An empirical investigation of Arbitrage Pricing Theory: A case Zimbabwe

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ABSTRACT

This study investigates the Arbitrage Pricing Theory for the case of Zimbabwe using time series data from 1980 to 2005 within a vector autoregressive (VAR) framework. The Granger causality tests are conducted to establish the existence of causality among the variables like inflation, exchange rate and Gross Domestic Product. The VAR estimates as shown by the impulse response and variance decomposition together with the Granger causality test show that there is unidirectional causality from Consumer Price Index to Stock Prices. Although the Granger causality test has indicated that there is no causality between RGDP and Stock Prices, the variance decomposition has shown that the real GDP explains deviations in the Stock Prices in the long run. Granger causality tests found no meaningful relationships between Stock Prices and Exchange Rate but considering impulse response functions the effect is significant as early as the first period.

Keywords: Arbitrage, Capital Asset Pricing Model (CAPM), Efficient Market Hypothesis, Vector Auto Regression Model (VAR), Impulse Response, Variance Decomposition

INTRODUCTION

The Capital Asset Pricing Model (CAPM) and the Arbitrage Pricing Theory (APT) have emerged as two models that have tried to scientifically measure the potential for assets to generate a return or a loss. Both of them are based on the efficient market hypothesis, and are part of the modern portfolio theory. The Efficient Market Hypothesis (EMH) (Fama, 1965), states that at any given time, security prices fully reflect all available information. If the asset is overpriced, then arbitrageurs will short the asset, until reduced demand for purchasing it caused the price to fall. The opposite is true for underpriced securities.

The CAPM is based on several simplifying assumptions and because most of these assumptions appear to be unrealistic in the real world, it has been argued that they are the cause of flaws in the CAPM (Watson and Head 1998; Harrington 1987). Several of the CAPM assumptions have been criticized. For instance, the assumptions that there are no taxes and no transaction costs do not conform to reality. In addition, the assumption of homogeneous expectations is also open to doubt, because investors usually have divergent expectations, apply various investment holding periods, differ in respect of their decision-making processes and so on. (Levy and Solomon 2000). Some researchers have also suggested that the CAPM is incorrect in respect of its description of expected returns and that a multi-factor model offers a better explanation. The Capital Asset Pricing Model (CAPM) has run into several roadblocks such as Roll's (1977) suggestion that it is not a testable scientific theory and a plethora of empirical anomalies which provide empirical evidence that the usual market proxies are not mean-variance efficient.

In 1976 Ross introduced the Arbitrage Pricing Theory (APT) as an alternative to the CAPM. The APT has the potential to overcome CAPM's weaknesses. It requires less and more realistic assumptions to be generated by a simple arbitrage argument and its explanatory power is potentially better since it is a multifactor model. The APT relates the expected rate of return on a sequence of primitive securities to their factor sensitivities, suggesting that factor risk is of critical importance in asset pricing (Gilles and Leroy, 1990). It tries to capture some of the non-market influences that cause securities to move together.

The APT rests on the hypothesis that the equity price is influenced by limited and non-correlated common factors and by a specific factor totally independent from the other factors. The main empirical strength of the APT is that it permits the researcher to select whatever factors provide the best explanation for the particular sample at hand (Groenewold and Fraser, 1997).

Scanty literature has tried to test the APT in Zimbabwe. Although, Chakaza (2008) has attempted to investigate the link between systematic factors and stock prices in Zimbabwe, he only focused on a unidirectional effect running from financial systematic factors to stock prices in the context of cointegration. The results he obtained supported that systematic factors influence stock prices but the issue of causality is unknown for the Zimbabwean economy and this is what this study seeks to investigate. This comes as a result of different studies carried out in different countries having yielded different results on the causality issue and the subject matter remains inconclusive. The issue of causality is far from being settled. Besides the study carried out by Chakaza (2008), the authors are not aware of any study which has been carried out for Zimbabwe in an attempt to answer the direction of causality. The study will add to the existing body of knowledge by determining the direction of causality between systematic factors and stock prices by employing a vector autoregressive (VAR) modeling framework.

The rest of the paper is organized as follows. Section II reviews the theoretical and empirical literature. Section III provides the methodology to be employed in this study. The main contribution of the paper is Section IV, where the Arbitrage Pricing Theory will be tested. The paper concludes in Section V, with brief final comments and policy recommendations.

LITERATURE REVIEW

The Arbitrage Pricing Theory (APT)

Ross (1976) developed the arbitrage pricing theory (APT) as an alternative model that could potentially overcome the CAPM's problems while still retaining the underlying message of the later. The core idea of the APT is that only a small number of systematic influences affect the long term average returns of securities. The first ingredient of Ross's APT is a factor model. Multi-factor models allow an asset to have not just one, but many measures of systematic risk. Each measure captures the sensitivity of the asset to the corresponding pervasive factor. If the factor model holds exactly and assets do not have specific risk, then the law of one price implies that the expected return of any asset is just a linear function of the other assets' expected return. If this were not the case, arbitrageurs would be able to create a long-short trading strategy that would have no initial cost, but would give positive profits for sure.

The intuition for the result when assets have no specific risk, is that all asset prices move in lockstep with one another and are therefore just leveraged 'copies' of one other. The result becomes more difficult when assets do have specific risk. In this case it is possible to form portfolios where the specific risk may be diversified away. To achieve full diversification of residual risk, however, a portfolio needs to include an infinite number of securities. With a finite set of securities, each of which has specific risk, the APT pricing restriction will only hold only approximately.

The advantage of factor analytic techniques is that the factors determined from the data explain a large proportion of the risks in that particular dataset over the period under consideration. The drawback is that factors usually have no economic interpretation. As Roll and Ross argue, "an effort should be directed at identifying a more meaningful set of sufficient statistics for the underlying factors".

An alternative to factor analytic techniques is to use observed macroeconomic variables as the risk factors. One of the first studies using observed factors was by Chen *et al* (1986). Their argument is that at the most basic level some fundamental valuation model determines the prices of assets. That is, the price of a stock will be the correctly discounted expected future dividends. Therefore the choice of factors should include any systematic influences that impact future dividends, the way traders and investors form expectations, and the rate at which investors discount future cash flows.

Empirical Investigation

Mpohamba (1955) used autoregressive distributed lag (ARDL) approach for the case of Germany covering the period 1935-1954. The results reviewed that, in the long-run, inflation and real interest rate exerted positive impact on stock prices. A stable long-run relationship between economic growth and stock prices was found. This method of estimation however, does not cater

for reverse causality and would be inappropriate for the estimation of causality in Zimbabwe. More so the feedback effect should have been considered.

By employing provincial panel data from Congo, Zhang (1967) examined to determine if diamond prices and money supply explained the stock prices in Congo for the period 1960-1966. He employed a provincial panel data. The results suggested that both variables influenced stock prices. He concluded that the findings revealed a significant and positive nexus between diamond prices and stock prices. This method however, assumes that all elements in the collection have the same economic structure which is not the case for all provinces or nations especially the developing ones.

Hamao (1988) replicated the Chen, *et al* (1986) study in the multi-factor APT framework. By applying an unbalanced panel data, he showed that the Asian stock returns were significantly influenced by the changes in expected inflation, and the unexpected changes in both the risk premium and the slope of the term structure of interest rates. However, different countries have different financial and economic structures which need to be estimated using different proxies and methodologies.

Maysami and Koh (1990) examined long-term dynamic interactions between the Botswana Stock Exchange and macroeconomic variables for the period 1978 to 1989 by employing a vector error correction model (VECM). The variables were seasonally adjusted money supply, industrial production index, foreign exchange rate, retail price index (inflation), domestic exports, and interest rates. Results indicated a cointegrating vector among returns on the Botswana Stock Exchange and money supply growth, inflation, term structure of interest rates, and changes in exchange rates. This study is going to employ a VAR instead of VECM because the variables are not integrated of the same order.

Akmal (1997) investigated the relationship between equity market prices and inflation in Algeria for the period 1971-1996 by employing the autoregressive distributed lag (ARDL) approach to observe cointegration among variables and provided evidence that equity returns are hedged against inflation in the long run. Though the study by Akmal (1997) is important in defining and providing a background for the inclusion of the explanatory variables, this study will adopt a different methodology, thus it is going to use the VAR model instead of ARDL. Mukherjee and Naka (2005) tested the dynamic relationship between six macroeconomic variables and the Japanese stock market, by employing a vector error correction to a model of seven equations. They found that a long-term equilibrium relationship exists between the Japanese stock market and the six macroeconomic variables which are exchange rate, money supply, inflation, industrial production, long-term government bond rate and call money rate. However, using money supply, inflation, government bond rate and call money rate as explanatory variables in one study may bring about the problem of multicollineality.

Maysami *et al* (2006) examined the long run relationship among macroeconomic variables and Stock prices in Angola and found stock prices to have long term relationship with industrial production, inflation, exchange rate, changes in the short and long-term interest rates and money supply.

METHODOLOGY

The study is going to employ the Vector Auto Regression (VAR) model to model the relationship between stock prices and certain macroeconomic variables. A VAR is an economic model that is used to capture the innovation and interdependency of multiple times series variables. The VAR model, developed by Sims (1980) represents dynamic models of a group of time series. In a VAR model each variable will have its own equation explaining the changes in that variable in question, in response to its own current and past values and the current and past values of all the variables in the model. Unit root tests will be conducted to test the data for stationarity. If the variables are integrated of the same order then a cointegration test will be performed.

Definition and Justification of variables

The dependent variable is stock prices. Stock prices are estimated by the industrial production total index. The industrial production total index is a proxy for the real activity. It shows the changes in production value added of branches of manufacturing industry. It is computed on the basis of production data collected for about 1500 factories, the production value added of which covers over 75% of the total value created by the manufacturing industry in Zimbabwe.

Independent Variables

a. **Gross Domestic Product (GDP)**
   GDP is a measure of corporate output and activity influencing possible future dividends. Industrial production index has been used as proxy to measure the growth rate in real sector. GDP presents a measure of overall economic activity in the economy and affects stock prices through its influence on expected future cash flows. It is hypothesized that an increase in industrial production is positively related to equity prices.
b. **Consumer Price Index (CPI)**
   Consumer Price Index is used as a proxy of inflation rate. CPI is chosen as it is a broad base measure to calculate average change in prices of goods and services during a specific period. Inflation is ultimately translated into nominal interest rate and an increase in nominal interest rates increase discount rate which results in reduction of present value of cash flows so it is hypothesized that an increase in inflation is negatively related to equity prices. Inflation is likely to influence stock prices directly through changes in the price level and through the policies designed to control it.
c. **Foreign Exchange Rate (ER)**
   This study employs foreign exchange rate as end of month US$/Z$ exchange rate. It is hypothesized that a loss in value of the home currency is negatively related to equity prices. A positive relation between the exchange rate and stock prices is conjectured. Persistent devaluation of the Zimbabwe dollar lures people to rather invest in strong international currencies usually by keeping them as idle balances. Thus resources that could be invested on the stock exchange are diverted into non-functioning assets usually comprised of dollars, Rands and pound sterling.

Empirical Model

The study is going to follow Mishra (1994) to identify factors in the Arbitrage Pricing Theory with macroeconomic variables that have an impact on stock market prices. Most studies employed this model in order to test the impact of macroeconomic variables on stock market prices. As stated in the previous chapter, it has advantages over the CAPM model as it allows the selection of whatever factors provide a better explanation of variations in stock market prices. The regression equation is specified as follows:

$$V_t = \sum_{i=1}^{k} A_t\, V_{t-i} + \varepsilon_t$$

$$V = (CPI, GDP, ER)$$

Where; V_t is a vector of endogenous variables, A_1-A_k are three by three matrices of coefficients and ε_t is a vector of error terms. Following Shan *et al* (2006) the variation is smoothed out in time series variables and further even and make the variables consistent in the model by transforming all of the variables into logarithm format.

ESTIMATION OF RESULTS

The unit root tests were conducted by applying the Augmented Dickey-Fuller test developed by Dickey and Fuller (1981) to test the stationarity of our variables. If the estimated Augmented Dickey-Fuller statistic is greater than the critical value the null hypothesis that the series is non-stationary in favour of stationarity will be rejected. To deal with the problem of high variability and unevenness of our data, all variables were converted into logs before being subjected to the tests for stationarity. A trend and an intercept were employed for the testing for stationarity in levels and only an intercept for successive test.

After running the data, it is only Exchange Rate (ER) that was stationary in levels. All other variables were found to be non-stationary. Appropriate differencing were conducted and it was found that the Stock Price (SP) became stationary after differencing twice, that is , it is integrated of order two I(2). After differencing once, Consumer Price Index (CPI) and the Real Gross Domestic Product (RGDP) were found to be stationary which means they are integrated of order one, I(1) as illustrated Table 1 below. This therefore, means that this study is going to perform the vector autoregression (VAR) analysis without proceeding to conducting the vector error correction (VEC) model.

Table 1: Augmented Dickey Fuller (ADF) test results after appropriate differencing.

Variable	t-ADF Statistic	Critical 1%	Critical 5%	Critical 10%	conclusion
SP	-5.1653***	-3.7667	-3.0038	-2.6417	Stationary I(2)
CPI	-2.7280*	-3.7497	-2.9969	-2.6381	Stationary I(1)
RGDP	-4.1381**	-3.7497	-2.9969	-2.6381	Stationary I(1)
ER	-4.2973**	-4.3942	-3.6118	-3.2418	Stationary I(0)

***Indicating stationarity at 1% level, ** stationarity at 5% level and * stationarity at 10% level of significance*

Table 2 reports diagnostic test results of residuals of the VAR model.

**Table 2: Diagnostic Tests of the residuals of the VAR**

Test	Ljung-Box	Lagrange Multiplier	ARCH
Variable	Q-statistic	F-statistic	$n*R^2$
ΔLOGSP	0.235	0.278	12.146
ΔLOGER	1.034	0.782	9.211
ΔLOGCPI	3.351	2.095	12.312
ΔLOGRGDP	4.611	2.009	11.665

Determined lag length of VAR

$F_{0.05,6,209} = 2.104$

$\chi^2_{0.05,6} = 12.592$

Inspection of the table regarding the VAR shows that the Q-statistic is insignificant at 5% confidence level, with large p-values. Consequently, the null hypothesis, that the residuals of the equations incorporated into the VAR up to order k are not autocorrelated, cannot be rejected. Moreover, the Breusch-Godfrey Lagrange Multiplier is reported. This is also a test of the null hypothesis that there is no serial correlation in the residuals up to the specified order. The reported F-statistics indicate no autocorrelation in the residuals at 5% confidence level. Also, the ARCH test for autoregressive conditional heteroskedasticity was applied. Ignoring ARCH effects may result in loss of efficiency. It is a test of the null hypothesis that there is no ARCH up to order k in the residuals. The reported $n*R^2$ (i.e. number of observations multiplied by R-squared) follows χ^2 distribution with k degrees of freedom. For the estimated VAR the observed value is lower than the critical value. Thus, the null hypothesis that there is no autocorrelation in the error variance is accepted.

Impulse Response

The long run relations among the variables of the systems have been determined. Subsequently, there should be examined the transmission mechanisms of the shocks among the variables, which determine the time paths of the systems and settle the equilibrium. Table 3 shows the impulse response functions for the variables.

Table 3: Impulse response functions

Response to One S.D. Innovations ± 2 S.E.
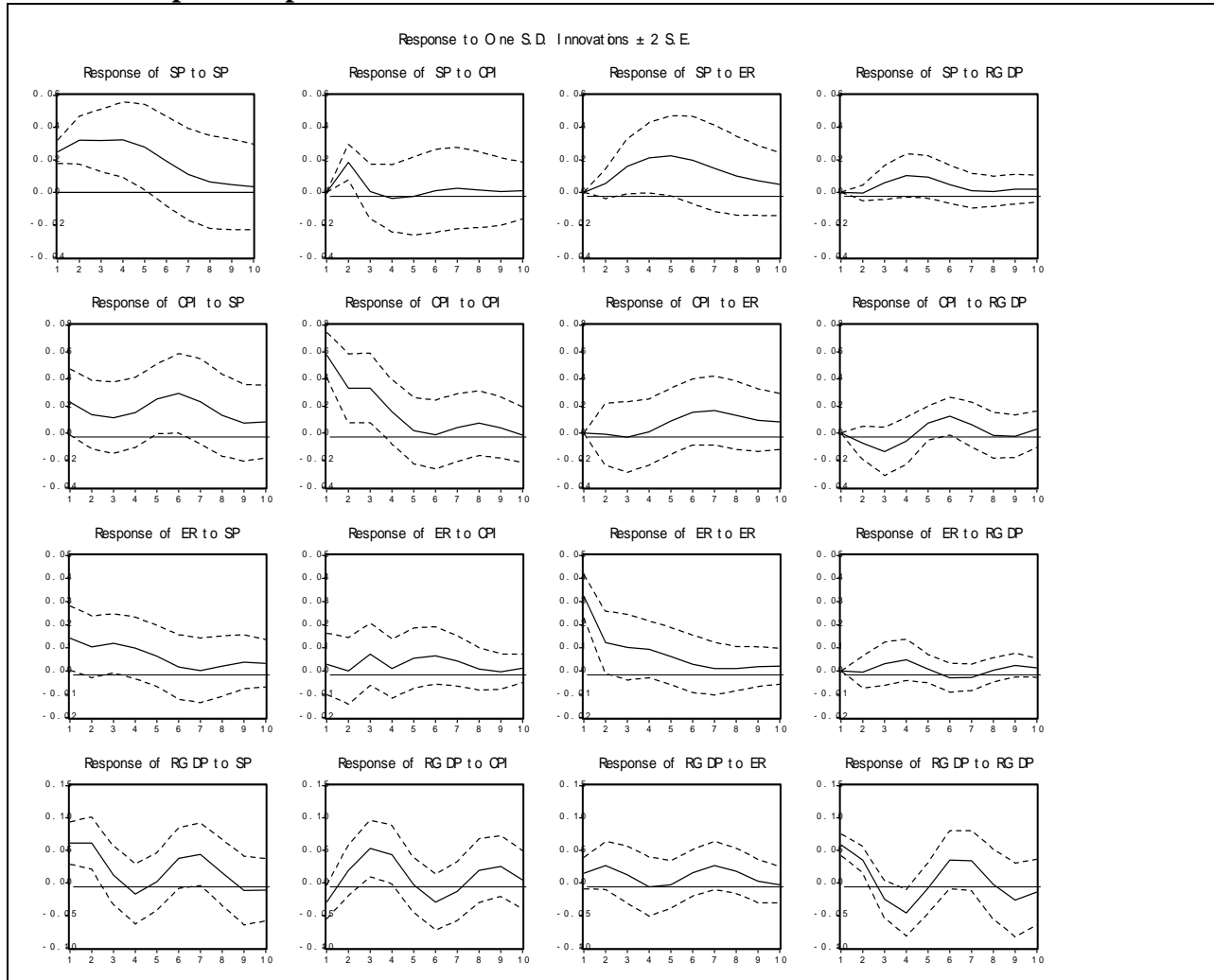
From table 3, it is shown that the response of stock price to its own shocks is firstly positive, achieving a stable response afterwards. The response of stock prices to own shocks is positive and becomes stable for longer periods. For the period plotted, it does not seem that previous values of the stock prices could used alone to forecast its future performance. The innovations of exchange rate have an immediate positive response on stock prices. The effect is significant as early as the first period. This result may imply that currency depreciation improves the competitiveness of the domestic industries, resulting to higher profits and higher stock prices. The immediate response of the CPI innovations is positive but over time, the effect of the shock stabilizes. This result is probably indicative of the fact that high inflation signals future growth, at least in the short run. There is no immediate influence of RGDP innovations but from period 2, it starts to influence stock prices. However, in the very long run, the effect becomes stable. The long run response is a rise in stock prices.

Variance Decomposition

The numbers in table 4 of the variance decomposition imply the percentage of the forecast error in each variable that could be attributed to innovations of the other variables.

Table 4: Variance Decomposition of stock prices

Period	se	SP	CPI	ER	RGDP
1	0.024945	100	0	0	0
2	0.045092	81.53365	17.02902	1.427411	0.009915
3	0.057816	80.07366	10.3653	8.487084	1.073957
4	0.070498	75.06878	7.252853	14.79643	2.881944
5	0.079681	70.96968	5.772153	19.58148	3.676695
6	0.084436	68.39067	5.151918	22.86946	3.587956
7	0.086452	66.85455	5.00152	24.71171	3.432217
8	0.087302	66.08463	4.935495	25.6103	3.369577
9	0.08775	65.69796	4.886814	26.02793	3.387294
10	0.087983	65.4975	4.875326	26.20542	3.421755

Table 4 reveals that the highest percentage error variance of stock prices originates from themselves. In earlier periods, inflation better influences stock prices but over time, the effect declines. The Exchange Rate (ER) over time influences stock prices. The effect is 1.4% in period 2, 14.8% in period 5 and it increases up to 20% in period 10. Real Gross Domestic Product (RGDP) stabilizes around nearly 9%. In the second month 81.53% of the variability in the stock prices fluctuations is explained by its own innovations. The proportion decreases for the following months (to 65.5% after period 10). The influence of CPI on stock prices innovations decreases with time (from 17% in period 2 to 5% in period 10). Therefore past values of stock prices seem to be the best predictor of stock prices as compared to inflation, real GDP and the exchange rate.

Granger Causality test

The table below shows the results from the Granger causality test and the number of observations, F-Statistic and probability. If the probability is less than 10% the null hypothesis is not accepted in favor of its rejection. However, if the probability is higher than 10% the null hypothesis is not rejected as there is a high likelihood that the null hypothesis is correct, implying a highly probability of no causality.

Table 5: Pairwise Granger Causality

Null Hypothesis:	Obs	F-Statistic	Probability
CPI does not Granger Cause SP	24	3.29990	0.05887
SP does not Granger Cause CPI		1.26156	0.30589
ER does not Granger Cause SP	24	2.18001	0.14050
SP does not Granger Cause ER		0.51906	0.60328
RGDP does not Granger Cause SP	24	1.79920	0.19250
SP does not Granger Cause RGDP		1.63575	0.22108

ER does not Granger Cause CPI	24	0.17234	0.84299
CPI does not Granger Cause ER		0.47750	0.62758
RGDP does not Granger Cause CPI	24	0.28781	0.75311
CPI does not Granger Cause RGDP		4.50577	0.02503
RGDP does not Granger Cause ER	24	0.34106	0.71528
ER does not Granger Cause RGDP		1.02716	0.37707

The test found uni- directional causality running from CPI to stock prices (SP). Uni-directional causality also runs from CPI to RGDP. The study has rejected any causality from SP to CPI. Causality was also not found between RGDP and SP. It has been expected that there exist causality running from RGDP but, the Granger causality test rejects any causality between the two. The same result was found between SP and ER.

The result shows that, for the period under review, the CPI does cause Stock Prices in the Granger causality test. The null hypothesis was rejected at the 10% level of significance. Feedbacks or a unidirectional causality was found not to exist between Stock Prices and the Consumer Price Index. This supports findings by Fama and Schwert (1977), and Roll and Ross (1986) who found inflation granger causing stock prices.

CONCLUSION

The study's main thrust has been to investigate whether there is causality between Stock Prices and some macroeconomic variables for the case of Zimbabwe as suggested by the study's hypothesis. The modern statistical tools were employed in exploring the relationship between the variables of concern. By recognizing the pitfalls of the non-stationarity of time series data, the study employed the Augmented Dickey-Fuller test to test for stationarity. The causality issues were catered for in the vector autoregressive model and further the Granger causality tests were conducted. The Augmented Dickey-Fuller test suggests that CPI was integrated of order two, RGDP integrated of order one and ER was stationary in levels and this did not call for the performance of the cointegration test, so the study was just restricted to the vector autoregressive model.

Considering the period from 1980 to 2005, the hypotheses was tested that there is a negative relationship between inflation and stock prices, the exchange rate positively influences stock prices and there is a positive relationship between Real Gross Domestic Product and stock prices. A structural VAR mode was adopted and complimentary Granger Causality tests. The major findings are there is uni- directional causality running from CPI to stock prices (SP). Uni-directional causality also runs from CPI to RGDP. The study has rejected any causality from SP to CPI. Causality was also not found between RGDP and SP. It has been expected that there exist causality running from RGDP but, the Granger causality test rejects any causality between the two. The same result was found between SP and ER.

It can therefore be concluded that past values of stock prices are a good predictor of stock prices, using variance decomposition results. It can also be found that GDP is a weak determinant of stock prices in Zimbabwe. It only influences stock prices in the long run. There is also a significant long run influence of the exchange rate and a short run influence of inflation on stock prices.

The main policy conclusions that may be inferred from these results are: firstly, since inflation Granger causes Stock prices, there is need for both fiscal and monetary authorities to

devise sound policies which keep inflation at low levels. High levels of inflation can be transmitted to stock prices, hence a negative impact on financial assets.

Impulse response and variance decomposition depicts a long run impact of RGDP on stock prices, hence economic policies which improve the country's Real Gross Domestic Product should be adopted. This will in the long run stabilize stock prices and investors may be attracted on the stock exchange. The exchange rate also has an immediate influence on stock prices. Policies which stabilize the exchange rate also may stabilize the stock prices. The exchange rate must therefore be predictable so that stock prices become predictable. Instability of the exchange rate may also imply instability in stock prices.

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