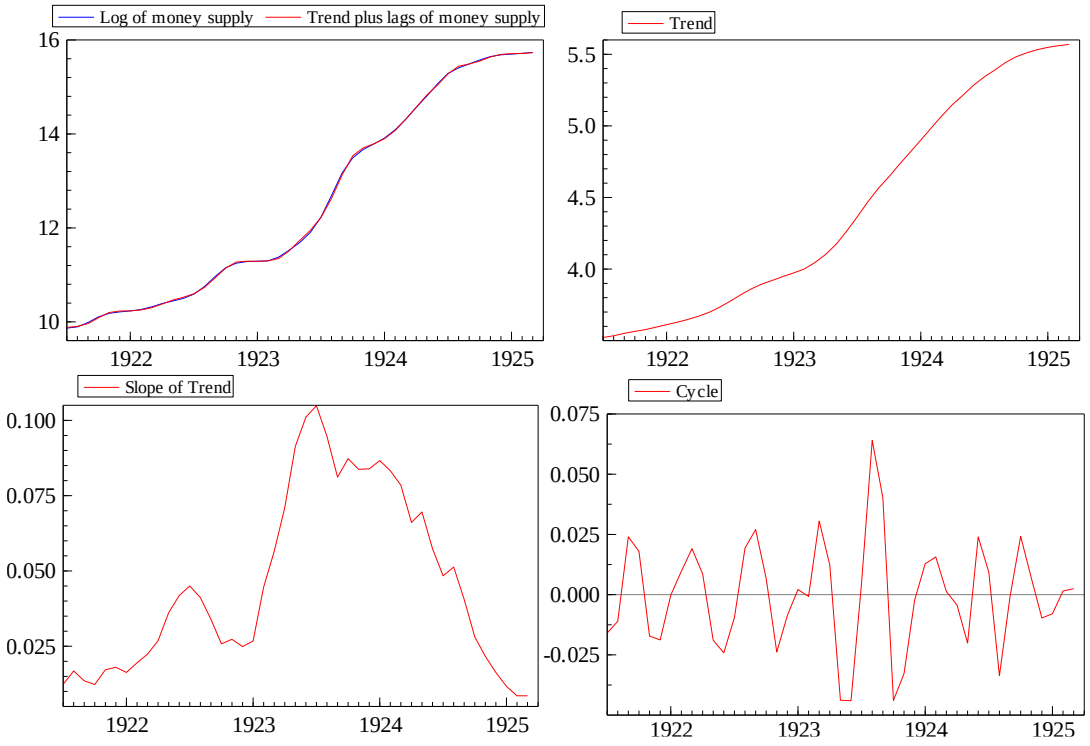


Figure 10 Structural Time Series Components of the Hungarian Composite Price Level (π_{1t})

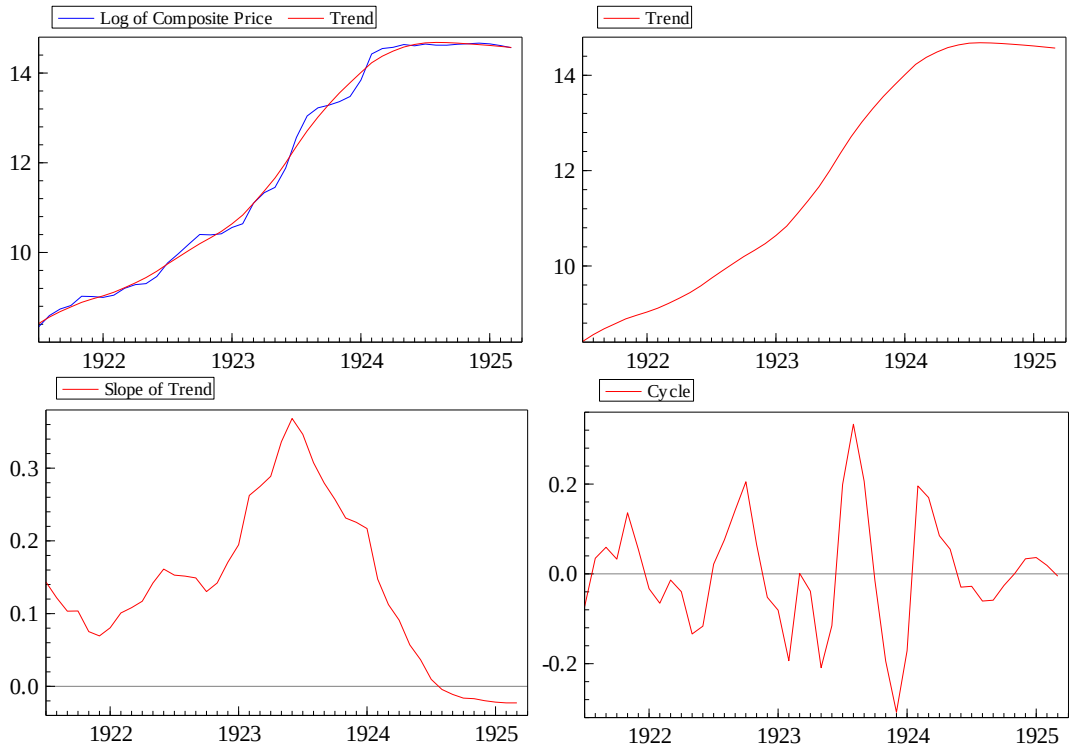


Figure 11. Structural Time Series Components of the Hungarian Exchange Rate (π_{2t})

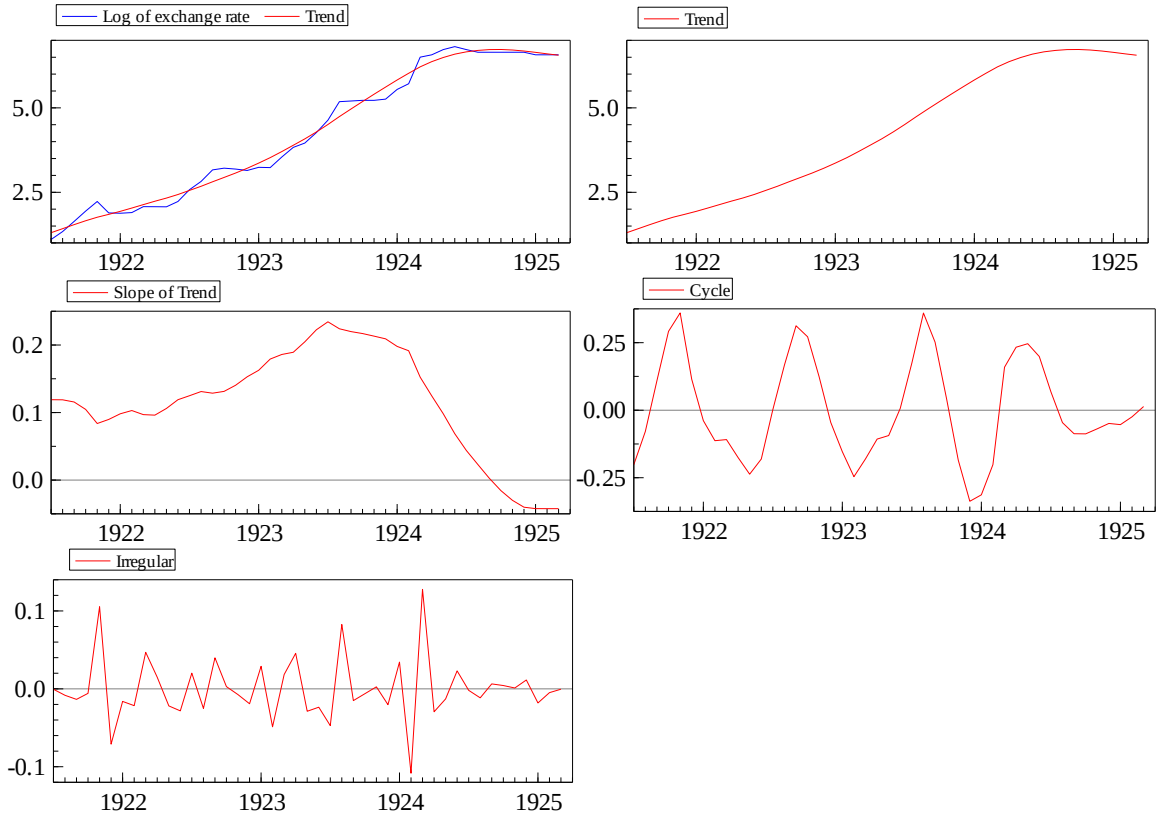


Figure 12. Structural Time Series Components of the Money Supply Change (ΔM_t) for Hungary

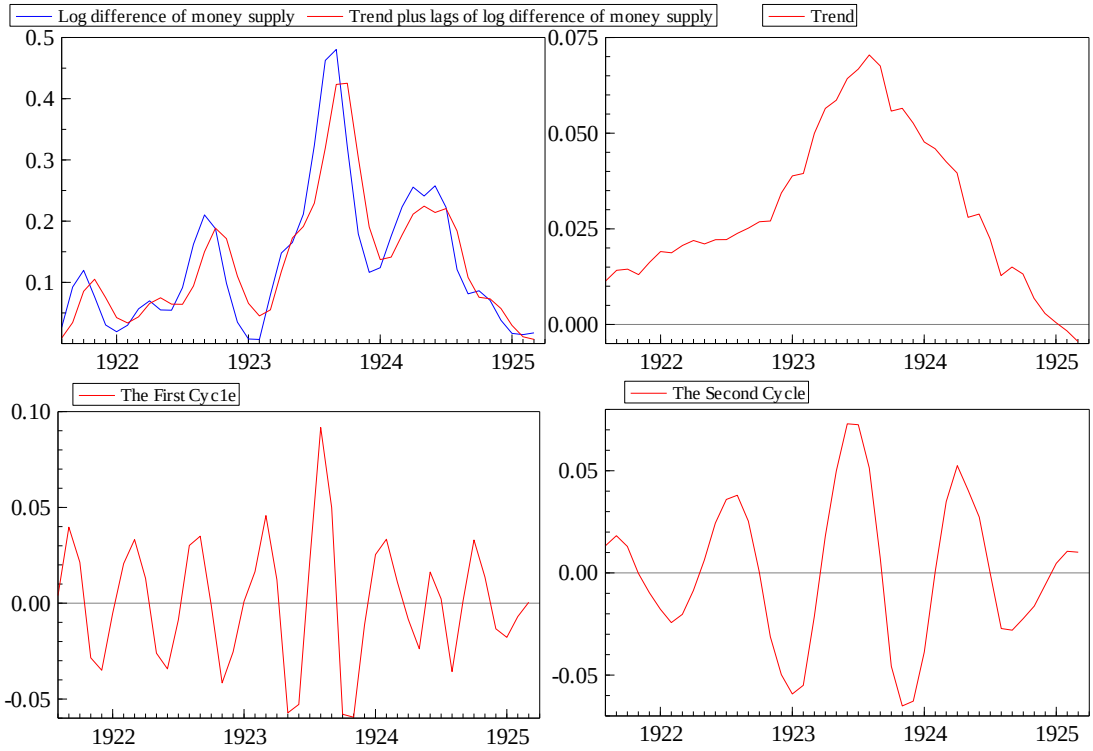


Figure 13. Structural Time Series Components of the Price Change ($\Delta\pi_{1t}$) for Hungary

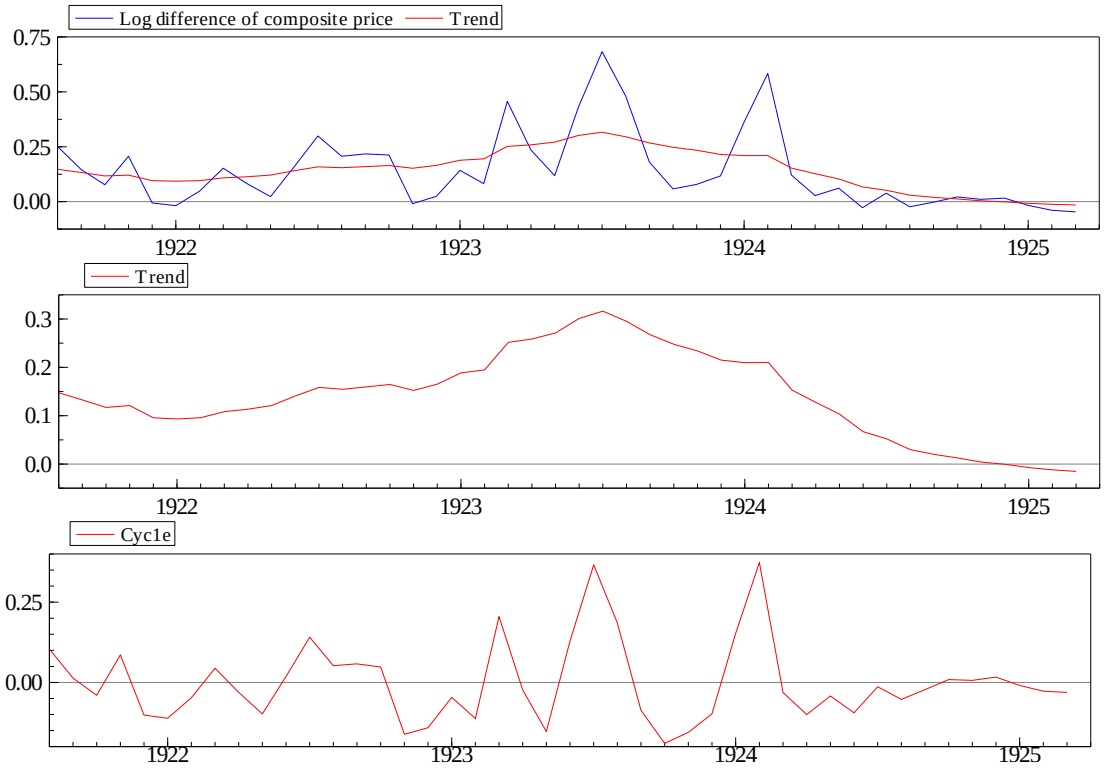


Figure 14. Structural Time Series Components of the Exchange Rate Change ($\Delta\pi_{2t}$) for Hungary

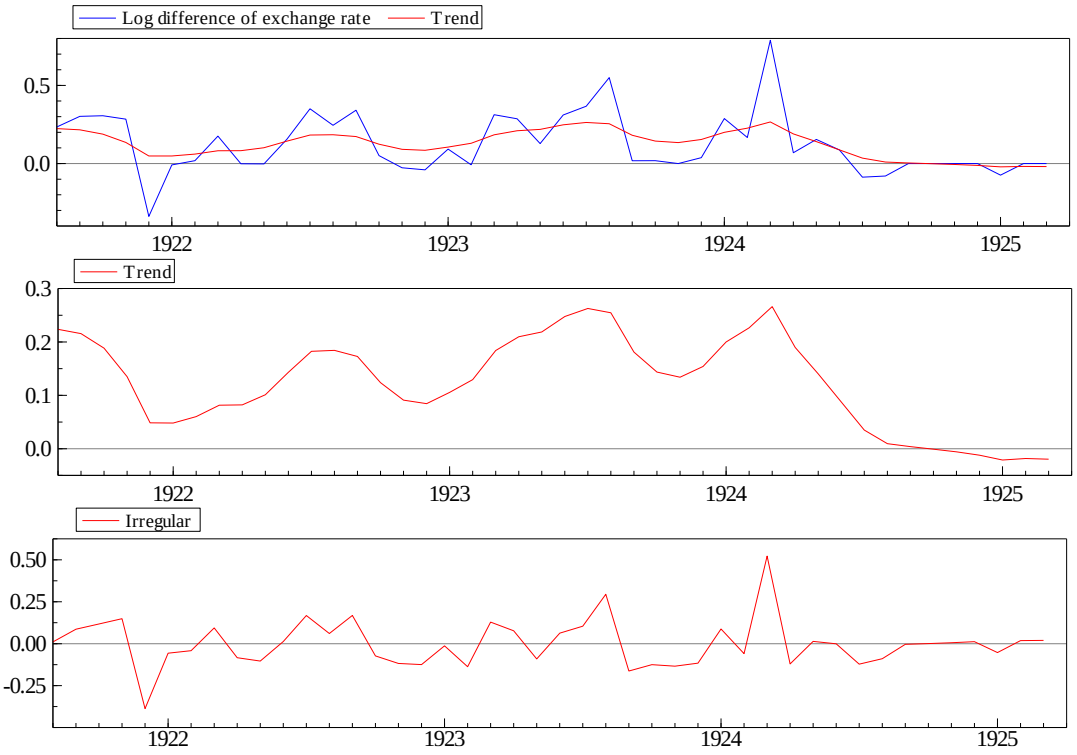


Figure 15. Structural Time Series Components of the Real Money Balance in terms of Composite Price ($M_t - \pi_{1t}$) for Hungary

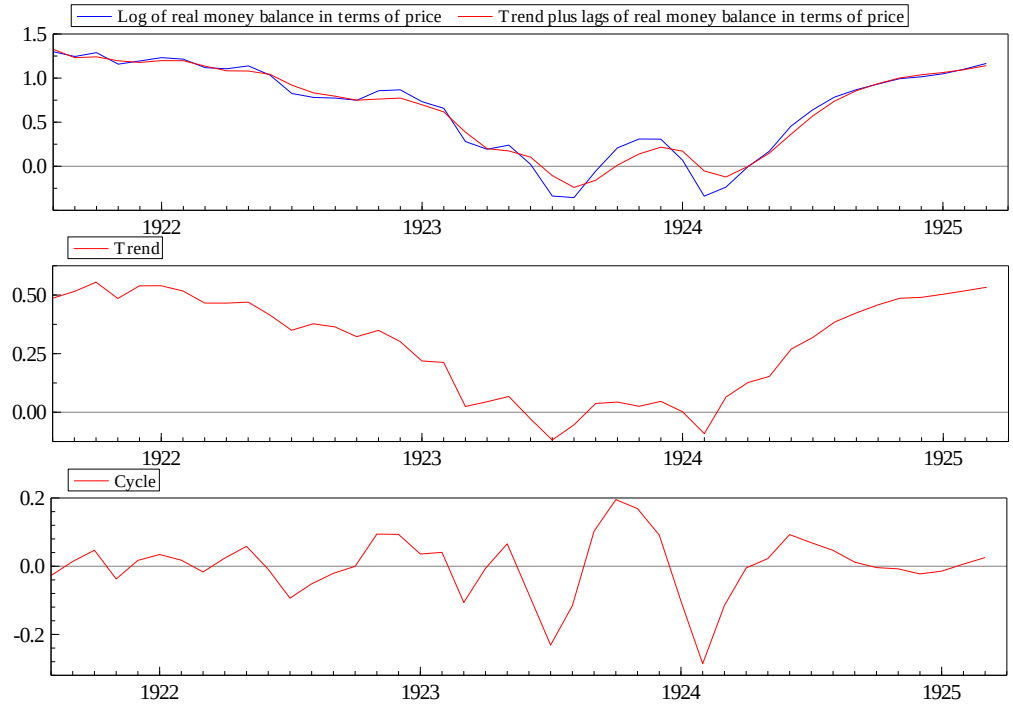
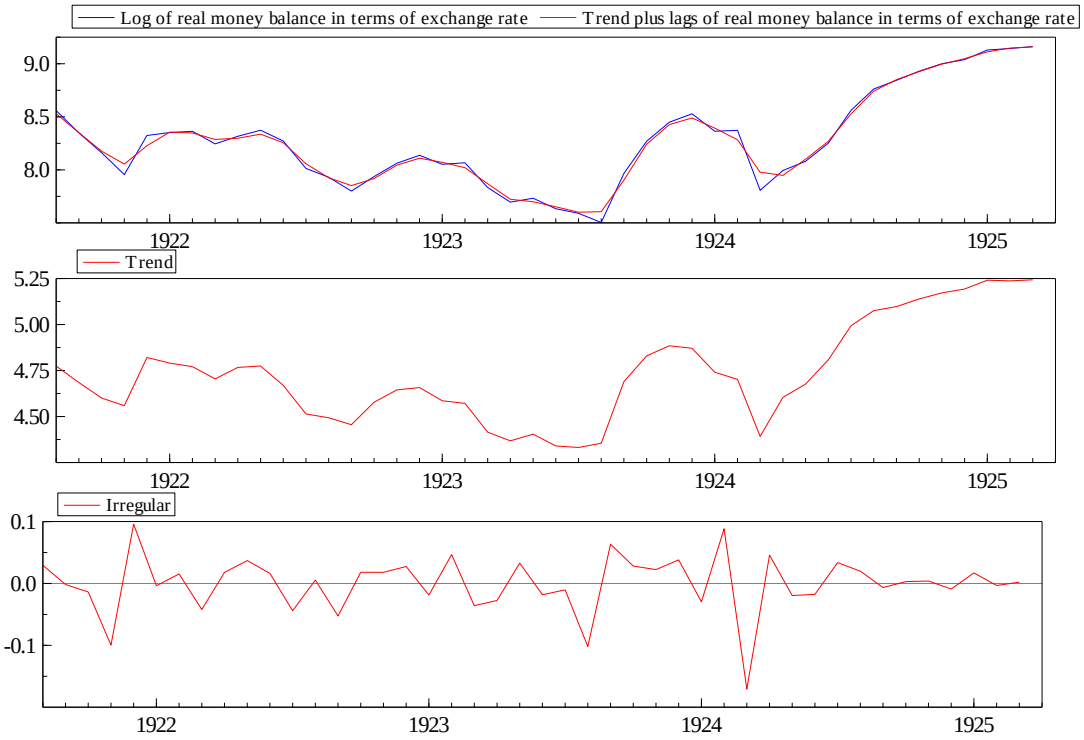


Figure 16. Structural Time Series Components of the Real Money Balance in terms of Exchange Rate ($M_t - \pi_{2t}$) for Hungary



3.3. Poland

The Polish data are collected from January 1921 to March 1924. The money supply includes notes in circulation, and the wholesale price index is chosen to represent the price level. The exchange rate series is transformed from US cents per Polish mark.

The empirical results of the structural models are shown in Table 3. As in the case of Hungary, all observed series under study do not contain any seasonal components. Only the models for the series of $\boldsymbol{M}_t$ and $\Delta\boldsymbol{M}_t$ include corresponding lagged dependent variables.

The trend components for the series of $\boldsymbol{M}_t$ and $\pi_{2,t}$ follow a second differencing specification, but the trend for $\pi_{1,t}$ is a smooth trend in which the irregular component exists. Moreover, $\pi_{1,t}$ and $\pi_{2,t}$ contain a stochastic cycle, which however cannot be found in $\boldsymbol{M}_t$.

Table 3. ML Estimation Results of the Structural Time Series Model for Poland

Variables	$\boldsymbol{M}_t$	$\pi_{1,t}$	$\pi_{2,t}$	$\Delta\boldsymbol{M}_t$	$\Delta\pi_{1,t}$	$\Delta\pi_{2,t}$	$\boldsymbol{M}_t-\pi_{1,t}$	$\boldsymbol{M}_t-\pi_{2,t}$
Estimated standard deviation of disturbances [q-ratio]								
σ_η	____	____	____	0.07877 [1.0000]	0.0608 [0.4229]	0.1068 [0.4595]	0.1468 [1.0000]	0.1159 [0.7036]
σ_ζ	0.0788 [1.0000]	0.0629 [0.4925]	0.0617 [0.3292]	____	____	____	____	____
σ_κ	____	0.1278 [1.0000]	0.1875 [1.0000]	____	0.0675 [0.4694]	____	0.0861 [0.5867]	0.1648 [1.0000]
σ_ε	____	0.0219 [0.1712]	____	____	0.1438 [1.0000]	0.2324 [1.0000]	____	____
Filtered estimates of final state vector at time T and the estimated coefficient of lagged dependent variable with the corresponding RMSE in the brackets								
μ_T	3.5694 (3.7453)	19.385* (0.2447)	11.350* (0.3109)	-0.2807** (0.1360)	0.4218* (0.1122)	0.2877** (0.1406)	0.2424 (0.1538)	8.1719* (0.1899)
β_T	-0.2807*** (0.1571)	0.4572* (0.1156)	0.4357* (0.1218)	____	____	____	____	____
φ_T	____	-0.1282 (0.2191)	0.0411 (0.3109)	____	-0.3867 (0.1127)	____	0.5860 (0.1538)	0.5837 (0.1899)
Ψ_i	0.8362* (0.1889)	____	____	0.8362* (0.1889)	____	____	____	____
Estimated parameters of cycle								
Variance	____	0.1384	0.1528	____	0.0392	____	0.0905	0.1114
ρ	____	0.9392	0.8774	____	0.9400	____	0.9581	0.8696

Period (yr.)	____	0.9567	1.0921	____	0.9142	____	0.7999	0.9153
λ_c	____	0.5473	0.4794	____	0.5727	____	0.6546	0.5720
Goodness-of-fit measures and diagnostic checking								
SE	0.0755	0.2104	0.2689	0.0766	0.2150	0.2880	0.1994	0.2399
R(1)	0.2588	-0.0226	-0.0386	0.2588	-0.0017	0.1144	0.1531	-0.0374
R(6)	-0.1492	-0.0100	0.0763	-0.1492	-0.0156	-0.0038	0.0433	0.0508
Q(4)	4.4356	1.4354	4.8692	4.4356	1.9140	3.0416	4.3929	6.2058
Q(7)	5.9300	2.6137	6.5065	5.9300	3.0594	6.6827	6.2526	8.1936
PEV	0.0057	0.0443	0.0723	0.0059	0.0462	0.0829	0.0397	0.0576
R_d^2	0.8936	0.4586	0.2024	0.3819	0.2135	0.2010	0.2749	0.1781
AIC	-5.0049	-2.8100	-2.3703	-5.0286	-2.8113	-2.3845	-3.0149	-2.6442
BIC	-4.8743	-2.5540	-2.1570	-4.9406	-2.5958	-2.2983	-2.8425	-2.4718
Max ln L	87.2775	55.8956	46.9873	87.2775	55.6872	45.3099	58.4529	51.9073

See Notes to Tables 1 and 2.

For the series of $\Delta \boldsymbol{M}_t, \Delta\pi_{1,t}$, $\Delta\pi_{2,t}$, $\boldsymbol{M}_t - \pi_{1,t}$ and $\boldsymbol{M}_t - \pi_{2,t}$, the fixed slope of the trend cannot be found. Also, the irregular components exist for the series of $\Delta\pi_{1,t}$ and $\Delta\pi_{2,t}$ only. Hence, the trend model for the series of $\Delta \boldsymbol{M}_t$, $\boldsymbol{M}_t - \pi_{1,t}$ and $\boldsymbol{M}_t - \pi_{2,t}$ follows a random walk but it follows a local level for the series of $\Delta\pi_{1,t}$ and $\Delta\pi_{2,t}$. Furthermore, the stochastic cycles remain in series of $\Delta\pi_{1,t}$, $\boldsymbol{M}_t - \pi_{1,t}$ and $\boldsymbol{M}_t - \pi_{2,t}$ but not in $\Delta\pi_{2,t}$.

From the movements of the trend as well as the slope of trend for the time series variables under study shown in Figures 17 to 24, some evidence of structural changes is found in the data generation that occurred in the late 1923.

Figure 17. Structural Time Series Components of the Polish Money Supply Level ($\boldsymbol{M}_t$)

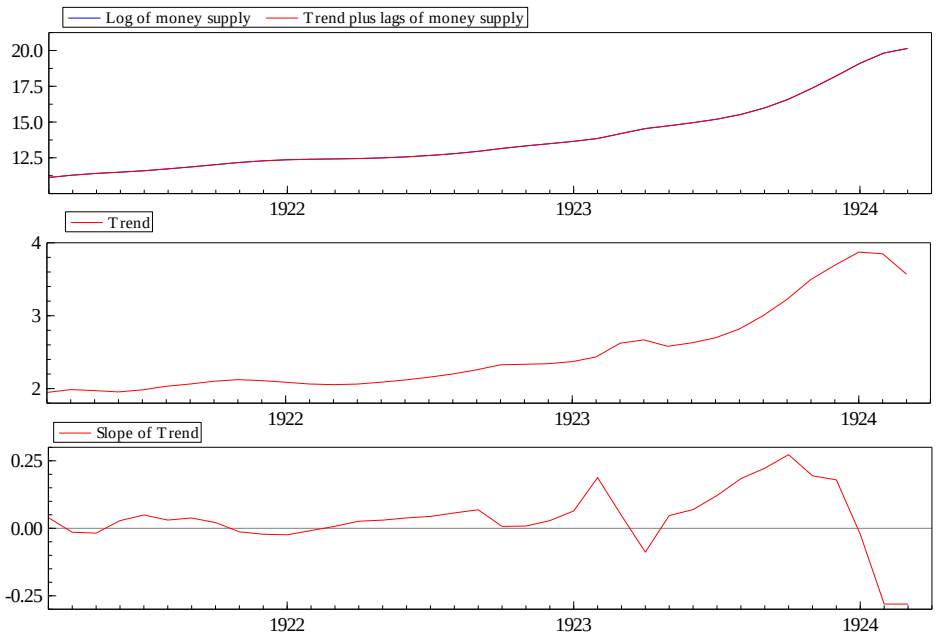


Figure 18. Structural Time Series Components of the Polish Wholesale Price Level (π_{1t})

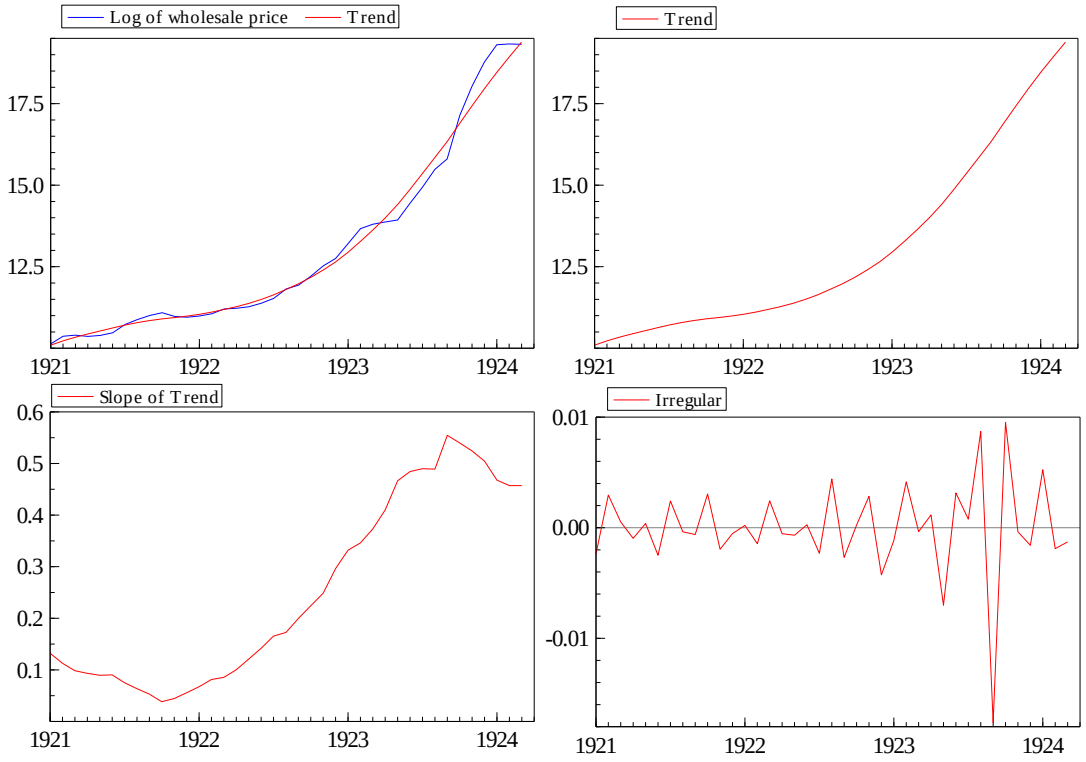


Figure 19. Structural Time Series Components of the Polish Exchange Rate (π_{2t})

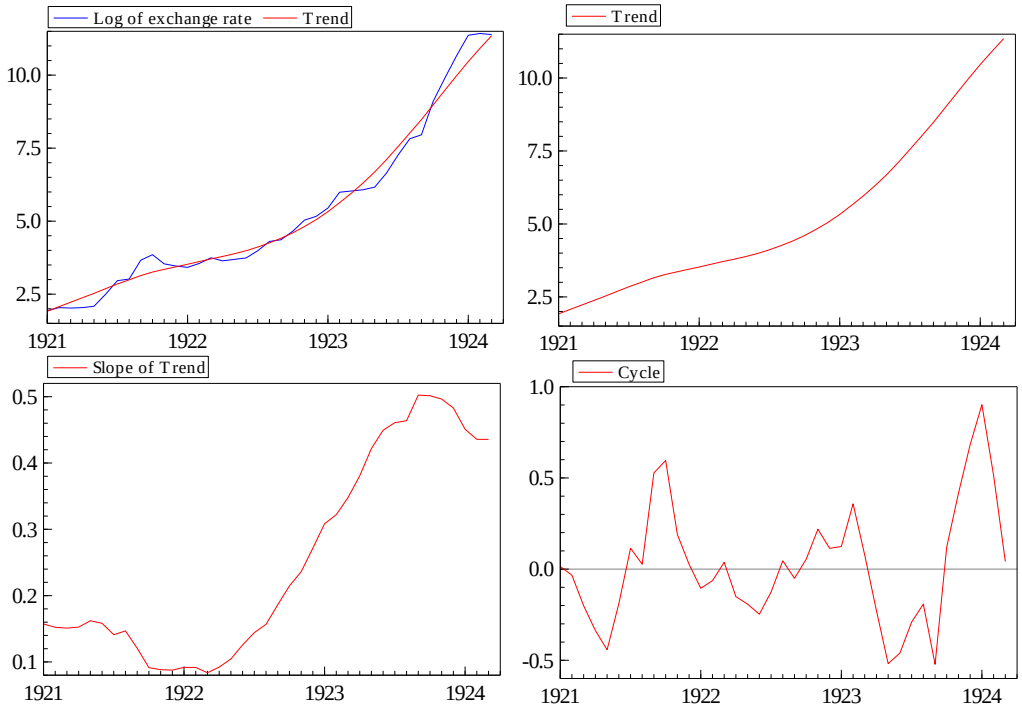


Figure 20. Structural Time Series Components of the Money Supply Growth (ΔM_t) for Poland

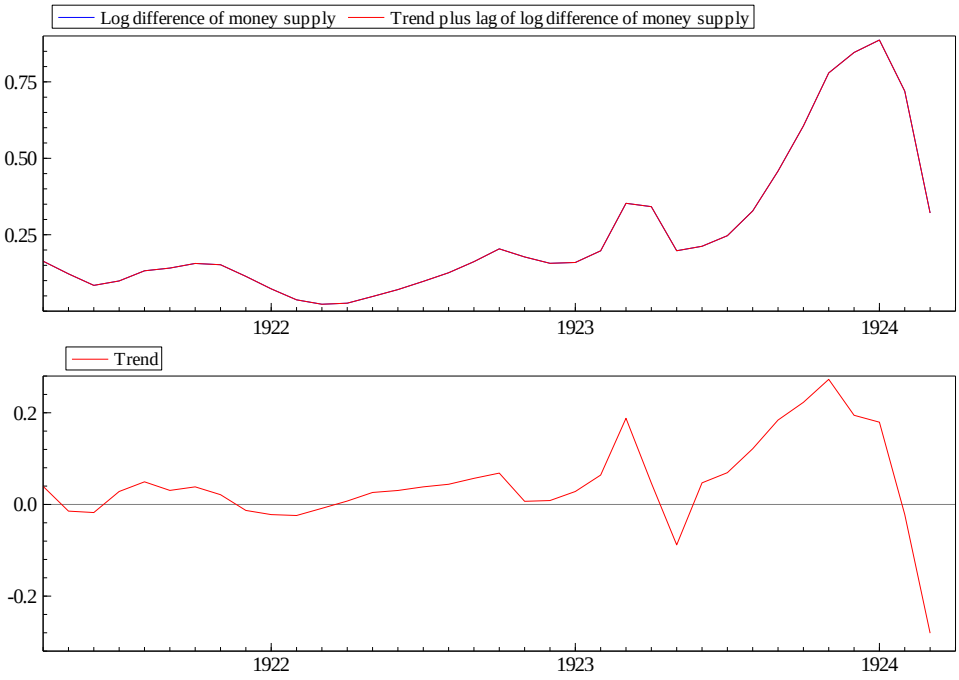


Figure 21. Structural Time Series Components of the Price Change ($\Delta\pi_{1t}$) for Poland

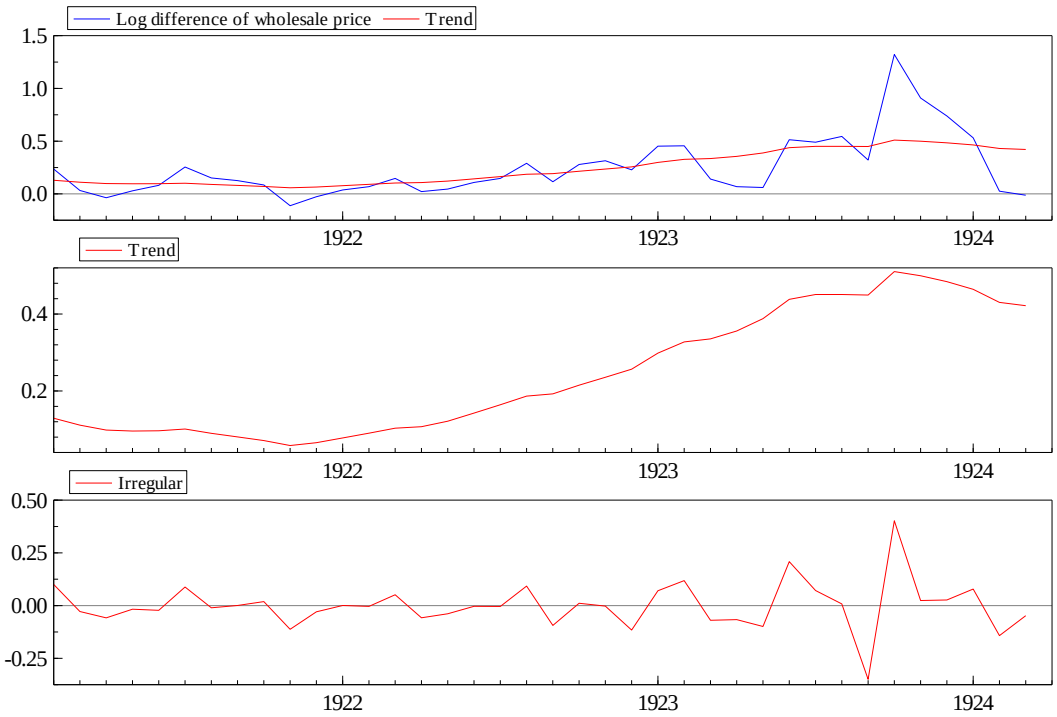


Figure 22. Structural Time Series Components of the Exchange Rate Change ($\Delta\pi_{2t}$) for Poland

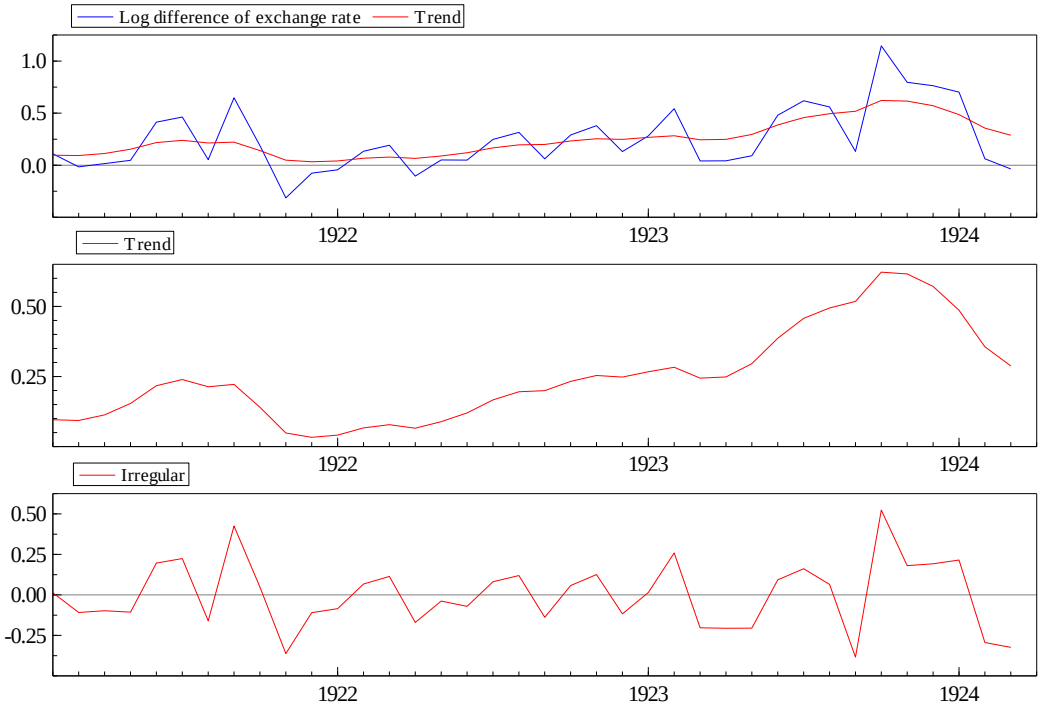


Figure 23. Structural Time Series Components of the Real Money Balance in terms of Wholesale Price ($M_t - \pi_{1t}$) for Poland

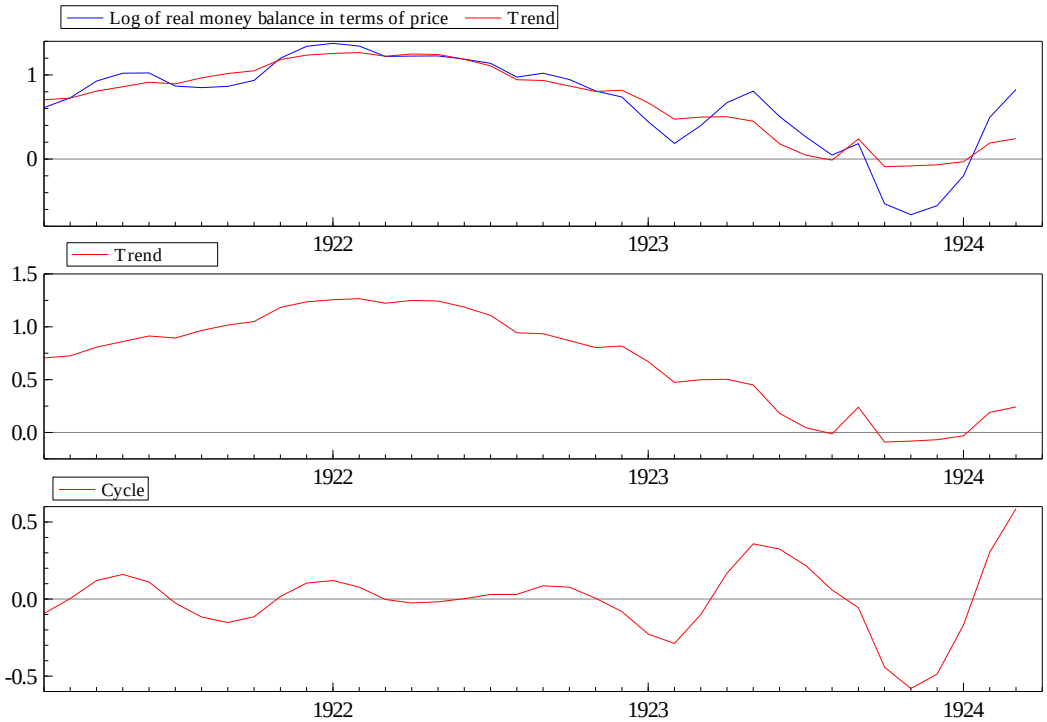
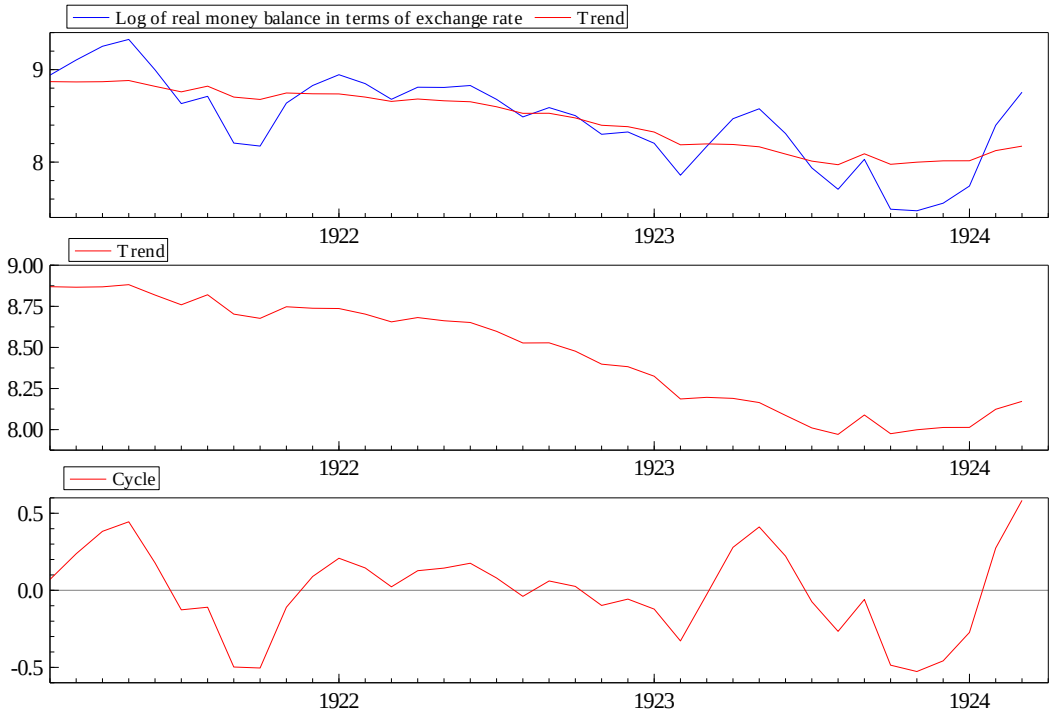


Figure 24. Structural Time Series Components of the Real Money Balance in terms of Exchange Rate ($M_t - \pi_{2t}$) for Poland



4. Conclusion

This paper is slightly modified from Chapter Three of Woo (2004). From the analysis of structural time series components, the cycles and seasonals are found in some data series. More importantly, the trend for the levels of money supply, price, and exchange rate is composed of a fixed level with a stochastic slope. From the reduced form of the structural time series models (Harvey, 1989), the integration order of these level series is two; in other words, they contain double unit roots. It is consistent with Haldrup (1998) that the economic variables are likely to be I(2) during hyperinflation. Also, the real money balances, the first-differenced price, and exchange rate series have a stochastic trend with a fixed or zero slope, implying that these series contain a unit root. From the figures of the structural components, it indicates possible regime changes in data generation, resulting from monetary regime changes.

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Chapter 5
Review of Behavioral Finance and Behavioral Econometrics: Theories and Applications

Wing-Keung Wong
Kai-Yin Woo
Hassan Zada
Shin-Hung Pan

Abstract

Traditional financial theories based on the assumption of rationality cannot explain many paradoxes and anomalies in the financial markets. Behavioral Finance models are then developed to incorporate ideas from psychology and financial economics to explain market phenomena. Additionally, advanced Behavioral Econometric methods are proposed for testing theories in Behavioral Finance. This review paper introduces readers to theoretical frameworks and econometric modeling techniques for studying Behavioral Finance, with numerous applications in the literature. This review provides comprehensive profiles of theoretical evolution, econometric methodology, and applied studies in Behavioral Finance, along with salient readings. The results emphasize the ongoing development of theories in Behavioral Finance and Econometrics, from risk-seeking utility functions and stochastic dominance to advanced risk measures, econometric testing methods, and ultimately financial applications with testable implications. These advancements help readers understand the main research areas and emerging trends in this field. This review paper is valuable for academics and practitioners, as it advances Behavioral Finance and Behavioral Econometric theories, and also supports their application to portfolio construction, investment analysis, and risk management. Our study contributes to decision sciences by helping financial analysts understand their clients' behavioral traits and make optimal decisions that improve their risk-return trade-off.

1. Introduction

Behavioral Finance is a key area of financial economics because many traditional theories have been shown to fail in explaining numerous paradoxes and anomalies observed in financial markets (Woo et al., 2020). For example, the efficient market hypothesis (Fama, 1970) claims that investors cannot consistently outperform the market. However, empirical evidence indicates that some investors can beat the market. These discrepancies drive the development of Behavioral Finance, which questions the assumption of full rationality and incorporates psychological factors into financial decision-making models. Along with the development of theoretical models, scholars have introduced Behavioral Econometric methods to empirically evaluate these models and test for behavioral patterns in markets.

However, existing review studies tend to analyze the main strands of Behavioral Finance separately. They focus either on theoretical models (Nawrocki and Viole, 2014), econometric testing methods (Harrison, 2019), or financial applications (Hon et al., 2021). What is missing is a comprehensive review that combines Behavioral Finance models, Behavioral Econometric techniques, and financial applications into a unified framework. This review paper fills that gap by integrating these areas to help readers understand how behavioral model development, testing, and financial practice are interconnected. As a result, it provides insights for researchers and practitioners on how econometric methods are used to test the validity of theoretical models and how Behavioral Finance and Econometric models influence real-world applications.

Our study is relevant to the discipline of decision sciences because it helps financial analysts optimally make financial and investment decisions, intending to maximize their risk-return tradeoffs when facing risk, uncertainty, and cognitive limitations.

This paper is structured as follows: Section 2 provides a brief review of selected theoretical models of Behavioral Finance. Section 3 discusses Behavioral Econometric methods and test statistics used to study topics in Behavioral Finance. Section 4 examines the financial applications. Section 5 concludes.

2. Theoretical Models

According to prospect theory, investors exhibit risk aversion with a concave utility function when experiencing gains but become risk-seeking with a convex utility function when facing losses. Consequently, their behaviors may deviate from rationality and then violate the predictions implied by market efficiency. To analyze both risk-averse and risk-seeking behaviours, researchers have proposed different utility function specifications and their corresponding indifference curves. In addition, stochastic dominance has been developed to analyze various risk measures under different utility functions and to examine portfolio optimization and diversification decisions. Furthermore, the two-moment decision model provides a tractable approach for investigating risk-taking behavior within the context of stochastic dominance theory and investors' risk preferences. Finally, behavioral heuristics embedded in pseudo-Bayesian models offer explanations for excess market volatility that cannot be reconciled with a fully rational and efficient market. This section reviews these theoretical contributions, which collectively form the foundational building blocks of Behavioral Finance in the literature.

2.1 Cost of capital and stock returns

Thompson and Wong (1991) estimate the cost of capital using a Discounted Cash Flow (DCF) method that requires forecasting dividends. They show that past dividend behavior may support more than one reasonable forecasting model and that such models

can yield divergent estimates of the cost of capital. They also find no way to select the best cost of capital estimate. Any choice must ultimately be based on the analyst's judgment. Thompson and Wong (1996) extend the theory by proving the existence and uniqueness of a solution for the cost of equity capital. They also show that the cost of equity function is continuously differentiable and derive the formula for its reliability. Wong and Chan (2008) extend their theory further by proving the existence and uniqueness of this reliability. In addition, they propose estimators for the reliability and prove that the estimators converge to the true parameter. The estimation approach is further simplified, hence rendering computation easier. In addition, the properties of the cost of capital and its reliability will be analyzed with illustrations of several commonly used Box-Jenkins models. Obrimah and Wong (2022) establish the relationship between stock returns and the random walk process for trade imbalances and for the evolution of information.

2.2 Utility

Jeremy Bentham (1748-1832) laid the foundation of utilitarianism through the “greatest happiness” or utility principle, known as “good" as the maximization of satisfaction and the minimization of pain. Building on this philosophical framework, economists such as William Stanley Jevons (1835-1882) and Carl Menger (1840-1921) further developed utility theory as a tool for assessing the pleasure or discomfort that individuals derive from, or seek to ward off through, the consumption of goods or services.

2.2.1 Risk aversion and risk seeking

Early economic and financial models are largely built on the assumption of risk-averse behavior, as reflected in the seminal contributions of Bernoulli (1738), Arrow (1965), and Markowitz (1952a), among many others. In contrast, the literature on risk-seeking behavior has expanded more recently, with notable advances by Chan et al. (2020, 2022), Guo and Wong (2016), and Wong, Ma, Qiao, Broll, and Vieito (2026). Prior to these studies, intermediate developments were offered by Wong and Ma (2008), Lam et al. (2006), Wong (2007), Wong and Li (1999), and Li and Wong (1999). The earliest foundations of this line of research can be traced to the works of Hammond (1974), Slovic (1964), Pratt (1964), Tobin (1958), and others.

2.2.2 (Reverse) S-shaped utility functions

The theoretical problems associated with strictly concave utility functions have attracted considerable attention in the literature (Friedman and Savage, 1948; Markowitz, 1952b). To address these shortcomings, some scholars introduce an S-shaped value or utility function, characterized by concavity in the domain of gains and convexity in the domain of losses (Kahneman and Tversky, 1979; Tversky and Kahneman, 1992). On the other hand, Thaler and Johnson (1990) propose a reverse S-shaped utility specification, under which individuals display a stronger aversion to

losses while exhibiting greater risk-seeking behavior when experiencing gains. Empirical evidence provided by Ranganathan (2018) suggests that both S-shaped and reverse S-shaped utility forms play a significant role in making investment decisions. Levy and Wiener (1998) lend support to the reversed S-shaped utility function while rejecting the S-shaped formulation. Subsequent studies, including Levy and Wiener (1998), Levy and Levy (2002, 2004), Wong and Chan (2008), Broll, Egozcue, Wong, and Zitikis (2010), Egozcue et al. (2011a), and others, further develop stochastic dominance frameworks tailored to investors with S-shaped and reverse S-shaped utility functions. More recently, Wong, Yeung, and Lu (2023) made a pioneering contribution by formally developing theories and establishing theorems for mean-variance rules applicable to investors characterized by reverse S-shaped utility functions.

2.2.3 Skewness seeking

Using invention data, Åstebro (2003) shows that the internal rates of return are characterized by a skewed distribution, based on an experiment investigating preferences for skewness. Complementary findings by Åstebro et al. (2015) indicate that both university students and experienced executives exhibit a greater willingness to take risks when lottery outcomes display positive skewness.

2.2.4 Regret-aversion

The notion of regret aversion was initially formulated by Loomes and Sugden (1982), who incorporated regret into models of individual decision-making. Around the same time, Bell (1982) introduced regret as a modifying element within expected utility theory, arguing that its inclusion enhances the framework's descriptive relevance. Loomes and Sugden (1982) also provided the earliest formal theoretical treatment of regret. Subsequent theoretical developments, including the specification of regret-averse utility functions, are presented in later studies such as Egozcue et al. (2015) and Guo et al. (2015), which propose several well-defined forms of regret-averse utility functions.

2.2.5 Disappointment Aversion

Guo et al. (2021) have developed the optimal production decision theory for firms with disappointment aversion utility functions.

2.2.6 Multivariate utility functions

A substantial body of the literature employs multivariate or multidimensional utility functions (see, for example, Eisner and Strotz, 1961; Guo and Wong, 2016). A commonly adopted simplifying assumption is that these utility functions satisfy the separability property (Keeney and Raiffa, 1976).

2.3 Stochastic Dominance (SD)

Stochastic dominance (SD), a form of stochastic ordering, is used to compare and rank

probability distributions. It plays a fundamental role in analyzing decision making under alternative utility functions and, therefore, constitutes a core component of the theoretical development of Behavioral Finance. This section outlines several key aspects of SD. Theoretical developments and practical implementations are thoroughly covered in key references, notably Sriboonchita, Wong, Dhompongsa and Nguyen (2009), Levy (2015), Egozcue and Wong (2010a), and related works.

2.3.1 Stochastic dominance (SD) for risk averters and risk seekers

Stochastic dominance (SD) serves as a central analytical framework for formulating portfolio and asset selection criteria for risk-averse and risk-seeking agents with a wide range of utility functions. The theoretical foundations of SD for risk-averse agents were established through early and influential studies by Rothschild and Stiglitz (1970, 1971), Tesfatsion (1976), and Meyer (1977), among others. In contrast, a distinct stream of research has expanded SD theory to accommodate risk-seeking behavior, with important contributions from Li and Wong (1999), Wong and Li (1999), Wong (2007), Levy (2015), Guo and Wong (2016), and subsequent studies. In addition, Wong, Ma, Qiao, Broll, and Vieito (2026) have developed a new SD theory for investors with both risk-averse and risk-seeking utilities.

2.3.2 Stochastic dominance (SD) for investors with (reverse) S-shaped utility functions

Second-order SD theory has been extended to accommodate investors characterized by reverse S-shaped utility functions (Levy and Wiener, 1998) as well as S-shaped utility functions (see, for example, Levy and Levy, 2002, 2004). Within this framework, SD theory for S-shaped preferences is referred to as prospect SD (PSD), whereas the corresponding concept for reverse S-shaped preferences is known as Markowitz SD (MSD). Further theoretical refinements and generalizations of both PSD and MSD were subsequently developed by Wong and Chan (2008).

2.3.3 Almost Stochastic Dominance

Leshno and Levy (2002) introduced the theory of ‘almost’ stochastic dominance (ASD) to identify preferences for “most" decision-makers. Since its introduction, ASD has been applied extensively in financial market studies, including those by Bali et al. (2009), Levy (2009), and Levy et al. (2010). Nonetheless, later research demonstrates that almost second-degree SD (ASSD) fails to satisfy expected utility maximization and does not preserve the hierarchy property (Guo et al., 2013; Tzeng et al., 2013). Guo et al. (2014) establish necessary conditions taking the form of restrictions on algebraic combinations of moments of the probability distributions for ASD criteria of various orders. Guo et al. (2016) extend the theory of ASD to include the ASD for risk-seeking investors.

2.4 Diversification Behaviors

Diversification is a core topic in Behavioral Finance. Much of the existing theoretical literature has focused on diversification decisions made by risk-averse investors, with comparatively less attention given to risk-seeking behavior. To address this imbalance, several studies have examined how risk-seekers diversify their portfolios. Wong and Li (1999) have extended the convex SD theorem to include any distribution functions and to apply to both risk seekers and risk averters. Li and Wong (1999) have developed results on diversification preferences for risk averters and risk seekers. Egozcue and Wong (2010b) have developed some results on diversification by using both majorization theory and the SD theory. In addition, Egozcue et al. (2011a) have developed results on diversification for Markowitz preferences, and Lozza et al. (2018) have provided a general valuation of investors' diversification attitude.

2.5 Indifference Curves

Tobin (1958) was the first to explain the upward (downward) convexity of indifference curves for risk-averse (risk-seeking) investors and their horizontality for risk-neutral investors. Subsequent extensions within the location-scale family were developed by Meyer (1987) and Wong and Ma (2008). Building on these insights, Broll, Clark and Lukas (2010) developed a theory of risk-hedging decisions grounded in S-shaped utility functions and specific properties of indifference curves.

2.6 Mean-Variance (MV) Portfolio Optimization

Markowitz (1952a) developed the MV portfolio optimization theory for guiding the construction of optimal portfolios, in which investors either maximize expected return subject to a given level of risk or minimize risk for a specified level of expected return. The theory is built on the assumption that investors are risk-averse. However, subsequent research has shown that Markowitz's (1952a) MV model substantially overestimates actual portfolio returns, a result first proved by Bai et al. (2009a, b).

2.7. Risk Measures

Risk measures are used to evaluate the risk and return performance of assets.

2.7.1 Selection rules

MV selection rules have been developed to account for both risk-averse behavior (Markowitz, 1952b; Tobin, 1958) and risk-seeking preferences (Wong, 2007). In addition, the relationship between MV rules and SD rules (Wong, 2007), as well as between the moment rules and SD rules for both types of investors (Chan et al., 2022).

2.7.2 Sharpe Ratio

Originating within the MV framework, the reward-volatility ratio, also known as the Sharpe ratio (Sharpe, 1966), measures performance as the risk premium per unit of risk.

Several extensions of this measure have been proposed, including multiple Sharpe ratios (Leung and Wong, 2008) and mixed Sharpe ratios (Wong et al., 2012). The linkage between the Sharpe ratio and SD for risk-averse investors is further analyzed by Chow et al. (2019). Additionally, alternative performance criteria based on mean-VaR and mean-CVaR measures have been developed (Guo, Chan, Wong, and Zhu,2019). Broader extensions and applications of these performance measures are documented in Leung and Wong (2008), Bai, Wang and Wong (2011), Bai, Li, McAleer and Wong (2015), Leung, Roura-Pascual et al. (2012), Ng et al. (2017), and Chan et al. (2020).

2.7.3 Omega ratio

Introduced by Shadwick and Keating (2002), the Omega ratio is the probability-weighted ratio of gains to losses relative to a specific threshold return target for performance evaluation. Guo, Jiang, and Wong (2017) investigate its relationship with SD. Building on this work, Chow et al. (2019) further develop the theoretical links between the Omega ratio and SD for both risk-averse and risk-seeking investors, demonstrating the superiority of the Omega ratio over the Sharpe ratio as a performance measure.

2.7.4 First- and higher-order risk measures

Niu et al. (2016) establish the consistency of the Farinelli and Tibiletti (FT) ratios with respect to first-order SD, and show that second-order SD is not consistent with the FT ratios. On the other hand, Niu et al. (2017) extend the theory of the Kappa ratio and SD and risk-seeking SD. For details, read Guo, Niu and Wong (2019).

2.8 Two-Moment Decision Model

According to SD theory and the preference structures of both risk-averse and risk-seeking investors formulated by Wong and Ma (2008) and related studies, a two-moment decision model has been developed. This framework has been applied widely in Behavioral Finance, with illustrative applications reported in Broll et al. (2006) and Broll et al. (2011, 2015).

On the other hand, Alghalith et al. (2016) present a stochastic factor model with an additive background risk and a dynamic model of simultaneous (correlated) multiplicative and additive background risks. In addition, Alghalith et al. (2017) examine the effects of joint energy and output price uncertainties on input demands in a mean–variance framework.

2.8.1 Two-Moment Decision Model with Background Risk

Alghalith et al. (2016) develop some results for the investment model with background risk, Guo et al. (2018) develop some results for the two-moment decision model with additive risks, and Guo, Chan, Wong, and Zhu (2019) develop some results for the

mean–variance, mean–VaR, and mean–CVaR models with background risk.

2.9 Behavioral Models for Overreaction and Underreaction

Drawing on the behavioral heuristics of conservatism and representativeness, a stream of studies has developed Bayesian models to account for short-run underreaction, long-run overreaction, the magnitude effect, and excess volatility (Barberis et al., 1998; Lam et al., 2010, 2012; Fung et al., 2011; Guo, McAleer, Wong and Zhu, 2017). In particular, Fung et al. (2011) incorporate financial crises into the analysis by modelling stock returns as random walks with and without drift, while Guo, McAleer, Wong and Zhu (2017) extend the theoretical framework by relaxing the distributional assumptions and allowing returns to follow an exponential family distribution.

2.10 Covariance and Copulas

Egozcue et al. (2009) derive some covariance inequalities for monotonic and non-monotonic functions. Egozcue et al. (2010) sharpen the upper bound of a Grüss-type covariance inequality by incorporating a notion of quadrant dependence between random variables and also utilizing the idea of constraining the means of the random variables. Egozcue et al. (2011a) show that Grüss-type probabilistic inequalities for covariances can be considerably sharpened when the underlying random variables are quadrant dependent in expectation (QDE). Egozcue et al. (2011b, c) establish new results for determining the covariance sign and provide further insights into the area. Egozcue et al. (2012) establish the smallest upper bound for the pth absolute central moment over the class of all random variables with values in a compact interval. Egozcue et al. (2013) establish general results that determine when convex combinations of arbitrary quadrant dependent (QD) copulas give rise to negatively or positively QD/QDE copulas.

2.11 Other Financial Economics Models

Egozcue and Wong (2010a) and Egozcue et al. (2014) have developed some results for the theory of the integration–segregation decisions. Alghalith and Wong (2022, 2024) and Alghalith et al. (2018) have developed some results for the theory of options, while Alghalith and Wong (2020a) have developed some results for the theory of macro hedging. Alghalith and Wong (2020b) have extended Stein's lemmas to include general functions and distributions, and Obrimah and Wong (2022) have developed some results for the theory of stock returns.

3. Behavioral Econometric Methods

With the evolution of theoretical models as shown above, various econometric methods, such as testing procedures, test statistics, and estimators, have been developed to evaluate the validity of Behavioral Finance theories and to enhance estimation

performance. In this section, we review several key Behavioral Econometric methods.

3.1 Investors' behavioral models by using conservative and representative heuristics

Lam et al. (2008) and Fabozzi et al. (2013) have developed three test statistics to examine the magnitude effects of the underreaction and overreaction phenomena in the stock market.

3.2 Stochastic Dominance (SD) Tests

A wide range of stochastic dominance (SD) testing procedures has been developed in the Behavioral Econometrics literature, with notable contributions from Davidson and Duclos (2000), Barrett and Donald (2003), Linton et al. (2005), Post and Versijp (2007), and Linton et al. (2010). Many existing SD tests, however, rely on technically complex formulae that limit their practical applicability. To address this issue, Ng, Wong and Xiao (2017) introduce a new class of SD tests that can be implemented using standard quantile regression routines available in commonly used software packages, including R, SAS, MATLAB, and RATS. Moreover, Bai et al. (2015) develop SD statistics for both risk-averse and risk-seeking investors, while Bai, Li, Liu, and Wong (2011) develop new statistics for both prospect and Markowitz SD of the first three orders. They have derived the asymptotic distributions and employed bootstrapped critical values. These SD test statistics have been applied to examine market efficiency and arbitrage opportunities. More recently, Chan et al. (2020) have developed a testing procedure for third-order SD applicable to both risk-averters and risk-seekers.

3.3 Tests for Market Efficiency

In its weak form, the efficient market hypothesis (EMH) holds that asset prices fully reflect all information contained in past market data, implying that historical price patterns cannot be systematically exploited to forecast future returns (Fama, 1970). Bai, Li, Wong and Zhang (2011), Bai et al. (2015) and Ng et al. (2017) developed SD statistics to assess market efficiency. Guo, Jiang and Wong (2017) further argue that both SD criteria and the Omega ratios provide effective tools for evaluating market efficiency. A large body of empirical research, including Lean, McAleer and Wong (2010), Lean et al. (2012), Tsang et al. (2016), Zhu et al. (2019), and Lv et al. (2023), applies SD tests and/or the Omega ratio and reports evidence inconsistent with market efficiency. Additional findings against market efficiency are documented in Sriboonchita et al. (2009), Woo et al. (2020), and Wong (2007). Beyond these approaches, alternative methodologies have also been employed. For instance, studies relying on technical analysis, such as Wong, Chew, and Sikorski (2001), Wong et al. (2003), Wong et al. (2005), and Kung and Wong (2009), demonstrate that trading strategies based on technical indicators can generate abnormal returns, thereby

challenging market efficiency. Further evidence using technical analysis is provided by Chan et al. (2014). Rejection of market efficiency supports the validity of the Behavioral Finance model in describing investors' behavioral patterns in financial markets.

3.4 Estimation Methods for Mean-Variance (MV) Portfolio Optimization

Recent advances in econometric techniques have enhanced the analysis of portfolio optimization. Prior research shows that estimates derived from the classical MV portfolio optimization model (Markowitz, 1952a) tend to substantially overstate actual returns (Bai et al., 2009a, b). To correct this bias, the bootstrap-corrected estimation methods have been proposed (Bai et al., 2009a, b; Bai, Li, Wong, and Zhang, 2011; Bai and Silverstein, 2010). Empirical evidence indicates that these approaches effectively alleviate over-prediction and significantly improve estimation accuracy. Leung, Ng, and Wong (2012) develop a new estimator for the optimal portfolio return based on an unbiased estimator of the inverse of the covariance matrix and its related terms, and derive explicit formulae for the estimator of the optimal portfolio return. Li, Bai, Wong, and McAleer (2022) have developed the spectrally corrected estimation for the theory of portfolio optimization. Li, Jiang, Chen, and Wong (2022) have proposed a new portfolio selection model with two mental accounts.

3.5 Tests for Risk Measures

Leung and Wong (2008) developed a multiple Sharpe ratio test statistic to assess the equality of multiple Sharpe ratios, along with their limiting distributions and related properties. Subsequently, Wright et al. (2014) proposed an alternative testing method for the equality of multiple Sharpe ratios and reported empirical findings that differ from those of Leung and Wong (2008). Moreover, many studies grounded in optimal stopping theory argue that the 'bang-bang' (intermediate buy-or-sell) strategy outperforms the conventional 'buy-and-hold' strategy. Nonetheless, Wong et al. (2012) developed the mixed Sharpe ratio to test the null hypothesis of equal performance between the two strategies, and their findings indicate that the 'bang-bang' strategy delivers superior performance. Bai, Wang, and Wong (2011) developed the mean-variance-ratio statistic to test the equality of the mean-variance ratios and prove that their proposed statistic is uniformly most powerful unbiased. Bai, Hui, Wong, and Zitikis (2012) have developed a uniformly most powerful unbiased (UMPU) mean-variance-ratio (MVR) statistic for comparing the performance of prospects after the effect of the background risk has been mitigated.

3.6 Covariance and Copula

The econometric concepts of covariance and copula are closely related to Behavioral Finance, as investors' behavioral patterns influence the dynamics of covariance, which

itself evolves. A copula, defined as a multivariate cumulative distribution function, provides a flexible and robust statistical framework for modeling such time-varying dependence structures. Covariance inequalities proposed by Egozcue, Garcia and Wong (2009) have been employed to support empirical investigations into phenomena such as excess stock market volatility arising from conservatism and representative heuristics in behavioral models. Subsequent refinements to these covariance inequalities were made by Egozcue et al. (2011b, c), further enhancing their applicability in Behavioral Econometric testing.

3.7 Robust Bayesian Estimation

Bian and Dickey (1996) developed a Bayesian estimation approach that remains robust across a broad class of distributions, including flat-tailed distributions commonly observed during periods of stock market crashes. Bian and Wong (1997) made further improvements to the Bayesian estimation method. Bian et al. (2013) applied the robust Bayesian estimator to reexamine the Capital Asset Pricing Model, showing that the resulting coefficient estimates are more efficient than those obtained using least-squares estimators.

3.8 Spurious model

The literature has found that regression of independent (nearly) nonstationary time series could be spurious. However, Cheng et al. (2021) have shown that under some situations, the regression of two independent and nearly non-stationary series does not have any spurious problem at all.

Cheng et al. (2022), Wong, Cheng, and Yue (2024), Wong, Pham, and Yue (2024), Wong and Yue (2024), and Wong and Pham (2022a, b; 2023a, b; 2025a, b; and 2026a, b) have further explored the theory. For example, Cheng et al. (2022) found that significant regression could appear significant in some cases, but significant regression cannot be treated as insignificant in some other cases. On the other hand, Wong, Cheng, and Yue (2024) have found that regression of stationary time series may yield spurious outcomes in some situations.

3.9 Other estimation and statistics

Bian and Wong (1997) have developed an alternative approach to estimate regression coefficients. Bian, McAleer, and Wong (2011) have developed a trinomial test for paired data when there are many ties. Tiku and Wong (1998) have developed a unit root test to test whether the variable following an AR(1) model has a unit root.

Wong et al. (2007) introduced a time-varying cointegration approach in which the cointegrating parameter is allowed to follow a smooth function of time. We apply this technique to study the cointegration relationship between the US mortgage and capital

markets and find that they are cointegrated after 1982 with a time-varying cointegrating parameter. Penm et al. (2003) proposed using a zero-non-zero (ZNZ) pattern for the vector error-correction model (VECM) and demonstrated the usefulness of the ZNZ-patterned VECM with applications.

Lam et al. (2006) have developed a new variance ratio test in which the autocorrelation of the k-period returns is not restricted to the AR(1) process but takes the form of a general ARMA process.

Bai et al. (2010) and Qiao et al. (2009) have developed a nonlinear causality test in multivariate settings. Bai, Li, Wong, and Zhang (2011) have developed a nonlinear causality test in multivariate settings and conducted simulations to demonstrate the superiority of their proposed test. In addition, Bai et al. (2018) have improved the statistics by re-estimating the probabilities and reestablishing the central limit theorem of the new test statistic. Moreover, Chow et al. (2018) have modified the test to be a panel nonlinear causality test.

Niu et al. (2018) have constructed a one-sample confidence interval for the economic performance measure (EPM), constructed confidence intervals for the difference in the EPM of two independent samples, and derived the corresponding asymptotic distributions.

Wong and Miller (1990) have developed a theory and methodology for repeated time series (RTS) measurements on an autoregressive integrated moving average-noise (ARIMAN) process. Wong, Miller, and Shrestha (2001) have extended the RTS model where the fundamental component follows an ARMA process by using the Kalman filter technique.

Matsumura et al. (1990) have introduced a multinomial distribution model within the dollar-unit sampling framework, with a Dirichlet prior distribution for auditing.

Tiku et al. (1999a) have introduced the modified maximum likelihood (MML) estimators to estimate the autoregressive model of order with asymmetric innovations represented by gamma and generalized logistic distributions, Tiku, Wong, Vaughan, and Bian (2000) have extended the work by using the Student's t distribution, and Wong and Bian (2005) have extended the work by using the generalized logistic distribution.

Tiku et al. (1999b) have introduced the MML estimators to estimate the simple regression model with autocorrelated errors, following the Student's t distribution. Bian, McAleer, and Wong (2013) have extended the work by developing the MML estimator for the multiple linear regression model with an underlying Student's t distribution. Wong and Bian (2000) have introduced the robust Bayesian estimator to the estimation of the Capital Asset Pricing Model.

Bian et al. (2011) develop a new test, the trinomial test, for pairwise ordinal data samples to improve the power of the sign test by modifying its treatment of zero differences between observations, thereby increasing the use of sample information. Simulations demonstrate the power superiority of the proposed trinomial test statistic over the sign test in small samples in the presence of tie observations. We also show that the proposed trinomial test has substantially higher power than the sign test in large samples and also in the presence of tie observations, as the sign test ignores information from observations resulting in ties.

4. Applications

In this section, we review the recent applications of Behavioral Finance theories and Behavioral Econometric methods to the analysis of real-world financial issues. These applications illustrate the practical relevance of psychological behavior in financial markets and the effectiveness of corresponding econometric techniques in explaining investors' behaviors and observed market anomalies in empirical studies.

4.1 Stochastic Dominance (SD)

Lv et al. (2021) conjecture that an optimal investment choice favors assets with high expected returns and low variance. By evaluating portfolio performance with and without healthcare and 6-month US T-bills, they provide empirical support for this conjecture, showing that portfolios containing such assets yield higher expected utility. Their analysis also reveals a limited number of arbitrage opportunities across the markets considered. Building on this line of inquiry, Wong, Yeung and Lu (2023) further suggest that portfolio performance measured by higher expected utility and/or potential arbitrage opportunities can be enhanced by including assets with the highest mean returns, assets that stochastically dominate a large set of other assets, and assets with minimal standard deviation. Using stocks from both emerging and developed markets, they confirm that these conjectures hold in terms of expected utility and identify a small number of stocks that exhibit first-order SD over others.

Extensions include adding other assets in the portfolios, for example, gold (Hoang, Lean, and Wong, 2015; Hoang, Wong and Zhu, 2015; Hoang et al., 2019 and 2020), oil (Lean, McAleer and Wong, 2010, 2015), real estate (Qiao and Wong, 2015; Tsang et al., 2016; Lv et al., 2023), wine (Bouri et al., 2018), warrants (Chan et al., 2012), futures (Clark et al., 2016; Qiao et al., 2013), etc. Extensions also include using more advanced portfolio estimation; see, for example, Bai et al. (2009a, b), Leung, B., Roura-Pascual et al. (2012), Li et al. (2018a, b), Li, Bai, Wong and McAleer (2022), Li, Jiang, Chen and Wong (2022), Chan et al. (2022), and Hui et al. (2024). Extensions could also include the preferences of different investors on the issue; see, for example, Fong et al. (2005; 2008), Egozcue et al. (2011a), Qiao et al. (2012), Lozza et al. (2018), Wong, Yeung and Lu (2023), and preferences of investors on different events, such as a crisis (Lean et al., 2015; Zhu et al., 2019).

4.2 Underreaction and Overreaction

Fabozzi et al. (2013) propose a set of three tests designed to detect short-term underreaction, long-term overreaction, and the magnitude effect, and their results provide support for the presence of these phenomena. In a related study, Wong et al. (2018) used questionnaire survey data to empirically assess the Bayesian models developed by Lam et al. (2010, 2012). By testing for conservative and representative heuristics among Hong Kong small investors who employ momentum and contrarian trading strategies, they find evidence consistent with the predictions of these behavioral models.

4.3 Herding Effect

We have been applying existing theories and methods from Behavioral Finance and Econometrics to study the herding effect. See, for example, Munkh-Ulzii et al. (2018), Batmunkh et al. (2018; 2020), Choijil et al. (2022), and others for more information.

Munkh-Ulzii et al. (2018) used the return dispersion model to study herding behavior in the Chinese and Taiwan stock markets. They observed significant herding in both markets overall, during periods of high and low trading volume, and in both bull and bear markets. Batmunkh et al. (2020) applied the cross-sectional absolute deviation (CSAD) model to analyze herding in the Mongolian stock market across the full sample, during bull and bear markets, under high- and low-volatility conditions, and around four major events in Mongolia. Choijil et al. (2022) employed bibliometric methods to review research on herding behavior in financial markets and documented substantial growth in this area. Conversely, Vieito et al. (2024) utilized a modified return dispersion approach to examine herding in the Latin American Integrated Market (MILA) and to assess the presence of ARCH or GARCH effects. Their results indicate strong herding under general market conditions, with moderate and partial herding during specific regimes, including bull and bear phases and high- and low-volatility periods. They also detected stronger herding in the pre-MILA period than in the post-MILA period, along with significant ARCH and GARCH effects associated with herding behavior.

4.4 Economic and Financial Indicators

In contrast to the efficient market hypothesis, which asserts that technical indicators cannot systematically outperform the market, a wide range of financial indicators have been shown to possess predictive power for market movements and to generate abnormal returns. For example, Wong, Chew, and Sikorski (2001) propose a novel forecasting indicator constructed from bond yields and earnings-price (E/P) ratios. They further introduce two test statistics to assess the indicator's effectiveness in evaluating stock market performance. Empirical results indicate that signals generated by this

indicator enable investors to mitigate losses during market downturns and benefit from market upswings, thereby achieving performance superior to the overall market.

4.5 Technical Analysis

Technical analysis has strong links to Behavioral Finance because it is capable of producing trading signals that distinguish between bull and bear market conditions, such as the financial indicator introduced by Wong, Chew, and Sikorski (2001). Extending this line of research, Wong et al. (2003) employ moving averages and the relative strength index as tools for generating buy and sell signals and develop corresponding test statistics to assess their performance. Their empirical results indicate that these indicators are able to deliver significantly positive abnormal returns. In a related study, Wong et al. (2005) analyze stock market profitability in Shanghai, Taiwan, and Hong Kong using entry and exit signals derived from various moving-averages strategies, and they further document that such strategies can indeed generate abnormal profits.

4.6. Contagion Tests

Wan and Wong (2001) develop a model of refinancing games under incomplete information that provides a theoretical explanation for financial contagion and inductance. In the Behavioral Econometrics literature, several empirical contagion tests proposed by Fry et al. (2010) and Fry-McKibbin and Hsiao (2018) are widely used to investigate cross-market contagion effects. Building on these contributions, Fry-McKibbin, Hsiao and Martin (2019) introduce joint contagion tests. Applying these tests to daily eurozone equity returns over the period 2005-2014, they uncover evidence of contagion transmission during the European debt crisis that is not captured by traditional correlation-based tests. These findings have important implications for risk pricing and the design of well-diversified portfolios.

4.7. Diversification Strategies

Investors may adopt a variety of diversification strategies. According to Markowitz's (1952a) MV portfolio optimization theory, complete diversification constitutes the optimal allocation. In contrast, when risk seekers follow the selection criteria proposed by Li and Wong (1999), they tend to concentrate their investment in a single asset. Nevertheless, some investors favor holding a limited number of assets rather than a fully diversified portfolio (Statman, 2004). Furthermore, Plakandaras et al. (2019) argue that diversification does not always lead to superior performance. In this context, Jiang et al. (2021) propose a smart beta strategy that outperforms naïve diversification.

5 Concluding Remarks

This review is driven by the need to unify the major strands of Behavioral Finance and Behavioral Econometrics. Although these fields are conceptually connected, the current literature often treats them separately. This fragmentation creates a knowledge gap by impeding a comprehensive understanding of how models are developed, how they are empirically validated, and how their insights can be applied practically in finance. Our review's originality lies in synthesizing these strands, thereby highlighting their natural interconnections and offering academics and practitioners a solid foundation for developing theories, conducting empirical research, and designing practical financial strategies. Interested readers are encouraged to consult the relevant literature in Woo et al. (2020) and Hon et al. (2021). The theories discussed here can be applied by both academics and practitioners across many areas, including stock markets (Demirer et al, 2019; Qiao et al., 2010; Gasbarro et al., 2007 and 2012; Cheng et al., 2019; Hassan, et al., 2023; Shrestha, 2024; Li et al., 2025; Wong et al., 2003, 2005, 2018), capital markets (Dev et al., 2023), commodity markets (Bai et al., 2013); futures markets (Lean, Lien and Wong, 2010; Lean, McAleer and Wong, 2010), housing markets (Gupta et al., 2019; Cho and Jung, 2024), Bitcoin (Wong, Zhu, Jiang, and Bouri, 2026). and beyond.

Additionally, this review paper has several limitations that should be acknowledged. Its scope is selective and does not encompass all topics in the literature. Although machine learning and artificial intelligence (AI) are increasingly applied in economics and finance (Ahmed et al., 2022), these areas fall outside the focus of this paper. For example, topics such as the use of AI and machine learning techniques to identify and predict investors' behavioral biases (Gupta et al., 2025), as well as quantitative methods for applying AI and machine learning in behavioral finance (Hojaji et al., 2022), are not addressed.

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among all Economists registered in RePEc in December 2023, etc. He has been serving international academies, Government, society, and universities, providing consultancy to several Government departments and corporations, and giving lectures and seminars to several universities. For example, he has been serving as editor, guest leading editor, advisor, associate editor for some international journals, appointed as an advisor/member of various international associations/institutes, serving as a referee for many journals/conferences, supervising solely or jointly several overseas graduate students, appointed as an external reviewer and external examiner by other universities, and invited by many universities/institutions to present papers or conduct seminars, for example, he is the Editor-in-Chief of Annals of Financial Economics, a Senior Co-Editor-in-Chief and Managing Editor for Advances in Decision Sciences, an Editor for Risk Management, Cogent Economics and Finance, Journal of Risk and Financial Management, Mathematical Problems in Engineering; Advisor for Asian Academy of Management Journal of Accounting and Finance; Associate Editor for International Journal of Emerging Markets, Financial Innovation, International Journal of Energy Research, Heliyon, Communications in Statistics: Theory and Methods, Communications in Statistics: Simulation and Computation, Asia-Pacific Journal of Operational Research, Studies in Economics and Finance, Bubbles and Behavioral Finance Investment Behaviour for Small Investors in the Hong Kong Stock Market 89 Economies, Journal of Infrastructure, Policy and Development, Communications in Statistics: Case Studies, Data Analysis and Applications, etc. He has published more than four hundred papers including papers published in journals ranked as A* in ABDC, Q1 in SJR Quartile, Q1 in JCR, and 4 in AJG and including papers published in Journal of Finance, Contemporary Accounting Research, Annals of Applied Probability, Scientific Report, Mathematical Finance, European Journal of Operational Research, Journal of Business and Economic Statistics, Economic Theory, Journal of Empirical Finance, Journal of Financial Markets, Journal of Economic Behavior and Organization, Economics Letters, Econometrics Journal, Quantitative Finance, Economic Inquiry, Energy Economics, Statistics and Probability Letters, Journal of Risk, Journal of Operational Research Society, Journal of Financial Econometrics, Journal of Forecasting, Journal of International Financial Markets, Institutions & Money, Transport Policy, Personality and Individual Differences, Journal of Time Series Analysis, Applied Economics, Journal of Multinational Financial Management, Journal of Behavioral Finance, Pacific-Basin Finance Journal, Global Finance Journal, Annals of Finance, Mathematics and Computers in Simulation, IMA Journal of Management Mathematics, Review of Quantitative Finance and Accounting, North American Journal of Economics and Finance, Accounting & Finance, Economic Modelling, Energy Policy, Applied Mathematics Letters, Journal of International Consumer Marketing, Statistical Papers, Japanese Economic Review, Global Economic Review, Multinational Finance Journal, Central European Journal of Mathematics, Journal of Asian Economics, Mathematical Scientist, Journal of Retailing and Consumer Services, International Review of Financial Analysis, Current Issues in Method and Practice, Sustainability, Risk Management, Scientific Reports, International Review of

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