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NEIFAR, MALIKA

IHEC UNIVERSITY OF SFAX

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NEIFAR MALIKA[1]

malika.neifar@ihecs.usf.tn and mneifar68@gmail.com

Abstract

In this study, we examined the impact of some relevant UK macroeconomic factors, such as consumer price, interest rate, and exchange rates on UK stock price fluctuation by using the monthly data from 2008m01 to 2018m04. A general form of asymmetric Non-linear Auto-Regressive Distributed Lag (NARDL) model is adopted to examine the Generalized Fisher hypothesis (GFH). The F_{pss} bound test of (Pesaran, Shin, & Smith, 2001) for no co-integration shows the evidence of co-integration between the underlying variables. The estimated NARDL model provides strong evidence of stable long-run relationship between stock prices and deflation while the relation with inflation is not present. Both interest rate and exchange rate as independent regressors show negative significant long-run relationships with the stock market price. However, it is only the interest rate which has a significant effect for the stock price short-run adjustment to the new long-run stable equilibrium.

Key words: UK Stock Market, Macroeconomic Factors, Generalized Fisher hypothesis (GFH), NARDL model.

Jel classification: C12, C22, E44, G14, G15.

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[1] Associate Professor in Quantitative Methods at New Economic Department.IHEC, Sfax University. Postal address: Route Sidi Mansour Km 10, B.P. 43, 3061. Sfax, Tunisia.

I. Introduction

Many articles investigate the relationship between the stock market prices and macroeconomic factors. Some works concluded that there is no clear relationship between the stock market and macroeconomic variables. Some economists, such as (Fama E. F., 1981; Fama E. , 1990; Schwert, 1989). Schwert (1990) confirm the link between the stock market and some macroeconomic factors in a country with unclear expected signs in some cases.

The generalized Fisher hypothesis states that the expected nominal return on common stocks consists of a "real" return plus the expected rate of inflation. It is commonly attributed to a simple extension of the well-known Fisher hypothesis (the basic theoretical concept for the stock returns-inflation relationship).

" (Fama and Schwert, 1977) explain the generalized Fisher effect such that the market, if it is efficient and reflects all the available information at time t – 1, will set the price of common stocks so that the expected nominal return from t – 1 to t is the sum of the appropriate equilibrium expected real rate and the market's assessment of the expected inflation rate for the same time period," (Al-Khazali, 2004).

"Viewed in this context, the Fisher effect represents a form of arbitrage between financial assets and real assets in a single country. When expected inflation is high, investors move out of financial assets into real assets. According to this hypothesis, equities serve as hedges against inflation because they represent claims to real assets, which suggests a positive stock price is correlated to expected inflation" (Al-Khazali, 2004).

Although inflation decreases the value of money, according to the generalized Fisher hypothesis (Fisher 1930), in an efficient market, investors should be fully compensated for the increased price levels with an increase in nominal stock returns, so that real stock returns should only reflect expectations about real factors. This implies that real stock returns and inflation should vary independently, that is, stock returns should serve as a hedge against inflation, and, if this theory holds, we should observe a positive and one-to-one relationship between nominal stock returns and inflation rates.

Our study tend to relate the UK monthly stock prices (SP) to consumer price index (CPI), Interest rate (INT), and Exchange rate (EXC) over the period from 2008m01 to 2018m04.

Inflation rates have always been a key variable of interest, and its stabilization constitutes one of the objectives of the UK monetary policy.

" (Firth, 1979) and (Gultekin, 1983) found that the relationship between nominal stock returns and inflation in the UK is reliably *positive*, which is consistent with the generalized Fisher hypothesis," (Al-Khazali, 2004).

Considering the possibility that an asymmetric impact exists from the consumer price to stock price, a general form of asymmetric Non-linear Auto-Regressive Distributed Lag (NARDL) model is adopted to examine the *Generalized Fisher hypothesis*.

Empirically, the generalized Fisher hypothesis (GFH) for equity markets states that the real rates of return on common stocks and the expected inflation rate are independent and that nominal stock returns vary in a one-to-one correspondence with the expected inflation rate.

This research observes the effects of macroeconomic factors on stock prices in the UK Stock Market (SM). In order to achieve the objective of the study, the following hypotheses are developed:

H_1: Interest Rate has negative relation with the Stock prices in UK SM,
H_2: Exchange Rate has negative relation with the Stock prices in UK SM,
H_3: Inflation Rate has negative relation with the Stock prices in UK SM,

and

H_4: Deflation Rate has **positive** relation with the Stock prices in UK SM.

(Tsai, 2012) analyzed the relationship between stock price index and exchange rate in six Asian markets. Adopting quantile regression, results indicates that the *negative* relation between stock and foreign exchange markets is more obvious when exchange rates are extremely high or low.

Recently, using wavelet analysis (Tiwari, Cunado, Gupta, & Wohar, 2019) analyzed the relationship between stock returns and the inflation rates for the UK over a long time period (February 1790–February 2017) and at different frequencies. They also compare the results for the UK economy with those for the US and two developing countries (India and South Africa). They concluded that, while the relationship between stock returns and inflation rates varies across frequencies and time periods, there is *no evidence of stock returns acting as an inflation hedge*, irrespective of whether they look at the two developed or the two developing markets in their sample.

Table A 1 in the Appendix gives a sum up of a selected empirical review.

This paper is organized as follow. After a brief introduction, section II presents data analysis, section III deals with the econometric model, section IV presents and discuss the empirical results, and conclusion is given at section V.

II. Data analysis

Is there truly a link between the UK stock market price and certain macroeconomic factors? Before going on answering this question, we have to analyse our data. Our study tend to relate the UK monthly stock prices to consumer price index, Interest rate, and Exchange rate, all in log over the period from 2008m01 to 2018m04 (T = 124). Table 1 present data notation and description of these variables as well as data sources.

Table A 2 (in Annex) presents descriptive statistics (average value, Median, Maximum, Minimum, standard deviation, Skewness, Kurtosis, Jarque & Bera (JB) statistic and its p-value) for stock prices in log, LSP = log (SP), consumer price index in log, LCPI = log (CPI), Interest rate in log, LINT = log(INT), and exchange rate in log, LEXC = log(LEXC). Not all skewness parameters are negative. Coefficient of kurtosis are not all equal to 3. JB test statistics do not reject the normality assumption except for LEXC. All considered series have not Gaussian distribution except for LEXC (we do reject null hypothesis that the sample is Normally distributed at 5% significance level).

Table 1 : Definition of variables

Notation	Description	Source
LSP	The market stock price (SP) in log: the price that it sells for on the open market.	OCDE
LCPI	Consumer price index (CPI) in log, a measure that examines the weighted average of prices of a basket of consumer goods and services.	IMF
LINT	Nominal interest rates (INT) in log.	IMF
LEXC	Nominal exchange rate (EXC) in log.	IMF
INF	Inflation rate = ΔLCPI.	

Note: IMF: International Monetary Fund. OCDE: Organisation de Cooperation et de Developpement Economique. SP : Prices of common shares of companies traded on national or foreign stock exchanges. INT: is the cost or price of borrowing, or the gain from lending, normally expressed as an annual percentage amount.

From Figure 1 for each variable, LSP, LCPI, LINT, and LEXC are likely to be not stationary. In addition, it is evident that during the whole period, LSP is characterized by an increasing trend except during 2008-2009 (GFC period) and post 2016. It is almost the same case for the LCPI process. Interestingly, the LCPI trend decreased significantly by the end of 2015. However, it increased post 2016. LINT is characterized by a decreasing trend during the considered period with a remarkable decline during 2008-2009. In addition, LEXC's graph showed a growth in the trend over the entire period. Furthermore, from 2016, it's trend took an upward until the end of 2017.

Prior to our empirical analysis, we carried out augmented Dickey–Fuller (ADF) and Phillips–Perron (PP) unit root tests to examine whether considered variables follow stochastic trend. The tests unambiguously suggest the existence of one unit root for every variable in level (stationary at first difference), indicating that the time-series are integrated of order 1, I(1) (see Table 2 (Panel A)) except for LINT series (may be stationary).

To test for no cointegration and before employing causation analysis, we specify how many lags to include in the VAR models. Therefore, in order to find out the lag length, we followed a lag length selection criterion, the AIC (Akaike information criterion), SC (Schwarz information criterion), and HQ (Hannan-Quinn information criterion) which suggest 3 lags for the time series data as given by the least value of AIC (see Table A 3 in Annex 1).

Table 2 (Panel B) presents two correlation matrices. An upper triangle matrix for variables in level and a downward triangle matrix for variables in first difference. From the upper one, all correlation are significant, while the downward one shows the presence of a negative significant linear relationship between INF and R (at 10% level) and between INTG and R (at 5% level). All other correlation are significant except correlation between EXCG and R.

Table 2 (Panel C) presents the OLS results from static linear regression of the dependent variable LSP on independent variables LCPI, LINT, and LEXC. Finding say that there is no risk of problem of multi-colinearity between regressors since all calculated values of the VIF indicator are less than 5 (Mean VIF = 1.87). But, DW statistic is very law indicating weak specification of static model; errors are auto-correlated and then model need to be dynamic. In addition, all considered independent variables are significant at 1% level except exchange rate in log (even at 10% level).

To identify the direction of causal association among considered variables, we used the pairwise (Granger, 1969) causality test on stationary series (variables in first difference). Results are reported at Table A 4 (in Annex 1). Table A 4 shows that UK Stock return Granger cause all the considered macro factors while no one of these factors has effect on UK Stock return. More developed investigations are needed to get robust and meaningful results.

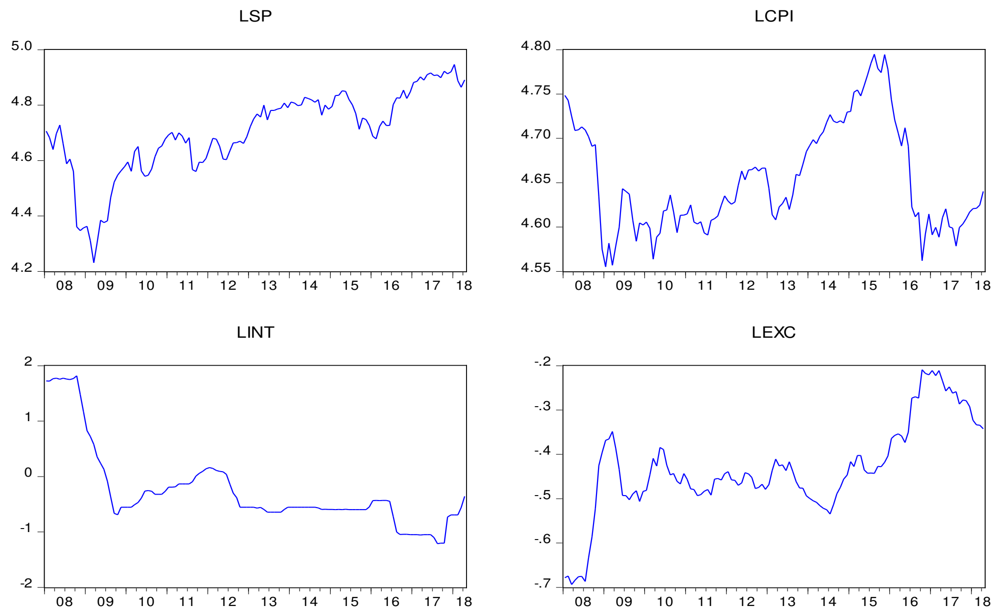

Figure 1: Nominal Stock price, consumer price index, Exchange rate, and interest rate evolution from January 2008 to April 2018.

Table 2: Unit root test results, Correlation Matrix and static model results.

Panel A Unit root test results

PP		**At level**				**At first difference**			
		LSP	**LCPI**	**LINT**	**LEXC**	**ΔLSP**	**ΔLCPI**	**ΔLINT**	**ΔLEXC**
With C	t-Stat	-1.4129	-2.2594	**-2.7200**	-2.4391	-9.7927	-9.4353	-5.5376	-8.0351
	Prob.	0.5740	0.1869	**0.0735**	0.1333	0.0000	0.0000	0.0000	0.0000
With C & Trend	t-Stat	-3.4658	-2.3831	-2.0134	-2.7088	-9.7794	-9.4272	-5.8829	-8.0523
	Prob.	0.0477	0.3865	0.5880	0.2350	0.0000	0.0000	0.0000	0.0000
Without C & Trend	t-Stat	0.3353	-0.5180	**-2.1984**	-1.4726	-9.8209	-9.4589	-5.4915	-7.9978
	Prob.	0.7806	0.4904	**0.0274**	0.1312	0.0000	0.0000	0.0000	0.0000
ADF		**At level**				**At first difference**			
		LSP	**LCPI**	**LINT**	**LEXC**	**ΔLSP**	**ΔLCPI**	**ΔLINT**	**ΔLEXC**
With C	t-Stat	-1.1259	-2.0814	**-2.8918**	-2.2451	-9.7561	-9.4353	-5.5376	-7.8278
	Prob.	0.7041	0.2526	**0.0492**	0.1917	0.0000	0.0000	0.0000	0.0000
With C & Trend	t-Stat	-3.1723	-2.2237	-2.2467	-2.1005	-9.7510	-9.4272	-5.8653	-7.8536
	Prob.	0.0949	0.4720	0.4594	0.5401	0.0000	0.0000	0.0000	0.0000
Without C & Trend	t-Stati	0.3951	-0.5570	**-2.3580**	-1.7928	-9.7791	-9.4589	-5.4915	-7.7832
	Prob.	0.7963	0.4740	**0.0183**	0.0695	0.0000	0.0000	0.0000	0.0000

Panel B: correlation matrix.

Correlation Probability	LSP	LCPI	LINT	LEXC	
R	**1.000000** -----	**0.241878** **0.0068**	**-0.586631** **0.0000**	**0.357394** **0.0000**	**LSP**
INF	-0.159308 0.0784	1.000000 -----	**0.157510** **0.0806**	**-0.423581** **0.0000**	**LCPI**
INTG	-0.225107 0.0123	0.330202 0.0002	1.000000 -----	**-0.689346** **0.0000**	**LINT**
EXCG	-0.135699 0.1345	-0.667621 0.0000	-0.141170 0.1194	1.000000 -----	**LEXC**
	R	**INF**	**INTG**	**EXCG**	

Panel C: Static OLS regression results.

LSP	**Coef.**	**Std. Err.**	**stat**	**p-value**	**VIF**	**1/VIF**
LCPI	.9877327	.190603	5.18	0.000	1.27 **< 5**	**0.786117**
LINT	-.1126902	.0192984	-5.84	0.000	1.99 **< 5**	**0.502761**
LEXC	.2088644	.148403	1.41	**0.162**	2.36 **< 5**	**0.423051**
cons	.1663881	.8599627	0.19	0.847		
F(3, 120)			**35.12**	**0.0000**		
R^2	**0.4675**					
Mean VIF					**1.87 < 5**	
DW			.14592			

Note: $INF_t = LCPI_t - LCPI_{t-1} =\Delta\, LCPI_t$, $R_t = LSP_t - LSP_{t-1} =\Delta\, LSP_t$, $INTG_t = LINT_t - LINT_{t-1} =\Delta\, LINT_t$, $EXCG_t = LEXC_t - LEXC_{t-1} =\Delta\, LEXC_t$.

III. Econometric Models

The first *static* linear model represent Generalized Fisher Hypothesis (GFH), relationship between stock prices to consumer price index is:

$$LSP_t = \mu + \beta\, LCPI_t + \Gamma\, Z_t + u_t, \quad (1)$$

where Z_t is a vector of money factors,

$$Z_t = (LINT_t, LEXC_t)',$$

u_t is the stochastic error term which is assumed to be i.i.d. $(0, \sigma^2)$, and μ, γ, and (Γ) are (vector) of real long-run parameters to be estimated. Our objective is to determine the characteristics of β. All of these variables are defined at Table 1.

To explore the *dynamic* linear relationships between stock market price and macro-economic factors, we consider the following equation in the ARDL *à la* (Pesaran, et al., 2001) form:

$$\Delta LSP_t = \mu(t) + \alpha\, LSP_{t-1} + \delta\, LCPI_{t-1} + \Xi\, Z_{t-1} + \Phi(L)\,\Delta LSP_t + \Theta(L)\,\Delta LCPI_t + \gamma(L)\Delta Z_t + \varepsilon_t, \quad (2)$$

Where $\Phi(L) = \sum_{i=1}^{p} \phi_i L^i$, $\Theta(L) = \sum_{i=0}^{q} \theta_i L^i$, $\gamma(L) = \sum_{i=0}^{q} \gamma_i L^i$, $Z_{t-1} = (LINT_{t-1}, LEXC_{t-1})'$,

$$\mu(t) = C_1 + C_2 t + \mu_1\, D2008 + \mu_2\, D2009 + \mu_3\, D2016,$$

D2008, D2009, and D2016 are indicator variables for year 2008, 2009, and 2016 respectively defined as follow:

D2008 = 1 for year = 2008 and zero if not,
D2009 = 1 for year = 2009 and zero if not,

and

$$D2016 = 1 \text{ for year} \geq 2016 \text{ and zero if not,}$$

$\mu(\mathrm{t})$ indicates changes of Stock Price by the end of 2007, by the end of 2008, and by the end of 2015, C_1 is the intercept of this equation, t is the trend, $\beta = -\delta/\alpha$, and $\Gamma = -\Xi/\alpha$ represent long-term relationship (all are real parameters). The terms Φ(L), Θ(L), and γ(L) are lag polynomials in the short-run variables with ϕ_i, θ_i and γ_i as short-run dynamic parameters, and $\varepsilon_t \sim$ WN (0, σ^2). α is the error correction parameter which measures the speed of adjustment to the long-run equilibrium following a shock and satisfies -1 < α < 0.

The *positive* relationship between stock prices and consumer price index in the long-run ($\beta = -\delta/\alpha$, > 0) is the *Fisher hypothesis*. It suggests that as inflation rises, investors on stock market are *compensated* for it in the long-run.

(Pesaran, et al., 2001) provided bound test [with two sets of critical values (lower and upper)] to resolve null hypothesis of no cointegration in the ARDL framework based on the *F*-type statistic (noted by F_{PSS}).[2] Bound test is applied regardless of whether the series are I (0) or integrated I (1).[3] If the F_{PSS} is greater than the upper critical bound, then the null hypothesis is rejected, suggesting that there is a stable long-run relationship between the variables under consideration. If the observed F_{PSS} lies within the lower and upper bounds, then the test is inconclusive. If the F_{PSS} falls below the lower critical bounds value, it suggests that there is no cointegrating relationship (we do not reject null hypothesis). If cointegrating relationship is established between stock returns and inflation, *Granger causality* test will be done in the following *error correction* model (ECM):

$$\Delta LSP_t = \mu(\mathrm{t}) + \alpha\, ECT_{1,t-1} + \Phi(L)\,\Delta LSP_t + \Theta(L)\,\Delta LCPI_t + \gamma(L)\,\Delta Z_t + \varepsilon_t, \quad (3)$$

where,

$$ECT_{1,t} = LSP_t - (\beta\ LCPI_t + \Gamma\ Z_t),$$

ECT_{t-1} is the error correction term representing the long-run relationship between stock prices and consumer prices, α captures the sensitivity of the error correction term. A *negative* and significant coefficient of the error correction term, α, indicates that there is a *long-run causal relationship* between stock prices and consumer prices. Precisely, α indicates a *causality from* consumer prices *to stock market* prices that implying that inflation drives stock returns toward long-run equilibrium and that stock price cannot be used as a *hedge* against inflation. In other words, the *unidirectional causality* from inflation (and Z_t) to stock returns hints an *inefficiency* of the stock market which suggests that information on past values of inflation could *provide opportunities* for abnormal *gains* from SP.

To investigate the possibility of asymmetry (the hypothesis that stock price responds differently to negative vis-à-vis positive consumer price change) and nonlinearity, equation (2) will be modified. Before developing the full representation of the Non linear ARDL model, let's start with the *asymmetric* long run regression of the stock price (LSP_t) − consumer price tradeoff :

$$LSP_t = \beta^+ LCPI_t^+ + \beta^- LCPI_t^- + \Gamma\, Z_t + u_t\,, (4)$$

where Z_t is a vector of control variables which enter the equation linearly,

$$LCP_t^+ = \sum_{j=1}^{t} \Delta\, LCPI_j^+ = \sum_{j=1}^{t} max\,(\Delta\, LCPI_j, 0) \quad (5)$$

and

[2] An other bount test based on *t* type statistic (noted by t_{BDM}) is proposed by (Banerjee, et al., 1998) is also needed to resolve hypothesis of no cointegration.

[3] The lower critical bound assumes that all the variables are I (0), meaning that there is no cointegration among the variables, while the upper bound assumes that all the variables are I (1).

$$LCPI_t^- = = \sum_{j=1}^{t} \Delta\, LCPI_j^- = \sum_{j=1}^{t} min\,(\Delta\, LCPI_j, 0),$$

are the partial sum process of the *positive* and *negative* changes in $LCPI_t$ (respectively *cumulative inflation* and cumulative *deflation*). Using this approach, we analyses the asymmetric pass-through from consumer price, decomposed as the partial sum processes of deflations and inflations, to stock prices.

By substituting for $LCPI_t$ in equation (2), the *asymmetric* ARDL model becomes

$$\Delta LSP_t = \mu(t) + \alpha\, LSP_{t-1} + \delta^+\, LCPI_{t-1}^+ + \delta^- LCPI_{t-1}^- + \Xi\, Z_{t-1} + \Phi(L)\,\Delta LSP_t + \Theta^+(L)\,\Delta LCPI_t^+ + \Theta^-(L)\,\Delta LCPI_t^- + \gamma(L)\Delta Z_t + \varepsilon_t, \quad (6)$$

or

$$\Delta LSP_t = \mu(t) + \alpha\, ECT_{1,t-1} + \Phi(L)\,\Delta LSP_t + \Theta^+(L)\,\Delta LCPI_t^+ + \Theta^-(L)\,\Delta LCPI_t^- + \gamma(L)\Delta Z_t + \varepsilon_t, \quad (7)$$

where

$$ECT_{1,t-1} = LSP_{t-1} - (\,\delta^+\, LCPI_{t-1}^+ + \delta^- LCPI_{t-1}^- + \Gamma\, Z_{t-1}),$$

$$\Theta^+(L) = \sum_{i=0}^{q} \theta_i^+\, L^i \text{ and } \Theta^-(L) = \sum_{i=0}^{q} \theta_i^-\, L^i,$$

$\delta^+ = -\beta^+/\alpha$ and $\delta^- = -\beta^-/\alpha$ are asymmetric long-run parameter, while θ_i^+ and θ_i^- are the asymmetric short-run parameters.

We need to test whether the 4 considered variables are cointegrated or not. If $\alpha = 0$, equation (7) reduces to the nonlinear regression involving only first differences, thus implying that there is no long run relationship between the levels of LSP_t, $LCPI_t^+$ and $LCPI_t^-$. We can consider two testing procedures based on the error correction model (7). (Banerjee, et al., 1998) proposed the use of the t-statistic testing $H_0: \alpha = 0$ against $H_a: \alpha < 0$, while (Pesaran, et al, 2001) proposed an F-test of the joint null,

$$H_0: \alpha = \delta^+ = \delta^- = 0 \; and \;\; \Xi = 0 \quad \text{Against } H_a: \alpha \neq 0 \cup \delta^+ \neq 0 \cup \delta^- \neq 0 \cup \Xi \neq 0$$

in model (6). These tests are based on t_{BDM} and F_{PSS} statistics respectively as denoted in (Shin, et al., 2014). Based on the (Pesaran, et al., 2001) bounds testing approach, rejection of the H_0 suggests the existence of long run asymmetric relationship.

Asymmetry is then tested via the Wald-test under H_0: $\delta^+ = \delta^-$ and $H_0: \theta_i^+ = \theta_i^-$ (or $H_0: \sum_{i=0}^{q} \theta_i^+ = \sum_{i=0}^{q} \theta_i^-$) for the long- and short-run, respectively.

A useful tool for analysing both the asymmetric short run adjustment and the asymmetric long run reaction is the *dynamic multipliers*. These multipliers represent the *transition* between the initial equilibrium, short run disequilibrium after a shock, and the new long run equilibrium. Indeed, the asymmetric dynamic multiplier measure the effects of one unit change in $LCPI_t^+$ and $LCPI_t^-$ individually on LSP_t and can be derived from equation (6). They are defined as:

$$\boldsymbol{m_h^+ = \sum_{j=0}^{h} \frac{\partial LSP_{t+j}}{\partial LCPI_t^+} \text{ and } m_h^- = \sum_{j=0}^{h} \frac{\partial LSP_{t+j}}{\partial LCPI_t^-} \quad for\ h = 0, 1, 2 \ldots} \quad (9)$$

where $m_h^+ \to \beta^+$ and $m_h^- \to \beta^-$ if $h \to \infty$. We calculate then the dynamic multipliers to obtain a measure of the cumulative effects of asymmetric consumer price shocks on stock prices and thus, to depict the adjustments of LSP in the disequilibrium stock-consumer prices relationship towards the new long run equilibrium.

IV. Empirical Results

Since considered variables are *not stationary* in level but stationary at 1st difference, we can pass for co-integration investigation. In order to test the no co-integration between time series we applied the (Johansen, 1988) test with p – 1 = 2. From Table A 5 (in Annex), result shows that there is *one co-integration* depending on the adequate case (case three). A VECM specification can then be explored. Long run cointegration relation results, impulse response function (IRF) results, and VECM Granger Causality/Block Exogeneity Wald Tests from VEC model (2) are respectively given at Table A 6, Figure B 2, and Table A 7 (all in Annex).

From Table A 6, LINT and LEXC have positive significant effect on LSP. From Table A 7, there are only the INT Growth (INTG) which cause à la Granger INF, and stock return and INF cause à la granger exchange rate growth (EXCG). From Figure B 2, the IRF say that: i) The graph shows that an innovation to the LCPI leads to a cumulative *increase* of about 0.1% in the 4 subsequent month on the LSP in UK; ii) An increase of 1 % in LINT leads to a cumulative effect on the LSP in UK; a *decrease* of less than 0.1% in the 5 subsequent month in LSP; iii) An increase of 1% in LEXC (depreciation) leads to a cumulative *decrease* of less than 0.02% in the 10 subsequent months in LSP; and iv) An increase of 1% in LSP leads to a cumulative *decrease* of more than 0.1% in the 6 subsequent month on the LSP in UK. All these cumulative effects are quite negligible.

Since LINT may be stationary, for testing the existence of a stable cointegrating long-run relationship, a pragmatic bounds-testing procedure which is valid irrespective of whether the underlying regressors are I(0) or I(1) will be used . Consequently, equations (2) and (6) will be estimated to capture both long-run and short-run dynamics relationships. We conduct a symmetric cointegration analysis using the ARDL model (2) and the asymmetric cointegration analysis by the nonlinear ARDL (NARDL) model (6). Nonlinear cointegration is validated by F_{PSS} bound test in 5% level (see Table 3) for NARDL specification (Panel (b)) and is not validated for the ARDL specification (Panel (a)).

Table 3: Bound test results.

	Value	Signif.	I(0)	I(1)	Conclusion
(a) ARDL model (Eq (2)); $k = 3$					
F_{PSS}	**2.725529**	**5%**	**2.79**	**3.67**	No cointegration
(b) NARDL model (Eq (6)) ; $k = 4$					
F_{PSS}	**3.743191**	5%	2.56	**3.49**	Cointegration

Note: Null Hypothesis: No levels relationship. The bound critical values reported in this Table are given by Eviews 10. From (Pesaran, et al., 2001, p. 300) Table CI, Case III, the upper bound critical value of the F-test for cointegration when there are [3] **4** exogenous variables is [3.77 (4.35)] 3.52 (4.01) at the 10% (5%) level of significance (critical values are computed via stochastic simulations using T = 1000 and 40,000 replications).

Table 4 contains the results of the asymmetric NARDL model which tests the hypothesis that inflation behave differently from deflation. *Long-run* symmetric hypothesis is rejected by Wald test (see Table 4). It means that the responsiveness of stock prices to consumer price shocks in UK market is asymmetric in the *long-run*. The estimated long-run coefficients on LCPI_t^- (cumulative deflation) and on LCPI_t^+ (cumulative inflation) are respectively equal to –0.3425 and –1.0618. Besides, the asymmetric *long-run* relation between stock prices and *inflation* is not significant while between the stock price and *deflation* is highly significant. Our estimate suggests that a 1% increase (decrease) in consumer price index leads to about 0.3425 %

(1.0618%) decrease in stock price given the NARDL model. This is not in line with (Neifar & al., 2021)'s results for pre 2008 GFC period based on ARDL model.

Table 4: Long-run relationship from NARDL model results.

Variable	Coefficient	t-Statistic	Prob.
$LCPI_t^+$	-0.342529	-1.129035	0.2613
$LCPI_t^-$	-1.061830	-2.502893	**0.0137**
$LINT_t$	-0.175775	-3.013704	**0.0032**
$LEXC_t$	-1.294549	-3.751034	**0.0003**
Symmetric hypothesis		**χ^2-stat**	**p-value**
W_{LR}		5.294987	0.0214
Diagnostic			
R^2		**0.954064**	
Breusch-Godfrey Serial Correlation LM Test:		3.522854	0.1718
Heteroskedasticity Test: ARCH(1)		0.004188	0.9484

Looking now to the analysis of *short-run* dynamic non-linearity from Table 5, we find that the ECM term has negative sign ($\widehat{\alpha} = -0.241592$) and is statistically significant at 1% level, ensuring that long-run equilibrium can be obtained in the case of NARDL model. The magnitude of the estimated coefficient α suggest that adjustment process is quite moderate. About 24% of the disequilibrium of previous month consumer price shock is adjusted back to equilibrium in the current month for UK stock prices. In addition, this results indicates a *causality from consumer prices to stock market* prices that implying that *deflation drives* stock *returns* toward *long-run equilibrium* and that stock price cannot be used as a *hedge* against inflation. However, from Table 5**,** both changes in $LCPI_t^+$ and in $LCPI_t^-$ have no effect (results do not provide possibility to check the existence of *short-run* asymmetry). It is observed rather that *only interest rate growth* which bring stock price back to the *long run* equilibrium.

Table 5: Short-run dynamic adjustment from NARDL model results.

Variable	Coefficient	t-Statistic	Prob.
ECM^*_{t-1}	**-0.241592**	**-4.842821**	**0.0000**
$\Delta LINT_t$	**-0.102192**	**-3.122145**	**0.0023**
D2008	0.047427	2.358523	0.0201
D2009	-0.016383	-1.419993	0.1584
D2016	0.007137	1.134325	0.2591

Note: D200j = 1 for year = 200j and zero if not, j = 8, 9, D2016 = 1 for year ≥ 2016 and zero if not. * p–value incompatible with t-Bounds distribution. From (Pesaran, et al., 2001, pp. 303, Table CII, Case III), the appropriate critical value for significance of ECM_{t-1} is -3.66 (-3.99) at the 10% (5%) level when k = 4.

Then, we derive the asymmetric dynamic multipliers characterizing asymmetries in the adjustment processes embedded in model (6). The predicted dynamic multipliers for the nonlinear adjustment of UK stock prices for the period 2008m01–2018m04 to the shock in the consumer prices are displayed at Figure 2. The black continue curves is for positive changes while discontinue black curves is for negative changes. Red curve is for the difference with its confidence intervals. The figure illustrates the adjustment paths from short-run disequilibrium to long-run equilibrium following consumer price shocks.

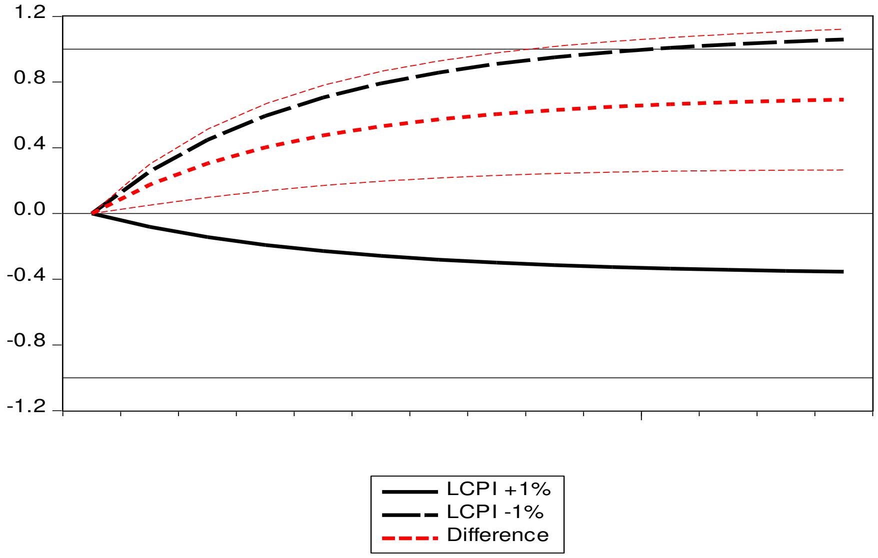

Figure 2: Cumulative asymmetric adjustments of LSP to LCPI (Dynamic multipliers and SR & LR asymmetry).

Results indicate that UK stock prices respond rapidly and strongly in the decrease (increase) of consumer price in the very short-run. The full adjustment to the new equilibrium is relatively slow process. Stock price exhibit relatively rapid adjustment in about 3 months with the absolute of deflation being significantly *larger* than that of inflation effect. Following these initial period, the speed of adjustment slows. It takes about 10 months to converge to the *long-run stable equilibrium*. Figure 2 demonstrates also the existence of asymmetric effects in the stock price-consumer price relationship dominated by the negative consumer price shock (deflation) which has *positive* cumulative effect on stock price in the UK stock market.

In other words, the *unidirectional causality* from deflation to stock returns hints an *inefficiency* of the stock market which suggests that information on past values of deflation could *provides opportunities* for abnormal *gains* from UK Stock Market.

In summary, the Fisherian assumption, that nominal return on the common stock varies in a one-to-one correspondence with inflation rate, is soundly rejected for UK SM. One of the implications of the results is that the market might be inefficient in impounding available information about future inflation into stock prices. The inefficient market means that stock prices may not adjust fully to expected inflation. Therefore, investors may not be able to construct a portfolio opportunity set based on information about future inflation in UK. More specifically, the generalized Fisher hypothesis may not represent a form of arbitrage between financial assets and real assets in UK.

We checked the adequacy of our dynamic asymmetric model based on various diagnostic statistic tests. Lagrange multiplier (LM) for autocorrelation up to lag (2) and the Breusch-Pagan-Godfrey statistic for heteroscedasticity. All these results are shown in the lower panel of the Table 4. To analyze whether or not the link between stock price and consumer price has been *stable* over time, Cumulative Sum (CUSUM) and CUSUM of Squares (CUSUMSQ) tests are used. Results for checking the structure stability are illustrated at Figure 3.

Model (6) is well specified since errors behave as White Noise; WN (Table 4). No serial correlation (p-value = 0.1718) nor heteroscedasticity (p–value = 0.9484) was detected from LM tests on the residuals. Results presented at Figure 3 gives a clear cut about stability of proposed model (both graph are inside limits). NARDL Model is stable as the QUSUM and QUSUM of square of recursive stability tests give the same conclusion (see Figure 3).

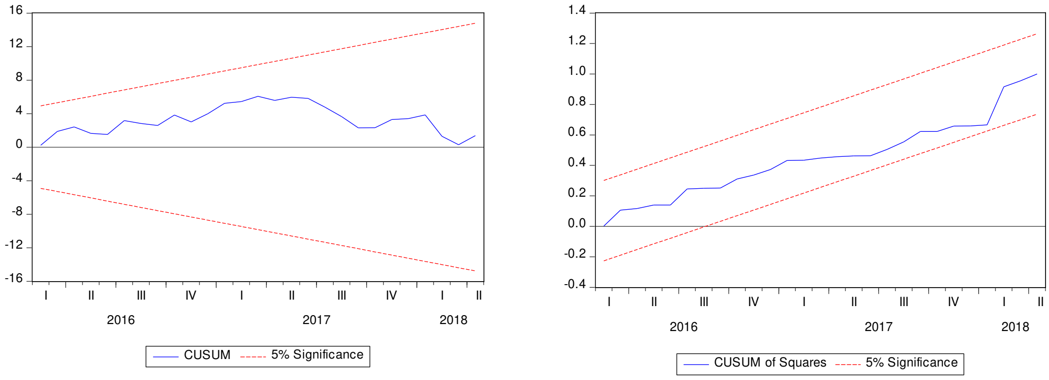

Figure 3: Stability Diagnostic Tests Post GFC; CUSUM and CUSUM of Squares.

V. Conclusion

In this study, we examined the impact of some relevant UK macroeconomic factors, such as consumer price, interest rate, and exchange rates on UK stock price fluctuation by using the monthly data from 2008m01 to 2018m04.

To examine validity of the Generalized Fisher hypothesis (GFH), we consider the possibility that an asymmetric impact exists from the consumer price (inflation and deflation) to stock price. A general form of asymmetric Non-linear Auto-Regressive Distributed Lag (NARDL) model is then adopted. For no co-integration hypothesis, the F_{pss} bound test of (Pesaran, et al., 2001) shows the evidence of co-integration between the underlying variables.

The estimated NARDL model provides strong evidence of stable long-run relationship between stock prices and deflation while the relation with inflation is not present. The asymmetric effects in the stock price-consumer price relation is dominated by a negative consumer price shock (deflation) which has positive cumulative effect on stock price in the UK stock market.

Both considered factors (interest rate and exchange rate) show statistically significant long-run relationships with the stock market. However, it is only the interest rate which has a significant effect for the stock price short-run adjustment to the new long-run stable equilibrium.

Appendix: A selective empirical review

Table A 1: A selected Empirical review.

Authors	**Variables**	**Model/Method**	**Sample: period and region**	**Effect of CPI / INF**	**Effect of INT**		**Effect of EXC**	
					-	**+**	**-**	**+**
(Fama & Schwert, 1977)	-SP -**CPI** –INF -EINF -TB (**INT**)	-Simple regression	**-**Monthly, quarterly and half-yearly data.1953-1971, United States					
(Gultekin, 1983)	-R –**INF** -EINF, UEINF -Short-term **INT**	-OLS -Cross-section -ARIMA	**-** Quarterly and monthly data**:**1947-1979 **-**.26 countries					
(Wongbangpo & Subhash, 2002)	-SP -GNP -M1 –**CPI** -**EXC -INT**	-Johansen cointegration -VECM -Granger's Causality	**-** Monthly data**:** 1985-1996 -. Indonesia, Malaysia, Philippines,Singapore, Thailand.		✓	✓	✓	✓
Gunasekarage and al. (2004)	-SP –M -TB (as a measure of **INT**) -**CPI** (as a measure of INF) -**EXC**	-Johansen cointegration -VECM	**--** Monthly data**:** 1985-2001 -. Colombo		✓			
(Ratanapakorn & Sharma, 2007)	-S&P500 **–INT** -M -IP -**Inflation (CPI)**	-VAR -Granger's Causality	**-** Monthly data**:** 1975-1999 - United States		✓			
(Adam & Frimpong, 2010)	-SP (DSI) **– INF** -**EXC -INT**	-Johansen's cointegration -VECM	**--** Quarterly data**:** 1991-2006 - Ghana				✓	
(Sohail & Hussain, 2009)	- LSE25 index **-CPI** -Real **EXC** -3-month **TB** -IIP - M2	-Johansen's cointegration -VECM	**-** Monthly data**:** 2002-2008 -. Pakistan					✓
(Geetha, Mohidin, Chandran, & Chong, 2011)	-SP **–INT -Inflation (CPI) -EXC** -GDP	-Johansen cointegration test -ECM	**-** Monthly data**:** 2000-2009 - United States, Malaysia, and China					

(Eita, 2012)	-The ratio of market capitalization to GDP -**EXC** - M2 -**Inflation (CPI)**	-VAR -VECM	**-** Quarterly data **:** 1998 to 2009 -. Namibia		✓			
(Dasgupta, 2012)	- SP (BSE SENSEX) - **Inflation** (CPI) -IIP – **EXC -INT** (Call Money Rate)	-Johansen's cointegration - Granger's Causality	**-** Monthly data**:** 2007-2012 - India				✓	
(Kuwornu, 2012))	-SP (ASI) –**INF -INT** –**EXC** -Oil prices	- Johansen's cointegration -ECM	**-** Monthly data**:** 1992-2008 - Ghana			✓		✓
(Khumalo, 2013)	-SP –**EXC** -M - **Inflation (CPI)** - GDP **-INT**	-**ARDL**-ECM-VAR	**-** Quarterly data**:** 1980 - 2010 - South Africa				✓	
(Olufisayo, 2013)	-SP **-INF(CPI) -INT** -GDP	-VAR-VECM	**-** Quarterly data**:** 1986-2010 -. Nigeria			✓		
Khan and Youssef (2013)	-SP (DSI) **-INT -EXC –CPI** -Crude oil prices - M2	-Johansen's cointegration-VECM	**-** Monthly data**:** 1992-2011 - Bangladesh			✓	✓	
(Issahaku, Yazidu, & Domanban, 2013))	-SP –**EXC** –**TB** -M **- CPI**	-Johansen's cointegration-VECM-Granger's Causality	**-** Monthly data **:** 1995-2010 - Ghana		✓			✓
Hunjra and al. (2014)	-SP –**INT -EXC** - GDP **-INF**	-VAR-Granger Causality	**-** Monthly data**:** 2001-2011 - Pakistan		✓		✓	
ZOA and al. (2014)	-SP (Nikkei 225) – **INF -EXC –INT** -IIP - Public debt	-Johansen's cointegration -VECM - Granger's Causality	**-** Monthly data**:** 2000-2012 -. Japan		✓			✓
Jareno and Negrut (2016)	-SP **–CPI** -IPI **–INT** – UNEMP - GDP	-Pearson correlation coefficients	**-** Quarterly data**:** 2008-2014		✓			

			- United States					
(Emeka & Aham, 2016)	-SP –**INF** -**EXC**	-Johansen's cointegration-AR(1) ARCH-S (1.1) - GARCH-X	**-** Quarterly data 1986-2012 - Nigeria				✓	
Saha, S. (2017)	- SP – **EXC** - **Inflation rate (CPI)** - M2 - IPI	**-ARDL-NARDL**	**-** Monthly data**:** 1973-2015 - Brazil, Canada, Chile, Indonesia, Indonesia, Japan, Korea, Malaysia, Mexico, United Kingdom and United States.					
(Bin & Celis, 2017)	-SP –GDP -The price of oil **-INF** The short-term **INT** **-EXC**	-Johansen's cointegration -VECM-Granger's Causality	**-** Quarterly data**:** 1996-2013 - Brazil, Russia, India, and China					
(Delgado, Bermudez Delgado, & Estefanía & Saucedo, 2018))	- SP – **EXC** -Oil prices -**CPI**	-Johansen cointegration -VAR-Granger causality	**-** Monthly data**:** 1992-2017 - Mexico					
(Neifar & al., 2021)	SP CPI Exchange rate, Interest rate, Inflation	Johansen's cointegration, Granger's and Toda Yamamote Causality, VAR Granger causality, ARDL model	**1999:m1-2007:12**	✓		✓		✓

Note: SP: stock price, R: stock return, RR; real Return, CPI: consumer price index, EXC: exchange rate, INT: interest rate, TB: treasury bond, INF: inflation, EINF: expected inflation, UEINF: unexpected inflation; RA: real activity, IIP: industrial production index, M (M1, M2): money supply, VT: volume of transaction, Unempl: unemployment rate, Annex: Some Tables and Figures

Table A 2: Descriptive statistics.

	LSP	LCPI	LINT	LEXC
Mean	4.701087	4.653406	-0.253260	-0.431679
Median	4.717635	4.634112	-0.553385	-0.443132
Maximum	4.946882	4.794893	1.818044	-0.209088
Minimum	4.230752	4.555019	-1.211669	-0.693580
Std. Dev.	0.152034	0.059928	0.740124	0.104922
Skewness	-0.847029	0.615232	1.661557	-0.054254
Kurtosis	3.510328	2.337925	5.165471	3.606086
Jarque-Bera	16.17307	10.08733	81.28383	1.958756
Probability	0.000308	0.006450	0.000000	**0.375545**

Note: lag 2 is used since p = 3.

Table A 3: Optimum lag length for VAR specification (2008m01-2018m04).

Lag	LogL	LR	FPE	AIC	SC	HQ
0	288.6543	NA	8.68e-08	-4.907832	-4.812881	-4.869288
1	966.9580	1298.133	9.54e-13	-16.32686	**-15.85210***	**-16.13414***
2	989.0631	40.78016	8.60e-13	-16.43212	-15.57756	-16.08522
3	1007.463	32.67	8.27e-13*	**-16.473***	-15.23912	-15.97241
4	1022.457	25.59483	8.45e-13	-16.45616	-14.84199	-15.80090

Table A 4: Pairwise Granger causality test results.

Null Hypothesis:	Obs	F-Statistic	Prob.	Conclusion
INF ↛ R	121	1.34584	0.2644	
R ↛ INF		4.35728	**0.0150**	R → INF
INTG ↛ R	121	0.38460	0.6816	
R ↛ INTG		3.83916	**0.0243**	R → INTG
EXCG ↛ R	121	2.67735	0.0730	
R ↛ EXCG		9.86489	**0.0001**	R → EXCG
INTG ↛ INF	121	0.68285	0.5072	
INF ↛ INTG		0.44233	0.6436	
EXCG ↛ INF	121	2.24526	0.1105	
INF ↛EXCG		4.56142	**0.0124**	INF →EXCG
EXCG ↛ INTG	121	1.59992	0.2063	
INTG ↛ EXCG		0.72074	0.4886	

Note: ↛ : does not Granger cause, → : Granger cause.

Table A 5: Sum up of Johansen test results for no cointegration hypothesis.

Trend: Test Type	None No Intercept No Trend	None Intercept No Trend	Linear Intercept No Trend	Linear Intercept Trend	Quadratic Intercept Trend
Trace	1	1	**1**	0	0
Max-Eig	1	1	**1**	0	0

Note: Used Series are LSP, LCPI, LINT, and LEXC. Lag = p-1=2 since optimal lag p for VAR representation is equal to 3 (based on information criteria AIC: Akaike information criterion:

AIC: Akaike information criterion, SC: Schwarz information criterion, and HQ: Hannan-Quinn information criterion. Exogenous series are D2008, D2009, and D2016.

Table A 6: UK normalized cointegrating coefficients from VEC(2) model.

LSP_{-1}	$LCPI_{-1}$	$LINT_{-1}$	$LEXC_{-1}$	C
1.000	-0.192564	0.291544	1.863009	-2.922638
	(0.37870)	(0.06301)	(0.50576)	
	[-0.50849]	**[4.62659]**	**[3.68355]**	

Table A 7: VECM Granger Causality/Block Exogeneity Wald Tests from VECM (2) model in first difference variables ($p - 1 = 2$).

Dep. var	**Test** P-value	**ΔLSP**	**ΔLCPI**	**ΔLINT**	**ΔLEXC**	**All**	**Conclusion**
ΔLSP	χ^2_Stat	_	3.63375	1.00460	3.61323	6.66284	
	p-value		(0.1625)	(0.6051)	(0.1642)	(0.3532)	
ΔLCPI	χ^2_Stat	2.59465	_	6.81823	4.51194	16.7650	ΔLINT→ ΔLCPI
	p-value	(0.2733)		(0.0331)	(0.1048)	(0.0102)	
ΔLINT	χ^2_Stat	2.76951	3.16772	_	4.08047	10.3156	
	p-value	(0.2504)	(0.2052)		(0.1300)	(0.1120)	
ΔLEXC	χ^2_stat	8.50903	6.23647	3.11489	_	24.0532	ΔLSP, ΔLCPI → ΔLEXC
	p-value	(0.0142)	(0.0442)	(0.2107)		(0.0005)	

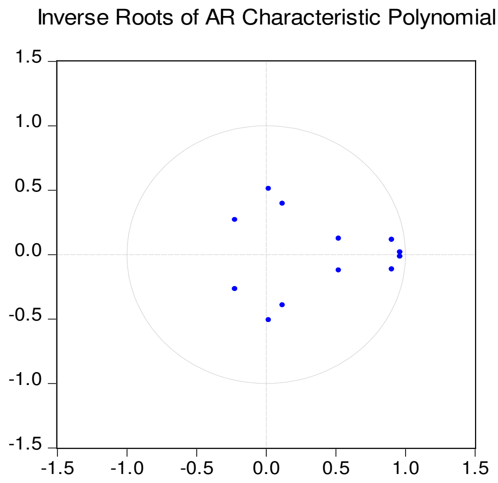

Figure B 1: VAR (3) stability condition; post GFC.

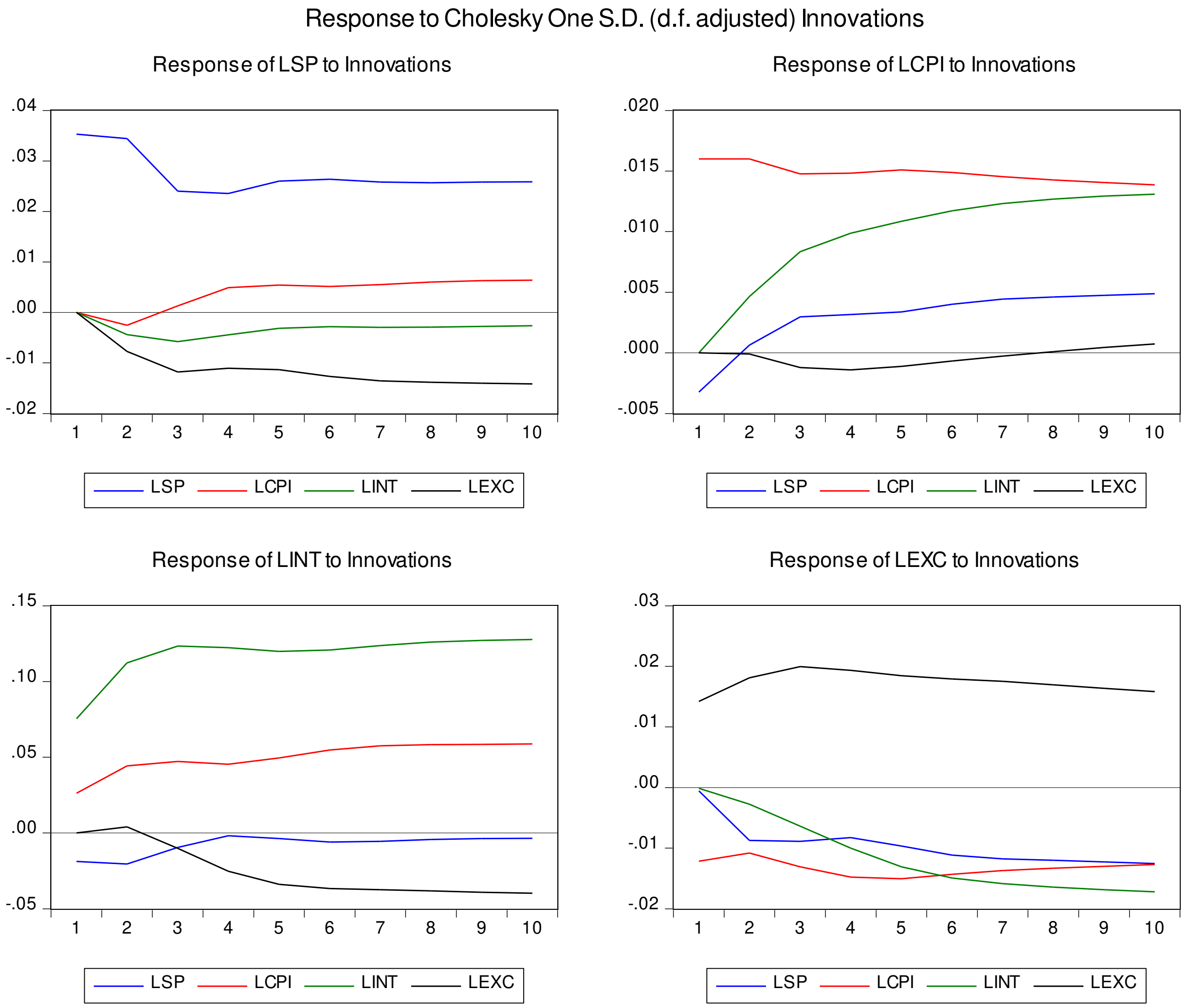

Figure B 2: Impulse response analysis from VECM (2).

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